44. ASTRONOMICAL OBSERVATIONS FROM OUTSIDE THE TERRESTRIAL ATMOSPHERE

(OBSERVATIONS ASTRONOMIQUES AU-DEHORS DE L'ATMOSPHERE TERRESTRE)

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INTRODUCTION

In view of the limitation on length set by the cost of producing the IAU Reports, the present report can only be a selection of the most important advances during the past three years and not a complete review of the field.

Attempting to pick out a few points of interest, since the last report improvements have been made in recording solar X-ray spectra and in high spatial resolution imaging; the OSO satellite programme continues to produce valuable data. The eclipse experiments planned for March 1970 will, if successful, provide a considerable amount of new information. The solar iron abundance is still a subject of interest in view of the revision of oscillator strengths used in the photospheric analyses. Further interplanetary observations have shown that the general nature of the solar wind at the Earth does not depend on the phase of the solar activity cycle, and have revealed large increases in the abundance of helium in the solar wind following solar flares.

There have been considerable advances in UV Astronomy. Good quality spectra of coarse resolution, obtained from pointing rockets, are now available for a number of bright early type stars, whereas the successful operation of the OAO-AS satellite is providing a large amount of new data, largely photometric but including a coarse spectral scan. Mass loss has been detected from the early type supergiants and the interstellar extinction curve has been extended to 1150 Å and reveals a fine structure near 2200 Å. Observations have been made of some of the brighter external galaxies and the nucleus of Andromeda shows an unexpected UV emission component.

One of the most exciting events in X-ray astronomy has been the discovery that the pulsar in the Crab Nebula has very strong X-ray emission pulsating with the same period as the radio and optical radiation. Observations of the soft X-ray cosmic background have shown that the intensity is larger than expected from a simple extrapolation of the power law spectrum in the 1–10 keV region, and the excess is probably of galactic origin.

The Report is divided according to subject matter into six sections. These sections have been prepared by R. Tousey, M. Neugebauer, H. E. Butler, L. Gratton, W. Kraushaar and F. G. Smith and deal respectively with solar astronomy, the interplanetary medium, stellar astronomy, X-ray sources, the X- and γ-ray cosmic background and radio-astronomy. I am extremely grateful to the above authors for their contributions, and to Dr Carole Jordan, who as Scientific Secretary to the Commission carried out much of the organization of this Report.

R. WILSON
President of the Commission

SOLAR ASTRONOMY

(by R. Tousey)

In the period since the 1967 IAU General Assembly there has been great activity in solar research, particularly in X-rays, imaging, and monitoring. Vehicles launched carrying solar experiments include the following: *Balloons:* Employed principally by France and the U.S.A.; equipped with solar pointing systems. *Rockets:* The Aerobee-150 and 170 (U.S.A.); Skylark (U.K.); Veronique (France); three-axis stabilization and solar pointing is accomplished with SPARCS (U.S.A.); and Stage-3 ACU (U.K.) with a stability of about 2 arc sec, peak-to-peak; biaxial pointing-controls continue in use. *Satellites:* Orbiting Solar Observatories, OSO III–VI (NASA); OGO IV–VI (NASA) and OV 1–10 and 17 (USOAR and Aerospace), all with solar-pointed sections; SOLRAD 9 (NRL) for monitoring; Cosmos-166, 230, 262, with solar-pointed sections (U.S.S.R.).

Vehicles soon to become available for solar research are: The Aerobee-350 and Black Brant V-B with greatly increased load-volume-altitude capability; both can be equipped with type II SPARCS solar pointing and stabilization to 0·5 arc sec peak-to-peak. Water recovery is now practicable. OSO is being improved; OSO-H by more than doubled size and power; and OSO-I will have telemetry increased up to 6400 bits/s, increased stability and additional commands. In the manned program, the Apollo Telescope Mount, ATM, (**1**), is to be launched in 1972 and operated in combination with the Orbital Workshop during three visits for a total of at least twenty weeks. Solar experiments proposed for automatic operation or operation by astronauts from a lunar base are under consideration by NASA.

Solar observations from rockets and balloons

The XUV spectrum

Advances include: a 30mÅ resolution 2000–2200Å echellogram (**2**); line spectra, 12–120Å and 140–800Å with intensities and $\Delta\lambda$ to ±40mÅ (**3**); photoelectric line and continuum intensities at 70mÅ resolution, 360–1340Å (**4**); photographic line and continuum intensities at 0·2Å, resolution, 1400–2200Å (**5**), and at 0·5Å, 20 arc sec resolution, 1984–2839Å (**6**); a continuing program of photoelectric spectral intensity measurements, 300–1300Å (**7**). Line lists expected during 1970 are 3000–2100Å (NRL), and 2200–2000Å (Culham). Line profile work includes: spectra of ±7 arc sec, 35mÅ resolution, 2770–2845Å, including Mg II, H, and K, from a balloon (**8, 9**); Mg II, H, and K with 30mÅ resolution and 6 arc sec spatial resolution along a solar diameter using a Fabry-Pérot and echelle (**10**); echelle-photographed profiles, at 15mÅ resolution and with partial spatial resolution, of H-$L\alpha$ (**11**), Si III 1206Å and O I 1302, 5,6Å (**12**), and C II 1334,6Å (**13**).

XUV imaging from rockets and balloons

Images in Mg II 2795·5Å, obtained with a double-Solč 2·1Å filter and resolution approaching 8 arc sec, are similar to but show more contrast than Ca K at 0·1Å bandpass (**14**). Broad-band (80Å), images at 1975, 2190, and 2235Å, with as much as 15 arc sec resolution, obtained from a rocket and two balloons show decreased limb-darkening and greater similarity to Ca K at 1975Å, which is below the 2090Å absorption edge and is chromospheric (**6**). With a scanning photoelectric technique the H-$L\alpha$ disc was shown to contain structural detail as small as 2 arc sec, the instrumental resolution (**15**). Spectroheliograms from 171 to 650Å were obtained on several rocket flights (**16**); on 4 November 1969 a spatial resolution near 5 arc sec was achieved; spicules are prominent in He II 304Å; the network is conspicuous in He I 584Å, He II 304Å, and O V 630Å, but is absent or masked in all lines from ions of higher excitation. Unpublished data show that plages retain their fine structure through Ne VII, lose it partially in Mg IX and completely in Fe XV and Fe XVI. Coronal emission is intense from Mg IX and higher excitation ions; the emission above the He II 303·78Å limb is from Si XI 303·31Å (λ from (**3**)), and is resolved in several spectroheliograms. Broad-band images, 171–500Å, continue to show emission far above the limb, reaching 30 arc min on some occasions (**16, 17**). X-ray images obtained by pinhole and zoneplate techniques (**18–20**), although of value, are less powerful than the Wolter lens (**21**), with which images having a few arc seconds resolution have been obtained (**22**). On two occasions these instruments were flown during a solar flare (**23**). Combined with a transmission grating, the X-ray lens has produced X-ray spectroheliograms of small active centers and flares (**23**).

White light and infrared corona

White light coronal photographs from 3 to $10 R_s$ were obtained together with XUV spectroheliograms and heliograms during the total eclipse on 22 September 1968, on 27 and 29 April 1968, and on 16 and 17 April 1969 (**24**). The principal findings are that the streamers are straight and nearly always approximately radial, and that they change greatly, even in 24 hours. The coronal streamers have also been photographed from balloons from 1·7 to $5 R_s$ (**25**). At $2{\cdot}2\mu$, with a coronagraph on a balloon at 93000 ft, measurement of the brightness from 3·5 to 9·2 R_s confirmed a peak at 4 R_s (**26**), whose origin had been proposed to be thermal emission from refractory interplanetary dust (**27**); the earlier observations were made from 13000 ft in Bolivia during the 1966 eclipse (**26, 27**).

Eclipse experiments

During the 12 November 1966 eclipse two rockets carrying solar-pointed photometers for 1050–1250 Å and 1250–1350 Å, were flown into the eclipse cone (**28**). After correction for a plage, the results from the better flight indicate that H-$L\alpha$ for the quiet sun is brighter by approximately 30 % at the center of a ring of 15 arc sec width, centered 6·4 arc sec inside the near-infrared limb. During the same eclipse, three rockets, each carrying eight curved-crystal monochromators for selected emission lines between 16 and 40 Å were launched into the cone. Less than 1 % of full-sun emission was recorded during totality (**29**). On 7 March 1970 the eclipse cone can be reached by rockets launched from Wallops Island, Virginia. Experiments are being prepared under NASA sponsorship for two launches; one by a consortium of Harvard and York Universities, Imperial College and Culham, the other by NRL. The principal experiments will photograph the flash spectrum and the corona in various wavelength ranges. NRL will fly also a photoelectric scanning spectrometer for the range 1300–2000 Å.

Orbiting Solar Observatory (OSO)

Highly successful launches took place with OSO-III on 8 March 1967; OSO-IV, 18 October 1967; OSO-V, 22 January 1969; and OSO-VI, 9 August 1969. Results from OSO-III are published (**30**), but only scattered reports from OSO-IV–VI have appeared. OSO-H is scheduled for 1971; this and later OSO's will have a pointed section of size up to 15 × 15 × 57 inches, and will carry up to 250 pounds. The wheel diameter will be 56 inches, and power 75 watts for OSO-H. Like OSO-VI, the follow-on spacecraft will have offset pointing and small rastering (5 × 5 arc min for OSO-H), and roll will be command-controlled by magnetic torquing. In OSO-H the pointed section will contain a group of Bragg spectrometers (6–25 Å), and a grazing incidence spectrometer (170–400 Å) equipped with an image-forming collector so that spectroheliograms in selected lines can be recorded by rastering (Neupert, GSFC); the other part of the pointed section will be instrumented to record in alternation the white light corona from 3–10 R_s using an SEC Vidicon and the sun-centered mode, and the XUV (171–500 Å) corona using a mirror-aluminium filter-channel photomultiplier instrument in the raster-mode, in order to observe coronal changes and transients and correlate them in white light and in the XUV (Tousey, NRL). In the wheel are soft and hard solar X-ray monitors by Peterson, University of California at San Diego, and Chupp, University of New Hampshire.

XUV imaging from satellites

The Harvard scanning spectrometers on OSO-IV and VI and the NRL spectroheliograph on OSO-V have been used in the spacecraft raster-mode to record many monochromatic solar images. On OSO-IV the entire sun was scanned once per minute in single, ground-commanded wavelengths between 300 and 1400 Å; on OSO-V with a similar raster-scan, images were obtained simultaneously in He II 304 Å and Ne VII 465 Å, and in Si XII 499 Å and H I 1216 Å. For both instruments the resolution was 1 × 1 arc minute. The OSO-VI experiment was like the OSO-IV, but with significant improvements: Spatial resolution 35 × 35 arc sec; scanning over a 46 × 46 arc min sun-centered area once per 8 min, or over a 7·5 × 7 arc min area once per 30 s; the latter area could be selected anywhere over the 46 × 46 arc min area by ground-command. From OSO-IV more than 4000 images were recorded in fifty-two wavelengths (31). Limb brightening was observed in various lines and used to derive a new model for the equatorial chromospheric-coronal transition region (32), with results for T_e vs height in good agreement with (33). Unpublished center to limb analyses by Noyes and Kalkofen, in different parts of the Lyman continuum show limb-darkening near the head. Withbroe and Noyes point out that the contrast between active and quiet regions appears to go through a minimum for lines in the chromospheric-coronal transition region. Also flown in OSO-IV was an X-ray spectroheliometer of the AS & E Corporation that produced one solar image per 5 min with several arc minutes spatial resolution for 3·5–12 Å (34). Both impulsive and gradual variations in plage X-ray emission were found (35). An X-ray imaging system built by Leicester and University College London is operating in OSO-IV.

