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Introduction: Space Astronomy, present and future

R.J. van Duinen

The coming of age of space astronomy is evident from the ever increasing involvement of astronomers with space observatories. In the last years we have witnessed a tremendous growth of papers in the literature on the interpretation of results from space observations. The range of astronomical topics affected by space observations is very wide, covering the gammut from stellar birth to cosmology. Chapters following this brief introductions amply illustrate this encouraging development. Space astronomy is no longer a field exploited only by a few specialists.

Wide acceptance and use of space observatories, as a valuable extension of classical astronomical tools, marks the recent past.

Concerning the near-future prospects for space astronomy, several new and potentially extremely rewarding missions will be launched in the next few years, the most important being Space Telescope, now scheduled for launch in 1985. Other space astronomy missions include

- EXOSAT, the European X-ray mission for launch in 1982;
- IRAS, the US/Dutch/UK infrared survey mission, to be launched towards the end of 1982;
- ROSAT, the German X-ray telescope, scheduled for 1985;
- HIPPARCOS, the European astrometry satellite, to be launched in 1985;
- ASTRO B and C, the Japanese X-ray missions, for launch in 1983 and 1986;
- ISPM, the ESA solar system mission to be launched in 1986;
- and several instruments in SALJOET and SPACELAB and smaller payloads to be flown in aircraft, balloongoldolae and in sounding rockets.

Whilst the present and near-term prospects for space astronomy are favorable, the longer-term outlook is less encouraging. The increasing requirements on the sophistication and size of instruments, resulting from the demands for sensitivity and spatial resolution, imply cost increases which can no longer be absorbed by the science budgets in governments and space agencies. The problem is compounded both by the shift in emphasis from pure space science to applied science and by the present economic conditions. These circumstances force us to apply most of our energy to maintain what we have got, rather than to work on an expansion of Space Astronomy. This trend, of course, is not new. In fact, the discussion in our Commission meeting in Montreal 1979 was an attempt to achieve the maximum scientific return at the lowest possible cost.

One particularly cost-effective approach is to foster international cooperation and collaboration. Especially the former requires intensive consultation both between space scientists - usually the initiators of new proposals- and between

https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

space science administrators in governments and agencies. Our commission should continue to serve as a forum for such international exchange and where possible attempt to increase such interactions. Members of our commission can certainly achieve a lot by intensifying contacts amongst themselves. We should encourage participation of "foreigners" in our space projects expecting in return to be involved in others, abroad. This active exchange enhances the overall world-wide return on investment. In addition we should attempt to influence and to encourage our administratos to participate in a true global planning of large space projects.

In doing so, we shall be able to continue our exploitation of space technology for the advancement of science.

https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

1. SPACE RADIOASTRONOMY

J.L.Steinberg

In the last three years, since the 1979 General Assembly, space radioastronomy has probably logged more results than in all the preceding years. And I cannot remember without a smile the times, not far behind, when F.G.Smith and myself were afraid that space radioastronomy would remain for ever a part of Geophysics.

Most of these results were obtained with special instrumentation developed for the Voyager-1 and -2 space probes which flew to Jupiter and Saturn and by receivers on ISEE-3. The managers of Space Science have finally been persuaded to finance the design, development and integration of sensitive receivers on sophisticated spacecraft. Polarization can be measured from the Voyager probes; size, direction and polarization from ISEE-3 (Knoll et al.,1978; Lecacheux et al.,1979; Manning and Fainberg,1980). The USSR launched the first space dish (Zakson et al.,1980). The feasability of VLBI between the Earth and a spacecraft was analyzed (Kardashev et al.,1980).

Many of the most important results were obtained, however, by comparing sets of measurements made from the distance (radio waves) and in situ (particles and waves in the plasma) in the Earth's and planetary atmospheres and magnetospheres. This is undoubtedly one of the directions of future progress. In what follows, we shall only consider radio waves proper, that is those which propagate at large distances from their source.

EARTH'S RADIATION.

Three broad categories are known: escaping or trapped continuum radiation, radiation from the bow shock upstream region, terrestrial or auroral kilometric radiation (TKR or AKR).

The low frequency continuum is made of two components; the non-thermal component exhibits a cut-off at the R=0 plasma frequency (Shaw and Gurnett, 1980). A detailed theory of that noise has been developed by Melrose (1981). A large part of the thermal component is now recognized as due to local electrostatic thermal plasma noise (Meyer-Vernet,1979; Hoang et al.,1980).

Upstream of the Earth's bow shock, emissions are observed at the local plasma frequency and its first harmonic; they are produced behind the magnetic lines of force of the interplanetary field which are tangent to the bow shock. Their mechanism might be the same as that which produces type III and II solar bursts (Gurnett et al.,1979). They have been observed and localized from ISEE-3 (Hoang et al., 1981).

