The Temperature, Luminosity, and Distance of the Exciting Star of the Planetary Nebula NGC 1514. NANCY D. MORRISON AND WILLIAM LILLER, *Harvard College Observatory*.—Photoelectric spectral scans of the suspected spectroscopic binary at the center of the planetary nebula NGC 1514 clearly reveal the presence of two stars, one of spectral type A0 V, the other having a purely continuous spectrum with an estimated temperature of 60 000 °K. The latter star is 0^m85 fainter at $\lambda=5500 \text{ \AA}$, and the system is seen through 2^m43 of absorption at the same wavelength. The H-gamma equivalent width, when corrected for the hot star radiation, leads to an absolute magnitude of the A star, $M_v=+0.4$, and thus for the hot star $M_v=+1.3$. The resulting distance for the system is 250 parsecs.

This research has been supported by the National Science Foundation.

The Far-Ultraviolet Spectrum of ζ Puppis. DONALD C. MORTON AND EDWARD B. JENKINS, *Princeton University Observatory*.—On 1 November 1967 at 11^h 30^m UT, an Aerobee rocket launched from White Sands Missile Range carried an all-reflective ultraviolet spectrograph to 175.9 km and oriented it in the direction of ζ Puppis. Fine stabilization to $\pm 30''$ in the dispersion direction was obtained with the passive gyro system used on previous Princeton flights. During a 120 sec exposure, spectra with 1 Å resolution were obtained of ζ Puppis (O5f) from 1100 to 1965 Å and γ^2 Velorum (WC7+07) from 1125 to 1190 Å.

In ζ Puppis the interstellar Lyman- α absorption line has an equivalent width of 5.1 Å, consistent with an earlier observation by Carruthers. If ζ Puppis is 450 pc away this width corresponds to an average atomic-hydrogen density of only 0.035 cm⁻³, but this number must be increased to account for the unknown fraction of the distance occupied by ionized hydrogen in the giant H II nebula surrounding the star. Unless this nebula extends to within 25 pc of the sun, the average H I density towards ζ Pup is abnormally low, as is the case for several stars in Orion.

Strong resonance absorption lines of C IV, N V, Si III, and Si IV and an excited line of C III, (6.5 eV) are present with velocity shifts averaging 1810 km sec⁻¹ towards shorter wavelengths. These lines must be formed in an expanding shell escaping from the star, similar to the shells found in the hot supergiants in Orion. Excited lines of He II (40.6 eV) and N IV (16.1 eV) have lesser shifts of 350 and 780 km sec⁻¹, respectively, and therefore must be formed lower in the atmosphere where the acceleration occurs. Emission lines of He II, C IV,

N IV, and N V are present close to their laboratory wavelengths. Wavelengths also have been determined for nearly 100 weaker absorption lines in ζ Pup. Most of these lines must be formed in the photosphere, but few have been identified. This rocket flight was supported by NASA contract NSr-31-001-090.

Periods of Novalike Variables. GEORGE S. MUMFORD, *Tufts University*.—A number of novalike variables that exhibit eclipses have been investigated for possible period changes at Kitt Peak National Observatory. While more data are required, some preliminary results are presented in the table. Computed times of minima were obtained from light elements summarized by Mumford (*Publ. Astron. Soc. Pacific* 79, 283, 1967). Interestingly enough, the two stars of shortest orbital period, WZ Sge and EX Hya, seem to have the most stable orbital motion despite pronounced evidence for gas streams.

Positive residuals for U Gem are confirmed by AAVSO light curves compiled from naked eye observations. In all instances where coverage was adequate and the time of minima accurately determined, a positive residual was found.

In the case of T Aur and EM Cyg the shape of the light curve is quite variable and observed times of minima are difficult to estimate precisely. About all that can be said here is that the periods given by Mumford seem to be verified.

Finally, the single observed minimum of V Sge apparently confirms Smak's suggestion (*Acta. Astron.* 17, 55, 1967) that the period of this system is decreasing.

TABLE I. Observations of novalike variables.