X-ray spectra

Spectra of plages and of flares have been obtained by several groups using Bragg crystal spectrometers in satellites:

OSO-III	1·3–3 Å and 8–20 Å ,	GSFC (36);
OSO-IV	0·5–3·9 Å, 1·4–8·5 Å ,	NRL (37);
OSO-V	1 –3·8, 3·6–8·4, 8·2–25 Å,	GSFC (Neupert);
OSO-VI	0·5–3·9 Å, 1·4–8·5, 5 –16 Å,	NRL (Kreplin);
OV 1–10	8 –25 Å ,	Aerospace (38);
OV 1–17	1·5–25 Å ,	Aerospace (39).

The results, although differing in details, show the following for the 1·6–25 Å range: Plages emit both continuum and lines; great intensity increases occur for all spectral features during a flare; many new lines are emitted during a flare; the lines include both optical and inner shell transitions from highly-stripped atoms. The broad 1·9 Å feature, prominent during flares, is associated with K-line emission from Fe in all stages between helium-like and 16-electron, and perhaps lower; a small peak at 1·86 Å, reported during the most intense flares, may be $L\alpha$ of one-electron Fe. Similar but less intense emission from 1·60–1·66 Å is the Ni counterpart. The changes with time of the lines during a flare show that the lines of highest ionization stage reach maximum intensity and decay soonest, in accordance with cooling of the flare plasma and recombinations. Several lines of previously doubtful identification have been explained as the helium-like ion resonance lines caused by single-photon decay of the $1s2s\,^3S_1$ level (40). The intensity ratio of the ^1S–^3P intercombination to the ^1S–^3S forbidden line allows derivation of the coronal density (41, 39). Within the continuum an edge observed at 3·59 Å is identified as recombination of bare S ions; edges at 2·06, 2·8, and 4·46 Å are not easily explained; dielectronic recombination has been suggested by Doschek and Meekins. The production of the continuum appears to be complex, perhaps involving more than one mechanism.

Solar monitoring

Experiments for monitoring the total solar flux in various spectral bands from the near ultraviolet all the way to 250 KeV X-rays have been flown by many groups and in many spacecraft. Data from the NRL Solrad 9 and the University of Iowa detectors on Explorers 33 and 35 are now published by ESSA in *Solar-geophysical Data*. Worldwide reception of solar data is available from Solrad and has been used by various observatories, e.g. by Arcetri (42). Solar X-ray maps (9·1–10·5 Å) produced by the University College London-Leicester experiment on OSO-V are being sent to ESSA on a regular basis. One or more monitoring experiments were placed in OSO-I–VI, OGO-IV–VI, and several Explorers of NASA; several OV satellites of the AFOAR; Vela of the AEC; ESRO IA, IB, and II. The principal groups providing instrumentation are: in soft X-rays, NRL, Aerospace Corporation, Lockheed, Los Alamas, the Universities of Michigan and Iowa, University College London, and Utrecht; in the XUV, AFCRL, the University of Colorado, and University College London; in hard X-rays, the Universities of Minnesota, California at San Diego and at Berkeley, and GSFC, together with many groups using balloons. The U.S.S.R. has a continuing program of

XUV and X-ray monitoring with "Cosmos" (**43**). At present reports of results are widely scattered (**44, 45**). Nevertheless the following facts seem to be established (**46**): High energy X-ray emission and radio noise increase together with rising solar activity, but the physics involved is still not well understood. Flares are usually preceded by a slow rise in X-ray flux that is greatest for <3 Å; during this period there are often precursors in Hα and in microwave emission. In the main phase the X-ray flux increases rapidly and is coincident with a microwave burst, whose structure is related to that in the accompanying burst of >20 keV X-rays. The X-ray flare peak is reached first in 0–3 Å and last in 8–20 Å or longer. X-ray flares always accompany an Hα flare but are sometimes present by themselves, presumably when the flare is located over the limb (**47**). Emission of X-rays extends high into the corona during a large flare. Quasi-periodic structure has been found in the output from 9-channel spectra of solar X-ray bursts (14–250 keV) recorded with 1·85 s time-resolution by a GSFC experiment in OSO-V (**48**).

Flare observations

Flare history data with 30-s time and 30-arc sec spatial resolution are being obtained with the Harvard spectrometer on OSO-VI; flares were recorded on OSO-IV with 5-min and 1-arc-min resolution. Flare histories without spatial resolution but with 0·16 s time resolution were recorded with the AFCRL spectrometer on OSO-III for lines in the range 260–1300 Å (**49**); these flare produced enhancements in total emission have been found to correlate well with ionospheric Sudden Frequency Deviations (**50**). Structure in X-ray images of flares has been found with scanning slit heliographs on Cosmos-230; these instruments produced 20 arc sec × 2 arc min resolution for 2–8 Å and 20 × 15 arc sec for 8–14 Å (**51, 52**). A grazing incidence X-ray telescope, and also a photoelectric scanning spectrometer (20–300 Å) are in orbit on Cosmos-262 (**43**). On a rocket flight on 8 June 1968 AS & E photographed fine structure in a Class 1N flare with a few arc seconds resolution (**23**). On near-simultaneous flights on 4 November 1969 AS & E obtained a series of X-ray images with great time resolution of a 1B flare near the limb, and NRL recorded the spectrum of the same flare, both with about 5 arc sec resolution (**23**).

Radio observations

Radio noise burst observations have been made by the Research Telecommunications Institute (Canada) from Alouette I and II (**53**), and by GSFC from ATS-I and -II, and RAE-I (**54**), and by the U.S.S.R. from Venus 2 (**55**). The frequencies covered are in the range 0·1–15 MHz. The results for type-III bursts indicate a high density, low-temperature model for coronal streamers to $50R_s$ but alternative models are possible.

Infrared

In the infrared (≈ 50–300μ), the sun's brightness gives directly the value of temperature at the minimum between the chromosphere and corona, because of the high opacity of H^-. Measurements made from an aircraft near the tropopause using high resolution Fourier spectroscopy, after correction for residual absorption, gave values from 4338 to 4438 K in four windows between 238 and 312 μ (**56**). From a balloon, 4600 K was found near 60 μ and 4000 K at 180 μ (**57**). In this difficult spectral region accuracies are less than desired. The Bilderberg Model value of minimum temperature (**58**), 4600 K, lies almost within the error bars of the infrared data.

Interpretation

The controversy over the ten times greater coronal than photospheric abundance of Fe, first noted by Pottasch from XUV spectra and confirmed by others, appears to be nearly resolved. New *f*-values of Fe I, lower than those of King and King, have been found by (**59, 60**), and by the beam foil method by (**61**). These results have been extended over a wide range of excitation potentials by means of a special arc by (**62**). According to (**63**) the new *f*-values imply an abundance increase by just the factor of 10 required to bring the photospheric abundance into agreement with the coronal. A somewhat similar conclusion has been reached by (**64**). Further consequences of this revision are expected. Dielectronic recombination (e.g., **65**), has been established as essential for interpreting XUV line intensities; with its use, temperature and abundance values from the XUV resonance lines and those from the visible forbidden lines come into reasonable agreement. For example for the quiet corona, Fe XI and Si X are the most abundant species and their resonance lines lead to $T_e = 1{\cdot}7 \times 10^6$ K, and $N_{Fe}/N_{Si} = 1{\cdot}5$ (**66**). For extensive calculations of ionization equilibrium for the most abundant solar atoms from carbon through nickel, see (**67**). Much work on abundances, and on the prediction of XUV line intensities and comparison with observation has been done by (**68**). The Bilderberg Model of the photosphere and low chromosphere, (**58**), has been subjected to some uncertainty in the neighborhood of the temperature minimum, for which 4600 K was assumed, as a result of a disagreement in the value of observed brightness temperature near 1650 Å (**69**): The NRL photographic spectra lead to 4650 K (**70**), while the Harvard photoelectric spectra give 4400 K (**4**). The higher temperature is supported by data for 2080–1950 Å (**71**), and the lower by results in the infrared (**56**). Additional work is required. XUV spectroheliograms have been analyzed and interpreted in terms of chromospheric structure (**72, 73**).

REFERENCES

1. *Trans. IAU*, **XIIIA** (Reports 1967), Commission 44, Solar Astronomy.
2. Jones, B. B., Boland, B. C., Wilson, R., Engstrom, S. T. F. 1970, *IAU Symposium* no. 36, Lunteren.
3. Jones, B. B., Freeman, F. F., Wilson, R. 1968, *Nature*, **219**, 252.
4. Parkinson, W. H., Reeves, E. M. *Solar Phys.* (in press).
5. Sandlin, G. D., Widing, K. G. 1967, *Astrophys. J.*, **149**, L129.
6. Bonnet, R. M., Blamont, J. E. 1968, *Solar Phys.*, **3**, 64.
7. Hinteregger, H. E. 1969, Ann. IQSY, *Solar-Terr. Phys.*, **5**, 305.
8. Lemaire, P., Blamont, J. E. 1967, *Astrophys. J.*, **150**, L129.
9. Lemaire, P. *IAU Symposium* no. 36, Lunteren.
10. Bates, B., Bradley, D. J., McKeith, C. D., McKeith, N. E., Burton, W. M., Paxton, H. J. B., Shenton, D. B., Wilson, R. 1969, *Nature*, **224**, 161.
11. Bruner, E. C., Jr, Parker, R. W. 1969, *J. geophys. Res.*, **74**, 107.
12. Bruner, E. C., Jr, Rense, W. A. 1969, *Astrophys. J.*, **157**, 417.
13. Berger, R. A., Bruner, E. C., Jr. 1969, *Astrophys. J.*, **155**, L115.
14. Fredga, K. 1969, *Solar Phys.*, **9**, 358.
15. Sloan, W. A. 1968, *Solar Phys.*, **4**, 196; **5**, 329.
16. Purcell, J. D., Tousey, R., Koomen, M. J. 1968, *Space Res.*, **8**, p. 450.
17. Tousey, R., Sandlin, G. D., Purcell, J. D. 1968, *IAU Symposium* no. 35, Budapest, p. 411.
18. Bol Raap, B. E., Le Poole, J. B., Dijkstra, J. H., De Graaff, W., Lantwaard, L. J. 1969, *Small Rocket Instrumentation Techniques*, North-Holland Publishing Co., Amsterdam, p. 203.
19. Burton, W. M. 1969, *Solar Phys.*, **8**, 53.
20. Unzicker, A. E., Meekins, J. F., Conrads, H. Submitted to *Appl. Opt.*
21. Mangus, J. D., Underwood, J. H. 1969, *Appl. Opt.*, **8**, 95.
22. Reidy, W. P., Vaiana, G. S., Zehnpfennig, T., Giacconi, R. 1968, *Astrophys. J.*, **151**, 333.
23. Vaiana, G. S., Reidy, W. P., Zehnpfennig, T., Van Speybroeck, L., Giacconi, R. 1968, *Science*, **161**, 564.
24. Koomen, M. J., Seal, R. T., Purcell, J. D., Tousey, R. 1969, *Sky Telesc.*, **37**, 356.
25. Dolfuss, A., Fort, B., Morel, C. 1968, *C. r. Acad. Sc. Paris*, **266**, 1537.
26. MacQueen, R. M. 1968, *Astrophys. J.*, **154**, 1059; *Appl. Opt.*, **7**, 1149.
27. Peterson, A. W. 1967, *Astrophys. J.*, **148**, L37.
28. Blamont, J. E., Malique, C. 1969, *Astr. Astrophys.*, **3**, 135.
29. Argo, H. V., Bergey, J. A., Evans, W. D., Singer, S. 1968, *Solar Phys.*, **5**, 551.
30. Brandt, J. C., Hinteregger, H. E., Hall, L. A., Neupert, W. M. *et al.*; Teske, R. G.; Hudson, H. S. *et al.*; Kaplon, M. F., Valentine, D.; Kraushaar, W. L. *et al.*; Neel, C. B. *et al.*; Papers. 1969, *Solar Phys.*, **6**, 171–240.
31. Goldberg, L., Noyes, R. W., Parkinson, W. H., Reeves, E. M., Withbroe, G. L. 1968, *Science*, **162**, 95.
32. Withbroe, G. L. 1969, To appear in *Bull. AAS.*
33. Dupree, A. K., Goldberg, L. 1967, *Solar Phys.*, **1**, 229.