TKR (or AKR) has received much attention since it can be observed in situ together with the characteristics of the agent which triggers it and those of the medium where it takes place. From ISIS-1 data obtained within the source region, Benson and Calvert (1979) showed that the radiation propagates in the extraordinary mode and emanates perpendicular to the magnetic field from sources located in local depletions of electron density. High resolution spectra were obtained and analyzed by Gurnett et al. (1979). The dynamic spectra are made of rapidly drifting structures comparable to solar type III and some Jupiter emissions. The source moves towards the Earth, in the auroral zone, at about 10 km/s and this points towards some kind of wave triggering agent. Good quantitative correlation is found between TKR intensity and the peak energy of inverted-V electron precipitation events observed in situ (Green et al.,1979). AKR has also been studied by looking back into ISIS-1 (topside sounder) data (Calvert, 1981). Intense noise bands are found between 700 kHz and a cut-off frequency higher than the cyclotron frequency. AKR appears to be generated directly in the X-mode and radiated perpendicular to the magnetic field.

Many theories of the TKR have been developed. Some of them assume direct radiation by particles, some others radiation through conversion of two or three plasma waves through linear or non-linear processes (See for example Wu and Lee, 1979; Roux and Pellat, 1979; Grabbe, 1981, for a review) The radiation mechanism of TKR is not yet understood.

SOLAR RADIATION.

Type III radio bursts.

Aksenov et al., (1979) used a 2-6 MHz receiver on board the Intercosmos-Copernicus 500 satellite to study type III radio bursts. Using the terrestrial ionosphere as a polarizing screen, they measured polarization of these bursts (Hanasz et al., 1980). If confirmed, these observations would fit with others made at meter wavelengths and the first component of interplanetary type IIIs might be the fundamental component of a pair. However, as far as we know, Voyager-1 and -2 have not observed any polarized solar event.

Using data from HELIOS-2, Kellogg (1980) followed the occurrence of a given type III at successive frequencies as a function of time. In three cases, the electrons associated with these events finally produced bursty plasma waves at the local plasma frequency. Extrapolating the frequency versus time curve, Kellogg showed that some interplanetary type IIIs do radiate at the fundamental frequency and others at its first harmonic.

Although particle measurements do not belong to the field of radioastronomy, we cannot forget that particles and waves interact in many places in the Universe. In connection with type IIIs the discovery of 2-10 keV solar electron events unassociated with flares (Potter et al., 1980) is important because those electron events are closely associated with type IIIs and seem accelerated in the corona.

The volume emissivity of type III sources has been measured over a large range of distances R to the Sun (Tokar and Gurnett, 1980) and found to decrease rapidly with increasing R. It is inferred from this finding that the associated plasma wave intensity also decreases rapidly with R.

All these observations have an important bearing on the theory of these radio events which is not yet understood. But great progress is undoubtedly to be expected soon since electron distribution functions, plasma and radio waves are systematically measured on board ISEE-3.

Type II solar events

These events are known to be triggered by shock waves in the solar corona and interplanetary medium. They could be used to study the properties of the corona providing we know how the radio properties of these events are linked to the shock characteristics. Some interplanetary type IIs have been observed by RAE-1 and IMP-6, but many more were recorded on board the Voyager probes at frequencies lower than 1.3 MHz. The accompanying shocks are thus tracked from 20 solar radii to 1 AU (Boischot et al., 1980). Still more events are recorded from ISEE-3 (Cane et al., 1980) and it is again to be expected that the mechanism of that radio emission will soon be understood.

JUPITER's RADIATION.

A new type of emission has been discovered from Voyager on its way to Jupiter: an hectometric (HOM) storm-type of emission, the morphology of which is similar to the decametric (DAM) emission observed from the Earth. But the HOM polarization is opposite to that of the DAM and its occurrence is modulated only by the rotation of the planet and not by the location of the satellite Io (Kaiser et al., 1979). Using data from RAE-1, IMP-6 and the Voyager probes which viewed the planet from a large enough range of latitudes, Alexander et al. (1979) have shown that the HOM emission is strongly beamed in latitude, sometimes inside a few degrees of latitude. Its spectral characteristics are fairly stable with the rotation of the planet but there are noticeable differences over intervals of months (Lecacheux et al., 1980). These characteristics are not a function of Io's location and independent of the observer's declination.

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As Voyager-1 approached Jupiter, many more characteristics of its emission were discovered. One of the most striking is the presence of several families of nested arcs in the dynamic spectra (intensity vs time and frequency). These arcs are always seen, at all longitudes; one set (lesser arcs) is Io-controlled and seen below 15 MHz; the other (greater arcs) is not Io-controlled and seen above 15 MHz. The arcs associated with the early sources have early vertices while the arcs associated with the late source have late vertices: they open towards decreasing time (Warwick et al., 1979b). This strongly argues for an origin connected to a simple but special relation to the observer. Many theories of that amazing effect have been developed; for instance, it has been suggested that the arcs could be produced by multiple reflections of standing Alfven waves current systems excited by Io (Gurnett and Goertz, 1981). But the most convincing and simplest explanation seems to be diffraction of the radiation from a single source by Io's plasma torus (Lecacheux et al., 1981).