Star	Date (UT)	Period	Cycle	O - C
WZ Sge	6 Oct 1967	1 ^h 21 ^m	39 196	0 ^d 0000
			39 197	-0.0003
EX Hya	9 Feb 1967	1 38	26 834	-0.0001
	15 May 1967		28 223	+0.0001
	27 Feb 1968		32 447	0.0000
U Gem	16 Apr 1966	4 15	9 064	+0.0019
	2 Feb 1967		10 677	+0.0019
			10 678	+0.0017
	27 Feb 1968		12 860	+0.0022
	4 Mar 1968		12 894	+0.0030
T Aur	5 Oct 1967	4 54	10 544	+0.001:
	26 Feb 1968		11 247	0.000:
EM Cyg	2 Oct 1967	6 59	6 479	-0.001:
	4 Oct 1967		6 486	-0.003:
V Sge	4 Oct 1967	12 ^h 20 ^m	3 652	+0 ^d 0077

Abundance of Hydrogen in White Dwarfs. KYOJI NARIAI AND DANIEL A. KLINGLESMTIH, *NASA, Goddard Space Flight Center*.—Equivalent

widths of $H\gamma$ in white dwarf spectra were calculated for models with various hydrogen abundances. Parameters used in our models are $Te = 16\,000\text{ }^\circ\text{K}$, $\log g = 8.0$, and $X = 1.0, 0.1, 0.01, 0.001$, and 0.0001 . In calculating the $H\gamma$ profile, the Stark broadening function which includes the correlation and shielding (Edmonds Jr., Shclüter, and Wells III, *Mem. Roy. Astron. Soc.* **71**, 271, 1967) was used.

As the hydrogen abundance decreases, the equivalent width of $H\gamma$ becomes larger until the continuous absorption due to hydrogen becomes smaller than that due to helium, and then, the equivalent width decreases. Therefore, when the deficiency in hydrogen is not large, it shows a "quasi-gravity effect." This effect was first studied by Strömgren analytically (*Publ. Kobenhagen Obs.* No. 138, 1944). Osawa (*Publ. Astron. Soc. Japan* **11**, 253, 1959) and Böhm-Vitense (*Astron. Phys. J.* **150**, 483, 1967) calculated helium rich models for main sequence stars and confirmed this effect. If the temperature is not high enough, the helium lines are not observable, therefore, it is hard to separate the effect of hydrogen deficiency from the effect of gravity. Greenstein [*Handbook der Physik*, S. Flüge, Ed. (Springer-Verlag, Berlin, 1958), Vol. 50, p. 161] has shown that the equivalent width of $H\gamma$ for DA type white dwarfs is a function of $U-V$ color. The dispersion in the equivalent width which amounts to 50% has hitherto been interpreted to be the dispersion in the gravity. But we wish to emphasize that this might be the results of hydrogen deficiency in the atmosphere.

One of the authors (K. Nariai) holds a National Academy of Sciences-National Research Council Resident Research Associateship.

Observations of Zodiacal Light, Airglow, and Stellar Extinction from Gemini Space Flights.

EDWARD P. NEY, *School of Physics and Astronomy, University of Minnesota*.—Wide angle cameras constructed at the University of Minnesota were carried on several Gemini space flights and operated by astronauts to acquire photographs of diffuse sources from above the airglow layer. The photographs of the zodiacal light confirm the ground observations of its geometry, but show it more clearly delineated in the absence of airglow contamination. Away from the Milky Way the zodiacal light is the principal source of extraterrestrial surface brightness, amounting to 2000 10th-mag visual stars per square degree at 30° elongation on the ecliptic and about 200 10th-mag stars per square degree at the 90° elongation on the ecliptic.

The airglow layer photographed in profile from above appears as a definite bright band above the horizon even with the earth lit by a nearly full moon. The maximum brightness occurs at an angu-

lar height that corresponds to an altitude of 90 km. The top of the layer is at 105 km and is quite independent of the position on the earth. (Photographs were taken with Tri X film in north, south, east, and west directions). The airglow represents a much more definite horizon than the less well-defined earth's limb.

On Gemini 9, Astronauts Cernan and Stafford succeeded in getting photographs in which the star β Ca Ma appeared in one exposure above the airglow layer and in a subsequent exposure the same star was centered in the airglow layer. Densitometry of these negatives made it possible to set a limit on the extinction produced by material at this altitude. Link has proposed a rather dense layer with optical depth of the order of .05. Our observations show that the vertical optical depth cannot be more than .0015.

Spectrophotometry of the Remarkable Nebula NGC 6302.