34. Paolini, F. R., Giacconi, R., Manley, O., Reidy, W. P., Vaiana, G. S. 1968, *Astr. J. Suppl.*, **73**.
35. Krieger, A. S., Vaiana, G. S., Special Meeting AAS. 1969, *Bull. AAS*, **1**, 283.
36. Neupert, W. M., White, W. A., Swartz, M., Young, R. M. 1969, *Solar Phys.*, **6**, 183.
37. Meekins, J. F., Kreplin, R. W., Chubb, T. A., Friedman, H. 1968, *Science*, **162**, 891.
38. Walker, A. B. C., Rugge, H. R. 1969, *Solar Flares and Space Research*, North-Holland, Amsterdam, p. 102.
39. Walker, A. B. C., Rugge, H. R. 1969, Submitted to *Astr. Astrophys.*
40. Gabriel, A. H., Jordan, C. 1969, *Nature*, **221**, 947.
41. Gabriel, A. H., Jordan, C. 1969, *Mon. Not. R. astr. Soc.*, **145**, 241.
42. Landini, M., Fossi, B. C. M., Poletto, G., Tagliaferri, G. L. 1968, *Solar Phys.*, **5**, 546.
43. Prokof'ev, V. K. Communicated to Commission 44.
44. Friedman, H. 1969, Energetic Solar Radiations, *Solar-Terrestrial Physics*, **4**, 36. MIT Press.
45. Hudson, H. S., Peterson, L. E., Schwartz, D. A. 1969, *Solar Phys.*, **6**, 205; *Astrophys. J.*, **157**, 389.
46. Kreplin, R. W., Moser, P. J., Castelli, J. P. To appear in *Space Res.*, Vol. 10.
47. Teske, R. F. 1969, *Solar Phys.*, **6**, 193.
48. Frost, K. J. *Astrophys. J. Lett.*, in press.
49. Hinteregger, H. E., Hall, L. A. 1969, *Solar Phys.*, **6**, 175.
50. Donnelly, R. F. 1969, *J. geophys. Res.*, **74**, 1873.
51. Vasil'ev, B. N., Žitnik, I. A., Corneev, V. V., Crutov, V. V., Mandel'stam, S. L., Tindo, I. P., Tsheremuchin, G. S., Shurigin, A. I. 1968, *Kosm. Issled.*, **6**, 420.
52. Beigman, I. S., Grineva, Yu. I., Mandel'stam, S. L., Vainstein, L. A., Žitnik, I. A. 1969, *Solar Phys.*, **9**, 160.
53. Hartz, T. R. 1969, *Planet. Space Sci.*, **17**, 267.
54. Alexander, J. K., Malitson, H. H., Stone, R. G. 1969, *Solar Phys.*, **8**, 338.
55. Slysh, V. I. 1967, *Soviet Astr.*, **11**, 389.
56. Eddy, J. A., Lena, P. J., MacQueen, R. M. 1969, *Solar Phys.*, **10**, 330.
57. Mankin, W. G., Strong, J. 1970, *Solar Phys.*, (in press).
58. Bilderberg Model: 1968, *Solar Phys.*, **3**, 5–239.
59. Huber, M., Tobey, F. L. 1968, *Astrophys. J.*, **152**, 609.
60. Grasdalen, G. L., Huber, M., Parkinson, W. H. 1969, *Astrophys. J.*, **156**, 1153.
61. Whaling, W., King, R. B., Martinez-Garcia, M. 1969, Report OAP-166, Cal. Inst. Tech.
62. Garz, T., Kock, M. 1969, *Astr. Astrophys.*, **2**, 274.
63. Garz, T., Holweger, H., Kock, M., Richter, J. 1969, *Astr. Astrophys.*, **2**, 446.
64. Withbroe, G. L. 1969, *Solar Phys.*, **9**, 19.
65. Burgess, A., Summers, H. P. 1969, *Astrophys. J.*, **157**, 1007.
66. Widing, K. G., Sandlin, G. D. 1968, *Astrophys. J.*, **152**, 545.
67. Jordan, C. 1969, *Mon. Not. R. astr. Soc.*, **142**, 499.
68. Nikolsky, G. M. 1969, *Solar Phys.*, **6**, 399. (See also Ivanov-Holodny, G. S., Nikolsky, G. M. 1969, *The Sun and The Ionosphere*, p. 455.)
69. Gingerich, O., Cuny, Y., Noyes, R. W. 1969, To appear in *Bull. AAS*.
70. Sandlin, G. D., Widing, K. G. 1967, *Astrophys. J.*, **149**, L129.
71. Bonnet, R. 1968, *Ann. Astrophys.*, **31**, 597.
72. Allen, C. W. 1969, *Solar Phys.*, **8**, 72.
73. Zirin, H. 1969, *Solar Phys.*, **9**, 77.

THE INTERPLANETARY MEDIUM

(by M. Neugebauer)

It is the purpose of this report to summarize briefly the most significant advances in our understanding of the interplanetary medium derived from satellite and space-probe experiments during the past three years and to suggest possible major future developments in this area of research.

Since 1965, the conditions in interplanetary space have been monitored not only nearly continuously, but often by more than one spacecraft simultaneously. One of the most important results is that the general nature of the solar wind near 1 A.U. does not depend in any spectacular way on the phase of the solar activity cycle, even though the average values of plasma density, velocity, etc., may vary due to changes in the number or intensity of high-velocity plasma streams.

At the time of the previous report, essentially nothing was known about the electrons in the solar wind. We now know that, as predicted, the electron convective (or flow) velocity is equal to that for the positive ions and that the solar wind is electrically neutral. The Vela 4 measurements (1) showed that in the solar-wind reference frame the electrons have an anisotropic velocity distribution function with the maximum velocity away from the sun and parallel to the magnetic field. The magnitude of the thermal anisotropy is smaller than that for protons; the electron anisotropy is probably collision limited. Vela 4 observed the electron temperature to range from 7×10^4 to 2×10^5 K when averaged over all directions; it varies less with time than does the proton temperature. The electron temperature was 1·5 to 5 times greater than the proton temperature; comparison of this temperature ratio with the value of ~ 16 predicted by a two-fluid model (2) of the solar wind indicates that more energy is transferred from the electrons to the positive ions than can be accounted for by ion-electron collisions.

Early measurements indicated a large temporal variation in the composition of the solar wind; the ratio of alpha-particle to proton number density varied from near 0 to 0·20, with rapid variations. Recent observations (3, 4) indicate that flare-associated plasmas are sometimes unusually helium rich. The alpha-particle thermal distribution is anisotropic and similar to that observed for protons. The fact that the ratio of alpha-particle temperature to proton temperature is often ~ 4 (corresponding to equal proton and alpha thermal velocities) is another indication of the collisionless transfer of energy from the electrons to the positive ions. The alpha-particle temperature is nearly equal to the proton temperature only when the protons are unusually cool; i.e., when little collisionless heating occurs (5).

When the proton and alpha-particle temperatures are unusually low, it is possible to resolve other helium ions and oxygen ions in the electrostatic-analyzer spectra. Vela measurements showed the following ranges of ion number density ratios (5); ^{3}He/^{4}He from $\leqslant 4 \times 10^{-4}$ to $1{\cdot}3 \times 10^{-3}$; ^{4}He$^+$/^{4}He^{++} from $\leqslant 10^{-3}$ to $\sim 3 \times 10^{-3}$; He/O from 25 to 80; and O^{+7}:O^{+6}:O^{+5} = ($\leqslant$ 0·2 to 3): 1:$\leqslant$ 0·1. The ratio of O^{+6} to O^{+7} is thought to indicate the temperature of the coronal region from which the solar wind emanated (6). Several different hypotheses have been proposed to explain the relatively large amounts of He$^+$ and O^{+5}.

Conflicting results have been obtained on the direction of the solar wind: the Vela data gave an average of 1·5° in the direction of corotation with the sun (7) for the period July 1964 through July 1965, while the IMP 1 data indicated 1·5° anticorotation for the period November 27, 1963, through February 24, 1964 (8).

The sector structure of the interplanetary magnetic field has shown a large amount of evolution with the increase of solar activity (9). The polarity of the field still remains steady for extended periods of time, but the very long-lived sectors of solar minimum are no longer evident (10). A study of the periodicities of the field direction has shown an apparent lengthening of the recurrence period which has been interpreted as an increase in the latitude of the solar source from 10–15 °N for IMP 1 to 20–25 °N for IMP 3 (11). There is some evidence for a correlation of the component of the field perpendicular to the ecliptic with the solar latitude of the point of observation (12).

Power spectra of variations in the interplanetary field have been determined over the frequency range $f = 3 \times 10^{-6}$ to $f = 5 \times 10^{-1}$ Hz (13–16). The spectral power density is generally proportional to f^{-x}, where $1 \leqslant x \leqslant 2$. This power density probably consists of contributions from both a large number of hydromagnetic discontinuities (15) and from large amplitude, aperiodic Alfvén (transverse) waves propagating outward from the sun along the field lines (14).

In addition to the by-now common plasma, energetic-particle and magnetic-field experiments, several recent space probes (Zond 3, Venus 2, Luna 11 and 12, Pioneers 8 and 9, and OGO 5) have carried apparatus for the measurement of the electric fields in space (17–19). Low-frequency (hundreds of Hz) electric-field oscillations are essentially always detectable; these waves have large amplitude variations which correlate with other changes in the solar wind. Large-amplitude high-frequency (tens of kHz) waves are also occasionally detected.

More data are slowly being acquired relevant to the radial gradients of properties of the interplanetary medium. Mariner 4 (20) observed a less rapid change in the pitch of the spiral angle between 1·0 and 1·5 A.U. than would be expected for a constant solar wind velocity whereas the field magnitude varied approximately as expected. The relative amplitude of the transverse fluctuations in the field (from 10^{-5} to 10^{-2} Hz) was independent of heliocentric distance and the amplitude of compressional fluctuations increased as $r^{0.69}$. Experiments to determine the gradient of cosmic-ray intensity between 0·7 and 1·5 A.U. have given contradictory results (**21–26**) ranging from -14 to $+500$ %/AU.