In the kilometer wavelength range, two kinds of emissions were discovered from Voyager-1 and -2. Broadband emissions last for about one hour, longer on lower frequencies than at the higher ones. They are seen in the 0.1 to 1 MHz frequency range, sometimes down to 10 kHz (Kurth et al., 1979). Half of these storms occur within 40 degrees of longitude 200°, some weaker ones near 20°. They are LH polarized. Their low frequency cut-off is much lower than the plasma frequency in Jupiter's atmosphere and therefore they must be associated with a source several jovian radii high. In situ plasma measurements show that the source must be Io's plasma torus which was discovered using radio measurements (Warwick et al., 1979a). Further studies of that radiation (Kurth et al., 1980) have shown that it is not observed in a shadow zone, near the equator of the planet, an effect probably due to the presence of Io's plasma torus; it is probable that we are dealing with a propagation effect implying that the source is close to the planet. Radio ray tracings (Green et al.,1980) in a model of Jupiter's atmosphere including Io's torus have reproduced that effect and provided an interpretation of the longer observability of the km radiation at the lower frequencies. Desch and Kaiser (1980) further studied that km radiation and showed that its occurrence morphology, dynamic spectrum and polarization characteristics are strong functions of the latitude and/or the local time geometry of the observer.

The beaming and other properties of the km radiation are interpreted in different ways. Some researchers (Warwick et al., 1979a) believe that the source is in Io's torus itself; some others (Green and Gurnett, 1980) that it lies along auroral magnetic field lines linked to Io's torus. Jones (1980) brought in the debate observations of the Earth's km radiation (TKR) from GEOS-1. He assumed that the source is at or beyond Io's torus so that beaming cannot be due to the presence of that torus, but rather to a focussing mechanism analogous to that which produces the same effect on the TKR.

The narrow band km emission (Kaiser and Desch, 1980) was observed from Voyager-1 between 0.1 and 0.2 MHz. It is LH polarized in the northern hemisphere and RH in the southern one. Its source rotates 3 to 5 % slower than the other radio emissions and it is assumed to lie near the magnetic equator plane at the outer edge of Io's plasma torus.

To summarize the present situation, we might say that there are essentially three kinds of emissions:

- a DAM-HOM emission which appears as arcs in the dynamic spectrum. Its source is close to the planet, distributed along magnetic lines of force through Io or the L=6 shell. Its dynamic spectrum characteristics are most probably due to diffraction by Io's plasma torus.
- a broad band KOM emission,
- a narrow band KOM emission.

The terminology used by the various teams involved in that research should be standardized as soon as feasible; this task is made difficult by the variety of instruments used on Voyager-1 and -2, by the variety of types of displays used by the various teams and by the obvious complexity of Jupiter's emissions. Great pro-

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gress will be made in that direction, however, in a forthcoming special issue of the JGR and a multi-authored book.

But that complexity in itself is a measure of the large quantity of information of astrophysical significance which has been and will be gained from the radioastronomical study of Jupiter from Voyager-1 and -2.

SATURN'S EMISSIONS.

A non-thermal emission from Saturn has been discovered from Voyager as soon as the probe was close enough to the planet (Kaiser et al., 1980). It is made of intense bursts at frequencies near 200 kHz. The radiation is RH polarized and mostly in the extraordinary mode from Saturn's northern hemisphere. From its modulation, one can obtain (Desch and Kaiser, 1981) the rotation period of the planet; this result was unpredictable since Saturn's magnetic dipole is axial. The dynamic spectrum of Saturn's kilometric radiation (SKR) shows narrow band drifting structures reminiscent of the arcs observed in Jupiter KOM. SKR polarization seems to be time-dependent.

Another emission is called Saturn electrostatic discharges (SED). It appears as bursts lasting about 0.1 second and occurring quite randomly in the frequency range 20 kHz-40 MHz. Since such SEDs are absent in the Earth's and Jupiter's spectra, it was suggested (Warwick et al., 1981) that SEDs are taking place in Saturn's rings. If this interpretation is confirmed, it might help understanding the structure of the rings by bringing electrostatic forces into the dynamics of the ring particles.

CONCLUSION.

This concludes a necessarily short review of space radioastronomy results published between January 1979 and June 1981. Many more will be published in the next few months.

No doubt the importance of these results will convince all astronomers that this branch of Astronomy is flourishing and has a lot to offer to the progress of Astrophysics. Space radio observations, together with in situ measurements of fields and particles allow us to do plasma physics in a wider range of plasma parameters, to study new radiation phenomena and to undertake detailed comparative studies of planetary atmospheres, ionospheres and magnetospheres. They are also capable of helping us to solve long standing problems such as the radiation mechanism of solar radio bursts of type II and III. Most of the mechanisms at work in the solar system plasmas are most probably operating in many intriguing objects in the Universe.

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More results will be published in a forthcoming special issue of the JGR and a multi-authored book: Physics of the Jovian Magnetosphere (A.J. Dessler, editor) to be published by Cambridge University Press.

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2. Infrared Space Astronomy

G. G. Fazio

Over the past decade infrared astronomy has made major contributions not only to the understanding of many new areas of astrophysics, but also to the development of new instrumentation and techniques. In particular, infrared observations have become essential in resolving such major astronomical questions as the birth and evolution of stars, the structure and evolution of galaxies, the properties of the interstellar medium, the nature of active galactic nuclei, the nature of the outer planets, and properties of the solar atmosphere. Infrared astronomy can no longer be considered an isolated field of research. It has become an active partner with other branches of astronomy in solving some of the most important problems in astrophysics.

