of this material to rotational studies of stars in OB associations is considered. It is found that disentanglement of V_e from $V_e \sin(i)$ is not possible on the basis of continuum studies alone.

Particle Sizes in Saturn's Rings. A. F. COOK AND F. A. FRANKLIN, *Smithsonian Astrophysical Observatory*.—Saturn's rings exhibit a vertical thickness which is two or more orders of magnitude greater than the thickness expected from thermal motions (Franklin, F. A., and Cook, A. F., *Astron. J.* 70, 704, 1965). In order to explain this difference, we propose that the ring particles carry electrostatic charges and that the accompanying electrostatic forces will be sufficient to maintain the required thickness. We find that the charges on the particles must be negative and propose that the ambient net space charge is due to positive sodium ions produced by sunlight. The analysis suggests that particle radii lie between 300 and 700 μ , with ion densities between 2×10^4 and 3×10^5 cm^{-3} . The corresponding neutral sodium concentrations yield equivalent widths of about 1 Å for the D lines on the damping portion of the curve of growth.

Influence of the Convection Zone on the Fraunhofer Spectrum of Stars. CHARLES R. COWLEY, *Yerkes Observatory*.—The excitation temperatures and turbulent velocities of metal-poor stars are lower than in stars with the same effective temperatures and normal metal abundances. We suggest that these differences arise because of a reduced non-radiative heating of the upper photosphere of the metal-poor stars. Order of magnitude calculations show that photospheric turbulence (and presumably also the consequent, nonradiative upward flux) could be suppressed by a magnetic field of the order of 100 G.

The boundary temperature of a star with little or no nonradiative outward flux would be considerably lower than in the sun if we assume equal effective temperatures. We have compared line strengths in all portions of the curve of growth based on a modern solar model, and an older solar model that reaches a low boundary temperature. There is little change in the line strengths of high excitation lines in the two models. The low excitation lines are enhanced in the low-boundary temperature model in the linear and transition regions of the curve of growth. In the linear portion the enhancement is due to reduced ionization. In the transition region the enhancement is due to the greater limiting line depth.

Suppression of H_ϵ in the Spectrum of AX Monocerotis. A. P. COWLEY, C. R. COWLEY, AND J. M.

MARLBOROUGH, *Yerkes Observatory*.—On several occasions a curious suppression of H_ϵ has been observed by Struve (*Astrophys. J.* 98, 212, 1943), the Burbidges (*Astrophys. J.* 119, 501, 1954) and Cowley (*Astrophys. J.* 139, 817, 1964) in the spectrum of AX Monocerotis. During a short interval of time, usually lasting several days, an absorption component with a large negative displacement totally disappears at H_ϵ while the corresponding line at the other members of the Balmer series remains unchanged. The emission which is often seen on the redward edge of the K line of calcium is not sufficiently strong to explain the phenomenon as a "filling-in" of H_ϵ by the emission from the H line of calcium. A possible explanation based on the assumption of flarelike activity on the surface of the K giant secondary is presented.

OH Emission Objects with Diameters as Small as 20". D. D. CUDABACK, *University of California*, R. B. READ, *California Institute of Technology*, AND G. W. ROUGOOR, *California Institute of Technology and Leiden Observatory*.—The twin 90-ft element interferometer of the Owens Valley Radio Observatory of the California Institute of Technology was used to measure diameters of three sources of OH emission: W3C, W49, and NGC 6334 at two frequencies, 1665 and 1667 MHz. Three baseline spacings (800' and 1600' east-west and 1600' north-south)—and observing the sources over a large hour angle range—gave a large number of projected baselines. All velocity features of all sources had constant visibility giving an upper limit of the size of 20". The brightness temperature is then at least 5×10^5 °K. An exception is the feature with a velocity of +17 km/sec at 1665 MHz in W49, where resolution is markedly present.

The measured phases were calibrated using small diameter sources for which high precision positions were known, giving positions for:

W3C	$\alpha(1950)=2^{\text{h}}\ 23^{\text{m}}\ 16^{\text{s}}.2\pm0^{\text{s}}.5$	
	$\delta(1950)=61^{\circ}\ 38'\ 53''\pm5''$	
W49	$\alpha(1950)=19^{\text{h}}\ 07^{\text{m}}\ 49^{\text{s}}.6\pm0^{\text{s}}.3$	
	$\delta(1950)=\ 8^{\circ}\ 59'\ 48''\pm5''$	} fringe ambiguity
	9 1 16	
	9 2 44	
NGC 6334	no position was measured.	

None of the sources could be identified with any object.

The position of W3C suggests a possible relation with an arc forming the border of IC 1795.

Possibility of Detecting Very Young "Cocoon" Stars. K. DAVIDSON AND M. HARWIT, *Cornell-Sydney University Astronomy Center*.—It is gener-

ally suspected that stars are presently being formed in regions of dense interstellar material. If this is so, very young stars might approach the main sequence while imbedded within a cocoon of gas and dust, perhaps about 10^{17} cm in radius. Most of the star's radiation would be absorbed by the dust and re-emitted in the far infrared—the spectrum would resemble that of a 100° blackbody. The star's radiation also clears the dust from a central region and ionizes some of the remaining gas. The resulting H II region would be a thermal radio source, opaque at wavelengths longer than a few centimeters. The nearest "cocoon" star might be several thousand parsecs distant; this would give a total infrared flux of 10^{-15} – 10^{-14} W cm $^{-2}$, and a maximum radio flux density of several times 10^{-26} W m $^{-2}$ cps $^{-1}$. This would probably be detectable.

RU Cam—Photometric and Spectroscopic Observations. SERGE DEMERS AND DAVID CRAMPTON, *David Dunlap Observatory*.—Photoelectric observations of the variable RU Cam, made in the fall of 1965, showed that the amplitude was about 0.13 mag. Observations made at the beginning of this year indicate that the amplitude of the light variation is less than 0.05 mag.

The final magnitude and colors are $V=8.505$, $B-V=1.175$, $U-B=1.00$. The colors still show small erratic variations. Present spectra of RU Cam are almost indistinguishable from the spectra of HD 156074, another carbon star, hence RU Cam is classified as R0 or C1 $_2$. No emission lines are visible on the five plates taken in January–February 1966 (40 Å/mm). The radial velocity is constant and equal to -16.9 km/sec ± 0.9 (s.e.). Velocity measures of two other carbon stars indicate that a correction of -5 km/sec is required to agree with the Mt. Wilson velocities. Hence, there is approximate agreement with the Sanford's gamma velocity of -24 km/sec.

One-Dimensional Driven Shock Fronts in Inhomogeneous Media. DAVID S. DE YOUNG AND W. I. AXFORD, *Cornell University*.—The one-dimensional propagation of a shock front being driven by a constant velocity piston into an ideal gas with various density and pressure gradients is considered. Only strong shock fronts are considered, and for density distributions proportional to x^k a similarity solution is found for positive and negative values of k . For Gaussian and stellar density distributions the shock behavior in the region of increasing density is found by using a constant pressure approximation for the gas between the piston and the shock front. This is matched to the solution of Hazlehurst (1962) to ob-

tain the propagation in the region of decreasing density. In regions of increasing density the similarity solution yields a constant shock velocity, and the constant pressure solution gives a shock velocity which is very nearly constant. Determination of the shock propagation by use of an artificial viscosity is also discussed.

Photoelectric Observations of M8, M16, M17 and M20. HÉLÈNE R. DICKEL, *University of Illinois Observatory*.—During the last two weeks of June 1965 observations were made of M8, M16, M17, and M20 with the 24-in. reflector and photoelectric spectrometer of the University of Michigan. The standard stars were ζ Oph and ϵ Aqr. The extinction star was γ Scu. The spectrometer was used as a simple monochromator with the width of the exit slit corresponding to 50 Å which allowed the [O III] N_1 and N_2 lines to be resolved. The north-south dimension of the entrance slit as projected on the sky was 150 sec of arc; the east-west dimension was 35 sec of arc. Six to eight individual measurements were made of a particular region of a nebula during a given night. Each nebula was observed for one night except for M17 which was observed on two separate nights.

For the four nebulae, the mean ratio of the measured surface brightnesses of the nebular line $\langle S(N_1)/S(N_2) \rangle$ was 2.98 ± 0.03 (probable error of the mean). The emission of the forbidden double [O II] $\lambda 3727$ was too weak to be measured except for M8, for which $S(3727)/S(H\beta) = 6 \pm 1$ (p.e. of the mean). The mean surface brightness of the H emission (in units of 10^{-4} erg cm $^{-2}$ sec $^{-1}$ sr $^{-1}$) is as follows: 17 ± 2 (p.e. of the mean) for M8, 1.6 ± 0.1 for M16, 4.0 ± 0.3 for M17, and 5.2 ± 0.5 for M20. The measured values of $S(H\alpha + [N II])/S(H\beta)$ are 6.8 ± 0.7 (M8), 8.3 ± 0.5 (M16), 12.6 ± 0.6 (M17), and 4.9 ± 0.6 (M20). This confirms the large amount of absorption found by other investigators. The values of $S(N_1)/S(H\beta)$ are 1.6 ± 0.1 (M8), 1.0 ± 0.1 (M16), 3.7 ± 0.1 (M17), and 0.8 ± 0.1 (M20).

The author wishes to thank Dr. O. C. Mohler and Dr. J. A. Williams for granting permission to use the Michigan telescope and D. F. Gray for his help in the operation of the equipment.

Microwave Spectrum of Venus. JOHN I. DICKEL, *University of Illinois Observatory*.—Venus was observed at a wavelength of 6 cm on four days during February 1966 using the 140-ft radio telescope at the National Radio Astronomy Observatory. The observations consisted of a series of on-off observations which included baselines surrounding the planet. The feed system consisted of a linearly polarized feed

probe which was switched versus either a sky horn for total intensity measurements or an orthogonal feed probe for polarization measurements. The feed could be rotated to any given position angle.

Although Venus was reasonably far from the zenith during the period of observation, it was only 1° south of the source Hydra A. Measurements of Hydra A by Dr. I. I. K. Pauliny-Toth, Dr. K. I. Kellermann, and Dr. C. V. Sastry were therefore used for calibration purposes. They adopted a flux density for Hydra A of 13.0 flux units at 6 cm. All observations were kept within two hours of the meridian.

The observations were made shortly after inferior conjunction of Venus at a mean phase angle of 215° , and the measured brightness temperature of Venus at 6 cm was $706 \pm 45^\circ\text{K}$ (mean error). This value is definitely greater than the temperature recorded near inferior conjunction at both shorter and longer wavelengths showing that the temperature does appear to reach a maximum value near this wavelength. The actual mean value of the brightness temperature is probably somewhat higher than the value recorded because of the phase variation of the observed temperature. There is some evidence for a degree of polarization less than 0.5%.

It is a pleasure to thank Dr. D. S. Heeschen and the entire staff of NRAO for their hospitality during the author's visit.

Formation of Graphite Grains in Cool Stars.

BERTRAM DONN, *Goddard Space Flight Center*, N. C. WICKRAMASINGHE, *University of Maryland and Jesus College, Cambridge, England*, J. P. HUDSON, *Rensselaer Polytechnic Institute*, AND T. P. STECHER, *Goddard Space Flight Center*.—The conditions for graphite grain formation in cool stars have been discussed on the basis of recent molecular equilibrium calculations (Tsuji, T., *Ann. Tokyo Astron. Obs.* **IX**, 1964). The Hoyle-Wickramasinghe mechanism for condensation in N stars has been re-examined taking into account the presence of H, O, and N. From Tsuji's computations we obtain a curve relating the temperature at which the partial pressure of free carbon in the atmosphere equals the vapor pressure of bulk graphite, to the C/O ratio, keeping the C/H, C/N ratios fixed at the values appropriate for an N star. For C/O=2, the saturation temperature is $\sim 2000^\circ\text{K}$, increasing to 2200°K as C/O increases.

Formation of graphite grains requires nucleation followed by crystal growth. Nucleation in a pure vapor may require a very high supersaturation, but it occurs at much lower supersaturations on ions or pre-existing nuclei. The stellar atmosphere is slightly ionized and contains an assortment of hydrocarbons including benzene (Duff and Bauer 1961) some of which could conceivably be effective as nuclei for

graphite condensation. Hence, we hypothesize that graphite condenses when the partial pressure of free carbon in an N star exceeds the vapor pressure of bulk graphite by only a moderate factor.

The radii of the platelets so formed are restricted by the available time scale for the growth and by the number of condensation nuclei. Radii in the range 10^{-6} – 5×10^{-6} cm are shown to result. Assuming a constant luminosity function $\sim 10^5$ N stars in the galaxy (at any time) operating over $\sim 10^9$ yr are able to maintain the grain density at the value required to explain the interstellar absorption of 1 mag/kpc.

Graphite grains may also form to a limited extent in the envelopes of ordinary M stars provided the C/O ratio is not much less than ~ 1.2 .

Emission Spectrum of a Comet, at Large Heliocentric Distance. FRANCOIS V. DOSSIN, *Institut d'Astrophysique, Liege, Belgium*.—The spectrum of comet Humason 1961e was photographed at McDonald Observatory, in February 1964. In addition to a faint continuum, confined to the central region, the picture shows several emission features, extending on both sides, along the slit image. The following transitions are easily identified:

CO⁺ bands: 3-0; 2-0; 1-0; 4-2; 2-1, (intense)
4-0; 3-2, (faint); 1-1 (trace).
N₂⁺ band: 0-0, (moderately intense).
CN band: 0-0, (faint, but definitely present).

The same emission bands, and a few more, had been observed when the comet was near perihelion (Greenstein, *Astrophys. J.* **136**, 1962; Dossin and Rousseau, *Compt. Rend.* **255**, 1962). But, in February 1964, the heliocentric distance of the comet was 5 a.u.

At the request of the author, another spectrogram of comet 1961e was obtained by Fehrenbach at Haute Provence Observatory at the same period. The exposure was shorter and the quality of the sky was not as good as it was in Texas; nevertheless, a few bands of CO⁺ appear clearly. In the discussion of the spectrographic results, two points must be stressed: On the one hand, it was the first time a spectrum of a comet at large heliocentric distance could be observed, in spite of a reported magnitude of about 17 for the object. On the other hand, the spectrum showed emissions, intense relative to the continuum, and mostly of ionized radicals.

In conclusion, the author suggests that every effort should be made to observe more often the spectrum of faint or distant comets. The increasing number of large telescopes and fast nebular spectrographs could provide new and important observational data about some cometary problems which are not well under-

stood. Strong emissions from ionized molecules in a comet at 5 a.u. from the sun are a puzzling phenomenon.

We are indebted to NASA Goddard Space Flight Center for financial support, and to H. J. Smith, Director of McDonald Observatory, for kind permission to use the 82" telescope.

Search for Correlation between Interplanetary Scintillations Observed with Spaced Antennas.