JOHN P. OLIVER AND LAWRENCE H. ALLER, *University of California, Los Angeles*.—Recent discussions by Minkowski and Hugh Johnson have called attention to the remarkable nebula NGC 6302, which does not lie far from the x-ray source Scorpio XR-2. Thompson and Colvin find it to have a thermal spectrum. Spectrophotometric observations have been made with the nebular spectrograph at the prime focus of the 120-in. Lick reflector.

The nebula shows very high excitation features combined with the low excitation $[\text{O II}] \lambda 3727$ pair. There appears to be no appreciable space absorption. The electron density in most of the bright filaments appears to be of the order of 0.3 to 0.1×10^4 electrons/cm³. The electron temperature appears to be about $18\,000\text{ }^\circ\text{K}$. It may fluctuate from one filament to another. Four times ionized neon appears to be more abundant than twice-ionized neon and we may conclude that most of the oxygen likewise exists in unobservable highly ionized stages. Thus NGC 6302 is one of the most highly excited gaseous nebulae known. The He/H ratio appears to be about 0.25, somewhat higher than the ratio ordinarily associated with gaseous nebulae or the "primordial" value.

NGC 6302 is probably not a planetary nebula, but the absence of nonthermal radio emission suggests that it may not be a supernova remnant either.

This research was supported in part by AFOSR Grant 83-65 to UCLA.

Rotational Velocities in Early-Type Binaries.

EDWARD C. OLSON, *University of Illinois Observatory*.—Projected rotational velocities, $v \sin i$, have

been determined for 40 component stars in 29 close binary systems, in order to study the state of axial-orbital synchronism. Most of the systems are eclipsing binaries with periods between 1 and 6 days and hot components between O9 and F0. Rotational velocities were determined from half-widths measured on direct-intensity tracings of 20 Å/mm spectra obtained at the Mt. Wilson Observatory. These velocities are compared to $v(\text{syn})$, the rotational velocity that would be synchronous with the mean orbital motion, and to $v_P(\text{syn})$, the velocity that would be synchronous at periastron. In either case, most of the components are very close to synchronism, although systems exist which rotate faster or slower than synchronously. The quantity $[v - v(\text{syn})]/v(\text{syn})$ decreases with increasing fractional radius of the components. Mass and angular momentum exchange, tidal interaction, and expansion with early evolution from the main sequence are probably jointly responsible for this correlation. The mean $\log(\text{surface gravity})$ for stars rotating slower than synchronously is 0.3 to 0.5 lower than for the synchronous rotators, suggesting directly the operation of the last of these mechanisms. The system AG Per, in optical coincidence with the II Per association which has a kinematic age of 1.6×10^6 years (Blaauw, *Ann. Rev. Astron. and Astrophys.* 2, 213, 1964), is near synchronism, implying that the momentum exchange leading to synchronism can take place rapidly.

This work was supported by the National Science Foundation.

The Stability of Massive White Dwarfs. JEREMIAH P. OSTRIKER AND JEAN-LOUIS TASSOUL, *Princeton University Observatory*.—Recently, Ostriker and Bodenheimer (*Astrophys. J.* 151, 1089, 1968) have calculated models of massive white dwarf stars ($1.0 \leq M/M_\odot \leq 3.5$) having nonzero angular momenta. These models are only of interest if they are dynamically stable to small perturbations. Since they satisfy the criteria established by Goldreich and Schubert (*Astrophys. J.* 150, 571, 1967) the models will be stable to the small-scale axisymmetric instabilities which might arise from adverse distributions of internal or rotational energy. It remains to consider the instabilities of radial collapse which may occur as nuclear density is approached and the dynamical overinstability and possible fission that is anticipated for large angular momentum.

Using the tensor virial equations reported on elsewhere we have calculated the eigenfrequencies for the lowest nonaxisymmetric modes of oscillation which could lead to fission. We find that all of the models presented by Ostriker and Boden-

heimer are stable to these modes. At a ratio of kinetic to gravitational energy $|T/W|$ of ≈ 0.14 a neutral point is reached where secular instability would be expected to occur in the presence of viscosity. Lacking significant viscosity the models are stable until $|T/W| \approx 0.26$ where overstability sets in. The same instabilities set in at nearly the same values of $|T/W|$ in the less complex, classical, Maclaurin spheroids. These ratios (≈ 0.14 and ~ 0.26) are very nearly independent of mass. Since the massive white dwarf models calculated by Ostriker and Bodenheimer had $|T/W| < 0.20$, they are expected to be stable to fissional instability.