The potential for new discoveries in this region of the spectrum, with its diverse scientific goals, has only begun to be realized. Rapid advances in infrared detector technology and the availability of near-space observational platforms have contributed significantly to the recent growth of space infrared astronomy. We are just on the threshold of a huge expansion in the field. Over the next few years, for the first time, space platforms will be available for observations. Through the use of cryogenically cooled telescopes in space the number of known infrared celestial sources will increase from the few thousand we know today to millions. Large area space telescopes will provide a major increase in spatial resolution and sensitivity. In the coming decade there will probably be no area of astronomy that will be as rich in new results as space infrared astronomy.

In this report some of the highlights of recent advances in space infrared astronomy during the past three years will be presented, as well as a discussion of recent technology developments and a summary of future infrared space programs.

I. SCIENTIFIC ACHIEVEMENTS

The recent scientific contributions of space infrared astronomy to our understanding of the universe have been numerous, and have been particularly important in the study of cosmology, extragalactic objects, our galaxy, and the solar system.

(1) Cosmology

The submillimeter wavelength band of the infrared spectrum is of particular importance in observational cosmology. Balloon-borne observations at submillimeter wavelengths have verified that the cosmic background radiation, the possible remnant of the primordial cosmic explosion, approximates a 2.9 K black body spectrum (Woody and Richards, 1979). The first spectrometric observations of the cosmic background radiation above the atmosphere were made by rocket-borne instruments (Gush, 1979). Balloon-borne measurements of the large scale angular distribution have also uncovered an anisotropy due to the earth's velocity relative to the source of the 3 K background (Cheng et al. 1979; Muehlner and Weiss, 1980; Boughn et al. 1981; Smoot and Lybin, 1979; Fabbri et al. 1980) as well as evidence for a quadrupole anisotropy. These observations have changed our understanding of the large scale structure of the universe.

(2) Extragalactic Objects

Many types of extragalactic objects are powerful sources of infrared radiation, but in spite of these large luminosities extragalactic objects are relatively faint compared to galactic infrared sources because of their large distances. Consequently far infrared studies of extragalactic objects have only just begun. To date approximately two dozen galaxies have been detected at far

https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

infrared wavelengths using the Kuiper Airborne Observatory. Observations by Telesco and Harper (1980), Becklin et al. (1980), Rickard, Harvey, and Thronson (1980), and Harper (private communication, 1981) have shown that most of the galaxies bright at 10 μm (Rieke and Lebofsky 1978) have even larger infrared excess near 100 μm. Sizes and spectral energy distributions have been determined for some of these objects. The high incidence of such large power outputs is a new and important input to theories of galactic evolution.

Spectroscopic observations of these objects are increasing rapidly, with improved sensitivity and resolution (Houck, Forrest, and McCarthy 1980; Cutri et al. 1981). These observations provide new information on the composition, density and ionization state of gas in the galactic nuclei.

Extragalactic research at far infrared wavelengths is a field experiencing rapid development. The next few years should produce a wealth of new information on both energetic nuclear events and more normal stellar evolution within galactic disks.

(3) Galactic Astronomy

The relationship between stars and the interstellar medium, including the exchange of material between them via star formation and mass loss from stars, are the major processes which determine the evolution of the galaxy. Infrared astronomy has recently provided new data and insights into all stages of these processes.

(a) Star Formation and Evolution One of the earliest stages of star formation may be the compact dark clouds called Bok globules. The first detection of thermal radiation from these objects has been made at submillimeter wavelengths (Keene et al. 1980; Keene 1981), and a temperature of about 15 K was measured.

Balloon-borne and airborne far-infrared photometry and mapping of cold molecular clouds, young main sequence stars and their associated H II regions, and luminous, compact infrared sources with no detectable ionized material around them, have been crucial in determining the sites of star formation, in measuring the luminosity and energy distributions of these objects, and in understanding the evolution of H II regions. Of particular interest have been the studies of M17 and the associated giant molecular cloud (Wilson et al. 1979; Gatley et al. 1979; Jaffe et al. 1981), the Carina H II regions (Harvey et al. 1979), W3 (Thronson et al. 1980; Werner et al. 1980), NGC 6334 (McBreen et al. 1979; Cudlip et al. 1981), compact H II regions (Thronson and Harper 1979), Mon R2 (Thronson et al. 1980), NGC 7538 (Werner et al. 1979), and the molecular clouds OMC-1 (Keene, Hildebrand, and Whitcomb, 1980) and Cepheus OB 3 (Evans et al. 1981). Medium to low resolution infrared surveys, made with balloon-borne telescopes measure the total infrared emission from molecular clouds, and this data can be used to examine the energetics in the molecular clouds surrounding the embedded infrared sources (Campbell et al. 1980; Gispert et al. 1981; Koppenaal et al. 1979; Sargent et al. 1981).