The increased data rates of recent spacecraft have allowed the study of some of the smaller-scale hydromagnetic structures. Observations of interplanetary shock waves have demonstrated that (i) the conditions across the shocks are not inconsistent with the Rankine Hugoniot relations (**27, 28**), (ii) the shock is greatly decelerated as it moves away from the sun (**28**), and (iii) the shock front can appreciably affect the spectrum of energetic solar particles incident upon it (**29**).

Discontinuities other than shocks have also been observed and studied in detail. That these surfaces are convected by, but do not propagate through, the solar wind is demonstrated both by the abrupt change in composition, as shown by the relative number of alpha particles (**30**), and by the velocity, as determined by sequential observations of the surface by more than one space probe (**31, 32**). The observed jump conditions across the surfaces (**30, 32, 33**) have all been consistent with theoretical predictions. The preferential alignment of the discontinuities along the spiral of the interplanetary field (**16, 32, 33**) has been suggested to cause a correlation between solar-wind velocity and direction with the faster streams coming from a more westerly direction (**33**). The thickness of these shocks and other "discontinuities" ranges from $\leqslant 500$ to ~ 20000 km (**16, 32**); current interest is focused on their internal structure, which is often fairly complicated.

Observations have also been made of what is believed to be the merging or reconnection of magnetic-field lines with accompanying plasma heating and high-frequency electrostatic waves (**34, 35**).

Much of the future progress expected in this field of research will be extensions of the best recent experiments; more information will be obtained on the details of the wave-particle interactions in the solar wind which transfer thermal energy from the electrons to the heavier ions and which limit the growth of the proton thermal anisotropy. More complete data will be obtained on the chemical (and isotopic) composition of the solar wind. Better and more complete measurements will be made on the long-term averages and variations in the flow direction of the solar wind. More detailed spectra will be obtained of magnetic- and electric-field oscillations. The cosmic-ray gradient will be better understood. The internal structure of collisionless shock waves, other discontinuities, and regions of field-line reconnection will be more accurately mapped to give a better understanding of the physical processes occurring within them.

Significant results can be expected from the spacecraft which go much closer to or much farther from the sun than the 0·7 to 1·5 A.U. studied to date. Data acquired close to the sun might reveal whether the solar wind is accelerated only in certain regions or whether the entire corona is involved. Outward from the sun, some of the major questions are: How far does the solar wind extend? What are the termination mechanisms? How and where is the galactic cosmic radiation modulated and what is the interstellar cosmic-ray spectrum and intensity?

Finally, the study of materials returned from the moon may determine the flux of many different elements in the solar wind over both short (but accurately measured) and very long (but not accurately determined) time intervals.

REFERENCES

1. Montgomery, M. D., Bame, S. J., Hundhausen, A. J. 1968, *J. geophys. Res.*, **73**, 4999.
2. Sturrock, P. A., Hartle, R. E. 1966, *Phys. Rev. Lett.*, **16**, 628.
3. Ogilvie, K. W., Burlaga, L. F., Wilkerson, T. D. 1968, *J. geophys. Res.*, **73**, 6809.
4. Hirshberg, J., Bame, S. J., Hundhausen, A. J. 1968, *Trans. Amer. geophys. Un.*, **49**, 728.
5. Bame, S. J., Hundhausen, A. J., Ashbridge, J. R., Strong, I. B. 1968, *Phys. Rev. Lett.*, **20**, 393.
6. Hundhausen, A. J., Gilbert, H. E., Bame, S. J. 1968, *J. geophys. Res.*, **73**, 5485.
7. Hundhausen, A. J., Ashbridge, J. R., Bame, S. J., Strong, I. B. 1967, *J. geophys. Res.*, **72**, 1979.
8. Egidi, A., Pizzella, G., Signorini, C. 1969, *J. geophys. Res.*, **74**, 2807.

9. Wilcox, J. M., Colburn, D. S. 1969, *J. geophys. Res.*, **74**, 2388.
10. Coleman, P. J., Jr., Davis, L., Jr., Smith, E. J., Jones, D. E. 1966, *J. geophys. Res.*, **71**, 2831.
11. Wilcox, J. M., Ness, N. R. 1967, *Solar Phys.*, **1**, 437.
12. Rosenberg, R. L., Coleman, P. J., Jr. 1969, UCLA Preprint no. 737.
13. Coleman, P. J., Jr. 1966, *J. geophys. Res.*, **71**, 5509.
14. Belcher, J. W., Davis, L., Jr., Smith, E. G. 1969, *J. geophys. Res.*, **74**, 2302.
15. Sari, J. M., Ness, N. F. to appear in *Solar Phys.*
16. Siscoe, G. L., Davis, L., Jr., Coleman, P. J., Smith, E. J., Jones, D. E. 1968, *J. geophys. Res.*, **73**, 61.
17. Slysh, V. I. 1967, *Soviet Astr.*, **11**, 72.
18. Slysh, V. I. 1967, *Soviet Astr.*, **11**, 389.
19. Scarf, F. L., Crook, G. M., Green, I. M., Virobik, P. F. 1968, *J. geophys. Res.*, **73**, 6665.
20. Coleman, P. J., Jr., Smith, E. J., Davis, L., Jr., Jones, D. E. 1969, *J. geophys. Res.*, **74**, 2826.
21. Anderson, H. R. 1968, *J. geophys. Res.*, **73**, 2897.
22. Krimigis, S. M. 1968, *Can. J. Phys.*, **46**, S976.
23. Krimigis, S. M., Venkatesan, D. 1969, *J. geophys. Res.*, **74**, 4129.
24. O'Gallagher, J. J. 1967, *Astrophys. J.*, **150**, 675.
25. O'Gallagher, J. J., Simpson, J. A. 1967, *Astrophys. J.*, **147**, 819.
26. Vernov, S. N., Chudakov, A. E., Vakulov, P. V., Logatchev, Yu. I., Lyubimov, G. P., Nikolaev, G. P., Pereslegina, N. V. 1967, *Spaceflight*, **9**, 168.
27. Sonett, C. P., Colburn, D. S., Davis, L., Jr., Smith, E. J., Coleman, P. J., Jr. 1964, *Phys. Rev. Lett.*, **13**, 153.
28. Gosling, J. T., Ashbridge, J. R., Bame, S. J., Hundhausen, A. J., Strong, I. B. 1968, *J. geophys. Res.*, **73**, 43.
29. Van Allen, J. A., Ness, N. F. 1967, *J. geophys. Res.*, **72**, 935.
30. Gosling, J. T., Ashbridge, J. R., Bame, S. J., Hundhausen, A. J., Strong, I. B. 1967, *J. geophys. Res.*, **72**, 3357.
31. Fairfield, D. H. 1968, *J. geophys. Res.*, **73**, 6179.
32. Burlaga, L. F., Ness, N. F. to appear in *Solar Phys.*
33. Siscoe, G. L., Turner, J. M., Lazarus, A. J. to appear in *Solar Phys.*
34. Burlaga, L. F. 1968, *Solar Phys.*, **4**, 67.
35. Scarf, F. L. 1969, talk presented at 16th General Assembly of URSI, Ottawa, Canada.

APPENDIX I: RESULTS FROM INTERPLANETARY "VENERA" STATIONS

(by V. G. Kurt)

Automatic interplanetary stations "Venera-4", "Venera-5" and "Venera-6" were used to carry out observations far from the Earth in three spectral regions: 1050–1340, 1225–1340 and 1050–1180 Å. Radiation in the spectral region including the H-$L\alpha$-line was discovered; it is concentrated to the plane of the Milky Way and has a maximum intensity of about 100 Rayleigh. Investigations of the scattered ultraviolet radiation in the vicinity of the Earth and of Venus were carried out with these stations. An extended hydrogen corona around Venus was discovered and an upper limit for the atomic oxygen density in the upper atmosphere of Venus was estimated.

ULTRAVIOLET STELLAR ASTRONOMY

(by H. E. Butler)

General

The past three years have seen appreciable advances in uv astronomy, the following being particularly noteworthy:

(a) The Orbiting Astronomical Observatory (OAO-A2), launched in December, 1968, has produced large amounts of high quality observational photometric and spectrophotometric data that must be most gratifying to the two astronomical groups concerned – the Smithsonian Astrophysical Observatory in Harvard and the Washburn Observatory, Wisconsin – as well as to all working in this field.

(b) Medium resolution (~ 1 Å) spectra of early type stars are now being obtained regularly from stabilised rockets, the uv region having been covered down to 928 Å. The spectra have shown a complex structure of absorption lines shortward of about 1800 Å. Early type supergiants have shown P-Cygni type profiles for several resonance lines, with ejection velocities of up to 3800 km s^{-1}: the consequent rate of loss of mass from such stars is appreciable.

(c) New spectrophotometric data have confirmed and extended the first uv interstellar extinction curve. Considerable theoretical efforts have been made to interpret the curve in terms of model absorbing grains of graphite and silicates with, and without, ice or solid H_2 mantles.

(d) Interpretation of the strength of the interstellar Lyman α absorption has led to a figure for the average density of neutral hydrogen along the line of sight to the stars being observed. In the direction of Orion the figure is 0·1 atoms cm^{-3}, approximately one tenth of the figure derived from 21-cm radio observations. The recent data that have been obtained for stars in other directions in the sky show larger figures, even exceeding the corresponding 21-cm values.

(e) Photometric and spectrophotometric absolute intensity observations have continued but with increasing awareness of the pitfalls associated with inadequate instrumental calibrations. Stellar model-atmosphere work has continued simultaneously and a series of line blanketed models is now in good agreement with observation for most of the UV region.

(f) At least four new groups (one in the U.S., two in Europe and one in Japan) have recorded their first stellar observations from rockets and there is the preliminary report of successful observations from a Russian orbiting astronomical satellite.

Stellar observations

Photometric observations of many thousands of stars have been made in four passbands within the spectral range 1050–3000 Å by Project Celescope, the Smithsonian Astrophysical Observatory cluster of uv television cameras on board the Orbiting Astronomical Observatory (OAO-A2). The faintest stars observed were of visual magnitude ten at spectral type A0 early in the life time of the instruments but the sensitivity has considerably decreased. The instrumentation is described by Davis (1). Observational results will be circulated to institutions and individual scientists in a series of "Celescope Observational Data Reports" (2). Only a small part of the data has as yet been completely reduced: Davis reports that the relative accuracy cannot be relied on to better than $0^{m}_{.}25$ in any channel. One consistent picture emerging from the data is that the observed stars are about equally divided between those that fall within $0^{m}_{.}5$ of the predicted uv brightness and those that are significantly fainter than predicted. Most of the giant stars exhibit these deficiencies, including stars for which no interstellar reddening is predicted.

The Wisconsin package on OAO-A2 has obtained medium resolution spectrophotometric data between 1050 and 3800 Å and photometric data in nine different passbands between $L\alpha$ and the visual blue region. None of these data is in print at the time of writing although four papers detailing them were read at the IAU Symposium no. 36 on *Ultraviolet Stellar Spectra and Related Ground-based Observations* in June 1969 (3–6). The spectrum scanning instruments (15 Å slit width; scanning in 10 Å steps) have been very successful in providing several hundreds of observations and, in particular, details were given of 50 stellar spectra having "a wide range of spectral type, luminosity class, reddening and peculiarities". It was stated that the calibration remained satisfactorily consistent to better than $0^{m}_{.}02$ throughout several months.

Comparison of observations with model atmosphere theories

The early photometric observations indicated that the continuum intensities of early type stars at wavelengths shorter than about 2000 Å were much less than contemporary models indicated.