Spatial Correlation Properties of Jovian Decameter Emission. LOUIS PATAKI, *Department of Astronomy, The University of Texas at Austin*.—Simultaneous observations of Jupiter's decameter flux at three observing sites confirm the hypothesis that the irregularities causing the L pulse amplitude fluctuations are moving rapidly outward from the sun.

Observations of Jupiter's decameter flux were carried out at a base station at the Yale University Observatory at Bethany, Connecticut, and at remote sites spaced 98.7 and 73.5 km from the base station. Three events in October and December 1965 have been reduced. The observations were made with crystal controlled receivers having a 6 kc/sec bandwidth centered at 22.20 Mc/sec. The audio output of these receivers was brought to the base station on telephone lines where it was rectified and recorded at high speed after an integration time of some 10 msec. The analog records were then digitized at 0.25 sec intervals for 2 or 3 min segments of the events. Thus, we are looking at time structure on the order of seconds in the data. These digitized data were then numerically analyzed.

The data were filtered to remove long-period systematic effects and corrected to take account of the presence of noise. Parameters are derived from these corrected data for the irregularities causing the fluctuations. They are referred to the plane perpendicular to the line of sight to Jupiter. The projected velocity ranges from 210 to 365 km/sec. It is directed outward along the ecliptic. These observations, made when the angle between the sun and the line of sight to Jupiter was between 116° and 172° , gave characteristic ellipses of equal spacial correlation with axial ratios ranging from 2.9 to 5.9. These are higher than ratios reported from observations of discrete sources near the sun. The derived correlation scale size along the major axis of the correlation ellipse for the three cases was 670 km, 780 km, and 950 km.

This work was supported by the NASA under grants NsG 407 and NGR 44-012-055.

Search for Emission from Intergalactic H I. A. A. PENZIAS AND R. W. WILSON, *Bell Telephone Laboratories, Inc., Crawford Hill Laboratory, Holmdel, New Jersey*.—An investigation of the spectrum of the sky brightness temperature between 1408 and 1433 MHz has been undertaken in search of a "step" in the spectrum (Goldstein, S. J., *Astrophys. J.* **138**, 978, 1963; Koehler, J. A., and Robinson, B. J., *Astrophys. J.* **146**, 488, 1966) of general neutral intergalactic atomic hydrogen in emission. Within the present sensitivity of our experiment, no such feature is apparent. A 0.1°K difference would have been clearly visible, so the effect, if present, must be smaller than this value. A temperature difference of 0.1°K corresponds to 4×10^{-6} atoms/cc for $H = 75 \text{ km sec}^{-1}/\text{Mpc}$, provided the spin temperature of the gas is significantly above that of the microwave background.

This experiment was done with a 20-ft horn reflector antenna (2° beam diameter) pointed at zenith ($\delta \approx 40^\circ$) between 8h and 15h LST. The antenna temperature was compared with that of a well-matched termination immersed in liquid helium, using a waveguide switch. Measurements were made over the frequency range indicated above ($\pm 2800 \text{ km/sec}$) with both a traveling wave maser and a transistor preamplifier. Similar negative results were obtained separately with the two systems.

In addition a search for hydrogen in clusters of galaxies has been undertaken. An investigation of the Virgo cluster yielded an upper limit of 0.02°K, in agreement with the results of other workers. Recently, a similar search in the Peg I cluster has been made using a new multichannel radiometer; here also, no line emission was discernible, and an upper limit of 0.01°K assigned.

The Absorption of Light in Space. BRUCE A. PETERSON, *Mt. Wilson and Palomar Observatories*.—The $V-R$ color and the V magnitude of the brightest elliptical galaxy in each of the nearby Abell clusters has been photoelectrically measured, and redshifts have been obtained for all of the program clusters. The $\cos b$ dependence of the colors and magnitudes is attributed to galactic absorption. Preliminary results indicate a value greater than five for the ratio of total to selective absorption.