Infrared observations have also been important in studying the properties of premain sequence stars of lower mass and luminosity ($\sim$ 100 $L_\odot$) (Harvey et al. 1979), post-main sequence stars with large amounts of mass loss, e.g. oxygen-rich red giants (Forrest, McCarthy, and Houck 1979) and OH/IR stars (Werner et al. 1980). Carbon-rich red giant stars have been studied extensively at infrared wavelengths, and airborne observations show that the atmospheric opacity of these objects is dominated by absorption features of polyatomic molecules (Goebel et al. 1980; Witteborn et al. 1980).

Observations of planetary nebulae by far-infrared photometry have been carried out for about two dozen objects, leading to the determination of the total luminosity and dust masses of the nebulae (Moseley, 1980). In NGC 7027 spectroscopic studies have been particularly fruitful. Atomic emission lines of [O IV] and [Ne V] have been detected (Forrest et al., 1980) as well as broad emission features due to dust, and the 63 μm line due to neutral oxygen.

Finally, in the last stages of stellar evolution, infrared studies of the spectra of remnants of supernovae show evidence only for synchrotron radiation and no direct evidence for dust (Wright et al. 1980).

(b) Interstellar Medium Infrared spectroscopy has recently made numerous contributions to the study of the interstellar medium, particularly in the regions of star formation. Of particular interest are the airborne observations cf the [C I] line at 610 μm (Phillips et al. 1980) using heterodyne techniques and the [C II] line at 157 μm (Russell et al. 1980) with a grating spectrometer. The [C II] line may be an important coolant of gas clouds and the [C I] observations indicate most of interstellar carbon may be tied up in CO or dust. Much of the current spectroscopic work in H II regions is concerned with the [O III] lines at 51.8 and 88 μm which are easily excited by collisions and the [S III] lines at 18 and 33 μm (Melnick, Gull, Harwit, 1979; Moorwood et al. 1980; Storey, Watson, and Townes, 1979; McCarthy, Forrest, Houck, 1979). These pairs of transitions are highly useful indicators of density and abundances in H II regions. The [N III] line at 57 μm has also been observed.

Intermediate resolution (∿ 100) observations of continuum spectra are important for interpretation of radiative models of protostellar objects and these data have revealed broad absorption and emission features thought to be due to water ice and silicates as well as other unidentified materials (Willner et al. 1979; Soifer et al. 1979; Thompson, 1980).

Infrared molecular lines from CO have been observed in emission at far infrared wavelengths from the Orion molecular cloud, and allow estimation of the temperature and density of the shocked material and fractional abundance of CO (Watson et al. 1980). Strong absorption lines of OH have been detected in the direction of Sgr B2 (Storey et al. 1981).

Over the past three years far-infrared and submillimeter spectroscopy has grown very rapidly and there is every indication this field will continue to expand.

(c) Galactic Structure and Evolution The diffuse infrared radiation from the galactic plane originates from the integrated light of late-type stars and from the thermal emission of interstellar dust which is heated by early-type stars. Observations with balloon-borne and rocket-borne infrared telescopes have therefore opened up a new method of investigating the distribution of a major fraction of the stellar population and the interstellar dust in the galaxy (Oda, et al. 1979; Hayakawa et al. 1979; Owens et al. 1979; Maihara, et al. 1979; Nishimura, et al. 1980; Boisse, et al., 1981; Hauser et al., 1981; Price and Marcotte, 1980; Okuda, 1981). These data in turn provide important input information for the development of new models of galactic structure and evolution (cf. references in Drapatz 1981). These studies have been one of the most important contributions of balloon-borne and rocket-borne infrared astronomy and major activity in this method of studying galactic structure is expected to continue.

(d) The Center of the Galaxy Large scale infrared and radio observations of the center of our galaxy is usually explained by reradiation of dust heated by a large density of late-type stars, a ring of molecular material and a number of active star formation regions (Gatley and Becklin, 1981). However recent airborne infrared observations show the central parsec to be a unique region of activity. High angular resolution and high spectral resolution observations of the Ne II line at 12.8 μm clearly show that Sgr A is not a normal galactic H II region (Lacy et al. 1980), but contains high velocity plasma clumps. The recent high angular resolution far-infrared maps of this region (Gatley, Becklin, and Werner, 1981) indicate the dust density in the central parsec is very low. The central source has a luminosity of $\sim$ 1-3 x 10^7 $L_\odot$, and is capable of ionizing the plasma clumps.

(4) Solar System

(a) Sun Increased accuracy in the absolute temperature measurements of the sun at far-infrared wavelengths allows the exploration of the transition region between the photosphere and the chromosphere and an assessment of various forms of energy transfer. Recent observations using an improved balloon-borne lamellar grating interferometer have been accurate enough to permit selection of one of the present models of the solar atmosphere. The results also show a dependence of the solar brightness temperature on solar activity (Rast, Kneubühl, and Müller 1978; Rast et al. 1980).

(b) Planets The outstanding problems in planetary astronomy today center around understanding the current conditions, evolution, and origin of the solar system, and attempting to trace the history of the solar system back to its origin. The outer planets emit most of their radiation at far-infrared wavelengths, and thus space infrared observations have already uncovered many discoveries about these objects.