Since the work of Morton, Mihalas and Guillaume prior to 1967, the following studies have been made. The line blocking to be encountered for each 100 Å of a spectrum between 1900 and 3000 Å has been calculated (7). Comparisons between models and observations have been made for a

B4V star (**8**), for O5V and B0V stars (**9**), and for O type stars (**10**). New scales of effective temperatures and bolometric corrections for main sequence stars hotter than the Sun have been suggested (**11**).

Wavelength lists of 283 lines observed within 1100–1950 Å in Orion stars (**12**), and of 100 lines from ζ Pup (**13**) have been published. Identifications are suggested for over half of the lines. Other wavelength lists include: 50 lines in the region 1050–1300 Å, also for Orion stars (**14**), 128 lines in the region 928–1350 Å for α Vir with identifications offered for most (**15**), and in particular identifications of all except one of the lines predicted for a B IV star (**16**). A low resolution study of ζ UMa (B3V), (**17**), has shown that line blanketing is still greater than recent models indicate by about $0^m.5$ and it is suggested that an additional source of continuous opacity is needed.

The results of Stuart (**18**) differed from those of other observers by as much as $1^m.2$ at 1376 Å and he generally obtained larger figures than others, being in agreement with Mihalas and Morton's B1·5 model. Intercomparison of many observations have shown (**19**), first, that about $0^m.25$ was a reasonable absolute accuracy for current photometric observations at that time, and, secondly, that blanketed models of Morton and colleagues, together with the Morton-Adams (**11**) temperature scale, adequately represented most of their observations. The inaccuracies associated with the large correction for uv interstellar absorption that has to be obtained by a considerable extrapolation from (U–B) observations are emphasised.

Carruthers (**20**) agrees that the position for main sequence stars is satisfactory but that the intensities of giants and supergiants are up to one magnitude less than those of main sequence stars at 1115 Å. Stecher (**21**) examining the spectra of 29 stars of types between O 5 and F 0 in the range 1700–3000 Å, shows that line blanketing is evident in the region 1800–2100 Å for the hotter stars but that the region moves to about 2300 Å for A and F types. Maran *et al.* (**22**) computed a synthetic spectrum for A stars between 2000 and 3000 Å, for given temperature and surface gravity. Bless (**3**) states that his recent observations suggest that earlier deficiencies were probably the result of calibration errors. However, late B and A types may well emit less in the uv than the models, which do not yet allow for Si, Mg or C opacities. Gingerich and Latham (**23**) agree for Si and C at type A0: Strom and Strom (**24**) consider the effect of Si opacity in B and A star atmospheres. Code and Bless (**5**) displayed 50 stars with 10 Å resolution within 1050–2000 Å to give a qualitative description of spectral variations with type. They compared the equivalent widths of Si IV (1403 Å) and C IV (1550 Å) with calculated values and suggested a revision of effective temperatures for stars earlier than B 3. Bless and Savage (**4**) made an important contribution by showing for a small sample that if two early type stars of luminosity classes II-V have the same visual spectral type, then they have essentially the same continuum in the ultraviolet.

Stellar mass loss

Morton (**25**) found that the uv spectra of certain hot stars in Orion showed not only that the resonance lines of Si IV (1403 Å) and C IV (1550 Å) were present strongly in emission, but that each was accompanied on its shortwave side by an absorption line shifted by up to 10 Å – i.e. a P Cygni-like profile – showing matter streaming outwards with velocities of up to 3800 km s^{-1}. The lines are considered to be formed in the expanding shell and since the ion states present in these hot atmospheres have all their resonance lines in the uv, the effect will not generally be present in the visible region. Later observations by the Princeton Group, (**12**, **13**) and by Carruthers (**14**) have extended the observations to 8 stars and to 8 lines (5 of which are resonance lines) of the ions He II, C III and IV, N IV and V and Si III and IV, showing various emission speeds up to 2140 km s^{-1}. Morton (**26**) reviews the data and concludes that probably all supergiants and some giants of type B 0·5 and earlier show the phenomenon. He does not anticipate that the rate of loss of mass – estimated to be of the order of 10^{-6} $M_{\odot}$ y^{-1} – is sufficient to affect the evolution of such a star. Lucy and Solomon (**27**) proposed that the outward velocity can be produced by the absorption of photons by the ions: for this case they compute a figure for the rate of mass loss smaller than Morton's by a factor of about ten. The effect of the phenomenon on stellar evolution is considered by Hartwick (**28**).

General interstellar absorption

A careful photoelectric comparison of the uv spectra of ε and ζ Per from a rocket (**29**), has produced an improved observational curve: further far-ultraviolet data have been given (**30**). Coincident with these observations, silicates were reported in space and Greenberg and Stoeckly (**31**) examined the new possibility of silicate grains, possibly with ice mantles. Hoyle and Wickramasinghe (**32**) in a review, and Wickramasinghe (**33**) have considered mixtures of graphite and silicates with and without ice or H_2 mantles. The first OAO has now made an appreciable contribution to our observational data on interstellar absorption and Bless and Savage (**4**), presenting it, conclude from spectra of about 50 stars that

(a) all extinction curves show a maximum at about 2200 Å
(b) most curves show a minimum at about 1750 Å
(c) all curves continue to rise towards shorter wavelengths
(d) there appear to be real differences between the curves for different stars.

Interstellar absorption by atomic hydrogen

Spectra showing the interstellar Lyman α absorption line were first reported by Jenkins (**34**) and Jenkins and Morton (**35**). Stecher (**36**) mentioned similar observations. The observations are interpreted as indicating an average density along the line of sight to Orion of about 0·1 atoms cm^{-3}, appreciably less than the 1 atom cm^{-3} computed from 21-cm radio observations. In general the density in other directions in the sky is more in accord with 21-cm results – see, for example, (**37**) for β^1, δ and π Sco. However, Carruthers (**30**) discusses anomalous results for θ Ori. The subject is discussed in detail by Jenkins (**34**) who considers the possibility of the hydrogen being in small, dense, hot clouds well separated from each other. Savage and Code (**6**) give probably the most consistent set of data for 48 stars measured with the OAO. They generally confirm the above conclusions and favour as explanation that the 21-cm emission mostly originates beyond Orion.

Interstellar absorption by molecular hydrogen

The first deliberate attempt to observe the interstellar molecular hydrogen bands shortward of 1108 Å was reported by Carruthers (**38, 14**). He interpreted the fact that he failed to see them superimposed on the spectra of γ Vel and ζ Pup as indicating that the number of hydrogen molecules in the line of sight to these stars was less than 10^{19} cm^{-2}. Likewise Smith (**15**) has an upper limit for the numbers of molecules in the line of sight to α Vir of $6{\cdot}5 \times 10^{16}$ cm^{-2} or a mean number density of less than $3{\cdot}1 \times 10^{-4}$ cm^{-3}.

Radiation from the celestial background in the region 1050–1350 Å

This radiation is of two different types: general continuum radiation due to the integrated light from hot stars and $L\alpha$ emission. The latter can be either (i) diffuse emission from the Galaxy or (ii) sunlight scattered by the geocorona, by interplanetary hydrogen or by hydrogen at the extreme edge of the solar system. Photometric observations have been made by both Russian and U.S. spacecrafts at considerable distances from the Earth where any geocoronal light can be discounted. Kurt and Dostovalov (**39**) report data from the satellite Venera 4 and Dimov *et al.* (**40**) give data for satellites Kosmos 51 and 213. Kurt and Sunyaev (**41**) review the observations where they quote that the $L\alpha$ intensity varies round the Milky Way in the wide range $2{\cdot}5 \times 10^{-5}$ to $2{\cdot}5 \times 10^{-4}$ erg cm^{-2} s^{-1} $ster^{-1}$. The integrated continuum intensity from hot stars in the Milky Way (i.e. omitting $L\alpha$) was found to be 3×10^{-7} erg cm^{-2} s^{-1} $ster^{-1}$ from the spectral band 1225–1340Å, a figure which is considerably greater than that which simple summation of observations of individual stars would suggest. They examine this problem in some detail. Barth (**42**) reports similar data for the $L\alpha$ and oxygen (1304 Å) intensities from the interplanetary flight of Mariner 5. He found 5×10^{-4}

erg cm^{-2} s^{-1} $ster^{-1}$ to the south of the galactic plane and 7×10^{-4} erg cm^{-2} s^{-1} $ster^{-1}$ to the north. There was an enhancement when crossing the galactic plane in Vela but none in Cygnus. Interpretation of the data in terms of atomic hydrogen within, and on the outskirts of, the solar system is given.

Extragalactic observations

There are two observations to date. Goldberg (**42**) reports an OAO spectral scan, supplied to him by Code, of the nucleus of the Andromeda nebula. The intensity is known from ground observations to decrease as we move to shorter wavelengths through the blue and near uv regions. The OAO data show this decrease as continuing until about 2700 Å where the trend reverses and the intensity is still steadily rising at 2000 Å, the shortest wavelength observed. Cruvellier *et al.* (**44**) report these data as being in agreement with two photometric observations made by them at 3450 Å and 2710 Å with rocket equipment. Goldberg comments on the data indicating the presence of hot stars in the nucleus and also on the possible cosmological importance of the observation should it be common to all galaxies.

Future work

Unmanned satellites

(i) OAO III will carry the Goddard 36-inch telescope and spectrograph. The spectral region is 1000–3000 Å, the resolutions are 2 Å, 8 Å and 64 Å and launch is expected in 1970.

(ii) OAO IV will carry the Princeton 80-cm telescope which is capable of being pointed to an accuracy of 0·1 second of arc on O and B stars as faint as $7^{m}_{.}0$. The spectral resolution will be 0·05 Å from 800 to 1600 Å and 0·10 Å from 1600 to 3200 Å. It will be used primarily to study the composition and physical state of the interstellar gas.

(iii) TD 1 is a European Space Research Organisation satellite with a stabilised scan and which will cover the whole sky in a period of 6 months: launch is expected in 1972. It will carry two UV astrophysical instruments. The first is a 290 cm^2 aperture telescope of Utrecht Observatory which will examine spectral regions centred on 2085, 2500, 2800 Å at a resolution of about 1 Å. Its magnitude limit is $V = 5$ for a B 0 star. The second instrument uses a 27-cm telescope which is being jointly provided by the Astrophysical Institute at Liège and the Royal Observatory at Edinburgh. It will examine four uv regions within the range 1450–3000 Å to give photometric observations and low resolution spectra. The limiting magnitude will be about 9 for photometric measures of early type stars.

Stabilised rockets

The work using these rockets is scheduled to continue in the U.S. with steadily increasing numbers of flights. The Culham and Edinburgh groups in Britain have plans for flights beginning in 1970 using Skylark rockets in the British National programme. Within the ESRO programme the Liège and Munich groups, as well as the Culham and University College London groups, have plans for flights in 1970 and 1971. All are for medium and high resolution spectroscopy of single stars except Edinburgh, which will fly wide angle, objective prism cameras.

Balloons

The group at the Geneva Observatory has further plans to obtain data in the 2000–3000 Å region from balloons.

Calibration

The importance of absolute calibration in stellar photometric and spectrophotometric work has led to increased efforts to ensure the highest possible individual accuracy: the interchange of absolute standards amongst groups is proposed.

