N-S. The reflector surface has been made of graded earth covered with sheets of asphalt liner for erosion control; on top of this is a galvanized steel wire mesh. The focal length is 155 ft and the focal line runs along the underside of a catwalk 4 ft wide and 10 ft high which is supported on four wooden towers. The reflector, towers, and catwalk are complete. The feed elements consist of 276 conical log-spirals which are spaced along the underside of the catwalk. The operating frequency is 611 Mc and the beam-width is 20 minutes of arc. Mechanical rotation of the feed-elements about their axes is used to alter the electrical phasing and thus to change the direction of the beam in the meridian plane. The scanning capability is estimated to be 30° on each side of the zenith. The first program will consist of a survey of all radio sources in the accessible region of the sky. The survey will give the positions and the flux densities of the sources.

Structure and Evolution of Globular Clusters.

RICHARD W. MICHIE, *Berkeley Astronomical Department, University of California*.—A three-parameter distribution function in terms of energy and angular momentum and with a cutoff at the energy of escape is used to describe the structure of a spherical stellar system. The corresponding density distribution for a specific set of parameter values is obtained numerically and the result agrees very well with observations of 47 Tuc from one to 50 parsecs by Gascoigne and Burr.

In obtaining the evolution of a spherical cluster, the basic assumption is that the continuous evolutionary process can be approximated by a series of successive equilibrium states. Therefore, the distribution function is assumed invariant in form and the problem is the calculation of the changes in the three parameters after a time interval. This is done by taking three moments of the Boltzmann equation with the assumption of dynamical equilibrium during the interval of time. These moments are mass, the sum over all stars of the kinetic energy, and the sum over all stars of the angular momentum squared.

An evolutionary time step of three quarters of a billion years is obtained numerically with an IBM 650. The results show a flow of stars inward within one parsec from the center and an expansion beyond twenty parsecs. The core of the cluster (within 1.6 parsecs from the center) contracts. In the inner regions the mean-square velocity decreases, and beyond twenty parsecs the mean-square velocity increases. The isotropy of the distribution in velocity space increases in the inner regions and decreases for the outer sections. This result can be explained by a few stars suffering encounters and being thrown into orbits of high energy and low angular momentum.

X Rays from Collisions of Stars. S. N. MILFORD, *St. John's University, Jamaica, New York*.—Collisions of stars can occur with high relative velocity during the collision of two galaxies. At relative velocities of order 2000 km/sec the kinetic energy dominates the gravitational energy and the two stars can slice through each other without much distortion, giving two partial stars A, B, and a collision complex C. For simplicity, the case of a star sliced exactly into two hemispheres is considered. The radiation from the surface of one half of a model star is integrated to give the total radiation. The calculated luminosities range from 10^{10} suns (K dwarf) to 10^{14} suns (B star), while the wavelength of maximum photon emission is in the range 2.0 to 6.5 Å. It may be possible to observe this x radiation from satellites; for example, a half B star at 3 billion parsecs would give a flux of 10^{-2} reddened photons $\text{cm}^{-2} \text{sec}^{-1}$ above the earth's atmosphere. It is probable that the collision complex C will radiate much more strongly than the partial stars A and B. Also, the radiation will rapidly shift to longer wavelengths as A, B, C expand and cool.

The frequency of such energetic B-star collisions is difficult to estimate; by assuming a stellar population similar to that of our galaxy, it is estimated that such energetic B star collisions may occur about once per thousand years in a sphere of radius 3 billion parsecs. Collisions of stars in single galaxies within the same volume occur much more frequently, but most of these are not energetic enough to release comparable amounts of energy.

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The Structure of Virgo A. ALAN T. MOFFET, *California Institute of Technology, Pasadena, California*.—The Caltech variable baseline interferometer has been used to measure the east-west brightness distribution of Virgo A at a frequency of 958 Mc. The source is found to be complex, consisting of a core with a diameter of 0.6, contributing 50% of the total flux, surrounded by a halo with a diameter of 6.5. This confirms the recent observations made at 1420 Mc by F. Biraud, J. Lequeux, and E. LeRoux (*Observatory* 80, 116, 1960), except that at the higher frequency they find the contribution of the core to be 60% and the halo to be somewhat larger in diameter. Observations of B. Y. Mills (*Australian J. Phys.* 6, 452, 1953) are consistent with a small-diameter component contributing not more than 25% at 101 Mc. This suggests that between 101 and 1420 Mc the flux density from the core varies less steeply than $f^{-0.35}$, while that from the halo varies approximately as $f^{-1.0}$.