Infrared spectral observations have been important in understanding planetary atmospheric composition and surface composition (Encrenaz and Combes, 1980; Morrison, 1980, Orton, 1980; McCord and Cruikshank, 1980). In the case of Jupiter and Saturn infrared spectroscopy was responsible for the detection of most of the minor molecules, particularly phosphene (PH_3) and germane (GeH_4) (Fink et al. 1978; Larson et al. 1980). Observations of the ammonia rotational emission bands at far-infrared wavelengths have been important for determining the atmospheric models of Jupiter (Furniss et al. 1979; Erickson et al. 1979; Baluteau et al. 1979, 1980; Witteborn et al. 1980) and Saturn (Marten et al. 1980; Haas et al. 1980). The Voyager 1 IRIS experiment acquired infrared spectral and radiometric data during its passage through the Jupiter system (Hanel et al. 1979) and through the Saturn system (Hanel et al. 1981). The H_2/He ratios were measured and the results imply a depletion in the atmosphere of Saturn relative to Jupiter. Infrared spectroscopy of Venus has also yielded information on the temperature and cloud structure of its atmosphere (Aumann and Orton 1979). The far infrared spectrum of the atmosphere of Titan has been measured and interpreted in terms as a thin dust haze high in the atmosphere (McCarthy et al. 1980).

II. TECHNOLOGICAL DEVELOPMENTS

To date all space infrared astronomical observations have been done from telescopes in aircraft, high altitude balloons, and rockets. More than 20 research groups from all over the world use balloon-borne telescopes with mirrors as large as 1.2 meters for far-infrared and submillimeter observations. The primary aircraft used are NASA's Lear Jet and the Kuiper Airborne Observatory, with 30-cm and 91-cm telescopes, respectively. The French Caravelle and NASA Convair 990 have also been used with a 32-cm telescope. The Air Force Geophysical Laboratory rocket-borne helium-cooled telescope has a diameter of 16.5 cm. The AFGL/NRL Far-Infrared Sky Survey Experiment (FIRSSE) will be launched in early 1982.

https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

Space infrared astronomy has benefited tremendously from the advancement in detector technology. Conventional germanium bolometers have improved considerably, particularly when cooled to 0.3 K with He^3 for low background applications. Newly developed photovoltaic and photoconductive detectors have exhibited marked increases in sensitivity, particularly under the conditions of low background radiation in space applications. The response of the Ge:Ga detector has been extended to 200 μm by stressing it. Infrared spectroscopic techniques include the use of filter wheels, and grating, Fabry-Perot, and Fourier transform spectrometers, and infrared heterodyne receivers have been developed for very high resolution ($\sim 10^6$) spectroscopic studies at submillimeter wavelengths. Array detectors in the 1-30 μm range are being developed and their use at ground-based telescopes is increasing. Imagery and spectroscopy will be enormously advanced by the introduction of these detector arrays.

III. FUTURE SPACE PROGRAMS

During the next few years the first results of infrared astronomical observations from satellites will appear. These missions will provide several orders of magnitude increase in the sensitivity of infrared observations and revolutionize our knowledge of the infrared sky. The first mission, scheduled for 1982, is the Infrared Astronomy Satellite (IRAS), which is a joint US-Netherlands-UK program to conduct a photometric all-sky survey of discrete sources in four bands at 12, 24, 60, and 100 μm, with a 60-cm cooled telescope. This will be followed in 1984 by the Small Infrared Telescope on Spacelab 2 (15-cm cooled mirror), which will map the diffuse infrared radiation and measure the Shuttle-induced background radiation. The Space Telescope (2.4-meter ambient mirror) will be launched in 1985, but no infrared experiments are planned for the first flight; however second generation instruments may include an infrared instrument. Missions planned for the latter part of the 1980's include the German Infrared Laboratory (GIRL), which is a Spacelab infrared telescope (40-cm cooled mirror) with photometric as well as spectroscopic capabilities, and the Shuttle Infrared Telescope Facility (SIRTF), a 1-meter cryogenically cooled telescope with a multiple instrument focal plane. The Cosmic Background Explorer (COBE) will be an Explorer class satellite to measure the 3 K cosmic background radiation. The USSR and France have engaged in preliminary discussions to build a 1-meter ambient telescope for submillimeter observations, and a 10 to 30-meter ambient telescope, called the Large Deployable Reflector (LDR), is being planned by NASA for the 1990's.

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https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

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3. Ultraviolet Astronomy

Anne B. Underhill and Albert Boggess

The progress of research in ultraviolet astronomy during the years 1979, 1980, 1981 has been defined mostly by means of spectroscopic observations made from IUE and by imaging observations carried out from sounding rockets and balloons. Research papers based on photometric observations made with the Astronomical Netherlands Satellite (ANS) are still appearing, as well as occasional papers based on Copernicus (OAO-3) observations. Progress has been made with the design and development of imaging and spectroscopic instruments for the space telescope and plans are being advanced for the development of other types of ultraviolet observing equipment to be used from the space shuttle.

Only selected topics will be reported here owing to the limited space available. Much detail on the scientific results attained can be found in the reports of Commissions dealing with specific areas of research. Part A, written by Underhill, summarizes the scientific results of ultraviolet astronomy in the years 1979, 1980, and 1981, while Part B, written by Boggess, summarizes the chief developments concerning instrumentation.