A Stellar Group in Line of Sight with the Large Magellanic Cloud. A. G. DAVIS PHILIP, *Dudley Observatory, State Univ. of New York at Albany* AND NICHOLAS SANDULEAK, *Warner and Swasey Observatory, Case Western Reserve University*.—In 1960, Bok and Bok (*Monthly Notices Roy. Astron. Soc.* **121**, 531), noted the possibility that there was a "loose stellar grouping" seen superimposed on the

Large Magellanic Cloud, in the region of the photoelectric sequence of Van Wijk (*Harvard Obs. Bull.* No. 921, 7, 1952). On deep, objective-prism plates taken of the Large Magellanic Cloud with the Curtis-Schmidt telescope on Cerro Tololo, a grouping of early-type stars can be noted in a region of relatively low surface density of background LMC stars at $\alpha = 5^{\text{h}} 18^{\text{m}}$, $\delta = -68.5^\circ$ (1950) with galactic coordinates $l^{\text{II}} = 279^\circ$ and $b^{\text{II}} = -34^\circ$.

An RH diagram was constructed of the majority of the brighter stars in the immediate vicinity. It shows an apparent main sequence with a turn-off point near A0. If one fits the observations to the zero-age main sequence of Johnson and Iriarte (*Lowell Obs. Bull.* **4**, 47, 1958), a distance modulus of $m - M = 7.8$ is derived, which when corrected for a visual absorption of 0.24 magnitudes yields a distance of approximately 330 parsecs to the group. Color excesses, computed from the $B-V$ colors and spectral types, showed that the average excess was 0.08 magnitudes, which is in good agreement with that of 0.07 found by Feast, Thackeray, and Wesselink (*Monthly Notices Roy. Astron. Soc.* **121**, 25, 1960) for stars in the foreground of the Large Magellanic Cloud. The photometry was done on the 36-in. telescope at Cerro Tololo in December 1967.

Part of this work was supported by NSF grant 6692.

Photometry of Some High Galactic Latitude Carbon Stars. A. G. DAVIS PHILIP, *Dudley Observatory, State University of New York at Albany*.—While classifying plates taken during a spectral survey of regions at high galactic latitudes, several carbon stars were noted. Their visual magnitudes ran from 11.7 to 13.3. Some of the survey plates were taken with the 4° prism on the Tonantzintla-Schmidt telescope on 103aO emulsion; others were taken with the uv prism on the Curtis-Schmidt telescope at Cerro Tololo on IIaO emulsion. In both cases, carbon stars can be identified by the distinctive break at $\lambda 4700$. On the night of 6 January 1968, eight carbon stars were measured photoelectrically with the 36-in. telescope at Cerro Tololo. Two of these stars had been measured previously at Kitt Peak National Observatory.

In a two-color diagram, the stars can be divided into two groups. Those closest to the galactic plane fall below the standard curve for Population I main sequence stars; those far above the plane fall above the standard relation. This is consistent if the more distant stars have ultraviolet excesses relative to the nearby stars. If one assumes an absolute visual magnitude of 0.4 for least red of these stars, appropriate if they are early R stars, their distances from the galactic plane range from 3500 pc.

to 650 pc for the distant group, and approximately 200 pc for the close group. More observations of high galactic latitude carbon stars are needed to help explain their presence at such great distances from the galactic plane.

One of the observed stars (Number 86 on the lists of McCarthy, Bertiau, and Treanor, *Ric. Astron. Specola Vaticana* 6, 576, 1964; and Philip, *Publ. Astron. Soc. Pacific* 79, 366, 1967) has varied since January 1967. The star has become very much redder (1.2 magnitudes in $B-V$) and brighter (0.9 magnitudes in V).

This work was supported by NSF grant 6692.

Photometry of Faint Objects around M87, RENÉ RACINE, *Mount Wilson and Palomar Observatories*.—Two-color photographic photometry to $B=23.0$ and star counts to $B=23.5$ are reported for the group of faint stellar objects around the giant elliptical M87. The color indices support their identification as globular clusters. The luminosity function is compared with the one for groups of globular clusters in the galaxy and in M31. A distance modulus $(m-M)_B = 30^m.7 \pm 0^m.2$ and a ratio $\langle V \rangle/d = 79 \pm 12$ km/sec/Mpc are derived.