REFERENCES

1. Davis, R. J. 1968, *Smithsonian Astrophys. Obs. Special Reports* no. 282 and 1969, *ibid.* no. 310.
2. Davis, R. J. 1969, *Celescope Observational Data Reports, Smithsonian Astrophys. Obs.*
3. Bless, R. C. 1970, *IAU Symposium* no. 36, Lunteren.
4. Bless, R. C., Savage, B. D. 1970, *IAU Symposium* no. 36, Lunteren.
5. Code, A. D., Bless, R. C. 1970, *IAU Symposium* no. 36, Lunteren.
6. Savage, B. D., Code, A. D. 1970, *IAU Symposium* no. 36, Lunteren.
7. Elst, E. W. 1967, *Bull. astr. Inst. Netherl.*, **19**, 20.
8. Adams, T. F., Morton, D. C. 1968, *Astrophys. J.*, **152**, 195.
9. Hickok, F. R., Morton, D. C. 1968, *Astrophys. J.*, **152**, 203.
10. Bradley, P. T., Morton, D. C. 1969, *Astrophys. J.*, **156**, 687.
11. Morton, D. C., Adams, T. F. 1968, *Astrophys. J.*, **151**, 611.
12. Morton, D. C., Jenkins, E. B., Bohlin, R. C. 1968, *Astrophys. J.*, **154**, 661.
13. Morton, D. C., Jenkins, E. B., Brooks, H. H. 1969, *Astrophys. J.*, **155**, 875.
14. Carruthers, G. R. 1968, *Astrophys. J.*, **151**, 269.
15. Smith, A. M. 1969, *Astrophys. J.*, **156**, 93.
16. Mihalas, D. M., Morton, D. C. 1965, *Astrophys. J.*, **142**, 253.
17. Opal, C. B., Moos, H. W., Fastie, W. G., Bottema, M., Henry, R. C. 1968, *Astrophys. J.*, **153**, L179.
18. Stuart, F. E. 1969, *Astrophys. J.*, **157**, 1255.
19. Bless, R. C., Code, A. D., Houck, T. E. 1968, *Astrophys. J.*, **153**, 561.
20. Carruthers, G. R. 1970, *IAU Symposium* no. 36, Lunteren.
21. Stecher, T. P. 1969, *Astr. J.*, **74**, 98.
22. Maran, S. P., Kurucz, R. L., Strom, K. M., Strom, S. E. 1968, *Astrophys. J.*, **153**, 147.
23. Gingerich, O., Latham, D. 1970, *IAU Symposium* no. 36, Lunteren.
24. Strom, S. E., Strom, K. M. 1969, *Astrophys. J.*, **155**, 17.
25. Morton, D. C. 1967, *Astrophys. J.*, **150**, 535.
26. Morton, D. C. 1969, *Astrophys. Space Sci.*, **3**, 117.
27. Lucy, L. B., Solomon, P. M. 1967, *Astr. J.*, **72**, 310.
28. Hartwick, F. D. A. 1967, *Astrophys. J.*, **150**, 953.
29. Stecher, T. P. 1969, *Astrophys. J.*, **157**, L125.
30. Carruthers, G. R. 1969, *Astrophys. J.*, **156**, L97.
31. Greenberg, J. M., Stoeckly, R. 1970, *IAU Symposium* no. 36, Lunteren.
32. Hoyle, F., Wickramasinghe, N. C. 1969, *Nature*, **223**, 459.
33. Wickramasinghe, N. C. 1970, *IAU Symposium* no. 36, Lunteren.
34. Jenkins, E. B. 1967, *Astr. J.*, **72**, 304.
35. Jenkins, E. B., Morton, D. C. 1967, *Nature*, **215**, 1257.
36. Stecher, T. P. 1968, *Bull. astr. Inst. Csl.*, **19**, 279.
37. Jenkins, E. B., Morton, D. C., Matilsky, T. A. 1969, *Astrophys. J.*, **158**, in press.
38. Carruthers, G. R. 1967, *Astrophys. J.*, **148**, L141.
39. Kurt, V. G., Dostovalov, S. B. 1968, *Nature*, **218**, 258.
40. Dimov, N. 1970, *IAU Symposium* no. 36, Lunteren.
41. Kurt, V. G., Sunyaev, R. A. 1970, *IAU Symposium* no. 36, Lunteren.
42. Barth, C. A. 1970, *IAU Symposium* no. 36, Lunteren.
43. Goldberg, L. 1969, *Sci. Am.*, **220**, 92.
44. Cruvellier, P., Roussin, A., Valerio, Y. 1970, *IAU Symposium* no. 36, Lunteren.

X-RAY SOURCES

(by L. Gratton)

Since the last Report of Commission 44 there has been a great advance in the study of X-ray sources. There are at present a score of groups engaged in active work on this field and already some general conclusions are beginning to take shape.

At the General Assembly of the IAU in Prague a joint discussion of Commissions 28, 33, 34 and 44 (Chairman: S. B. Pikelner) was held (1) on the subject of X-ray astronomy; in November 1968 a one-day conference was organized by the Royal Society in London (**2**) and a three-day Symposium cosponsored by IAU and COSPAR was held in May 1969 in Rome (**3**) on non-solar gamma and X-ray Astronomy. The papers presented in this last Symposium (see especially the invited papers by H. Gursky, G. W. Clark, L. E. Peterson, R. Giacconi, H. M. Johnson, L. Gratton, L. Woltjer, J. E. Felten) cover the field very thoroughly, so that the present report, and especially the bibliography, can be made quite short. Among other review papers there may be mentioned those by Gould (**4**), Friedman (**5**), Rossi (**6**) and by Giacconi *et al.* (**7**) and also L. Gratton's lecture at the 1969 NATO summer school in Lagonissi (Greece) (**8**).

The individual X-ray sources known at present number about 50, but there is still considerable disagreement in several cases concerning whether a particular source noted by two observers is really the same source with a large error in the given positions. For six sources there is a definite identification with optical objects and two more may be accepted with reasonable confidence, although some observers are still expressing reserve.

A point which perhaps should be discussed by Commission 44 is that of the naming of the sources; the present system is very unsatisfactory, each group naming the sources according to its own system. This adds considerably to the confusion which naturally arises from the poor determination of the positions; a procedure similar to that in use for naming variable stars or minor planets might be desirable.

The eight identified objects fall into (at least) three categories:

(a) *supernova remnants*, which include Tau X-1 (Crab nebula), Cas XR-1 (Cas A) and an unnamed source coincident with Tycho SN 1572;

(b) *peculiar starlike objects*, including 4 objects, two of which are still doubted by some observers: Sco X-1, Cyg X-2, Cen XR-2 (WX Cen) and GX 3 + 1;

(c) *radiogalaxies*, including at present only Vir XR-1 identified with M 87 (Virgo A).

Long series of photometric observations of Sco X-1 (**9**) and spectral and color data (**10–13**) will have been published for objects of class (b) showing light variations and spectral features reminiscent of those of old novae, but no known old nova has been yet discovered to possess a detectable emission in the X-ray domain. It was also noted that the galactic sources – which appear in their majority to belong to class (b) – follow a galactic distribution closely resembling that of known novae. But the proper motions of Sco X-1 and Cen XR-2 (**14, 15**), point towards a membership of these objects in the Scorpio-Centaurus group. This however contradicts Wallerstein's earlier results from the interstellar Ca II lines (**16**). The whole situation concerning the physical nature and statistical properties of the objects of this class (e.g. their stellar population type) is very obscure and conclusions concerning the theoretical interpretation – except perhaps very rough and qualitative ones – might be at present premature and misleading. The binary nature of Sco X-1 and Cyg X-2 suggested by the radial velocity variations is also doubtful (**17**). Thermal bremstrahlung from an optically thin plasma in the X-ray domain and optically thick in the visual and radio spectrum seems to be a likely mechanism of radiation (**18–21**) the temperatures required are of the order of 10^6 K. Apparently the X-ray flux from these objects is subject to large variations not correlated with similar variations in the visual spectrum; the large decrease of the X-ray flux from Cen XR-2 in 1967 and the outburst – or "birth" – of a source between Lupus and Centaurus in 1969 are especially noteworthy.

The only object of class (c) discovered so far is M 87 and this might well be an exceptional case, since as a radio-source it belongs to the relatively rare "core-halo" class of objects. The physical interpretation of M 87 has been discussed by Felten (**22**). A large number of faint and distant X-ray sources is postulated in some theories of the diffuse X-ray background radiation.

One of the most exciting discoveries in the field of the X-ray Astronomy was made almost simultaneously by the NRL (**23**), the MIT (**24**) and the Rice University (**25**) groups early in 1969. They found that the pulsar, NP0582 in the Crab nebula has very strong X-ray emission pulsating with the same period as the radio and optical radiation. Indeed the power emitted in the X-ray domain far exceeds that in the rest of the electromagnetic spectrum. If, as many now believe, the pulsar mechanism is the source of the energy radiated by the entire Crab nebula, these observations and those of the X-ray emission from the nebula may be of enormous importance in providing experimental evidence for the mechanism itself.

All X-ray observations of individual sources have been obtained by means of rocket experiments; there can be little doubt that great advances will be made when it will be possible to fly a satellite borne experiment. This will permit detection of fainter sources and a great improvement of the position of the stronger ones. An Explorer satellite is planned by the ASE group in 1970, which will probably detect sources of an intensity $10^{-4} \times$ Crab; Gursky estimates that this experiment will detect as many as 10^3 sources, compared with the 50 reported so far. A satellite experiment will also permit long series of simultaneous X-ray and optical observations of some objects. A grazing incidence telescope giving images of the Crab, M 87 and other extended or multiple sources with a resolution of a few arc sec may bring decisive results for the physical interpretation of these objects.

Another field in which decisive advances may be expected from a satellite borne experiment is that of X-ray spectroscopy; at present spectral data of sources are very rough and may be compared to those obtained in broad band multicolor photometry of stars. Perhaps before the 1973 General Assembly various experiments of this sort will have been made.

REFERENCES

1. *Highlights of Astronomy* presented at the XIIIth General Assembly of the IAU. 1968, Ed. L. Perek, p. 177.
2. *Proc. R. Soc. London* (in press).
3. 1969, *IAU Symposium* no. 37, Rome, in press.
4. Gould, R. J. 1967, *Am. J. Phys.*, **35**, 376.
5. Friedman, H. 1967, *Ann. Rev. Nucl. Sci.*, **17**, 317.
6. Rossi, B. 1969, *Astronomia in raggi X* – Lecture held at the Accademia Nazionale dei Lincei, published in *Annuario della ES & T*, Mondadori, Milano, p. 272.
7. Giacconi, R., Gursky, H., Van Speybroeck, L. R. 1968, *A. Rev. Astr. Astrophys.*, **6**, 373.
8. Gratton, L. 1969, NATO International Summer School at Lagonissi (Greece), in press.
9. Among others Hiltner, W. A., Mook, D. E. 1967, *Astrophys. J.*, **150**, 851.
10. Westphal, J. A., Sandage, A. R., Kristian, J. 1968, *Astrophys. J.*, **154**, 139.
11. Eggen, O. J., Freeman, K. C., Sandage, A. R. 1968, *Astrophys. J.*, **154**, L27.
12. Lynds, C. R. 1967, *Astrophys. J.*, **149**, L41; Burbidge, E. M., Lynds, C. R., Stockton, A. 1967, *Astrophys. J.*, **150**, L95; Kraft, R. P., Demoulin, M. H. 1967, *Astrophys. J.*, **150**, L183.
13. Peimbert, M., Spinrad, H., Taylor, B. F., Johnson, H. M. 1968, *Astrophys. J.*, **151**, L93.
14. Gatewood, G., Sofia, S. 1968, *Astrophys. J.*, **154**, L69.
15. Eggen, O. J. 1969, *Astrophys. J.*, **158**, L31.
16. Wallerstein, G. 1967, *Astrophys. Lett.*, **1**, 31.
17. Sofia, S., Wilson, R. E. 1968, *Nature*, **218**, 73.
18. Meekins, J. F., Henry, R. C., Fritz, G., Friedman, H., Byram, T. E. 1969, *Astrophys. J.*, **157**, 197.
19. Shklovsky, I. S. 1967, *Astrophys. J.*, **148**, L1.
20. Prendergast, K. H., Burbidge, G. R. 1968, *Astrophys. J.*, **151**, L83.
21. Neugebauer, G., Oke, J. B., Becklin, E., Garmire, G. 1969, *Astrophys. J.*, **155**, 1.
22. Felten, J. E. 1968, *Astrophys. J.*, **151**, 861.
23. Fritz, G., Henry, R. C., Meekins, J. F., Chubb, T. A., Friedman, H. 1969, *Science*, **164**, 709.
24. Bradt, H., Rappaport, S., Mayer, W., Nather, F. H., Warner, B., McFarlane, M., Kristian, J. 1969, *Nature*, **222**, 728.
25. Haymes, R. C., Freeman, K. C., Harnden, F. R., Jr. 1969, *Astrophys. J.*, **156**, L107.