A. THE IMPACT OF ULTRAVIOLET OBSERVATIONS

I. Imaging Observations

Astronomical imaging investigations in the ultraviolet wavelength range below 3000Å are being carried out by groups led by A. M. Smith, R. C. Bohlin and T. P. Stecher of the Goddard Space Flight Center, and by G. R. Carruthers of the Naval Research Laboratory, using sounding rocket vehicles. Balloon-borne imaging investigations are also being carried out by J.DeHarveng and co-workers at the Laboratoire d'Astronomie Spatiale in France.

Stecher and Smith have used an f/9 Ritchey-Chretien telescope with image intensifier detectors yielding a 40 arcmin field-of-view to obtain ultraviolet images of M31, M33, M51, and M101, as well as images of the Orion nebula. In addition, Smith has used a wide-field Schwarzschild camera with image intensifier to observe the Cygnus Loop, the Large Magellanic Cloud, M33, and Virgo Cluster. A spatial resolution of 10 arcsec has been attained. Point sources can be detected to mag 20, extended sources to mag 26. Photometry of more than 200 galaxies in the Virgo Cluster has been obtained in middle ultraviolet wavelengths.

The French LAS group has observed the Andromeda Galaxy, M31, in the balloon-accessible middle ultraviolet, 1900-3000Å. The NRL group has used an f/2 electrographic Schmidt camera to observe the Andromeda Galaxy and the North American Nebula (NGC 7000). Previous sounding rocket and Apollo 16 imagery obtained using a smaller, but similar camera is in final stages of analysis. A near future sounding rocket experiment is planned to observe the Orion region in the 750-1080Å wavelength range using an indium-filtered, correctorless electrographic Schmidt camera.

II. Spectroscopic Observations

The spectrographs of the International Ultraviolet Explorer (IUE), sponsored and operated by the National Aeronautics and Space Administration of the United States, by the Science and Engineering Research Council of the United Kingdom, and by the European Space Agency, continue to be used fully and to return excellent data. By mid 1981, 221 scientific papers based on IUE observations had appeared in print. They are distributed in all fields of astronomical spectroscopy. The distribution of topics is as follows:

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Topic	No.	Topic	No.
O, B, WR stars	37	X-ray sources	15
A, F, T Tau stars	19	novae	9
G, K, M stars	37	interstellar medium	22
subluminous stars	15	planetary nebulae; SNR	20
symbiotic stars	6	galaxies; glob. clusters	29
		solar-system objects	12

One very striking result is that evidence is found for mass loss from almost every type of star. Not all of each spectral class show mass loss, but some do, whether the class be that of the subluminous central stars of planetary nebulae or that of supergiants. It seems well established that superheating, outflow, and inhomogeneity may be observed in the outer atmosphere, or mantle, of every type of star. The visibility of criteria indicating the presence of superheating (that is electron temperatures greater than the effective temperature of the star), of outflow at velocities exceeding the velocity of escape from teh photosphere of the star, and of inhomogeneity (indicated by the temporary presence of sharp rather discrete absorption components for some of the resonance lines) is different in different types of star. Conditions in the mantle cannot be correlated uniquely with the effective temperatures and log g values for the stars. The meaning of these observations in the case of single stars is being actively studied at this time. We appear to be seeing the effects of the deposition in the mantle of non-radiative energy and of non-radiative momentum. Considerable uncertainty exists about the source of the non-radiative energy and momentum, but it seems clear that the source is situated in the envelope of the star, below the photosphere.

Likewise, the observations of the interstellar lines from high and low ions in the interstellar medium and in nebulae of all sorts are leading to new information about the distribution of energy and momentum in the various bodies of rarefied gas in the Galaxy and to new hypotheses about the origin of the energy and detected momentum.

B. ULTRAVIOLET INSTRUMENTATION

I. Operational Spacecraft

During the past three years, ultraviolet astronomical data have been received from four spacecraft: Copernicus, IUE and Voyagers I and II. Operations with the Copernicus satellite ceased on February 15, 1981. Although the equipment was still in good working order, the instrumental sensitivity had slowly decreased to the point where operational costs could no longer be justified. The instrument was turned off after eight and one-half years in orbit. The IUE satellite has continued to work satisfactorily since its launch in January, 1978. The three sponsoring agencies operate the satellite as an international facility and run independent observing programs, based on research proposals that are reviewed annually. Scientists interested in observing with the IUE should contact either the ESA IUE Observatory Controller at VILSPA, the SERC IUE Observatory Committee at Rutherford Laboratory, or NASA IUE Observatory Administrator at Goddard Space Flight Center. The far ultraviolet spectrometers on board Voyagers I and II are continuing to provide valuable data on the interplanetary and nearby interstellar medium.

II. Current Projects

Construction of the Space Telescope is now underway with its initial complement of instruments including two imaging systems, two spectrographs, a polarimeter, and a guidance system capable of astrometric measurements.