F. D. DRAKE AND R. D. ECKERS, *Cornell-Sydney University Astronomy Center and CSIRO*.—Simultaneous observations of interplanetary radio scintillations have been made on four days using the 210-ft antenna and two arms of the Mills Cross at Molonglo, New South Wales. Observations with two arms of the Mills Cross separated by 0.8 km show a perfect correlation between the scintillations observed with each antenna, consistent with the interplanetary explanation of the scintillations. The correlations between Parkes and Molonglo observations, made with a separation of 298 km, are very weak, much less than that reported for a 53 km baseline by Hewish, Dennison, and Pilkington, and vary from source to source apparently as a result of peculiarities in geometry. If the correlations are significant, the solar wind velocities implied are consistent with the results from spacecraft observations. These results indicate that observations with telescopes spaced roughly 100 km can be very effective in producing two-dimensional maps of the solar wind density variations and velocity.

High-Resolution Radio Map of the Galactic Center.

F. D. DRAKE, E. B. JENKINS, E. GUNDERMANN, D. L. JAUNCEY, AND Y. TERZIAN, *Cornell University*.—A radio map has been made of approximately 4 sq deg in the region of the galactic center with the NRAO 140-ft telescope. The observing wavelength of 2.0 cm provides a resolution of 2 min of arc. Data were recorded and analyzed digitally with suitable corrections for pointing errors, sidelobes, and atmospheric extinction. The resultant radio map shows resolution of the region into a large number of sources. The central nonthermal source is nearly symmetrical with a volume emissivity which decreases from its center outward. Several apparent point sources appear. The distribution of sources shows much less symmetry with respect to the center than in lower frequency maps. The complex of sources is sharply bounded on the northern side of the center. An unusual thermal source with the appearance of a shell structure appears very near the galactic nucleus.

Helium Stars of Small Mass. J. L'ECUYER, *Verkes Observatory*.—An evolutionary sequence of models is constructed for each of two stars of mass $0.5 M_{\odot}$ and $0.7 M_{\odot}$ initially made of pure helium. The whole life span from the helium-burning main sequence to the white-dwarf stage is covered. The Henyey method is used throughout with a special surface approximation. The resulting paths in the H-R diagram are compared with that of the nuclei of planetary nebulae. There is indication that, at least in similar stars, the onset of carbon or oxygen burning does not take place at sufficiently high degeneracy to become a flash.

Part of this work was done at the University of California (Berkeley) with the support of Air Force Grant AF-AFOSR-171-65.

Radar Observations of Venus at 23- and 3.8-cm Wavelength.

J. V. EVANS AND R. P. INGALLS, *Lincoln Laboratory, Massachusetts Institute of Technology*.—During the early part of 1966 the Lincoln Laboratory Millstone Hill Radar ($\lambda=23$ cm) and Haystack Radar ($\lambda=3.8$ cm) were employed to observe the planet Venus. The cross section observed at the longer wavelength was about 15% of the projected area of the disk. This is in agreement with earlier measurements (Evans *et al.* 1965) but at the shorter wavelength the cross section was only one-tenth as much. This finding supports the low value for the cross section reported by Karp *et al.* (1964), though in contrast to these workers the echo spectrum is found to be comparatively narrow, suggesting the solid surface as the reflecting agent. No echo power can be observed outside the frequency limits expected on the basis of the known rotation rate and the center Doppler shift measured using the $\lambda=23$ cm radar. If any energy is reflected by the atmosphere it appears to be only a small portion of the total. Confirmation that the surface is the scattering agent has been provided by near simultaneous ranging experiments at the two frequencies, which showed that the echo delay times agreed to 5 μ sec, which is well within the experimental accuracy. The depolarized component of the echoes was observed at both wavelengths and found to be of the order of 14 dB weaker than the expected component. The implications of these results concerning model atmospheres for Venus are discussed.

The Lincoln Laboratory is operated with support from the U. S. Air Force.

Measurement of Stellar X-Ray Spectra.

PHILIP C. FISHER AND PAUL KIRKPATRICK, *Lockheed Palo Alto Research Laboratories*.—As has proven true for the sun, $\sim 1\%$ energy resolution studies of the spectra of stellar x-ray sources may lead to determina-

tions of elemental abundances and the variation with time of these abundances. By evaluation of absorption effects on the lower-energy portion of a source's x-ray spectrum, information relative to distance and/or the interstellar medium might also be obtained. Fisher and Meyerott (*Astrophys. J.* **139**, 123, 1964) had such investigations and a concept for an appropriate spectrograph in mind when they pointed out that a 4–8 keV x-ray flux of the order of 0.3 photons $\text{cm}^{-2} \text{sec}^{-1}$ seemed sufficiently high to encourage attempting detailed spectral measurements. Tests to investigate the validity of this spectrograph's design are currently being made. Continuous sensitivity to photons throughout the 0.2 to 2 keV range is maintained by combining a special curved diffraction grating with a Venetian blind x-ray collector. These optics provide a line image, position along the line being a measure of the energy of the dispersed x ray. Utilizing several spectrograms obtained from a laboratory mockup of the instrument, a brief description is given of the spectrograph's characteristics. A conservative estimate indicates that a complete 3-m-long instrument may possess a minimum effective aperture (allowing for the inefficiency of all of the vital components) of at least $\frac{1}{8} \text{ cm}^2$ for photons less energetic than one keV. Improvements might conceivably increase this aperture by a factor of 10.

Between January 1963 and April 1964, this work was supported by the Lockheed Independent Research Program. Since the latter time, most all of the effort has been under contract NASw-917 of the National Aeronautics and Space Administration.

Evidence of Tidal Effects in Some Pulsating Stars. WALTER S. FITCH, *Steward Observatory*.—Periodogram analysis of the light variation of the δ Scuti type star CC Andromedae (Fitch, W. S., *Astrophys. J.* **132**, 701, 1960) shows the three most strongly excited frequencies are related as n_0 , $n_0 - 2n_L$, and $n_0 + n_L$, where the fundamental $n_0 = 8.0059 \text{ C/D}$ and the long-period frequency $n_L = 0.09555 \text{ C/D}$ ($P_L = 10.466 \text{ days}$). The same kind of relationships among the strongest terms in the variation of the β Cephei star ν Eridani, as implied by Van Hoof's analyses (*Z. Astrophys.* **53**, 106, 124, 1961), suggest a common explanation.

In CC Andromedae, fitting the fundamental and its first harmonic to observations on individual nights proves conclusively that the fundamental is nonlinearly modulated with both amplitude and phase zero point showing two different maxima and minima during the 10.466-days period. The double maxima and minima argue a tidal cause.

A similar analysis of the radial velocity measures of the β Cephei star σ Scorpii (Levé, *Astrophys. J.* **115**, 402, 1952; Struve, McNamara, and Zebergs,

Astrophys. J. **122**, 122, 1955), a single-line spectroscopic binary, demonstrates a very strong correlation between the variations in the pulsation phase zero point and the tide raising potential at the center of the primary's apparent disk with a weaker correlation between the variations in the pulsation amplitude and the tide raising potential.

It is suggested that all the β Cephei and δ Scuti stars showing long-period modulation, and probably also the RR Lyrae stars exhibiting a Blazhko effect, are stars whose normal radial pulsations are caused to vary zonally over the stellar surface in amplitude and phase by the tidal deformations produced in the hydrogen- and/or helium-ionization zones by a faint companion. The observed variations in the pulsations are attributed primarily to the changing aspect of the tidal zones and secondarily to the companion's eccentric orbit.

Mean Motion of Stars in the Bars of Barred Spiral Galaxies. K. C. FREEMAN AND G. DE VAUCOULEURS, *University of Texas*.—One of us (Freeman, K. C., *Monthly Notices Roy. Astron. Soc.*, to be published) has constructed self-consistent stellar dynamical models of rotating barred systems. Referred to a nonrotating frame, the rotational component of the mean motion of stars near the minor axis of a model bar is retrograde (in the opposite sense to the rotation of the figure of the bar) but approximately equal in modulus to the rotational velocity of the bar. This effect may be understood by the decomposition of each stellar orbit in the plane of the galaxy into a direct drift of the guiding center around the bar, with frequency α , and a retrograde gyration about the guiding center, with frequency β . For a rapidly rotating bar, $\alpha \ll \beta$.

To verify the existence of this effect in a real SB galaxy, we need a system such as NGC 4027, for which the line of nodes lies near the minor axis of the bar (de Vaucouleurs, G. and A., *Astron. J.* **68**, 278, 1963). In such a system we expect the mean rotational motion of the interstellar gas to be in the same sense as the rotation of the figure of the bar. Spectra in position angles near the line of nodes should then show opposite inclination of stellar absorption lines and interstellar emission lines.

The inclination of absorption lines was determined by autocorrelation techniques applied to microdensitometer measurements of glass positive enlargements of spectrograms taken with the 82-in. reflector. Preliminary results indicate that the absorption and emission lines in spectra near the minor axis of the bar of NGC 4027 are inclined by approximately equal amounts but in opposite directions. The tilt of the emission lines is consistent with the general rotation of the system. The velocity gradient of the absorp-

tion lines across the width of the bar is of the order of 100 km sec^{-1} over $8''$ or 400 pc for an assumed distance of 10 Mpc.

This effect tends to support present ideas on the structure and stellar dynamics of SB galaxies. Further verification is important, and work in this direction is in progress.

Gas Flows through a Model Spiral Arm. M. FUJIMOTO, *Columbia University*.—It has been suggested by Lin that coherent and persisting spiral arms may be due to self-sustaining density waves in the stellar and gaseous components of a galaxy. In the stellar components gravitational forces would be of dominant importance, but in the gas specific gas-dynamic effects must also be considered. To study this problem we analyze the flow of an isothermal gas in a gravitational field corresponding to a reasonably realistic model of highly twisted spiral structure.

Extensive numerical calculations have been made which indicate that a small gravitational force due to the spiral arm leads to rather large density fluctuations (factors of 4 or so) and deviation from circular rotation (15 km/sec) in the gas. The density is highest immediately behind a shock front which takes place along the arm. The shock front and the bump (or dip) of the rotational velocity may either precede or follow the arm axis depending upon the arm spacing and the angular velocity of the spiral pattern. On the basis of these results the possibility of constructing a fully self-consistent solution for nonlinear density waves in the gas is discussed. For the larger (smaller) angular velocity of the spiral pattern, the spiral arm is less (more) tightly twisted and the central part where there is no arm is smaller (larger).

The research was sponsored by the Air Force Office of Scientific Research, Office of Aerospace Research, United States Air Force, under AFOSR contract Number AF 49 (638) 1358.

Expansion of a Relativistic Gas into Extragalactic Space. T. GOLD, *Cornell University*.—A relativistic gas which is generated in a burst inside a galaxy will be restrained by galactic magnetic fields before expanding into the surrounding space and it could be restrained by fields in extragalactic space if those exist. It is shown that such an expansion is likely to result in jets in the vicinity of the galaxy and in two centers moving away from the galaxy in opposite directions when the expansion has proceeded farther out. The comparison is made with various features of radio sources including the double nature which is commonly observed.

More on Spin-Orbit Coupling in the Solar System. PETER GOLDREICH AND S. J. PEALE, *University of California, Los Angeles*.—Previous work has shown that a satellite or planet whose spin axis is perpendicular to its orbital plane is likely to be trapped at a spin rate which is commensurate with its mean motion but not synchronous only if the orbital eccentricity is fairly large. However, if the spin axis is inclined to the orbital plane, capture into these spin states may be likely even with very small values of the orbital eccentricity. The possibility that some satellites and planets may not always rotate about their principal axes is also investigated.

Interstellar Polarization and the Strength of Galactic Magnetic Fields. J. MAYO GREENBERG, *Rensselaer Polytechnic Institute*.—The unified model of interstellar extinction and polarization (Greenberg and Shah, *Astrophys. J.* **145**, 63, 1966) based on calculations of long cylindrical particles is combined with the recent work on the Davis-Greenstein orientation mechanism by Jones and Spitzer. Calculations of the functional dependence of the degree and wavelength of polarization of incompletely oriented grains are made. The results lead to the possibility of making quantitative estimates of the magnetic field strength. Based on a simplified model of a single cloud producing the polarization it is shown that an increase of the ratio of polarization to extinction by a factor of 3 (from $\Delta m_p/\Delta m \approx 0.02$ to $\Delta m_p/\Delta m \approx 0.063$) requires an increase of magnetic field strength by a factor of about 2.3. Using an imaginary part of the magnetic susceptibility of the form $\chi = 2.5 \times 10^{-12} (\omega/T_g)$, where ω is the grain angular velocity and T_g is the grain temperature one finds the field strength required for the maximum observed polarization to extinction to be $B \approx 10^{-5} \text{ G}$. For a polarization to extinction ratio of 0.01, the minimum required field (if untangled) is $B \approx 3 \times 10^{-6} \text{ G}$.

Radio Rotation Period of Jupiter. SAMUEL GULKIS, *Arecibo Ionospheric Observatory*, AND THOMAS D. CARR, *University of Florida*.—It has been concluded from a re-examination of the results of 18 Mc/sec observations of Jupiter that the apparent rotation period drifts cyclically about a constant mean value. The most probable drift period appears to be 11.9 yr, Jupiter's orbital period. The mean rotation period during one orbital period is about 0.3 longer than the System III (1957.0) period. This is in close agreement with the rotation period deduced from decimetric observations, and probably represents the true rotation period of the magnetic field. The cyclic drift in the rotation period of source A at 18 Mc/sec is explained on the basis

of beaming of the escaping radiation at an angle 6° north of the magnetic equator. The apparent rotation period of source A depends on the rate of change of the Jovicentric declination of the earth.

The Arecibo Ionospheric Observatory is operated by Cornell University with the support of the Advanced Research Projects Agency under a research contract with the Air Force Office of Scientific Research. The research at the University of Florida is supported in part by the National Aeronautics and Space Administration. A full account of the material covered by this abstract has been submitted for publication in *Science*.

Luna 9 Pictures and the Lunar Surface. B. W. HAPKE AND T. GOLD, *Cornell University*.—The small-scale morphology of the lunar surface seen in the Luna 9 pictures has been interpreted either as a porous volcanic rock froth or as a moderately cohesive soil saturated with primary and secondary impact craters. Without additional information it is not possible to differentiate between the two models. Such information is provided by radar, radio-thermal, infrared and optical investigations of the moon, which indicate that the lunar surface is almost everywhere covered with a porous material to a depth of at least several meters. The near-universal distribution of the material strongly implies that it is externally generated. The visible scattering and polarimetric evidence indicates that this material is largely fine rock dust. Craters have been generated in the laboratory in powders by both impacts and explosions. The resulting morphology bears a remarkable resemblance to that seen in the Luna 9 pictures. Features seen on both the laboratory and lunar surfaces include: rimmed craters, rimless craters, piles of gravel-like rubble, "rocks," steep slopes, and raised linear features. It is concluded that the landscape shown in the Luna 9 pictures is largely dust of undetermined depth and undetermined degree of cohesion.

The Surveyor 1 photographs have shown that the surface near the landing site consists of dust (i.e., extremely fine-grained, moderately-cohesive rock powder). The similarity between both the appearance and the physical properties of the Luna 9 and Surveyor 1 areas suggests that the Luna 9 site also consists of similar material.