The core source is presumably to be identified with the well-known jet extending from the nucleus of M87. In a separate observation, Bolton has found the radiation from the core to be $\gtrsim 3\%$ polarized at 958 Mc. At very much higher frequencies, the radiation from the core should dominate. However, existing measurements at about 8000 Mc require that the spectrum of the core becomes steeper above 1420 Mc.

Preliminary analysis of brightness distributions in 130 sources has shown that such a complex structure is quite common. Some sources contain a core plus a halo, while others display a double peaked structure resembling that of Cygnus A.

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Estimation of the Dispersion of Redshift for Field Galaxies. JERZY NEYMAN AND ELIZABETH L. SCOTT, *Statistical Laboratory, University of California, Berkeley 4, California*.—It is assumed that the redshift Z of a field galaxy at distance D is a random variable with expectation HD , where H is the Hubble constant, and with variance $\sigma^2 = E(Z - HD)^2$ independent of distance. The problem treated is the estimation of σ^2 using the values of redshift Z and of apparent magnitude m of field galaxies in a catalogue, that is, subject to selection. The theory developed assumes (i) a catalogue of field galaxies resulting from an effort to include all galaxies observable with given instruments; (ii) the galaxies in the catalogue are reliably classified into morphological types fine enough to ensure that the ease of observing any two galaxies of the same type depends on their apparent magnitude only. Working in Euclidean space, it is found that among catalogue galaxies of a fixed type: (a) the regression of Z on $x = 10^{m/5}$ must be linear, $E(Z|x) = Ax$; (b) the regression of $Y = (Z - Ax)^2$ on x has the form $E(Y|x) = \sigma^2 + Bx^2$. Here A and B depend on the type of galaxy; the actual shape of the two regressions may be vitiated if the classification of galaxies is not fine enough. The formula for $E(Y|x)$ implies that the estimation of σ^2 reduces to that of the intercept of a quadratic regression. Preliminary results using the data of Humason, Mayall, and Sandage indicate that σ^2 must be small.

Tidal Deformations and the Origin of the Moon. ERNST J. ÖPIK, *Department of Physics, University of Maryland (on leave from Armagh Observatory, Northern Ireland)*.—Results of a provisional survey of the ellipticities of lunar craters in selected areas of Kuiper's *Atlas* are discussed. The rms random ellipticity is found to be 0.070 near the center, 0.096 near the limb, and is probably due to oblique impact. Small preferential components of ellipticity are indicated and interpreted as possible after-effects

of past tidal deformations. Formulae for tidal-rotational deformations of line elements on an elastic nonresisting surface are given. The smallness of the preferential effects is in itself significant, without regard to their absolute value. They suggest that the craters were formed when the earth-moon distance was of the order of 30 000–50 000 km. The undamaged appearance of the craters except for impact erosion and flooding, and the absence of signs of major crustal deformations indicates that since crater formation the moon could not have been at a closer distance. From theoretical rates of accretion as based on probabilities of interplanetary collisions, possible modes of origin of the moon are discussed. If the pre-mare craters mark the end of a continuous process of accretion which built the moon, the observed small systematic deformations of the craters are only compatible with the moon having accreted from a cloud of fragments circling the earth in direct orbits at a distance of 5–8 earth radii or greater. The assumption of different processes for accretion of the moon and for the formation of pre-mare craters leads to improbable consequences. Only when the preferential ellipticities are discounted as due to other causes or to chance, is it possible to accept the alternative of the moon having accreted from interplanetary material orbiting the sun. Accretion must then have run simultaneously with tidal evolution following initial tidal capture, the pre-mare craters having formed at a distance of over 200 000 km from earth as the final stage of this accretion.

Free-Free Emission in the Radio-Frequency Range. LUDWIG OSTER, *Yale University Observatory, New Haven, Connecticut*.—Classical and quantum-mechanical calculations for the free-free emission (bremsstrahlung) of electrons in a completely ionized plasma are critically investigated. Avoiding altogether the sometimes misleading assumptions found in the literature, it is concluded that the several classical computations are in complete agreement with the quantum-mechanical approach. Numerical coefficients are derived for a Maxwellian distribution of electron velocities. It is shown that for temperatures below, roughly, 550 000°K the classical results can be safely used; however, for higher temperatures quantum corrections are required. Finally, examination of the problem of a cutoff of the ion's Coulomb potential shows that this cutoff can be neglected for all frequencies above the plasma frequency in the range where the refractive index is effectively unity.

Heating of the Solar Chromosphere, Plages, and Corona by Magnetohydrodynamic Waves. DONALD E. OSTERBROCK, *Institute for Advanced Study, Princeton, New Jersey*.—The energy carried upward by sound waves generated in the hydrogen