The Observed Change of Period in the Light Curves of Magnetic and Spectrum Variable Stars. KARL D. RAKOS, *Lowell Observatory, Flagstaff, Arizona*.—The photoelectric investigation of magnetic and spectrum variables at the Lowell Observatory carried out in the years 1960–1961 (*Lowell Obs. Bulletins* Nos. 117 and 121) and 1963–1964 (to be published) shows definite changes in the periods of four stars.

For the star HD 32633 the following times of maximum light and corresponding period lengths have been obtained:

Jarzebowski, Rakos.....	(1959) JD 2436573.6	$P=6^d4383$
Rakos.....	(1960) JD 2436959.9	$P=6^d4315$
Rakos.....	(1961) JD 2437307.2	$P=6^d4287$
Rakos.....	(1963) JD 2438380.8	

For the star HD 71866, if we include Babcock's value for the period of magnetic variations in 1954 using the epoch of maximum of the negative magnetic field, there are five epochs for calculation of the period length:

Babcock.....	(1954) derived period	$P=6^d7991$
Babcock.....	(1954) JD 2435060.72	$P=6^d7980$
Jarzebowski.....	(1959) JD 2436658.55	$P=6^d7976$
Rakos.....	(1960) JD 2437311.12	$P=6^d7605$
Rakos.....	(1964) JD 2438406.33	$P=6^d77$
Rakos.....	(1964) JD 2438541.7	

For the well-known star HD 215441 with the unique magnetic field strength of 34 kG the following epochs of the maximum of light are established:

Jarzebowski.....	(1959) derived period	$P=9^d49$
Jarzebowski.....	(1959) JD 2436865.0	$P=9^d475$
Cameron and Perry, Abt	(1960) JD 2437196.6	$P=9^d4898$
Rakos.....	(1963) JD 2438325.87	$P=9^d482$
Polosukhina, Lebedeva	(1964) JD 2438648.3	
Rakos.....	(1963) derived period	$P=9^d472$

It seems that this star changes the period within 1000 days periodically.

It should be mentioned that there is some observational evidence that the real period of this star is actually slightly shorter than one day.

The star HD 224801 has now four established epochs of maximum light:

Babcock.....	(1950) JD 2433552.8	$P=3^d7430$
Provin.....	(1952) derived period	$P=3^d7422$
Provin.....	(1952) JD 2434222.8	$P=3^d7397$
Rakos.....	(1960) JD 2437240.74	$P=3^d7394$
Rakos.....	(1963) JD 2438317.69	

Since well-established changes in the period of magnetic and spectrum variables are necessary for better theoretical understanding, a new series of photoelectric observations of these stars is now in progress at Lowell Observatory.

This work has been supported in part by the National Science Foundation.

Evolutionary Tracks and Mass Exchange in Close Binaries. SJUR REFSDAL, *University of Nebraska* AND ALFRED WEIGERT, *Universitäts Sternwarte, Göttingen, Germany*.—The evolution of close binaries with a constant total mass of $2.5 M_\odot$ are calculated from the zero-age main sequence through the red subgiant phase of the original primary. The original primary starts to lose mass when it exceeds its Roche lobe. Different initial mass ratios and initial distances have been considered. In many of these systems the original primary, after its rapid mass loss will develop into a low mass ($0.9 M_\odot$ – $0.4 M_\odot$) red subgiant which now slowly continues to lose mass at a rate about $1.5 \times 10^{-9} M_\odot$ per year. In a time scale of 10^8 – 2×10^8 years the original primary can become as much as 6 mag brighter than a main-sequence star of the same mass. These time scales seem to be sufficiently large to explain the observed systems of that type. However, for systems with the initial mass ratio less than about 1.2, or for systems where the mass loss starts before hydrogen is exhausted in the center, the original secondary will develop into a red subgiant before the original primary has

completed, or even reached, this evolutionary stage. When this happens, the system will very soon change from a semidetached to a contact system and the evolution becomes too difficult to follow. As the initial mass ratio is increased, more mass is lost by the original primary during the rapid mass loss, and its time scale in the red subgiant phase is reduced. The longest time scale for the red subgiant phase of the original primary is thus obtained when the mass loss starts after hydrogen is exhausted in the center, and for initial mass ratios between about 1.2 and 1.6.