Radar evidence indicates that the depth of the soil is at least several meters, and the detailed Surveyor photographs do not contradict this.

Paradox of Classical Particles in Cosmology. E. R. HARRISON, *Goddard Space Flight Center* (Now at: Department of Physics and Astronomy, Univer-

sity of Massachusetts).—In classical cosmology the expanding universe originates from a space-time singularity of infinite density. However, if the universe consists of particles of mass m , then prior to a certain epoch of $t \sim Gm/c^3$ the classical view encounters a paradox. Either the particles can continuously subdivide as we go back in time prior to Gm/c^3 , or they are smaller than their gravitational radius. Rejecting the latter as impossible and assuming that the particles are "elementary" and indivisible we are led to the paradox. Whether the dilemma can be resolved by merely abandoning the idea of classical particles, or by sacrificing the classical view of the universe in its earliest stages, is a matter for further study.

Orbits of Sun-Grazing Comets. MARTIN HARWIT, *Cornell-Sydney University Astronomy Center*.—Comet Ikeya-Seki (1965f) was part of a family, all of whose members come very close to the sun. A number of these comets have broken into fragments and this has led to the belief that all family members are descendants of a single progenitor. If this idea is correct, one should be able to account for observed differences in the orbital parameters of fragments. We evaluate the possible changes caused by the breakup process and find that one cannot account for some of the orbital differences in this way. Planetary perturbations then are evaluated. The results allow one to decide whether or not certain doubtful family members should be considered true members of the group.

Lunar Occultation Studies of Weak Radio Sources of Small Angular Size. C. HAZARD, S. GULKIS, AND A. D. BRAY, *Arecibo Ionospheric Observatory*.—Since the beginning of 1965 about 80 occultations of radio sources by the moon have been observed using the 1000-ft spherical reflector at the Arecibo Ionospheric Observatory. The majority of these sources which lie in the flux range 0.5 to 3×10^{-26} W m $^{-2}$ (cps) $^{-1}$ at 430 Mc/sec are unlisted in existing catalogues and were found in a special zodiacal source survey made using the Arecibo instrument. The preliminary analysis of these observations confirm the conclusions drawn for previous occultation observations namely that the majority of radio sources are complex consisting of two or more components and usually contain structure of a few seconds of arc or less in size. About five sources have been observed which contain as many as five components spread over several minutes of arc but in general the radiation from sources ≤ 3 flux units arises in a region of only a few seconds of arc extent and contains structure $\leq 1''$. This paper presents the results of an analysis of several of these small angular

size sources which demonstrate the power of the Arecibo Instrument for occultation studies. The brightness distribution for these sources are given at a resolution of $0''.5$ or less and in most cases a reliable optical identification is given.

The Arecibo Ionospheric Observatory is operated by Cornell University with the support of the Advanced Research Projects Agency under a research contract with the Air Force Office of Scientific Research.

Measurement of the Electron Density in the Solar Corona at 80 Solar Radii. C. HAZARD, S. GULKIS, AND A. D. BRAY, *Arecibo Ionospheric Observatory*.—Observations of the immersion phase of a lunar occultation of the double radio source 3C273 were made at the AIO on three frequencies, 41.7, 195, and 430 Mc/sec. The circumstances of the occultation were such that the two components of the source passed successively behind the moon with an apparent separation of 15 sec of arc thus allowing a clear separation of the two sources.

The relative positions of the two components agree within experimental error at 195 and 430 Mc/sec whereas the 41.7 positions are displaced by about 5 sec of arc from the higher frequency observations and in a sense corresponding to an earlier immersion time. It is shown that the most probable explanation for the apparent displacement is that it is due to refraction in either the solar corona, the lunar atmosphere, or both.

On the assumption that all the refraction occurs in the solar corona, the electron density at 80 solar radii is 380 electrons/cc, this value being nearly independent of the density power law. Assuming that the density decreases as inverse square of the distance from the sun then the electron density at 1 a.u. is 44 electrons/cc. This value is consistent with the values estimated from observations of the zodiacal light.

The Arecibo Ionospheric Observatory is operated by Cornell University with the support of the Advanced Research Projects Agency under a research contract with the Air Force Office of Scientific Research.

Absolute Radio Luminosity and Surface Brightness of Extragalactic Radio Sources. D. S. HEESCHEN, *National Radio Astronomy Observatory*.—An empirical relation between absolute radio luminosity and surface brightness of extragalactic radio sources is described. The relation is well defined over a range of at least nine orders of magnitude in each parameter. Spiral and irregular galaxies appear to form a separate sequence, distinct from

that of the more intense radio galaxies. Quasi-stellar sources form a continuation of the radio galaxy sequence, if they are at cosmological distances.

It is suggested that the sequences represent the loci of stationary points in the evolution of extragalactic sources.

Diminution of Cometary Heads during Perihelion Passage. W. F. HUEBNER, *University of California, Los Alamos Scientific Laboratory* (introduced by SIDNEY N. STONE).—The amount of icy conglomerate that is sublimated from the surface of a cometary nucleus is calculated from the time integral of the sublimation rate. The sublimation rate used (Huebner, W. F., *Z. Astrophys.* 63, 22, 1965) gives general agreement with estimates made by Biermann and Trefftz (*Z. Astrophys.* 59, 1, 1964) for gas productivities for comets in which the forbidden [O I] lines have been observed, and is by powers of 10 higher than the estimates based on the intensity of observed molecular bands. The amount of sublimation is correlated with data reduced from observations of some comets. The mass loss calculated for comet Encke agrees with that from Whipple's "pinwheel" effect. The calculated mass loss for comet Halley is larger than the one estimated from intensities of molecular bands in the tail, and suggests that there are more nonluminous molecules in the tail than had been assumed.

The average reduction of reduced brightness per perihelion passage for the above comets cannot be explained to be due to the reduction of gas producing surface area; the reduction being caused by the sublimation of a layer of ice. The gas production rate itself must decrease, presumably through the accumulation of meteoritic material acting as an insulation layer on the surface. On the other hand, for sun-grazing comets, the reduction of gas producing surface area is an important factor in explaining the reduction of reduced brightness after perihelion passage as compared to that before perihelion passage.

This work was performed under the auspices of the U. S. Atomic Energy Commission.

Evolution to the Giant Phase for Low-Mass Population I Stars. ICKO IBEN, JR., *Massachusetts Institute of Technology*.—Evolution from the main sequence to the red-giant phase is discussed for Population I stars of mass $M/M_{\odot}=1, 1.25, \text{ and } 1.5$. Time spent by a star burning hydrogen in a thick shell relative to the time spent in the core hydrogen-burning phase is found to be a strongly decreasing function of stellar mass. Partially responsible for this mass dependence are three factors: (1) for more massive stars, the mass fraction in the convective

core, and hence the mass over which hydrogen is exhausted at the end of the core hydrogen-burning phase, is closer to the effective Schönberg–Chandrasekhar limit; (2) with decreasing stellar mass, the variation of hydrogen through the shell becomes more gradual, and (3) with decreasing mass, electron degeneracy becomes more important in the hydrogen-exhausted core during the thick shell-burning phase. The latter two factors have the effect of increasing the Schönberg–Chandrasekhar limit.

During and following the shell-narrowing phase in all three stars, the surface Li abundance decreases regularly with decreasing surface temperature as envelope convection extends deeper and deeper into the star. Such is the case also for the surface ratio of ^{12}C to ^{14}N . Comparatively large amounts of ^3He are made in all three stars and it is suggested that a large fraction of the ^3He in the Galactic disk was perhaps formed in ordinary stars.

Comparison of individual tracks with cluster diagrams for NGC 188 and M67 provides evidence for the qualitative correctness of several characteristic features of the theoretical tracks. The pronounced and rapid change in luminosity and in surface temperature during the phase of over-all contraction is related to a "gap" in M67; the decrease with decreasing mass in the magnitude of the luminosity drop during the shell-narrowing phase is related to the change with cluster age in the slope of the subgiant branch; for a given luminosity the decrease with decreasing mass in surface temperature along the giant branch is related to the decrease with increasing cluster age in surface temperature along the cluster giant branch. The ages of NGC 188 and M67 are estimated to be $(11 \pm 2) \times 10^9$ yr and $(5.5 \pm 1) \times 10^9$ yr, respectively.

Comparison of Exact with Approximate Solutions of the Equation of Transfer for very Elongated Phase Functions. WILLIAM M. IRVINE, *Harvard College Observatory and Smithsonian Astrophysical Observatory*.—The scalar equation of radiative transfer in a homogeneous medium is solved for phase functions characteristic of terrestrial clouds and hazes. Parallel radiation from a distant source is assumed to be incident on a layer which contains no internal sources. The albedo and transmissivity, as calculated from the Neumann solution and the "doubling" method of van de Hulst, are compared with the corresponding results obtained from Eddington's approximation and the two-stream (Schuster–Schwarzschild) approximation. The two-stream approximation is more accurate for small to medium optical depths, while the Eddington approximation becomes increasingly better for thicker layers. Both approximations fail for large angles of incidence.

A comparison of the reflected and transmitted intensities with corresponding results obtained by Romanova is made.

UBV Photometry of SV Centauri. JOHN B. IRWIN, *Carnegie Institution of Washington, La Serena, Chile*.—The 1.66-day variable SV Centauri has one of the most remarkable variations of period known. *UBV* observations have been made with the Cerro Tololo 16-in. reflector. A complete light curve was obtained in 1965 and an accurate time of both primary and secondary minima in 1966. The 34-yr cyclic variation of O'Connell (*Riverview College Obs. Publ.* No. 9, 69, 1949) has not been confirmed; the residuals, $(O-C)$'s, from O'Connell's parabolic formula were $+0.977$ days (at $E=10589$) and $+1.083$ days (at $E=10859$). These indicate that very large changes have taken place in the parabolic variation and that patrol plates should be analyzed for the times of minima over the last 17 yr.

The three-color photometry indicates an ultraviolet color excess of 0.7 mag provided that the spectral type of B8 is correct. The photometric observations alone imply a heavily reddened star, earlier than B0. Spectroscopic observations of the spectral types, the velocity curves, evidence of a third component and of mass loss would be desirable in order to more fully understand this uniquely peculiar Beta Lyrae type system.

Photochemical Effects in the Formation of Cometary Radicals and Ions. WILLIAM M. JACKSON AND BERTRAM DONN, *Goddard Space Flight Center*.—Calculations of the photochemical yield of radicals and ions for a region within 5000 km of the nucleus have been carried out. In this region the photochemical loss of daughter molecules can be neglected. The theoretical basis for the determination of the density of the parent species is the continuity equation in which we include a term to account for photodissociation or ionization. The variation of lifetime for these processes with nuclear distance because of changing optical depth within the coma was allowed for.

The solution of the equation yielded equidensity contours for both radicals and ions for nuclear radii of 0.5, 1, and 5 km. The C_2 radical density was calculated to be $2 \times 10^2/\text{cm}^3$ at 10^3 km, for a 0.5 km comet radius, a relative abundance of 10^{-4} for the C_2 parent molecule, and a dissociation cross section of 10^{-17} cm^2 . CO^+ densities at 1000 km were of the order of $10^4/\text{cm}^3$ for relative CO concentrations of about 0.5. The ion distributions were strongly concentrated in the sunward direction for nuclear radii greater than 1 km. As CO^+ and C_2 have comparable f values, CO^+ will be visible near the nucleus.

The density of the observed species depends directly upon the corresponding parent densities and the flux of solar radiation. Rapid changes in either of these quantities will cause rapid changes in the densities and hence luminosities of these ions and radicals.

The present calculations are based upon a reasonable model of the composition of the nucleus of a comet and show that the parents of the observed radicals represent only a minor constituent. The large CO concentration in some comets is consistent with molecular equilibrium calculations for the primordial solar nebula.

Temperature Distribution in the Solar Corona.

CAROLE JORDAN (introduced by R. H. Garstang), *Joint Institute for Laboratory Astrophysics*.—The intensity of an extreme ultraviolet emission line can be used to give the quantity of emitting material in the temperature range relevant to the formation of that line. Analysis of emission lines from a range of elements and ions enables the distribution of the above quantity, usually expressed as $\int_R N_e^2 dh$, with temperature to be found (Pottasch, S. R., *Astrophys. J.* 137, 945, 1963).

The analysis of Pottasch has been repeated using ionization equilibrium calculations which have included the process of di-electronic recombination. The results have been extended by the inclusion of recently identified lines of Fe VIII–XIV and Ni X–XIII which have enabled the high-temperature part of the distribution to be determined more accurately. The distribution now shows a maximum at a temperature of 1.5×10^6 °K, indicating a basically isothermal corona with a temperature near this value. Ions formed at greater temperatures should, and do, show variations with solar activity.

Using the equation of hydrostatic equilibrium the observed distribution of $\int_R N_e^2 dh$ with temperature has been interpreted in terms of the temperature gradient with height. The range of possible models has been limited by boundary conditions set by other types of observations. The final model is characterized by a very sharp rise in temperature from about 25 000 ° to 560 000 °K over a height of 200 km, a constant value of $N_e T_e = 5.6 \times 10^{14}$ °K cm⁻² over this transition region, and an isothermal temperature of 1.8×10^6 °K reached about 40 000 km. In accordance with the ideas of Suemoto and Moriyama, the transition region should form a layer around spicules where these exist. Between spicules it is suggested that the transition will occur at a height of about 2500 km above the base of the chromosphere.

Instrumentation Program for an Improved Meridian Circle at the U. S. Naval Observatory.

B. L. KLOCK, *U. S. Naval Observatory*.—In recent years requirements have arisen for greater precision in the positions and proper motions of the coordinate system defined by the fundamental stars. To obtain this increased accuracy, a program for improved instrumentation has been planned by the U. S. Naval Observatory's meridian circle department. The program is designed to span a five-year time interval, during which the Observatory would sequentially obtain the following instrumentation: (1) an electronic angular readout system, (2) an automatic star tracker, (3) a new meridian telescope.

Subsequently, in order to realize the full precision of the new instrument, it will be necessary to design and construct a new pavilion at a site where the number of clear nights, seeing conditions, and transparency will give maximum utilization of the new instrumentation.

The estimated date for completion of this program for improved meridian circle instrumentation is 1970. The program is being sponsored through funds made available by the Office of Naval Research.

Observations of Intergalactic H I. J. A.

KOEHLER, *Arecibo Ionospheric Observatory*.—Intergalactic H I in the Virgo cluster of galaxies was detected in observations made with the 210-ft radio telescope of the CSIRO, Australia. The 21-cm spectra of Virgo A and 3C273 showed absorption features with a peak optical depth of 6×10^{-3} at a velocity of 1100 km/sec. The dispersion of the profiles was ~ 600 km/sec. The radius of the cluster as defined by H I is ~ 3 Mpc. The spin temperature of the H I was theoretically estimated to be 4°K and on this basis, the total H I mass of the Virgo cluster is $\sim 10^{13} M_\odot$.