THE X- AND GAMMA-RAY BACKGROUND RADIATION

(by W. Kraushaar)

Observational status

Prior to 1966, there was good evidence for cosmic background radiation (or at least spatially unresolved radiation) in the 1 keV to 1 MeV energy region. The region below 1 keV was not yet seriously examined and only tentative evidence existed for cosmic gamma radiation at energies larger than a few MeV. Spectral measurements could be fitted satisfactorily to a single power law of the from $I \sim E^{-\gamma}$ with γ near 2·3 and with I at 5 keV about 1 photon cm^{-2} sec^{-1} sterad^{-1} keV^{-1}. Little attention had been given to a possible anisotropic nature of the radiation. The earlier observations and their interpretation have been summarized by Gould (1), and the following paragraphs review briefly the highlights of extended observations made since late 1966.

Rocket-borne (**2–10**), satellite-borne (**11, 12**), and balloon-borne (**8, 13, 14**) detectors have all contributed to a vast amount of new data in the 1 keV to 1 MeV energy region. Much of the new data were discussed at the Rome IAU Symposium no. 37 and will be published in the forthcoming proceedings of that meeting. An overall view suggests that no single power law can be made to fit the accumulated data satisfactorily and that certainly a single power law with index as large as 2·45 is ruled out. Various authors have suggested the existence of "breaks" in the photon number spectrum. It seems likely that positioning of these breaks is at present largely subjective. There is fairly good evidence, however, that γ, the logarithmic slope of the differential photon number spectrum, is about 1·5 or 1·6 near 5 keV, has become about 1·8 near 50 keV and has become 2 or more in the region between 100 keV and 1 MeV. Only better quality data can determine whether these changes are gradual or do indeed occur at reasonably well-defined energies.

Few groups have given serious attention to the important question of just how isotropic the background radiation in the 1 keV to 1 MeV region really is. The LRL group (**2**) noted an approximately 10 % enhancement of the background intensity near the galactic plane over the intensity at high galactic latitudes. The statistical significance of the measurement was marginal, however. The Nagoya-Tokyo group (**10**) divided the parts of the sky their detector scanned into cells and examined the data for fluctuations beyond those to be expected from counting statistics. No unexpected fluctuations were found. The A.S.E. group (**3**) reported the background radiation to be uniform in intensity to within 8 % over the narrow strip of sky scanned by their detector. The Leicester group (**15**) has reported a statistically significant increase in the intensity of the diffuse radiation near the galactic plane in a region ($l_{\text{II}} = 220°$ to $320°$) where there are no reported discrete sources. They suggest that the enhanced intensity may arise from unresolved galactic plane sources.

Measurements of the background radiation in the energy region just below the carbon K absorption edge (0·28 keV) have been carried out by several groups (**16–20**). The measurements and data reduction procedures are less straight-forward here than in the higher X-ray energy regions and there exist significant differences in the reported intensities. At the time of writing (October 1969) there is fair evidence that the soft X-ray background intensity is larger than one would expect on the basis of a simple extrapolation of the power law spectrum that seems most appropriate in the 1–10 keV region. There is good evidence that at energies near the carbon K edge (280 eV) the intensity does not fall off with decreasing galactic latitude in the manner one would expect were the radiation all extragalactic. Involved in this conclusion is the calculation of X-ray absorption coefficients from radio astronomy 21-cm emission measurements of the columnar hydrogen density and the assumed universal abundance of the elements. At energies near 1 keV, on the other hand, there is some evidence, though of poor statistical quality, that the apparent absorption based on the above reasoning is about as to be expected for extragalactic origin (**20**). (Effective X-ray absorption cross-sections per hydrogen atom have been assembled (**21**), and revised somewhat (**22**) to take into account improved partial cross sections for helium and molecular hydrogen and an assumed lower universal abundance of neon.)

Until very recently, the especially important energy region from 1 to 100 MeV has remained unexplored. A scintillation detector sensitive in the 0·25 to 6 MeV energy region has been flown aboard a small satellite (**11**). The preliminary results indicate a quite unexpected (positive) deviation from the nominal E^{-2} power law spectrum extrapolated from lower energies. Up to 1 MeV the data are consistent with this extrapolated power law. At 6 MeV the reported intensity is about a factor of 4 higher. The physics of gamma-ray interactions in the MeV region makes directional detection especially difficult and background effects are hard to evaluate.

In the 100 MeV and greater energy region, a large flux of gamma rays coming preferentially from the galactic plane and particularly from the galactic center region has been observed (**23**). The intensity variation with galactic longitude matches rather well the galactic longitude variations of non-thermal galactic radio noise. Structure in galactic latitude is unresolved by the broad (25° FWHM) angular response of the orbiting instrument. There is apparently also a diffuse or isotropic flux with an intensity in approximate agreement with an extrapolation of the power law evident in the 100 keV to 1 MeV region. A number of other groups (**24–28**) have provided supporting evidence, though of low statistical significance, for enhanced ~ 100 MeV gamma-ray emission from the galactic plane. On the other hand, the results of balloon-borne spark chamber investigations (**29**) indicate a discrete source of gamma rays near $\alpha = 288°$ $\delta = -35°$ and provide no evidence for the galactic plane emission so evident in the data reported by (**23**).

Interpretive status

Initial discussions of the possible origin of the diffuse X-radiation included synchrotron radiation (**30**), bremsstrahlung from otherwise unsuspected galactic electrons in the kilovolt region (**31**), a hot intergalactic medium (**31**), production in intergalactic space through electron-photon collisions (**32**), and production in distant unresolved galaxies (**33, 34**). Gould's review paper (**1**), quoted earlier, and that of Ginzburg and Syrovatsky (**35**) summarize the early interpretative as well as observational results. Mechanisms that appear plausible in the light of more recent and more refined observations are discussed briefly below. A review of X-ray mechanisms has been prepared recently (**36**).

Inverse Compton collisions of energetic *galactic* electrons with either stellar or the universal 3 K photons fall far short of explaining the observed X- and gamma-ray intensity (**37–40**). (The exact factor depends on how the galactic electron intensity and extent is estimated.) In addition, it is difficult to reconcile a galactic origin with the observed X-ray isotropy. These facts have led to the suggestion (**37**) that remote electrons in radio galaxies or possibly in intergalactic space are responsible, through Compton collisions with photons of the universal radiation field, for the diffuse X-ray intensity. These first considerations, made without the inclusion of detailed general relativistic and evolutionary effects, indicated that the required remote electron flux was very large. General relativistic and evolutionary effects pertaining particularly to the inverse Compton universal radiation field phenomena have been discussed by a number of authors. Inclusion of these effects tends generally to aggravate rather than relieve the remote electron flux problem (**41**). If one considers only those electrons confined in strong radio-emitting objects (radio galaxies and quasars) magnetic fields must be taken to be more than an order of magnitude less than the equipartition or minimum energy values in order to reconcile radio and X-ray background data (**42, 43**). If instead one imagines the electrons to have had their origin in strong radio galaxies but to have escaped into intergalactic space, one is forced to adopt relatively small leakage times and, therefore, (probably) unrealistic values for the efficiency (per unit galactic mass) of energetic particle production. Brecher and Morrison (**44**) have suggested that electrons that have escaped from normal galaxies are sufficient to provide the required intergalactic electron flux. This suggestion relieves somewhat the difficulty of the high electron acceleration efficiency, basically because a larger total number (and therefore larger total mass) of galaxies is assumed to be contributing.

Bremsstrahlung by known non-thermal electrons (e.g., electrons in radio galaxies) is not capable of explaining the X-ray background radiation. Silk and McCray (**45**) have suggested that the remnant particles of an *ad hoc* burst of electrons at a remote epoch ($z \approx 10$) could, through bremsstrahlung in a low density intergalactic gas, account for the background flux.

Protons in the tens of MeV region are capable of producing bremsstrahlung X-rays through collisions with ambient electrons (**46–48**). If protons in this energy region exist at the levels needed to account for the heating of interstellar H I regions (**48**), a marginally detectable X-ray flux would be expected from the galactic plane. While this may conceivably be the mechanism responsible for the slight intensity enhancement detected by the Leicester group (**15**), it does not seem capable of explaining the general X-ray background unless a very large and otherwise unsuspected intergalactic flux of protons is assumed.

As mentioned earlier, observations of the diffuse X-radiation at energies below 1 keV are on a considerably less firm basis than are the observations at higher energies.

Numerous causes of the apparently anomalous soft X-ray absorption by galactic gas have been suggested. There may be unsuspected local (solar or terrestrial) sources of soft X-rays (**20**). There may be numerous unresolved soft X-ray emitters within a few hundred parsecs of the solar system (**18, 20**). The interstellar gas may be non-uniformly distributed to the extent that to soft X-rays some parts of the sky are essentially opaque while other parts are relatively open (**20, 49**). There may be less helium in the interstellar medium than has been supposed (**16, 18, 22**). None of these possibilities can at present be easily dismissed and so it is by no means clear that the soft X-rays detected are of extragalactic origin. Because an excess soft X-ray flux (e.g., a flux larger than that to be expected from an extrapolation of the power law appropriate at energies greater than 1 keV) can be taken as providing evidence for a hot extragalactic ionized gas, the interpretation has received considerable attention (**16, 19, 20**). Several authors (**50–52**) have made predictions of incident radiation intensities for various intergalactic gas temperatures, densities and various cosmological models, some (**51, 52**) including detailed models for the heating (and cooling) of the supposed gas. Sunyaev (**53**) has suggested that the ultraviolet radiation from any hot intergalactic plasma, if it exceeds 10^{-23} erg cm^{-2} sterad^{-1} Hz^{-1} in intensity, would ionize the H I regions on the edges of galaxies. While this argument would apparently exclude extremely hot and dense intergalactic media (**19**), a recent re-examination of the question (**54**) relaxes the Sunyaev condition considerably. Shklovsky (**55**) has suggested an entirely different origin of the excess soft-X-ray intensity – the cosmologically superposed line radiation from the O VII, O VIII (20 Å) transitions in the remnants of type-II supernovae in remote galaxies.