Grazing Incidence Optics for a Focusing Astronomical X-Ray Spectrometer. W. REIDY, T. ZEHPHENNIG, AND G. VAIANA, *American Science and Engineering, Inc.*—High resolution crystal spectroscopy in the wavelength region from 4 to 20 Å can be performed with the use of large area ($\sim 100 \text{ cm}^2$) focusing x-ray optics. The focusing properties of the mirror results in a combination of large collecting area and minimum detector size which greatly enhances the sensitivity of the instrument. The design and performance of grazing incidence optical systems for this application will be discussed. Laboratory measurement of resolution (several sec of arc), reflection efficiency ($\sim 50\%$ at 8 Å), and image distribution will be presented and compared to theoretical values. Potential improvements in optical performance due to changes in surface contour, improvements in surface finish, and deformation of the image plane will be evaluated.

H II Regions and Galactic Dynamics. E. C. REIFENSTEIN, T. L. WILSON, B. F. BURKE, *Research Laboratory of Electronics, Massachusetts Institute of Technology*, AND P. G. MEZGER, *National Radio Astronomy Observatory*.—A survey of 109 α hydrogen recombination lines has been completed, using the 140-ft telescope of the National Radio Astronomy Observatory. One hundred twenty sources were observed, including nearly all sources having a flux density greater than $8 \times 10^{-26} \text{ mks}$ at 5009 MHz. The H II kinematics do not appear to differ radically from the H I motions observed at 21 cm, and by using 21-cm rotation laws, we have derived models of the distribution of ionized hydrogen regions in the galaxy. From $R=4$ to $R=6$ kpc there are many giant H II regions, with a smaller number at greater distances from the center. Very few prominent H II regions were found at radial distances greater than that of the sun. An unexpectedly large fraction, roughly one-third of the sources studied, exhibited no recombination line, although their distribution in longitude is similar to that of the normal H II

regions. Preliminary indications are that most of these are supernova remnants.

The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under contract with the National Science Foundation. The work at the Research Laboratory of Electronics, MIT is supported in part by NSF (Grant GP-7046).

Shock Formation in Galactic Spirals. WILLIAM WOODRUFF ROBERTS, JR., *Massachusetts Institute of Technology*.—The problem of shock formation in a disk-shaped galaxy and its possible implication on star formation are discussed in this paper. We consider the motion of an isothermal gas moving in a gravitational field consisting of a two-armed spiral field superposed on the Schmidt model for the Milky Way system. Previously M. Fujimoto (preprint, Columbia University, 1966) considered the problem only on the basis of a local theory. Also, in contrast to Fujimoto's work which contained a pattern speed of about 45 km/sec/kpc, we adopt a pattern speed of 12.5 km/sec/kpc determined from other studies of spiral patterns. Numerical calculations for regions at several typical radii (10, 8, and 6 kpc) in the galactic model confirm the compatibility of two periodically-located shock waves lying along and within the imposed spiral arms. The pressure jump across each shock is approximately 8:1 if the gravitational field is equal to about 5% of the symmetrical field. It is suggested that galactic shock waves may very well form the triggering mechanism for the gravitational collapse of gas clouds, leading to star formation. L. Spitzer (1963, in Vol. VII of *Stars and Stellar Systems*, 1968) pointed out that some of "the clouds . . . are not far from the critical condition where collapse becomes possible." Indeed, calculations show that imposing a shock pressure jump of 8:1 will compress the "intermediate" and "large" clouds discussed by Spitzer beyond the critical limit where gravitational collapse becomes possible.

If an upper bound of $3 \times 10^7 \text{ yr}$ is assumed for the process of formation of relatively massive stars initiated at the shock, calculations indicate that the regions of newly-born luminous stars and H II regions lie on the inner side of the observed gaseous spiral arm, extending from the inner edge to approximately the middle of the arm, in general agreement with observations.

Supported by the National Science Foundation.

Luminosity Function and Color-Magnitude Diagram in a Central Region of the Coma Galaxy Cluster. HERBERT J. ROOD, *Van Vleck Observatory, Wesleyan University*.—Photovisual magnitudes de-

rived from 200-in. plate major and minor axes brightness profiles of 315 galaxies in a 0.32-square-degree central region of the Coma Cluster are used to construct an integrated luminosity function. Its bright end agrees with that derived by Abell for the cluster as a whole, but the faint end is less steep, signifying a deficiency of faint galaxies. This observed difference may be a result of dynamical relaxation in a stable core.