No similar absorption feature due to the Fornax cluster of galaxies was observed in the spectrum of Fornax A. However, an absorption feature due to general, noncluster, intergalactic H I was detected. Assuming the spin temperature of the H I is 4°K, the optical depth of 2.4×10^{-3} corresponds to a mean atom density of 4.4×10^{-7} atoms/cm³.

The Arecibo Ionospheric Observatory is operated by Cornell University with the support of the Advanced Research Projects Agency under a research contract with the Air Force Office of Scientific Research.

Interaction of Neutral Hydrogen and Electrons and Protons in the Radiation Belts: and the Consequent Lyman- α Emission. YOJI KONDO AND J. E. KUPPERIAN, JR., *Goddard Space Flight Center*.—A new theory is proposed in this paper to explain the diffused nighttime Lyman- α radiation

observed from the rocket-borne instruments carried to the height of about 120 km or higher.

The theories thus far advanced interpret the diffused nighttime Lyman- α radiation primarily as solar Lyman- α photons scattered by neutral hydrogen atoms, be they interplanetary, geocorona, geocoma or geotail hydrogen.

The recent observations obtained by rocket-borne instruments at White Sands, New Mexico, suggest that there exists a directional variation of the Lyman- α intensity which is correlated with the geomagnetic field. This correlation consists of three features: namely, (1) the general increase of the flux in the direction of the geomagnetic north pole and the general decrease in the direction of the geomagnetic equator; (2) a trough of lower intensity along the geomagnetic dipole plane containing the observer's geomagnetic zenith; and (3) the symmetric increase of the flux on both sides of the trough. Also, the direction of decrease does not agree with the antisolar direction, as was previously thought. This suggests an association of the Lyman- α emission with the Van Allen radiation belts.

The theory proposed in this paper principally attributes the diffused nighttime Lyman- α radiation to the collision between the neutral hydrogen atoms and the electrons and protons in the radiation belts, though there will be some contribution from the scattered solar Lyman- α photons and the Lyman- α photons of interstellar origin.

Proposed Hydromagnetic Model for Comets.

N. S. KOVAR AND J. W. KERN, *University of Houston*.—Today it is widely thought that Type I comet tails are caused by an interaction between the solar wind and cometary molecules evaporated from the nucleus. Here loading of the solar wind by ionization of neutral cometary molecules is calculated. Four ionization mechanisms are considered: collisional ionization by solar-wind electrons; charge exchange between solar-wind protons and neutral comet molecules; photo-ionization; and cascade ionization by cometary ions accelerated by the solar plasma flow.

Equations for continuity of energy, momentum, mass, and solar-wind electron flux are formulated and an adiabatic relation between the solar wind pressure and the density of original solar-wind electrons is assumed. Expressions are obtained for the velocity, mass density, and Mach number of the flow. The distance at which pressure and density go to zero is calculated.

Several conclusions are drawn. The momentum flux density is reduced in the comet head, especially in the vicinity of the nucleus. The distances at which the momentum flux density goes to zero for reasonable solar-wind parameters are in accord with

Wurm's observation that the tail ions are limited to a distance of less than 10 000 km centered on the nucleus. The derived comet ions that load the solar wind have number densities which may be too small to be observed—of the order of 0.01 cm^{-3} or less. The Mach number of the flow is found to increase in the vicinity of the nucleus, making the presence of a shock upstream unlikely. For radial distances larger than the characteristic size of the ion coma, the most important loading mechanism is found to be charge exchange between neutral cometary molecules and solar-wind protons.

This research was supported by NASA Grant 44-005-022.

Studies of Stellar Rotation. IV. Rotational Velocities of Stars in the α Persei Cluster.

ROBERT P. KRAFT, *Mount Wilson and Palomar Observatories, Carnegie Institution of Washington, California Institute of Technology*.—The quantity $\langle V \sin i \rangle$, the mean rotational velocity as a function of M_V , has been determined from spectrograms of a sample of stars in the α Per cluster, virtually complete to $M_V = +3.5$ (80 stars). The α Per and Pleiades clusters are compared with respect to color-color and color-magnitude diagrams as well as binary frequency and $\langle V \sin i \rangle$. It is found that $\langle V \sin i \rangle$ in α Per is similar to, but is nevertheless somewhat larger than, $\langle V \sin i \rangle$ in the Pleiades over the full range of M_V under investigation.

Ohio State University Sky Survey. JOHN D. KRAUS, *Ohio State University Radio Observatory*.

—A source and mapping survey of the sky has been in progress for 3 yr using the Ohio State University 260-ft radio telescope. About 4500 sq deg of sky have been surveyed to date. Observations have been made at 610 and 1415 Mc/sec with the latter as the principal survey frequency. Digital output and data reduction by computer programs are employed to prepare the source lists and contour maps (Kraus, Dixon, and Fisher, *Astrophys. J.* **144**, 559, 1966; Scheer and Kraus, *Astron. J.* **71**, 179, 1966). For a limit of 0.3 flux units at 1415 Mc/sec the source density is about 1 per 3 sq deg or 25 beam areas per source. This amounts to about 1500 sources in the area covered so far. The survey is continuing at the rate of several thousand square degrees per year and will soon enter a new phase with the addition of a third survey frequency at 2700 Mc/sec.

Comparisons are made between sources on the Ohio list and the Cambridge (3C revised and 4C) and Illinois lists with respect to position and between these lists plus the Parkes and Sydney lists with respect to number-flux density counts.

Cosmological Distortion Effect. JEROME KRISTIAN, *Washburn Observatory*.—An upper limit has been set on the incident magnetic-type gravitational field by an attempt to measure the distortion effect (Kristian and Sachs, *Astrophys. J.* **143**, 379, 1966). Certain components of the large scale curvature of space time would, if great enough, produce systematic distortions of the images of distant objects, including an alignment of the images of galaxies located in a given direction. Existing direct photographs of clusters of galaxies taken with the Hale telescope were measured to give a firm upper limit for the effect and for the corresponding components of the curvature tensor.

Two Lunar Occultations of Radio Sources. T. KRISHNAN AND K. LANG, *Stanford Radio Astronomy Institute*.—Two recent occultations of the radio sources MSH 19-23 and 3C444 have recently been observed, at 425 and 406 Mc/sec, respectively, at Stanford using the SRI/SU 150-ft diameter paraboloid. Their flux densities are ~ 30 and ~ 20 flux-units.

Comparison of the occultation curves of MSH 19-23 with theoretical diffraction patterns specifies the angular diameter along the position angle P of occultation. For disappearance, $P=3^\circ.3$, the diameter is $8''.2$ and for reappearance, $P=327^\circ.1$, the diameter is $7''.4$. Convolution with a $3''$ restoring function gives brightness distributions along the position angle of half-power widths $7''.75$ and $6''$ for disappearance and reappearance, respectively. The position of MSH 19-23 as determined from occultation times is

$$(1950) \alpha = 19^h 12^m 52^s.34 \pm 0''.4, \\ \delta = -26^\circ 57' 22''.7 \pm 6''.$$

The errors quoted are estimated limits of error.

Restoration of the occultation curve of 3C444 at disappearance reveals the existence of three components, A, B, and C, whose peak intensities are in the ratio 4:2:1, running east to west at a mean position angle of 90° . The respective half-widths of the equivalent Gaussian sources are $22''$, $16''$, and $35''$. The separation between A and B is $72''.5$ and between B and C is $55''$. At reappearance, a position angle of 205° , a single source of width $25''$ is observed, though there is some indication of an unresolved double at the $10''$ restorations. The position of the source is difficult to determine in the presence of the complex nature of the source, but the position of greatest flux is, within the combined limits of error, in agreement with the value given by De Jong (De Jong, M. L., *Astron. J.* **71**, 373, 1966). A more detailed comparison with De Jong's curves, and observations of two more occultations due at Stanford this year, are being undertaken which would enable

a more complete understanding of the structure of the source.

This work was supported by the Air Force Office of Scientific Research under Contract AF49(638)-1375.

Preliminary Report on Intermediate-Bandwidth Photometry of E and S0 Galaxies. BARRY M. LASKER, *Mount Wilson and Palomar Observatories*.—A system of intermediate-bandwidth photometry whose eight passbands, located between 3400 and 8000 Å, generally avoid strong-line features for redshifts up to ~ 5000 km/sec is used to observe E and S0 galaxies selected from the general field, from small groups of galaxies, and from the rich clusters. The principal purposes of this program are to determine (a) how homogenous the continuous spectral energy distribution is among the normal giant E's and S0's ($-20 > M_r > -22$) and (b) what color-magnitude relations exist among such objects when a greater range of absolute magnitude is considered.

From a preliminary analysis of the data for about 50 galaxies it appears that, at least for $\lambda \geq 4700$ Å, the observed colors are generally homogenous to better than 0.1 mag among objects with large absolute luminosity. Furthermore, it is found that the galaxies fainter in absolute luminosity are systematically bluer than the giant ones. These results strengthen the hypothesis that a well-defined K correction exists for E and for S0 galaxies.

Variations of K -Emission Lines in Late-Type Stars. WILLIAM LILLER, *Harvard College Observatory*.—Intensities and shapes of emission components of the K line in nine stars of spectral type G2 to M0 were monitored photoelectrically for 11 months in 1964-65. Small changes were frequently observed as shown, and a flare was seen on Aldebaran.

Support of the Envelopes of Be Stars. D. NELSON LIMBER AND J. M. MARLBOROUGH, *Yerkes Observatory*.—The problem considered is that of the support of the envelopes of Be and shell stars. The traditional view that the circular velocity in such an envelope decreases outward from a value equal to the star's critical equatorial velocity just above its equator in such a way as to correspond to the conservation of angular momentum with respect to the rotation axis is shown to be untenable. Evidence is presented to support the view that the circular velocity law is, instead, such that the centrifugal force balances the star's gravitational force at all points in the equatorial plane. The nature of the viscous

agent that is responsible for this velocity law is considered. It is shown that turbulence of the kind to be expected in such differentially rotating envelopes can account for the viscosity in question and for the support of the envelopes perpendicular to their equatorial planes. Certain implications are drawn from these results.

Surface Temperatures in Late-Type Model Atmospheres. JEFFREY LINSKY, *Smithsonian Astrophysical Observatory*.—In a study of model atmospheres of late-type stars presently under way by Owen Gingerich, David Latham, and myself, we have noted that the temperatures of the superficial layers of these stars vary appreciably for stars with the same effective temperature but different gravity or opacity sources. In these models Rayleigh scattering of molecular and atomic hydrogen dominates at short wavelengths at small optical depths and H^- , H_2^- , and He^- are the important opacity sources in the infrared, if water vapor is not considered.

Assuming radiative equilibrium and LTE, the surface temperatures of these stars are controlled by the frequency-dependence of the surface opacity, exclusive of scattering, and the radiation field. For models of 2500°K effective temperature, molecular hydrogen rapidly dominates over atomic hydrogen as one goes from a supergiant to a dwarf, so that H_2^- and He^- increasingly overwhelm H^- in the infrared. The effect is to redden the opacity and to lower the surface temperature, as shown in Table I.

TABLE I. Effective temperature 2500°K.

log g	Surface temp	Temperature inversion	Remarks
All	2028°K	0°K	Grey opacity
1	1925	63	Minimum at $\tau_{1\mu}=0.03$
1	1992	118	Metals lowered by factor of 100
3	1720	130	Minimum at $\tau_{1\mu}=0.01$
3	1412	0	H_2O included
5	1435	0	

Typically, the relative importance of H_2^- and He^- to H^- in the infrared decreases with height at small optical depths, leading to temperature inversions as large as 130°K. At higher temperatures the relative importance of H_2^- and He^- compared to H^- rapidly decreases, so that for models of 3500°K no such gravity dependence occurs. The inclusion of water vapor also reddens the opacity, thereby depressing the surface temperature further.

These models suggest that temperatures derived by analyses of molecular lines and bands can differ considerably from the effective temperature of the star.

Evolution of the Great Sun-Grazing Comet Group. B. G. MARSDEN, *Smithsonian Astrophysical Observatory*.—The apparent distribution of the times of perihelion passage of the known members of the sun-grazing comet group is far from uniform. There are good reasons for including comets 1689, 1695, 1702a and Tewfik (the eclipse comet of 17 May 1882) among the group, and then the three clusters, separated in time by a century or two, are even more obvious. In view of this, it is reasonable to suppose that, if the observed comets are indeed returning fragments of a larger comet that broke up at its perihelion passage, then that breakup took place the *last* time around. It is tempting to identify the parent comet with the enigmatic comet of 1106, and then with an alleged daylight comet of 368 and the celebrated comet of -371, described by Aristotle. There is some observational evidence that all but possibly the principal fragments of a comet that has split do not survive more than one or two further returns to perihelion. The clusters would be associated with multiple nuclei similar to those observed in comets 1882 II and 1965f, and the individual comets would have been indistinguishable even if present observing techniques had been available. It has been found that the orbital elements of the best observed comets may be represented very closely by

$$\left. \begin{aligned} \omega &= 68^{\circ}.94 & +17^{\circ}.87 & \sin(\lambda' + 99^{\circ}.18) \\ \Omega &= 346^{\circ}.84 & +20^{\circ}.75 & \sin(\lambda' + 100^{\circ}.81) \\ i &= 142^{\circ}.23 & +2^{\circ}.50 & \sin(\lambda' + 108^{\circ}.15) \end{aligned} \right\} 1950.0$$
$$q = 0.007487 - 0.002307 \sin(\lambda' + 105^{\circ}.98) \text{ (a.u.)},$$

where λ' is the longitude of Jupiter when the comets are at perihelion. Assuming that the orbits of the fragments differed at the breakup only in semimajor axis (and hence revolution period), expressions similar to the above arise from the subsequent differential attraction of Jupiter, except that the calculated coefficients are about an order of magnitude smaller than those observed. Since this result has been obtained both by a simple general theory and by direct numerical integration of typical orbits, it is hard to believe it is incorrect. One concludes that the differences among the orbital elements of the members of the group cannot be explained by planetary perturbations and that the apparent dependence upon the position of Jupiter is probably fortuitous.

Survey of High Negative-Velocity Hydrogen Clouds. D. S. MATHEWSON, S. Y. MENG, W. D. BRUNDAGE, AND J. D. KRAUS, *Ohio State University Radio Observatory*.—A sky survey of discrete neutral hydrogen clouds at galactic latitudes greater than $\pm 10^{\circ}$ is in progress using the Ohio State University 260-ft radio telescope. The sensitivity and stability of the eight-channel hydrogen-line parametric

receiver allow the measurement of antenna temperature differences of 0.5°K. The velocity resolution of each channel is 20 km/sec. Drift scans, spaced 1° in declination, are made with 16 different radial velocity settings which cover the range from -250 to +60 km/sec. New high-velocity clouds of the type discovered by the Leiden group (Hulsbosch and Raimond, *IAU XII*, 1964) at intermediate and high galactic latitudes are being found.