Most mechanisms suggested to explain the isotropic X-radiation in the 1 to 1000 keV region do not predict large departures from the power law spectrum extrapolated to 100 MeV or greater. The isotropic observation (**23**) at ~ 100 MeV may, therefore, require no special explanation. This is not so of any excess radiation, such as that reported (**11**) in the region of 6 MeV. It has been pointed out (**56, 57**) that π° mesons produced by cosmic rays at some early epoch would decay into gamma rays which, when detected now, would have a maximum flux at an energy near $70/(1+z)$ MeV where z is the red shift parameter.

Clayton and Silk (**58**) have suggested that if ^{56}Fe is synthesized as ^{56}Ni, the superposed decay gamma rays from remote galactic matter could produce detectable intensities near 1 MeV.

The galactic or non-isotropic component of the 100 MeV gamma ray intensity was at first thought to be too large to be accounted for by π° meson production in the galaxy through cosmic ray interstellar gas collisions (**23**) and a number of alternative mechanisms have been suggested (**59–62**). However, a re-evaluation of the effective meson production cross-sections (**63**), based on recent high energy accelerator data, has the effect of increasing the predicted intensities over the values based on the earlier cross section evaluations by a factor of nearly three. It is possible that the remaining apparent discrepancy is within the uncertainty of the columnar hydrogen and gamma-ray intensity measurements.

REFERENCES

1. Gould, R. J. 1967, *Am. J. Phys.*, **35**, 376.
2. Seward, F., Chodil, F., Mark, H., Swift, C., Toor, A. 1967, *Astrophys. J.*, **150**, 845.
3. Gorenstein, P., Kellogg, E. M., Gursky, H. 1969, *Astrophys. J.*, **156**, 315.
4. Cooke, B. A., Pounds, K. A., Stewardson, E. A., Adams, D. 1969, *Astrophys. J.*, **150**, L189.
5. Green, D. W., Wilson, B. G., Baxter, A. J. 1969, *Space Res.*, vol. 9, p. 222.
6. Ducros, G., Ducros, R., Rocchia, R., Tarrius, A. 1969, preprint.
7. Boldt, E. A., Desai, U. D., Holt, S. S., Serlemitsos, P. J. 1969, *Nature*, **224**, 677.
8. Bleeker, J. A. M., Deerenberg, A. J. M. 1969, submitted to *Astrophys. J.*
9. Brini, D., Fuligni, E., Horstman-Moretti, E. 1969, *IAU Symposium* no. 37, Rome.
10. Matsuoka, M., Oda, M., Ogawara, Y., Hayakawa, S., Kato, T. 1969, *Astrophys. Space Sci.*, **4**, 44.
11. Vette, J., Matteson, J. L., Gruber, D., Peterson, L. E. 1969, *IAU Symposium* no. 37, Rome.
12. Mandel'stam, S. L., Tindo, I. P. 1967, *Soviet Phys. JETP Lett.*, **6**, 251.

13. Rocchia, R., Rothenflug, R., Boclet, D., Ducros, G., Labeyrie, J. 1967, *Space Res.*, vol. 7, p. 1327.
14. Agrawal, P. C., Biswas, S., Gokhale, G. S., Iyengar, V. S., Kunte, P. K., Manchanda, R. K., Sreekantan, B. U. 1969, *IAU Symposium* no. 37, Rome.
15. Cooke, B. A., Griffiths, R. E., Pounds, K. A. 1969, *Nature*, **224**, 134.
16. Bowyer, C. S., Field, G. B., Mack, J. E. 1968, *Nature*, **217**, 32.
17. Baxter, A. J., Wilson, B. G., Green, D. W. *Can. J. Phys.* (in press).
18. Hayakawa, S., Kato, T., Makino, F., Ogawa, H., Tanakya, Y., Yamashita, K., Matsuoka, S., Miyamoto, S., Oda, M., Ogawara, Y. 1969, *IAU Symposium* no. 37, Rome.
19. Henry, R. C., Fritz, G., Meekins, J. F., Friedman, H., Bryman, E. T. 1969, *Astrophys. J.*, **153**, L11.
20. Bunner, A. N., Coleman, P. L., Kraushaar, W. L., McCammon, D., Palmieri, T. M., Shilepsky, A., Ulmer, M. 1969, *Nature*, **223**, 1222.
21. Bell, K. L., Kingston, A. E. 1967, *Mon. Not. R. astr. Soc.*, **136**, 241.
22. Brown, R. L., Gould, R. J. *Astrophys. J.* (in press).
23. Clark, G. W., Garmire, G. P., Kraushaar, W. L. 1968, *Astrophys. J.*, **153**, L203.
24. Delvaille, J. P., Albats, P., Greisen, K. I., Ogelman, H. B. 1968, *Can. J. Phys.*, **46**, S425.
25. Fichtel, C. E., Kniffen, D. A., Ogelman, H. B. 1969, *IAU Symposium* no. 37, Rome.
26. Hutchinson, G. W., Ramsden, D., Wills, R. D. 1969, *IAU Symposium* no. 37, Rome.
27. Sood, R. K. 1969, *Nature*, **222**, 650.
28. Valdez, J. V., Waddington, C. J. 1969, *Astrophys. J.*, **156**, L85.
29. Frye, G. M., Staib, J. A., Zych, A. D., Hooper, V. D., Rawlinson, W. R., Thomas, J. A. 1969, *Nature*, **223**, 1320.
30. Giacconi, R., Gursky, H., Paolini, F. R., Rossi, B. B. 1962, *Phys. Rev. Lett.*, **9**, 439.
31. Hoyle, F. 1963, *Astrophys. J.*, **137**, 993.
32. Felten, J. E., Morrison, P. 1963, *Phys. Rev. Lett.*, **10**, 453.
33. Gould, R. J., Burbidge, G. R. 1963, *Astrophys. J.*, **138**, 969.
34. Oda, M. 1965, *Proc. Intern. Conf. Cosmic Rays*, (London).
35. Ginzburg, V. L., Syrovatski, J. 1965, *Space Sci. Rev.*, **4**, 267.
36. Setti, G., Rees, M. J. 1969, *IAU Symposium* no. 37, Rome.
37. Felten, J. E., Morrison, P. 1966, *Astrophys. J.*, **146**, 686.
38. Fazio, G. G., Stecker, F. W., Wright, J. P. 1966, *Astrophys. J.*, **144**, 611.
39. Maraschi, L., Perola, G. C., Schwarz, S. 1968, *Nuovo Cim.*, **53B**, 443.
40. Shen, C. S., Berkey, G. 1968, *Astrophys. J.*, **151**, 895.
41. Brecher, K., Morrison, P. 1967, *Astrophys. J.*, **150**, L61.
42. Bergamini, R., Londrillo, P., Setti, G. 1967, *Nuovo Cim.*, **52B**, 495.
43. Fukui, M., Hayakawa, S. *Prog. Theor. Phys.* (in press).
44. Brecher, K., Morrison, P. 1969, *Phys. Rev. Lett.*, **23**, 802.
45. Silk, J., McCray, R. 1969, *Astrophys. Lett.*, **3**, 59.
46. Hayakawa, S., Matsuoka, M. 1964, *Prog. Theor. Phys. Suppl.*, **30**, 204.
47. Hayakawa, S. 1969, *IAU Symposium* no. 37, Rome.
48. Boldt, E., Serlemitsos, P. 1969, *Astrophys. J.*, **157**, 557.
49. Bowyer, C. S., Field, G. B. 1969, *Nature*, **223**, 573.
50. Field, G. B., Henry, R. C. 1964, *Astrophys. J.*, **140**, 1002.
51. Weymann, R. 1967, *Astrophys. J.*, **147**, 887.
52. Bergeron, J. 1969, *Astr. Astrophys.*, **3**, 42.
53. Sunyaev, R. A. 1969, *Astrophys. Lett.*, **3**, 42.
54. Felten, J. E., Bergeron, J. *Astrophys. Lett.* (in press).
55. Shklovsky, I. 1969, *Astrophys. Lett.*, **3**, 1.
56. Ginzburg, V. L. 1968, *Astrophys. Space Sci.*, **1**, 125.
57. Stecker, F. W. 1968, *Nature*, **220**, 675; 1969, *Astrophys. J.*, **157**, 507.
58. Clayton, D. C., Silk, J. 1969, *Astrophys. J.*, **158**, L43.
59. Ogelman, H. 1969, *Nature*, **221**, 753.
60. Shen, C. S. 1969, *Phys. Rev. Lett.*, **22**, 568.
61. Cowsik, R., Pal, Y. 1969, *Phys. Rev. Lett.*, **22**, 550.
62. O'Connell, R. F., Verma, S. D. 1969, *Phys. Rev. Lett.*, **22**, 1443.
63. Stecker, F. W. *Astrophys. Space Sci.* (in press).

RADIO ASTRONOMY

(by F. G. Smith)

Observations of radio noise from space vehicles are directed towards four objectives; solar radio waves, Jovian emissions, the background from galactic and extragalactic sources, and the noise which is generated locally in the magnetosphere by streams of high energy particles. Although it has been difficult to calibrate the sensitivity of even simple receiving systems, because of the effects of the ionosphere on antenna impedance, the general shape of the background spectrum is becoming known. The sharp drop at frequencies below 1 MHz is attributed to absorption in Galactic ionised hydrogen (**1**, **2**).

Solar outbursts extending to low radio frequencies have been recorded by the Alouette satellites, the U.S.S.R. satellites (**3**), and by the U.S.A. satellite RAE I. Most of these are outbursts of type 3, sweeping downwards in frequency as a disturbance travels out from the Sun. They can be followed to frequencies below 250 KHz, at which frequency they are apparently generated at distances of the order of 1 A.U. from the Sun.

Noise from particle streams occurs in frequency bands defined by the electron density and magnetic field strength in the ionosphere. Observations from the U.K./U.S.A. satellite Ariel 2 suggested that part of this noise was associated with the inner trapped radiation belt (**4**). Observations from satellite Ariel 3 showed that part of this noise was due to auroral particles (**5**).

Accurate measurement of noise power in space depends on the theory of the behaviour of antennae immersed in plasmas. Theory and measurements directed to this problem are to be found in papers referred to in a recent review by T. R. Kaiser and J. K. E. Tunaley (**6**) and in papers by D. Walsh and H. Weil (**7**) and G. J. Daniell (**8**).

Further results are to be expected shortly from the RAE I satellite, whose long antennae have considerable directional properties, and from the satellites OGO 3 and OGO 5.

REFERENCES

1. Weber, R. R., Stone, R. G., Somerlock, C. R. 1969, *Astr. Astrophys.*, **1**, 47.
2. Alexander, J. K., Brown, L. W., Clark, T. A., Stone, R. G., Weber, R. R. 1969, *Astrophys. J.*, **157**, L163.
3. Slysh, V. I. 1967, *Kosm. Issled.*, **5**, 897.
4. Harvey, C. C. 1969, *Nature*, **217**, 50.
5. Gregory, P. C. 1969, *Nature*, **221**, 350.
6. Kaiser, T. R., Tunaley, J. K. E. 1968, *Space Sci. Rev.*, **8**, 32.
7. Walsh, D., Weil, H. 1968, *Radio Science*, **3**, (New Series), 936.
8. Daniell, G. J. 1968, *Proc. R. Soc. London*, **A303**, 157.