A preliminary color-magnitude diagram in the brightest 4 mag range shows a tendency for color index to decrease with decreasing luminosity. This is interpreted as a possible cosmogonical consequence of galaxy collisions preferentially sweeping metal-rich gas out of smaller galaxies so that they have a larger fraction of first-generation metal-poor Population II stars, the horizontal-branch causing the blue color. This explains the constant $B-V$ of the brightest 3 mag Virgo cluster ellipticals (de Vaucouleurs, *Astrophys. J. Suppl.* **5**, 33, 1960) as a natural consequence of the much smaller density of that cluster.

The Coma ellipticals and S0+SB0 galaxies have different luminosity functions but similar color-magnitude diagrams.

Neutrino Emission and the Onset of Carbon Burning in the Evolution of a $1.45M_{\odot}$ Star. WILLIAM K. ROSE, *Massachusetts Institute of Technology*.—Models for a $1.45M_{\odot}$ star have been computed up to the ignition of carbon burning. The models studied consist of a pure helium envelope, a helium-burning shell and a degenerate carbon-oxygen core. Although the envelopes of the computed models are hydrogen deficient, the star becomes a red giant before the onset of carbon burning.

For the computed models, the time scale for the evolution of the star prior to carbon burning is sufficiently long so that neutrino emission (neutrino emission rates given by Beaudet, Petrosian, and Salpeter, *Astrophys. J.* **150**, 979, 1967, were used) strongly inverts the temperature distribution in the degenerate core. Initially the temperature minimum associated with temperature inversion is at the center. However, as the star evolves the neutrino emission rates are quenched by the very high degeneracy of the core, and consequently the temperature minimum moves away from the center. The temperature at the center increases until carbon burning commences. The total rate of energy generation due to carbon burning reactions exceeds the energy loss rate due to neutrino emission when the density at the center of the star becomes about 10^9 g/cm³. Although the development of this delayed carbon core flash has not yet been followed, the very degenerate conditions inside the core at

the time of the flash suggest that the outcome will be a hydrodynamic event.

Previous calculations of carbon and oxygen burning phases of stellar evolution (Kutter and Savedoff, *Astron. J.* **72**, 811 1967; Rakavy, Shaviv and Zinamon, *Astrophys. J.* **150**, 131 1967) have assumed that gravitational contraction is the only energy source prior to either carbon or oxygen burning. When this assumption is not made, carbon and probably oxygen burning occur at densities considerably higher than those found in the previous calculations. Consequently, the likelihood of a hydrodynamic event caused by carbon and oxygen burning is increased.

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The Effect of Density Inhomogeneities in H II Regions. ROBERT H. RUBIN, *National Radio Astronomy Observatory*.—The effects of density fluctuations on the thermal and ionization equilibria in gaseous nebulae are computed. We use a model of uniform clumps randomly distributed throughout an otherwise empty medium. The fraction of the entire nebular volume occupied by clumps will be termed the clumping factor, f . It can be readily demonstrated that for an ionization bounded nebula with constant average density, the volume of the nebula is essentially proportional to f . Hence, for a spherically symmetric nebula, the radius of the nebula, R_s , is proportional to $f^{1/3}$. Since Osterbrock and Flather (*Astrophys. J.* **129**, 26, 1959) find for the Orion nebula that $f \approx 1/30$, the effect on R_s can be considerable. We compute model H II regions assuming spherical symmetry and allow for a varying average density distribution with the clumping factor modifying the density at each position. The calculation involves the solution of the thermal and ionization equilibrium equations and is coupled with the radiative transfer solution for the diffuse Lyman continuum radiation. The resulting electron temperature distributions show that when the value of f is smaller (all other parameters of the model being the same), the temperature in the central region is higher, the minimum temperature is higher, the maximum temperature is lower, and the average temperature with respect to mass is higher.

In the case of a completely arbitrary density distribution, we can relate L_c , the total number of Lyman continuum photons/sec exciting the nebula, D , the distance to the nebula, and S_{ν} , the total flux density of free-free emission at a radio frequency ν . There is no restriction on the geometry of the H II region except that it be completely ionization bounded. As long as ν is large enough to