In particular, a number of relatively bright clouds (2° to 3° T_b) have been found within 10° of the direction $l^{II}=188^\circ$, $b^{II}=+66^\circ$ with velocities ranging from -80 to -120 km/sec (relative to the local standard of rest) and with velocity half-widths not much greater than 20 km/sec. In the same general area many lower velocity clouds (0 to -80 km/sec) have been found with very similar intensities and angular sizes. They appear to be part of a very extensive neutral hydrogen structure which extends over a large part of the sky. At lower latitudes, in the direction $l^{II}=184^\circ$, $b^{II}=-11^\circ$, a very high-velocity cloud (-205 km/sec) has been discovered. It is to be noted that in directions near $l^{II}=180^\circ$ the radial velocities should be almost entirely free of differential rotation effects.

Electromagnetic Spectrum of η Carinae. RICHARD MCCRAY (introduced by Stanton Peale), *University of California, Los Angeles*.—A physical model for the object η Carinae is described under the assumption that the optical continuum is synchrotron radiation. The absence of measurable radio emission is interpreted as the Tsytovich effect. Strong radio emission at higher frequencies is predicted. The x-ray and γ -ray flux from the object due to inverse Compton scatterings is estimated. It is shown that the flux of 100 MeV γ rays should be measurable, while the x-ray flux is more uncertain. The interrelationship of fluxes in the centimeter millimeter radio band, infrared, x rays, and γ rays is discussed.

Brightness Temperature Distribution, Flux Density Ratios, and Polarization of the Strongest Nonthermal Radio Sources at $\lambda=1.95$ cm Wavelength. P. G. MEZGER AND J. SCHRAML, *National Radio Astronomy Observatory*.—The flux densities of six nonthermal radio sources relative to the flux density of Taurus at 15.3 GHz have been determined by integrating contour maps obtained with the NRAO 140-ft telescope. The results are given in column 4 of Table I. Column 5 gives the results obtained in 1964 using the NRAO 85-ft telescope No. 1 (Baars, Mezger, and Wendker, *Astrophys. J.* 142, 122, 1965).

There is good agreement between the two sets of flux density measurements with the exception of the flux density of Cassiopeia A, where the 1966 observations yield a flux density which is 26% higher than the value obtained in 1964. This new result yields a straight Cassiopeia spectrum in the frequency range 300 MHz $\leq \nu \leq$ 15 GHz. Columns 2 and 3 of Table I give the parameters of the integrated linear polarization of the investigated sources. Only in the case of Taurus A do the polarization parameters pertain to an area of about 2 min of arc diameter around the center rather than to the integrated brightness temperature distribution.

Source	Integrated polarization		$S_{15.3}(\text{Source})$	$S_{14.5}(\text{Source})$
	p (%)	ϕ_p	$S_{15.3}(\text{Tau A})$ Epoch 1966.3	$S_{14.5}(\text{Tau A})$ Epoch 1964.4
Tau A	11.4 $\pm$ 0.3	150° $\pm$ 2°	1.000	1.000
Cas A	...	...	0.829 $\pm$ 5%	0.657 $\pm$ 8%
Cyg A	3.1 $\pm$ 0.9	0° $\pm$ 8°	0.207 $\pm$ 5%	0.223 $\pm$ 9%
Vir A	3.9 $\pm$ 0.4	58° $\pm$ 6°	0.064 $\pm$ ^{7%} _{5%}	0.068 $\pm$ 10%
NGC 1275	0.80 $\pm$ 0.45	139° $\pm$ 34°	0.070 $\pm$ 5%*	
3C273	0.65 $\pm$ 0.3	150° $\pm$ 27°	0.109 $\pm$ ^{10%*} _{5%}	
Ori A	0.40 $\pm$ 0.1	133° $\pm$ 18°	...	

* Observations made on 29/30 March 1966.

With an angular resolution of 2 min of arc it was possible to separate the polarization of east and west components of Cygnus A. The values obtained ($p=5.2\pm2.5\%$; $\phi_p=165\pm5^\circ$) show that the "uniform field" polarization model recently proposed by Soboleva (*Astron. Zh.* 43, 266, 1966) cannot be correct.

Large Telescope Proposal. RICHARD H. MILLER, *University of Chicago*.—A scheme for constructing large telescopes is proposed in which the heavy complex tube structure (normally used to maintain the precise positioning of the prime focus relative to the primary mirror) is replaced by a servo system that derives its input from an elaborate measurements system. Loads at the prime focus are supported by a single beam reaching from the primary mirror mounts. An altazimuth mounting keeps the design of this beam especially simple. We are considering whether to undertake a program to construct a modest telescope (~ 60 –80 in.) according to these ideas, to determine by actual use whether the design would be feasible for large telescopes.

Observations of CG Cygni. EUGENE MILONE, *Yale University Observatory* and *Kitt Peak National Observatory*.—*UBV* observations of this 0^d.6 period eclipsing binary obtained at Kitt Peak, Dyer, and Yale Observatories in 1965 are compared to earlier photographic and visual data, and reveal a changing

light curve. The light curves show asymmetries in the maxima of the order:

δm	Band	Year	Observer	Reference
-0.06	V	1965	Milone	unpubl.
-0.07	B	1965	Milone	unpubl.
-0.10	U	1965	Milone	unpubl.
+0.01	visual	1921	Williams	<i>Monthly Notices Roy. Astron. Soc.</i> 82 , 300, 1922
+0.05	Pg	1922	Yü	<i>Astrophys. J.</i> 85 , 75, 1923
+(?)0	visual	1931	Tsesevicha	<i>Odessa Izv.</i> 4 , I, 1954
+0.00	Pg	1951-3	Tsesevicha	<i>Odessa Izv.</i> 4 , I, 1954

where $\delta m=m'-m$, m is the apparent magnitude at post-primary eclipse maximum, m' is the apparent magnitude at pre-primary eclipse maximum.

The current sign of the δm differs from that of most of the stars tabulated by O'Connell (*Riverview Pubs.* **II**, 85, No. 6) although the wavelength dependence of the magnitude of the effect agrees.

Some provisional comments are made about the components of the system in the light of the *UBV* observations and the past photometric history of the binary.

Observations of the Moon near 1-cm Wavelength. J. M. MORAN, JR., AND D. H. STAELIN, *Massachusetts Institute of Technology*.—Observations of the moon were made with the 28-ft antenna at Lincoln Laboratory and a receiver with channels at 32.4, 29.5, 25.5, 23.5 and 21.9 GHz (Staelin and Barrett, *Astrophys. J.* **144**, 1, 352). A total of 340 drift scans were taken between 15 June and 15 August 1964.

Because of long-term gain fluctuations, the harmonics of the equatorial brightness temperature were found from the slopes of the drift scans rather than their amplitudes. These slopes, computed by fitting a straight line to the center half of each scan, vary harmonically with time. The constants of proportionality between the harmonics of the brightness temperature and those of the slopes involve convolution integrals which are virtually independent of the lunar model. The presence of higher harmonics in the brightness temperature is more readily detected by this technique. The average lunar brightness temperature was assumed to be 217°K. The system was not otherwise calibrated.

The results are listed in Table I. The first harmonic amplitudes are consistent with other published results. This is the lowest frequency at which the second harmonic has been measured and its amplitude appears to be higher than that predicted by a homogeneous model. The second and higher harmonics should yield information about the vertical stratification of the lunar surface.

TABLE I.

Frequency (GHz)	T_{B0} (°K) (assumed)	T_{B1} (°K)	Ω_1 (°)	T_{B2} (°K)	Ω_2 (°)	T_{B3} (°K)
21.9	217	21±2	41±5	5±1	38±5	<1
23.5	217	22	48	6	31	<1
25.5	217	25	42	6	40	<1
32.4	217	29	41	8	38	<1

With another receiver at 35.0 GHz drift scans across the center of the moon were made near transit alternately with vertical and horizontal polarization. The peak difference in antenna temperatures was 5.5% of the central temperature which implies an effective dielectric constant of 1.5.

The measurements were made with the assistance of the staff of Lincoln Laboratory, MIT, and supported principally by the National Aeronautics and Space Administration (Grant NsG-419).

Ephemerides of the Earth and Venus from Radar. D. O. MUHLEMAN, *Cornell University* and *Jet Propulsion Laboratory*.—Corrections to the classical orbital elements of the earth and Venus and the astronomical unit have been obtained from radar observations of Venus carried out at the Jet Propulsion Laboratory. The observational material consists of Doppler velocity and range measurements taken over the period from March 1961 to April 1966.

A new determination of the astronomical unit consistent with 149 598 000 km has been obtained as well as a statistically significant correction to the mean longitude of Venus relative to the earth of 0.9 sec of arc. Significant corrections were also obtained for the eccentricities of the orbits of the two planets.

A new working ephemeris of Venus relative to the earth has been computed and comparisons with radar observations from other observatories are presented.

Self-Consistent Models of Disk Galaxies. EDWARD WAI-KWOK NG, *Columbia University*.—Time-independent models have been constructed for disks made up of stars with long mean free paths. A stellar distribution function $f(E,J)=Ae^{-\alpha E+\beta J}$, cut off at the velocity of escape, has been assumed, where E and J are the energy and angular momentum integrals, and A , α , and β are free parameters. Such a distribution function satisfies the time-independent collision-free Boltzmann equation with an axisymmetric potential. The disks are self-gravitating. Thus the above distribution is substituted in the right-hand side of Poisson's equation, which then becomes a nonlinear equation for the potential. An iterative procedure for

the solution of this equation has been developed and numerical results have been obtained with the Columbia IBM 7094 computer for different values of the relevant parameters.

This research was supported in part by National Science Foundation Grant GP4194.

Center-to-Limb Variations of the Solar Continuum in the Far Infrared and Millimeter Wavelength Regions. R. W. NOYES, *Smithsonian Astrophysical Observatory*, J. M. BECKERS, *Sacramento Peak Observatory*, F. J. LOW AND A. W. DAVIDSON, *Lunar and Planetary Laboratory of the University of Arizona*.—Observations of the intensity distribution near the solar limb at $24.3\ \mu$ have been obtained, and show that limb darkening at this wavelength persists at least to within 10 arc sec of the limb. This implies that the temperature minimum in the solar atmosphere must be broader and/or lie higher than indicated in either the Pagel (*Astrophys. J.* 133, 924) or Utrecht (*Bull. Astron. Inst. Neth.* 17, 442) models.

Drift curves of the sun and moon at 1.2-mm wavelength, obtained in 1965 at NRAO, have also been examined. Although the curves do not explicitly show brightening at the solar limb, the presence of considerable solar limb brightening at this wavelength is deduced. The excess flux due to this brightening amounts to 14% of the flux from a uniform disk with intensity equal to that at the center of the solar disk. This amount of limb brightening is in good accord with published absolute brightness temperature observations throughout the millimeter region.

Construction of Galactic Stellar Orbits Similar to Harmonic Oscillators. A. OLLONGREN (introduced by G. M. Clemence), *Yale University Observatory and Central Computing Institute, Leiden, Netherlands*.—Numerical computations of orbits of stars in galactic potential functions have indicated the existence of orbits which trace curves in a moving meridian plane topologically equivalent to curves of harmonic oscillators in two dimensions. This observation raises the question whether a dynamical connection can be established between galactic stellar orbits and two-dimensional harmonic oscillators. The affirmative answer can be given in the following way:

Starting from a two-dimensional harmonic oscillator with its own configuration space and with a given ratio of frequencies of oscillation, it is possible to construct a galactic stellar orbit of the required kind. This is done by applying a coordinate transformation and a transformation of the time such that the topology of the orbits in the configuration space is pre-

served. The resulting galactic orbits may be called *similar* to the given harmonic oscillator.

The transformation functions have to satisfy a system of partial differential equations, and they imply a given form of the galactic potential function. Particular solutions for the transformation functions are easily obtained; these can be used for the construction procedure. It is shown that for galactic stellar orbits in the vicinity of the sun, this construction implies that the ratio of frequencies of oscillation in the radial direction and perpendicular to the galactic plane is less than 1.

Mass and Density Measurements of Micrometeorites. HARVEY PATASHNICK AND CURTIS L. HEMENWAY, *Dudley Observatory and the State University of New York at Albany*.—A new instrument has been developed and employed to make direct measurements of the masses of micrometeorites. The device utilizes a metal-coated quartz fiber oscillating in an electric field as the sensor. The fiber is held rigidly at one end and the mass to be measured is attached to the free end. The fiber is set into oscillation electrically and the resonant frequency is found to be dependent on the mass added.

Preliminary results indicate sensitivity approaching 10^{-10} g and further refinements are expected to increase this sensitivity. Calibration has been accomplished through the use of aluminum and nickel microspheres of known diameter and density. Initial measurements of the masses and densities of micrometeorites are given. This work has been supported by NASA Grant NsG 155-61 and an NSF undergraduate assistantship.

Maser Action in Interstellar OH. F. PERKINS, T. GOLD, AND E. E. SALPETER, *Cornell-Sydney University Astronomy Center*.—Recent observations at the OH microwave frequencies have shown that there are small patches of intense emission associated with H II regions. The high lower limit on the

brightness temperature ($>10^3$ °K), narrow line-widths, and high polarizations suggest that maser action is occurring. An optical pumping mechanism for obtaining population inversions in interstellar OH is presented. The mechanism depends on the presence of anisotropic ultraviolet radiation near 3080 Å where the $^2\pi_{3/2} \rightarrow ^2\Sigma^+$ transitions of the OH molecule are located. The population inversions depend on the quantum number M (M is the projection of the angular momentum on the direction of the ultraviolet radiation) and result in maser amplification of linearly polarized radiation. The predictions of this model give some qualitative agreements with experiment.

High Galactic Latitude A Stars. II. A. G. DAVIS PHILIP, *University of New Mexico*.—Photoelectric measures have now been made in the Strömgren four-color system of a number of stars in two of the high galactic latitude regions under investigation, the north galactic pole and 1-HLF-5 (at $l^{\text{II}}=76^\circ$, $b^{\text{II}}=+60^\circ$). The stars measured so far can be divided into two major groups, those with normal and those with abnormal characteristics. The brighter groups of stars, which are less than 500 pc above the galactic plane, generally have normal characteristics, i.e., they are like the stars in the solar neighborhood. The fainter group of stars generally have abnormal characteristics. If they are assumed to be horizontal branch stars, their distance moduli can be computed using the absolute magnitudes calculated by Klemola (*Astron. J.* 67, 740, 1962). If one uses this assumption, the average distance from the galactic plane for the faint group is 700 pc.

Some of the abnormal characteristics found are: (1) Color excesses close to 0.0. (Some stars, closer to the galactic plane have color excesses of about 0.1, but this estimate of their color excesses needs to be checked by obtaining higher dispersion spectrograms for a more accurate spectral classification.) (2) larger than normal C_1 indices. For the group, the C_1 index was 0.18 mag too large. (3) Lower than normal M_1 indices. For the group, the M_1 index was 0.09 mag too low. For some of the stars, the abnormal characteristics disappear if it is assumed that the spectral classification is in error. From a study of Johnson's Q , and the star's position in the $U-B, B-V$ diagram, the following stars may be assumed to be B stars, not A0.

Star	Source	Catalogue spectral class	Probable class
SS156	Slettebak and Stock	A0	B5
HD110932	Perry	A0	B8
HD103376	Perry	A0	B7

Four known metal-deficient stars, which have been classified as horizontal branch stars (HD 86986, 106223, 109995, and 161817 plot in the same areas of the $b-y, c_1$ and $b-y, m_1$ diagrams as do stars in the abnormal group mentioned above. Thus there is a strong possibility that the majority of stars in the abnormal group are horizontal branch stars.

This research has been supported by grants from the National Science Foundation and the Research Corporation. The observations were made with telescopes at the Kitt Peak National Observatory.

Photometry of composite plates of M31. RENÉ RACINE (introduced by S. van den Bergh), *David Dunlap Observatory*.—Plates taken with the 48-in. Palomar Schmidt and the 52-in. Tautenburg Schmidt have been used to study Variable Star Field IV in M31. In each color four 48-in. plates and five 52-in. plates were combined into a single enlarged composite. In each color the limiting magnitude of the composite plate was about 1^m.5 fainter than that of the best of the original plates. Comparison with the 200-in. photometry of Baade and Swope shows satisfactory agreement down to $B \simeq 22.0$.

The composite plates were used for photographic UBV photometry of 125 stars. A color-color plot shows that most of the stars with $(B-V) > 0.5$ are stars of the galactic halo population which exhibit large ultraviolet excesses. The OB stars in M31 show that the mean reddening E_{B-V} of Field IV stars is 0^m.15. The differential reddening in M31 itself is found to have a range of at least 0^m.20.

Broad-Band H α Observations. HARRY E. RAMSEY AND SARA F. SMITH, *Lockheed-California Company*.—In the fall of 1965 broad-band H α (3 Å) observations were made in an effort to more successfully correlate photospheric and chromospheric observations. The broad-band observations provided the necessary intermediary between white light and narrow-band H α ($\frac{1}{2}$ Å) observations. A sufficient number of time-lapse films have been made to evaluate the potential of broad-band flare observations. Five major flares and a larger number of subflares have been recorded. The broad-band films offer three distinct advantages as an observational tool.

(1) A low-cost flare patrol is possible since all important flares are easily seen. Broad-band interference filters are relatively inexpensive and readily available.

(2) Features not seen in narrow-band ($\sim \frac{1}{2}$ Å) flare patrols are visible in a broad-band patrol. The most interesting of these features are sunspot changes, Ellerman bombs, Doppler-shifted components, and the broad profile characteristics of flares.

(3) The above broad-band features can easily and unambiguously be correlated with narrow-band features. This is possible since certain background chromospheric structures show in both.

Many more broad-band observations are needed before particular relationships can be established, such as the associations of flares with sunspots and sunspot changes, Ellerman bombs, and Doppler-shifted features.

Application of Automatic Measuring Machines to Astrometry. R. K. RIDDLE AND CHARLES E. WORLEY, *U. S. Naval Observatory*.—A number of preliminary parallaxes and proper motions have been determined from measurements made with the new automatic measuring machine and from a similar set of measurements made with a Mann two-screw comparator. Electronic computer programs were written and used for the determination of plate constants and for the computation of parallaxes and proper motions. A comparison of the results of the two sets of measurements shows a 24% reduction in the mean error of unit weight in the parallax solutions, a factor of 6 gain in measurement speed, and both a short- and long-term repeatability of $\pm 1 \mu$ through the use of the automatic measuring machine. The results of a number of experiments designed to test the accuracy and stability of the machine are discussed.

21-cm Line Observations of Galactic H II Regions. KURT W. RIEGEL, *University of Maryland*.—Twenty-seven Galactic H II regions have been observed in the 21-cm spectral line using the 300-ft transit radio telescope and the 100-channel digital autocorrelator of the National Radio Astronomy Observatory. Neutral hydrogen components associated with IC 5146, NGC 281, S170, and S222 have been detected. IC 5146 has an H I mass of $670 M_{\odot}$ and an H II mass of $20 M_{\odot}$, and is not a simple isolated gravitationally bound system. NGC 281 has an H I mass of at least $16\,000 M_{\odot}$, and an H II mass of $800 M_{\odot}$, and has a 21-cm systemic velocity in perfect agreement with the optical value. IC 5146 and NGC 281 both contain star clusters, and all four objects with H I associated with them have patches of obscuration crossing them. There is no observational evidence for the existence of an expanding H I component containing an appreciable fraction of the observed neutral hydrogen mass in any of the cases reported. Seven high-latitude H II regions have no neutral hydrogen associated to an upper limit of 8°K brightness temperature. The 16 remaining H II regions either had no clear H I features visible above

the large-scale background, or were located in regions so complex as to make detection impossible.

Models of Reflection Nebulae. TERRY P. ROARK AND J. MAYO GREENBERG, *Rensselaer Polytechnic Institute*.—Theoretical models are constructed for plane-parallel slabs of scattering material. The light incident on the elemental scattering volume is assumed to be scattered only once. However, this single scattering model is modified by including the physical extinction of the incident and scattered light as it traverses the nebula. Exact Mie theory is used to calculate the scattering cross sections for graphite, iron, and dielectric spheres. The models thus constructed yield predicted nebular colors on the *UBV* system, as a function of offset distance from the source of illumination. It is shown that no single physical or geometrical parameter will characterize any given color relation between the model and the star.

The Maia, Merope, and Alcyone nebulae in the Pleiades and NGC 7023 have been observed photoelectrically. The differences in both (*B*−*V*) and (*U*−*B*) colors between the illuminating star (as observed) and points on the nebula were obtained. The “instrumental” scattered light was determined and used to correct the observed nebular colors. This correction is found to be very important at small offset distances.

A comparison between the observed nebular colors and those predicted by the models indicates that the scattering particles in the nebulae do not behave as predicted for lossy spheres. The observations are consistent, however, with dielectric scattering particles having mean sizes slightly larger than those yielding the “standard” interstellar reddening law.

Radio Detection of Interstellar $^{18}\text{O}^1\text{H}$. A. E. E. ROGERS AND A. H. BARRETT, *Massachusetts Institute of Technology*.—Previous radio observations of interstellar OH have been due to the most abundant isotopic species $^{16}\text{O}^1\text{H}$. These observations have allowed the computation of the detection possibilities and accurate line frequencies of the isotopic species $^{18}\text{O}^1\text{H}$ (Barrett and Rogers, *Nature* **204**, 62, 1964). In particular the $F=2\rightarrow 2$, $^2\pi_{3/2}$, $J=3/2$ Λ -doublet transition was calculated to occur at 1639.3 ± 0.2 Mc/sec. We have observed this line in the absorption spectrum of the galactic center (Sag A) using the NRAO 140-ft radio telescope during the period 30 April–4 May 1966. Eighteen hours of data were averaged to give an rms noise level of 0.03°K . The observations reveal absorptions approximately 0.4° and 0.1°K at radial velocities of +40 and −135 km/sec, respectively, if the rest frequency is taken to be 1639.460 Mc/sec. The velocities of the ab-

sorptions are in excellent agreement with those of $^{16}\text{O}^{1}\text{H}$ given by Bolton, Gardner, McGee, and Robinson (*Nature* 204, 30, 1964) and the rest frequency is in good agreement with the predicted value. The observations enable one to estimate the $^{16}\text{O}/^{18}\text{O}$ isotopic abundance ratio for the interstellar medium in the vicinity of the galactic center. The value obtained agrees with the terrestrial value of ~ 500 , at least within a factor of 2. Complete interpretation of the observations must await a better understanding of the $^{16}\text{O}^{1}\text{H}$ population mechanisms which give rise to absorption in the galactic center.

The observations were conducted with the assistance of the staff of the National Radio Astronomy Observatory and was supported by the National Aeronautics and Space Administration (Grant NsG-419).

Finite-Amplitude Oscillations of the Maclaurin Spheroids. LAWRENCE F. ROSSNER (introduced by S. Chandrasekhar), *University of Chicago*.—The work of Dirichlet, Dedekind, Riemann, and Chandrasekhar on self-gravitating, homogeneous ellipsoidal configurations has been extended to treat the large amplitude oscillations of the Maclaurin spheroids corresponding to their second harmonic normal modes. These oscillations preserve the ellipsoidal nature of the surface and generate internal motions having a uniform vorticity.

This problem is made tractable by the circumstance that the relevant partial differential equations may be replaced by a set of ordinary differential equations for the lengths of the semi-axes of the configuration, the components of the angular velocity of the surface and of the vorticity of the internal motions, and the central pressure. These equations, which are equivalent to those first obtained by Riemann, have special integrals for the cases of interest in virtue of the validity of Dedekind's theorem for their nonstationary solutions.

The results of numerical integration of these equations for that oscillation by which the Maclaurin sequence bifurcates and elsewhere becomes unstable are given for various choices of the unperturbed configuration and various energies, both negative and positive, of the perturbed configuration.

Elevation Differences on Mars. CARL SAGAN AND JAMES B. POLLACK, *Harvard College Observatory and Smithsonian Astrophysical Observatory*.—Observations of apparent frost phenomena, occurring preferentially in the Martian bright areas, have in the past led to the conclusion that the bright areas are elevations. The argument hinges on the implicit assumption that near midday highlands should be

at lower temperatures than lowlands. On the earth this assumption is valid, because of adiabatic cooling of rising air, a diminished greenhouse effect, and a greater inclination of surfaces to the sun's rays for highlands than for lowlands. It is shown that these factors are unlikely to be important on Mars, and that the polar cap recession data, in particular, suggest that the dark areas are highlands.

From the quasi-specular component of the radar power reflectivity, and from the radar Doppler spectra, both as a function of Martian longitude, the Martian dark areas are found to have systematically higher elevations than the adjacent bright areas (Sagan, C., Pollack, J. B., and Goldstein, R. M., to be published). This evidence is reviewed. Slopes of a few degrees are deduced, and elevation differences up to 17 km are inferred. The picture of Mars which emerges is similar to that expected for the earth if oceans were removed, water erosion nonexistent, and the relief amplified by the ratio of the gravitational accelerations on the two planets. These results may bear on the discrepancies between ground-based spectrometric and Mariner IV occultation values of Martian surface pressure, and on those between the optical and dynamical oblateness of Mars. They suggest that pressures ~ 20 mbar are typical of the centers of bright areas, while 6 mbar is a typical dark area pressure.

Interplanetary Scintillations. I. Theory. E. E. SALPETER, *Cornell University*.—The scintillations of small-diameter radio sources over time periods of the order of 1 sec are thought to be caused by electron density fluctuations in the interplanetary medium, carried along by the solar wind. Some aspects of the theory had been presented by previous authors, all in the "thin phase-screen approximation," but not for all possible regimes. This theory has now been extended to the regime where the rms phase fluctuations are large and distances to the screen are comparable with typical "focal lengths." A simple formula has been derived for the effect of a finite angular source size on the frequency spectrum of the scintillation autocorrelation function for any regime. Sufficient conditions for the validity of the "thin phase-screen" approximation have been derived. The cross correlation between scintillations at different radiofrequencies has been discussed.

This work supported in part by the Advanced Research Projects Agency and Air Force Office of Scientific Research under Contract No. AF 49(638)-1156.

Linear Polarization of Discrete Sources at 6 cm. C. V. SASTRY, K. I. KELLERMANN, AND I. I. K.

PAULINY-TOTH, *National Radio Astronomy Observatory*.—Linear polarization characteristics of 55 discrete sources were measured at a wavelength of 6 cm using the NRAO 140-ft telescope. A tunnel diode receiver with a bandwidth of 400 MHz was used to measure the difference in the power received by two orthogonal probes in a circular feed horn at the focus of the telescope. For each source this difference was measured with the source in and out of the beam a number of times, and the procedure was repeated in each of five other orientations spaced at 30° . A sine curve fitted to these measurements gave the amplitude and position angle of the polarized component of the source. Flux densities measured in a separate experiment by Kellermann and Pauliny-Toth were used to derive the degree of polarization. The observations have been corrected for instrumental effects using the radio sources Cas A, Orion A, and Hydra A as calibrators. Observations on these sources indicated that the instrumental polarization was between 0.4 and 1.0% at a position angle of approximately 0° in the declination range $+52^\circ$ to -12° .

The present observations have been combined with measurements at other wavelengths to determine the rotation measures and depolarization effects for some of the sources. A study of the connection between degree of polarization and source parameters such as luminosity, surface brightness, spectral index, and magnetic field strength is made. No strong dependence is found except for a slight inverse correlation between magnetic field strength and the degree of polarization similar to the effect observed at 10 cm by Seielstad *et al.* (*Astrophys. J.* **140**, 53). The significance of these results is discussed.

The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under contract with the National Science Foundation.

Possible γ -Ray Source in Cygnus. M. SAVEDOFF, R. COBB, T. L. CHOW, AND J. G. DUTHIE, *University of Rochester*.—Evidence has been found for the existence of a source of energetic γ rays in the constellation Cygnus. The region of interest appears to be emitting γ rays, which, at the earth, results in a flux of $1.5 \pm 0.8 \times 10^{-4} \gamma \text{ cm}^{-2} \text{ sec}^{-1}$ of about 100 MeV. The direction of the source is $20^{\text{h}} 15^{\text{m}}$ in right ascension and $35^\circ N$ declination with an uncertainty of 6° in all directions.

The experimental details may be found in another publication (to be published in *Phys. Rev. Letters*, 1 August 1966). Approximately 32 events are attributed to a region counting the source as compared to a background of 20. Coulomb scattering leads to a wider opening angle distribution for the produced electron pairs than typical for the background. A χ^2

analysis indicates this difference is significant at the 0.3% level.

Of all classes of known objects, the sources Cygnus XR1 and Cygnus A appear to be most likely associated with the γ -ray source.

Cosmic-ray interactions, proton-antiproton annihilation, synchrotron radiation, bremsstrahlung and the inverse Compton process were briefly discussed. At present, bremsstrahlung appears to be the most likely mechanism of photon production. For an interstellar gas density of $n_p=1$, and a distance of 1 kpc, approximately 3×10^{55} electrons with energies greater than 10^8 eV are required.

This work was supported by NASA and NSF.

Testing Gravitational Theories with Planetary Radar Observations. IRWIN I. SHAPIRO, MICHAEL E. ASH, AND WILLIAM B. SMITH, *Lincoln Laboratory, Massachusetts Institute of Technology*.—Radar measurements of interplanetary time delays are being made with a precision as high as one part in 10^8 , which is almost three orders of magnitude more accurate than planetary optical observations. The increased sensitivity of radar systems now allows useful data to be obtained from Mercury and Venus at almost all orbital positions relative to the earth. Three years of such radar time-delay data, augmented only by the well-established orbits of the other planets, should allow the advance of Mercury's perihelion position to be determined with an accuracy of about 0.5 of arc per century. If general relativity is correct, the effect of a gravitational field on the speed of propagation of a radar wave will be measurable with an error of between 5 and 10%. General relativity leads to the further prediction that near superior conjunction the Doppler shift of a radar wave reflected from Mercury will undergo an additional change of up to 13 cps at X-band; this effect too may be detectable. Analysis of these radar measurements also enables the masses of the inner planets to be estimated accurately from the short-period perturbations caused by each on the others' orbits. Computer sensitivity studies demonstrate the accuracies achievable in these determinations. An operational approach in testing general relativity is essential; its neglect has led to the appearance of a number of erroneous conclusions in the recent astronomical literature. For example, it has often been overlooked that planetary orbital elements are theory-dependent as well as measurement-dependent numbers.

The Lincoln Laboratory is operated with support from the U. S. Air Force.

Geocentric Initial Conditions of Trajectories Originating at the Moon's Surface. BARBARA E. SHUTE (introduced by John O'Keefe), *Goddard*

Space Flight Center.—A reduced form of the patch conic method has been employed to determine the initial orbital elements of a particle launched or ejected from the moon's surface with any arbitrary starting conditions. The reduction was obtained by considering the selenocentric velocity asymptotes. Explicit and tractable analytic functions have been derived for the geocentric energy, the Jacobi constant, the angular momentum, standard orbital elements, and conditions for moon-to-earth trajectories. A minimum value of 2.51 km/sec ejection velocity is necessary for moon-to-earth trajectories, provided that the selenocentric velocity asymptote is opposed to the direction of the moon's motion. As the ejection velocity increases, the region where the velocity asymptotes may be located moves along the plane of the moon's orbit about the earth toward the earth-moon line. The maximum percent of material thrown into a direct moon-to-earth trajectory is 3.3% at a value of 2.62 km/sec ejection velocity.

Evolution of Dense Star Systems. M. SIMON AND T. GOLD, *Cornell University*.—Star systems of high density and high mass may reach time scales for their evolution that are short enough to come into cosmological times. The fate of such systems would then be an accelerated shrinkage with the emission of stars until eventually direct collisions between stars become a major phenomenon. Star velocities, energy released by collision, and time variations of the energy output are calculated.

Since there appears to be a strong correlation between the emission of radio noise and dense old star systems, it is discussed whether star collisions may lead to the generations of a relativistic gas. The conditions necessary for this process to account for quasars are also discussed.

Numerical Solution of the Equation of Transfer for a Two-Level Atom when Treated as a Two-Point Boundary Value Problem. A. SKUMANICH, *High Altitude Observatory*.—The Eddington approximation to the equation of transfer of radiation in a spectral line in the presence of continuous absorption for a plane stratified atmosphere is considered in which the source function is that for a two-level atom (essentially a source function with noncoherent scattering and selective absorption) (cf. Jefferies, J. T., and Thomas, R. N., *Astrophys. J.* 127, 667, 1958). This second-order equation is transformed to two linear first-order equations for which the boundary conditions are expressible in mathematically convenient form. The method of discrete ordinates reduces the frequency quadrature in

the source function to a discrete sum and one obtains a vector differential equation with matrix coefficients.

Introducing a central difference approximation for the first-order derivatives one obtains a system of vector equations which are solved by means of a variant of Gauss elimination (one reduces the grand matrix of the system to upper triangular form; cf. Henyey, Forbes, and Gould, *Astrophys. J.* 139, 306, 1964).

Parametric solutions for constant ϵ , viz., collisional to radiative de-excitation, and constant r_0 , viz. continuum to line center opacity, have been obtained for lines with Doppler, dispersion, and Voigt profiles both for isothermal and nonisothermal atmospheres with depth-dependent line broadening.

In the case of a linear continuum source function it is found that the line source function is defined by a universal power-law dependence on line center optical depth with the exponent determined by the form of the absorption profile, being 0.5 for a Doppler profile, 0.25 for a dispersion profile. In the presence of continuous absorption with $r_0 \geq \epsilon^2$, one finds that the Doppler source function is farther from LTE than the dispersion source function, while when $r_0 < \epsilon^2$ the reverse becomes true.

Results for atmospheres with a chromospheric temperature rise are also presented.

Preliminary Results from Processing Radar and Optical Planetary Observations. WILLIAM B. SMITH, IRWIN I. SHAPIRO, AND MICHAEL E. ASH, *Massachusetts Institute of Technology*.—Preliminary values of a number of astronomical constants have been obtained from the simultaneous processing of planetary radar data spanning the interval from 1959 to July 1966 and of U. S. Naval Observatory optical data extending from 1950 to 1965. Results obtained using general relativity (Newtonian) theory with their formal standard errors are: a.u., 499.004786 (499.004785) $\pm$ 0.000005 light-sec; Mercury radius, 2434 (2440) $\pm$ 2 km; Venus radius, 6056 (6056) $\pm$ 1 km; Mercury mass, 6021000 (6029000) $\pm$ 53000; Venus mass, 408250 (408450) $\pm$ 120; earth plus moon mass, 328900 (328950) $\pm$ 60; Mars mass, 3111000 (3107000) $\pm$ 9000; earth-moon mass ratio, 81.3030 (81.3024) $\pm$ 0.005. The planetary masses are given as inverses in terms of the solar mass. The orbital elements of Mercury, Venus, and the earth-moon barycenter were obtained simultaneously, and the accompanying formal standard errors are substantially lower than heretofore achieved. The over-all goodness-of-fit measure

$$\epsilon \equiv \frac{1}{N} \sum_{i=1}^N [(O-C)_i / \sigma_i]^2$$

was 0.63 for general relativity theory and 0.65 for Newtonian theory. Only for the fraction of data comprising time-delay observations of Mercury was a significant difference between the two theories noted; for this fraction general relativity gave $\epsilon=0.70$ and Newtonian theory 1.3.

Model for the Dynamics of the Explosion in M82. ALAN B. SOLINGER, *The University of Michigan*.

—Previously suggested mechanisms for producing the H α emission in the filaments of M82, based on synchrotron emission beyond the Lyman limit, are difficult to reconcile with the observed radio spectrum, since Dent has shown that the synchrotron flux falls off faster at the high-frequency end than was previously suspected. Further, the linear relationship between velocity of the filamentary material and distance from the center of the galaxy, observed by Lynds and Sandage, has not been well explained.

Since the high velocities observed imply the existence of a shock, a hydrodynamic approach is adopted. A self-similar blast wave solution, neglecting asymmetries, gravity, and magnetic effects, but including bremsstrahlung, is constructed and a linear velocity-distance relationship is predicted. The solution depends on the similarity variable

$$\lambda \equiv (\rho_1 r_1^2 \alpha / E_0)^{1/3} r t^{-2/3},$$

where ρ_1 is the ambient (extra)galactic density at a distance r_1 from the center of symmetry; E_0 the energy of the explosion; r and t distance and time; and α is a nondimensional parameter of order unity introduced to ensure $\lambda=1$ at the shock front. There the relation can be inverted to obtain E_0 , which falls between 10^{56} – 10^{58} ergs for reasonable estimates of the density and shock radius. The H α emission is explained as a collisional and recombination spectrum with cooling occurring just beyond. Both line and continuum x-ray emission are predicted beyond the filaments, the line emission being the principal cooling mechanism.

Observations of Venus and Jupiter near 1-cm Wavelength. DAVID H. STAELIN AND ROGER W. NEAL, *Massachusetts Institute of Technology*.

—A search for spectral features on Venus and Jupiter was made from January to March 1966. Five Dicke-type radiometers were connected simultaneously to the antenna feed by means of frequency-selecting filters. They operated at 19.0, 21.0, 22.235, 23.5, and 25.5 GHz. The antenna was a 28-ft paraboloid operated by Lincoln Laboratory, MIT, in Lexington, Massachusetts. The measured antenna patterns were used to relate the planetary observations to those of the

TABLE I.

Freq. (GHz)	Venus (T_B) (°K)	rms error		Jupiter (T_B) (°K)	rms error	
		Rel. (%)	Abs. (%)		Rel. (%)	Abs. (%)
19.0	477	± 8	± 12	105	± 20	± 20
21.0	451	± 4	± 9	106	± 9	± 10
22.235	436	± 4	± 9	98	± 10	± 11
23.5	418	± 4	± 9	116	± 8	± 9
25.5	400	± 4	± 9	123	± 7	± 9

moon, which was used for calibration. The equipment and procedures were similar to those described earlier (*Astrophys. J.* **144**, 1, 352). Venus and Jupiter were observed 13 and 7 days, respectively, yielding the results given in Table I.

The relative error does not include systematic sources of error which do not affect spectrum shape, whereas the absolute error includes all sources of error. There is no evidence for fluctuations in the spectral shape of Venus greater than 4% during the period 11 January to 20 February 1966.

The measurements were made with the cooperation and assistance of the staff of Lincoln Laboratory, MIT. The work was supported principally by the National Aeronautics and Space Administration (Grant NsG-419).

Application of Secondary Electron Image and Storage Tubes to Space Astronomy. E. J. STERNGLASS (introduced by M. Harwit), *Westinghouse Research Laboratories*.

—The potential uses of a new family of electronic image storage tubes for astronomical observations has been examined. These devices (Goetze, G. W., and Boerio, A. H., *Proc. IEEE* **52**, 1007, 1964) are based on the formation of secondary electrons from low-density insulating targets located on the exit side of thin conducting membranes. When used with uv-sensitive cathodes, integration times of many hours have been obtained without detectable loss of resolution, which in present tubes has a limiting value of about 30 line pairs per millimeter. The targets have been shown to permit repeated quantitative photometric readout of the stored charge to better than 2% over a dynamic range of 150:1 for area sources, and more than 10 000:1 for point sources. These devices are therefore of interest for quantitative photometry and spectroscopy of astronomical objects in remote locations such as required in space astronomy, as well as in connection with the automated reduction of data from ground-based telescopes.

By virtue of the inherently higher quantum efficiency of photoelectric devices as compared to the photographic plate, use of such camera tubes permits relatively small, lightweight telescopes to achieve the equivalent performance of much larger instru-

ments for many purposes. Thus, a 12-in. aperture telescope as might be used for exploratory observations from the lunar surface, operating in the extreme uv (1000–2000 Å) should permit threshold images of 23^m AO stars in 10^4 sec, at a limiting angular resolution of 0.1 arc sec. By the addition of a high-gain transmission-type image intensifier (Sternglass, E. J., and Wachtel, M. M., *Phys. Rev.* **100**, 1239, 1955) now being used in ground-based astronomy (Livingston, W. C., and Lynds, C. R., *Astrophys. J.* **140**, 818, 1964), a further gain in speed of 200 would be possible. This is equivalent to an effective increase in aperture to 170 in. without the increase in weight proportional to the cube of the aperture diameter.

When x-ray sensitive phosphors are used on the outside of an image-intensifier preceding the camera tube, relatively small but sensitive x-ray telescopes should become possible which would permit the imaging of stellar and solar sources in 10^3 – 10^5 sec which are 10^6 – 10^8 times weaker than can presently be recorded by rocket techniques.

Strength of $H\gamma$ as an Indicator of Surface Gravity in A- and B-Type Stars. F. M. STIENON, *Smith College*.—A comparison of theoretical $H\gamma$ profiles with observations shows that stellar surface gravities can be obtained with a probable error of 0.35 in the logarithm. Different ways of treating the electron contribution to the line broadening will lead to values of $\log g$ which differ systematically. To reduce all results to those of the revised Kolb–Griem theory the following corrections must be applied: -0.65 for the Holtmark theory for ions only, -0.05 if electrons are added, and $+0.4$ for the original Kolb–Griem theory.

Systematic changes in the line profile due to different types of line source function have been looked for but if coherent scattering is ruled out there is no difference except in the line core. Profiles based on noncoherent scattering show a deep narrow core in qualitative agreement with observations.

The effect of departures from LTE has been investigated using the models published by Strom and Kalkofen (*Astrophys. J.* **144**, 76, 1965). Line profiles for these models are the same as LTE profiles of higher effective temperature and surface gravity.

New Automatic Measuring Machine. K. A. STRAND, *U. S. Naval Observatory*.—The U. S. Naval Observatory has recently acquired a machine which is designed to locate automatically a star image on a photographic plate from approximate coordinates on a punched card and to measure and record its position with a precision of 1μ . The machine was manufactured by Nuclear Research Instruments, Inc.,

Berkeley, California, according to the Observatory's design specifications.

The main frame of the machine is made of granite as are the x and y coordinate carriages which move on air bearings against granite ways.

The system is capable of making measurements continuously over a 10×10 in. range by means of a Ferranti moiré fringe system.

Further details are described.

Analysis of F and G Subdwarfs. S. E. STROM AND J. G. COHEN, *Harvard College Observatory and Smithsonian Astrophysical Observatory* AND K. M. STROM, *Smithsonian Astrophysical Observatory*.—Spectrum scans and model stellar atmospheres have been used to locate in the ($L/L_\odot$, T_{eff}) plane F and G subdwarfs having known parallax. A comparison is made between their position on the H-R diagram and the evolutionary tracks for Population II models of low- and high-helium content recently computed by Faulkner and Iben (*Astrophys. J.* **144**, 995, 1966). The lower-helium-content models are found to give somewhat more plausible ages than the high-helium models. Nevertheless, for both the low- and high-helium-content models, we find several subdwarfs with ages apparently greater than 10×10^9 yr.

A grid of model atmospheres has been used to perform an abundance analysis of two extreme Population II stars in this group, HD 19445 and HD 140283. The abundances determined from the models confirm the general results of previous investigations, namely, that metals are deficient by a factor of about 100 relative to average Population I abundances. A marginal deficiency of s -process material relative to the average deficiency is found for HD 140283, and the carbon deficiencies are comparable to those of the other elements. Unfortunately, it is difficult from our results to comment in a definitive way of the nature of element building at the early stages of galactic evolution.

Deviations from LTE and their Effect on Stellar Spectra in the Range B5 to F0. S. E. STROM AND W. KALKOFEN, *Smithsonian Astrophysical Observatory and Harvard College Observatory*.—We have computed a grid of model stellar atmospheres for the effective temperature range $6000 < T_{\text{eff}} < 15\,000^\circ \text{K}$ in which departures from LTE in atomic hydrogen and the negative hydrogen ion have been included. In the case of H, we have computed departure coefficients for the three lowest bound states under the assumption of detailed balancing in the strong hydrogen lines. The effects of bound-free radiative and collisional transitions and bound-bound collisions have

been included. For H^- we calculated the radiative dissociation rate and assumed that collisional destruction takes place only through the associative detachment reaction $H^- + H \rightleftharpoons H_2 + e$. A range of rate coefficients for this reaction is assumed in our computations.

We conclude that for main sequence stars ($\log g = 4$) earlier than A0 (hotter than 10 000°K), the magnitude of the departures from LTE depends on the assumed value of the bound-bound collision rates. For stars of lower surface gravity, where the number of collisions is reduced, we find the departures from LTE much less sensitive to the atomic parameters adopted.

A major observational prediction of the non-LTE models concerns the size of the observed Paschen discontinuity D_P for a given observed Balmer discontinuity D_B . For LTE models, $D_P/D_B = 0.165$ for $9000 < T_{\text{eff}} < 15\,000^\circ\text{K}$. The non-LTE models in this T_{eff} range predict $D_P/D_B \gtrsim 0.21$, while the best available observations of D_P and D_B give $D_P/D_B \gtrsim 0.185$. More accurate and well-calibrated observations of D_P and D_B are needed in order to test critically the predictions of the non-LTE models.

For stars later than A5, the non-LTE atmospheres suggest that values of T_{eff} obtained from LTE atmospheres are too high by up to 0.02 in $\log T_{\text{eff}}$, and moreover that the surface gravities obtained from comparison of observed Balmer discontinuities and LTE models may be overestimated by as much as 0.5 in the logarithm.

Observations of the Radio Source CTA 102.

YERVANT TERZIAN, *Arecibo Ionospheric Observatory*.—In November 1965 a regular observing program was started in order to follow the variability of CTA 102 as reported by Sholomitskii (*Inform. Bull. Var. Stars, IAU*, No. 83, 1965). The Arecibo Ionospheric Observatory's 1000-ft dish was used for all the observations. Simultaneous observations were performed at the frequencies 611 and 430 MHz; a few observations at 195 MHz were also made. All three feeds were concentric and were composed of a series of dipoles illuminating only about 60% of the spherical dish. One 4-h observing period per week was devoted to the project. All the observations covered a period of eight months.

Three radio sources, 3C435, CTA 102, and 3C14, were observed and their intensities were compared with each other. The observations were performed by repetitive "pointing" of the sources, i.e. north and south declination scans and right ascension scans. An argon noise-tube calibration was taken before and after each observation.

Intensity ratios between the three sources were obtained and plotted against time. The results show

that there is no variation greater than 8% for CTA 102 at the observed frequencies. These results are in agreement with the evidence presented by Maltby and Moffet (*Astrophys. J.* **142**, 409, 1965). The derived flux densities for CTA 102 at 611, 430 and 195 MHz are 7.70 ± 0.35 , 6.95 ± 0.30 , and 3.92 ± 0.25 flux units ($10^{-26} \text{W m}^{-2} \text{Hz}^{-1}$), respectively.

The Arecibo Ionospheric Observatory is operated by Cornell University with the support of the Advanced Research Projects Agency under a research contract with the Air Force Office of Scientific Research, OAR.

Ion Condensation and the Nature of the Two Sequences of White Dwarfs.

H. M. VAN HORN, *University of Rochester*.—As the temperature of the degenerate core of a white dwarf decreases, the ions must at some point undergo a phase transition to a condensed state. By qualitative arguments, we establish the temperature-density relation at the transition point to be approximately given by

$$T \simeq 5 \times 10^4 Z^{5/3} \rho^{1/3},$$

where Z is the mean nuclear charge and ρ is the density in g/cc. By analogy with normal metals, the latent heat evolved in the phase transition is expected to be

$$\Delta Q/kT \simeq 2 \text{ to } 12,$$

where T is the temperature at the transition point.

The stars which are currently undergoing this transition to the condensed state are found to form a sequence which lies in the observed region of the white dwarfs and which furthermore precisely duplicates the slope of the brighter sequence of white dwarfs as observed by Eggen and Greenstein. We show that the lifetimes predicted by this model are compatible with the hypothesis that the brighter sequence is the "condensation sequence," while the fainter group consists of more massive stars which have already passed through the transition region. Finally, the implications of these results for the evolutionary prehistory of the white dwarfs are briefly discussed.

Fine Structure of the Brightness Distribution of Cygnus A.

C. M. WADE, *National Radio Astronomy Observatory*.—It has been known for many years that most of the radio emission of Cygnus A arises in two discrete regions separated by somewhat less than 2 min of arc, with the associated galaxy lying between them. Observations with the NRAO interferometer at $\lambda 11.1$ cm have yielded a map of the brightness distribution with an effective angular

resolution of 8 sec of arc. Each of the two major components of the source is found to consist of several "hot spots" superimposed on an apparently filamentary background. These features account for approximately 90% of the radio emission of Cygnus A at $\lambda 11.1$ cm.

Spectrum of Tonantzintla 1542. E. JOSEPH WAMPLER, *Lick Observatory*.—Following the discovery by Hiltner and Shield (private communication) of strong emission lines in the spectrum of Ton 1542 photoelectric observations were obtained at Lick Observatory using the prime focus scanner. The continuum is nearly flat in the region $\lambda 3150$ – 6000 Å but rises steeply in the infrared. In this respect Ton 1542 is very similar to 3C273. It is not a known radio source although 4C20.30 lies about $15'$ south of Ton 1542 and is listed as being confused with a weaker source. The observed ratios $H\delta/H\beta$ and $H\gamma/H\beta$ agree closely with the theoretical calculations of a hydrogen recombination spectrum. The ratio of $H\alpha/H\beta$ is found to be about 4.5, which disagrees with the value (~ 2.7) calculated for radiative recombination. The strength of $H\alpha$ may be enhanced by undetected [N II] emission. A contribution from collisional excitation or from a region in which the nebula is optically thick to Balmer radiation could also increase the strength of $H\alpha$ relative to the higher members of the Balmer series. The widths of the Balmer lines indicate gas velocities in excess of 1500 km/sec. The $\lambda 4958$ and $\lambda 5007$ lines of [O III] are substantially narrower than the Balmer lines. The redshift corresponds to a symbolic recessional velocity of 19400 km/sec. The apparent magnitude was observed to be about 15.5 and there is some indication that this magnitude is variable. Prata (*Publ. Astron. Soc. Pacific* **78**, 61, 1966) finds the object to be possibly nonstellar and lists the magnitude, which he considers to be too bright, as 16.6.

Interstellar Reddening in the Direction of the Galactic Center. PETER A. WEHINGER, *The University of Michigan Observatories*.—*UBV* photoelectric photometry of field stars in the direction of the galactic center ($l^{\text{II}}=358^\circ$ to 2° , $b^{\text{II}}=-2^\circ$ to $+2^\circ$) has been carried out at Kitt Peak National Observatory. *BVI* photographic photometry and near-infrared objective-prism spectra of field stars and *M*-giant stars obtained at Warner and Swasey Observatory have been combined with the photoelectric data to yield color-excess data out to an uncorrected distance modulus of 17 mag. At $V-M_v=16.5$, $E_{B-V}=1.0$. If we assume $A_v=3.2 E_{B-V}$, then $A_v=3.2$ at a distance of 5 kpc from the sun corrected for absorption in the direction of Sgr A. The

photoelectric observations cover a range of V magnitudes from 8 to 15 and B magnitudes from 9 to 17. Extensive checks on the accuracy of the photoelectric photometry were carried out.

Color-excess data were determined to a distance of 6 to 8 kpc from the sun. No sharp increase in E_{B-V} was detected over this range of distances. If the 3-kpc spiral arm, described by Rougoor and Oort, extends in a circular fashion through $l^{\text{II}}=0^\circ$ at 3 kpc from the galactic center, then the color-excess data begin to suggest that this spiral arm contains little or no detectable interstellar dust. However, it must be stressed that the data at this distance are somewhat marginal.

Photoelectric Polarimetry of Comet 1965f. J. L. WEINBERG, *Haleakala Observatory*.—Multicolor observations were taken of the principal Stokes parameters of the night-sky radiation over a 9×20 deg section of the sky containing Comet 1965f. The total and polarized components of radiance, the degree of polarization, and the orientation of the plane of polarization are derived (at 5300 Å) both along and normal to the axis throughout the tail of the comet, and a preliminary interpretation is given on the implications in terms of the nature and distribution of the particles.

Preliminary results are also presented on fluctuations in the zodiacal light resulting from the presence of the newly injected cometary material.

Detection of Water on the Moon. M. WERNER, T. GOLD, AND M. HARWIT, *Cornell University*.—If water percolates up from the interior of the moon and evaporates from its surface it may be indirectly detected by coronagraphic observations. The technique we propose involves a search for the OH radical produced by the dissociation of lunar H_2O . One should be able to observe the 0–0 and 1–1 vibrational bands covering the range from 3075 to 3105 Å and 3135 to 3160 Å, respectively, provided OH is sufficiently abundant. Both these bands are observed in cometary spectra. In computing the minimum detectable amount of OH we have made use of published figures on (a) the night sky brightness at 3100 Å, and (b) atmospheric light scattering coefficients obtained from solar coronagraphic work. The minimum detectable value of OH is found to be of the order of $5 \times 10^4/\text{cm}^3$ under the most favorable observing conditions. We have computed the dissociation rate of H_2O and the mean life of the OH radical in the vicinity of the moon.

For a given rate of outgassing of water out of the moon the amount of OH to be expected depends upon the unknown probabilities for the formation of H_2O

at each contact of an OH molecule with the lunar surface. Outgassing rates similar to those appropriate for the earth may lead to observable results.

Some Implications of Solar Differential Rotation. MARVIN L. WHITE, *Air Force Cambridge Research Laboratories* AND KOO SUN KIM, *Lowell Technological Institute Research Foundation*.—The empirical law for differential rotation in the photosphere

$$\omega = 14^{\circ}.38 - 2^{\circ}.77 \cos^2 \theta \quad (1)$$

is substituted into the law for conservation of vorticity and solved for the meridional velocities. It is found that (1) real values for the meridional velocities are restricted to the region between $\pm 40^{\circ}$ latitude, that is, to the active region and (2) the derived vector velocities make roughly the same angle with the equator as the line joining the centers of bipolar sunspot groups, namely 7° at the higher latitudes and zero degrees near equatorial latitudes. (This is understandable if the stream lines and the magnetic lines of force point in the same direction.)

Comparison of the derived meridional velocities with observed values of meridional velocities as obtained from sunspots, show the derived values to be two orders of magnitude larger than the observed values, assuming that the latter are really statistically different from zero. This discrepancy may be due in part to the simplifying assumptions used in the vorticity equation, namely (1) radial velocity set equal to zero, (2) ideal fluid, (3) use of the barotropic model. However, it is considered more likely that these derived and observed velocities are not really comparable, particularly if the observed north-south sunspot motions are *affected* by the presence of the zonal magnetic field. In other words, the motion of sunspots may not accurately represent the velocity field in the photosphere.

Approximating Formulas for Eclipse Functions. ROBERT E. WILSON AND HENRY F. FLIEGEL, *Georgetown College Observatory*.—Computer programming of eclipsing binary problems, such as solution of light curves, would be much simplified, and running times would be much reduced, if the α and p eclipse functions could be computed by simple approximating formulas. The exact expression for $\alpha(p, k)$ involves complete and incomplete elliptic integrals of the first and second kind, whose evaluation by suitable transforms is an iterative process. There is no known exact expression for $p(\alpha, k)$, so this is ordinarily computed by entering a preliminary estimate of p , computing α , and iterating until the value of p entered gives the correct α . We have approached

the problem by trying to find series expressions which will compute $\alpha(p, k)$ and $p(\alpha, k)$ directly. Many different series with many different transformations of the arguments have been tried. Several means have been used to find the coefficients, but the principle way has been least-squares fitting on the Georgetown 1620 II computer. Our intention is to find, not just formulas which will yield α and p to a prescribed degree of accuracy (about ± 0.0001), but the simplest such formulas. Therefore it may be some time before our final results are published. However, our preliminary results should be useful in many applications.

The help of Mr. Donald Wright and Dr. Herbert Maisel of the Georgetown Computation Center is gratefully acknowledged. Mr. Wright's modification of the library program STUFF, to operate with double precision, was quite indispensable.

Determination of Direction and Antenna Temperature of a Celestial Radio Point Source by Mean of Convolutions. LOUIS WINKLER, *The Pennsylvania State University*.—The signal variations discussed refer to those caused by variations in the propagation characteristic of the medium through which the radiation passes. Since these signal variations cause uncertainties in measurements of source direction and antenna temperature, it is common practice to repeat these measurements and subsequently average them to decrease the uncertainty in the average values. Alternative methods based on convolutions are presented here for the direction and temperature determinations. In addition, the convolution approach can be used to establish the existence of weak sources. Long-term statistics concerning the fractional absorption and thermal re-emission of the medium as a function of the zenith angle in the vicinity of the observatory is necessary for the convolution approach.

Mathematical expressions are developed to estimate the uncertainty of the computational results obtained from repeated measurement and convolution approaches.

Shock Tube Measurements of Absolute gf Values for Neutral Chromium. S. J. WOLNIK, E. H. CARNEVALE, R. O. BERTHEL, G. S. LARSON, *Parametrics, Inc.* AND GORDON W. WARES, *Air Force Cambridge Research Laboratories*.—A conventional pressure-driven shock tube has been used to heat known test-gas mixtures of neon and chromium carbonyl to approximately 7000°K. Time-resolved photoelectric observations of Cr I emission were made through a side-wall window to determine the extent and duration of relaxation effects and of steady state

conditions following reflection of the incident shock at the end wall. Gas temperatures of the thermal equilibrium period were measured directly by an ultrasonic method. Simultaneous temperature measurements under similar conditions by the ultrasonic method and by a line-reversal method indicated that local thermodynamic equilibrium is established in the reflected region of the shock-heated gases since the two independent methods, the ultrasonic measuring a translation temperature and the line-reversal measuring an excitation temperature, were in excellent agreement. Spectrograms of line emission were obtained by viewing across the 2-in. width of the shock tube and using a high-speed electromechanical shutter to permit emission only during the equilibrium period to reach the photographic plate. This condition was verified on each shot by time-coordinated records from a photomultiplier inside the 2-m spectrograph. Also, photoelectric observation of gas emission along the shock tube axis were made through an end-wall window to study the effects of self-absorption as a function of chromium carbonyl concentration (80 to 500 ppm) in neon. Absolute intensities of "flat-topped" lines were determined by photographic photometry using a carbon arc as the primary standard with Euler's calibration data. Absolute gf values of 37 lines of Cr I over the spectral range 3894–5410 Å are presented. The lines are distributed over 10 multiplets. The results are compared with values reported elsewhere (Corliss and Bozman 1962; Penkin

1964; Allen and Asaad 1957). In most cases our values are within 20% of those in the latter two studies. Our gf values are generally lower than those of Corliss and Bozman by factors of 2 or more.

Radiation from Jupiter at Long Wavelengths.

F. R. ZABRISKIE (present address: The Pennsylvania State University, W. A. SOLOMON, AND J. PETER HAGEN, JR. (present address: University of Toronto) *Wesleyan University*.—During the 1964 apparition of Jupiter, observations were made at several frequencies between 3.5 and 7.3 Mc/sec. Analysis of these records shows about 32 events that are probably Jupiter. To be seen with certainty on our records for a typical night, the flux density must exceed $2 \times 10^{-21} \text{ W m}^{-2} \text{ cps}^{-1}$, although some nights are much better. This is a large flux and probably explains our low occurrence probability.

Certain other details appear: emission, in two cases only, can be traced down to 3.5 Mc/sec. However, the flux density falls to one-tenth or less that recorded above 5 Mc/sec. The longitude profile shows a broad maximum between 300° and 50° , a secondary peak near 150° , and a quiet zone between 200° and 240° . When radiation is observed from the broad peak, the satellite Io has a strong tendency to lie between 210° and 250° from superior conjunction. Radiation from 150° peak does not show this tendency, but the statistical sample is small.