Fabrication is expected to be complete by August, 1984 and will go into the final phases of integration and testing in preparation for its launch early in 1985. About one year prior to launch, the ST Science Institute will issue an announcement soliciting proposals for the early general observing programs to be conducted with the ST. At about this same time, the ST principal investigators and other participating scientists will prepare their definitive observing programs so that scheduling of the first months of observations can proceed. During 1982 it is expected that the NASA will ask for proposals from the scientific community to carry out design studies for possible second generation scientific instruments for the ST.

An Ultraviolet Astronomy Payload is under development by NASA for the Space Shuttle, consisting of three independent, co-aligned instruments. The instruments are an imaging system (T. P. Stecher, P.I.), a far UV spectrometer (A. F. Davidson, P.I.), and a spectropolarimeter (A. D. Code, P.I.); they have similar pointing requirements and a sufficient number of common targets so that they can be flown together as a single payload for several shuttle flights. A version of the LAS balloon payload is also scheduled to fly on a spacelab mission in 1983.

III. Sub-orbital Payloads

In addition to the on-going instrumentation programs mentioned in Section A.I. rocket payloads are under development for far-ultraviolet high-dispersion spectroscopy by T. P. Snow at the University of Colorado and by E. B. Jenkins at Princeton. A large general-purpose telescope payload has been developed by A. F. Davidson at the Johns Hopkins University. Additional flights are being planned forthe Balloon Ultraviolet Spectrograph (BUS) under the direction of C. de Jager.

IV. Future Projects

Canada, Australia and the United States are pursuing joint studies for a cooperative program to develop and fly a one meter class telescope facility designed primarily for ultraviolet and visible wavelength imagery. The facility, named Starlab, would provide a 30 arcmin flat field with about 0.2 arcsec resolution. Starlab is intended for a series of missions lasting six months or more each on a space platform.

NASA has started the definition of a Far Ultraviolet Spectrograph (FUSE) to obtain astronomical spectra over a broad wavelength range, but optimized for 900 to 1200Å. ESA has also begun studies of a project named Magellan, with similar objectives. Both FUSE and Magellan are viewed as potential follow-on missions utilizing the IUE concept of a facility instrument with real time interaction between the observer and the telescope.

Studies are continuing in the U.S. for an ultraviolet Schmidt survey telescope, to be proposed for Spacelab flights.

4. X-Ray Astronomy

M.Oda

A. INTRODUCTION

The past three years have continued to be an exciting period for X-ray astronomy. Observational data are mainly provided by the X-ray satellite missions, SAS-3, Ariel-5, Ariel-6, HEAO-1, Hakucho and the EINSTEIN Observatory (HEAO-2). Some important contributions have come also from piggy back experiments on other satellites and from rocket and balloon experiments. The luminosity of known X-ray sources ranges over $10^{26} \sim 10^{46}$ erg/s, some are compact and some are diffuse: they are associated with a great variety of astronomical objects and with many different emission mechanisms. X-ray astronomy which has been categorized in terms of its methodology is now no longer a confined branch of astronomy limited to X-ray emission but has grown into a field which provides profound understanding of dynamic processes in various objects.

This short report cannot be a comprehensive review of this vast and rapidly growing field, but I will try to survey at least superficially the observational aspects of a great variety of astrophysical objects. Since the number of important papers is enormous, references included in this report will be limited and they are only intended for convenience in looking up for further references, not for the sake of proper crediting; often the name of the satellite mission or experiment will be quoted instead of the authors. The description will be more oriented to missions and observational programs rather than to the results.

Among the satellite missions which provide major inputs to this report as quoted above, SAS-3 (G.Clark, H.Bradt, W.Lewin and the MIT group) and Ariel-5 (K.Pounds, Leicester, Imperial College and University College groups, and GSFC group) reentered in April 1979 and March 1980 respectively. The data from the Sky Survey Instrument on Ariel-5 collected over a $5 \sim 6$ year period have produced the 3A catalogue (Warwick et al. in press, McHardy et al. in press), the revised version of the 2A catalogue, containing 250 X-ray sources.

The HEAO-1 mission (see, e.g., review by Boldt 1981 and references therein), operated during the period August 1977 $\sim$ 1979 with scanning and pointing modes, has greatly expanded the scope of X-ray astronomy with the following four sets of instruments which are all distinguished by their large size compared to similar devices in earlier experiments:

i) A-1 (H.Friedman and the NRL group): Large area proportional counters for high sensitivity sky survey.
ii) A-2 (E.Boldt and the GSFC group, G.Garmire S.Bowyer, G.Riegler and the Cal Tech, UCB and JPL): Proportional counter spectrometers covering a wide energy band ($0.15 \sim 60$ keV).
iii) A-3 (H.Bradt and the MIT, and D.Schwartz and the SAO): Modulation collimator proportional counters.
iv) A-4 (L.Peterson and UCSD, and W.Lewin and the MIT): A set of scintillation phoswich detectors for the higher energy band (10 keV $\sim$ 10 MeV)

The HEAO-1 Soft X-ray Catalogue has been completed containing 114 sources. The A-3 experiment provides error boxes for source location typically a factor of 100 smaller than previous error boxes. A number of stellar optical counterparts have been identified directly from the X-ray source location. The A-4 (hard X-ray) Sky Survey Catalogure is in preperation.

The X-ray sky observation over a medium energy range (say, 2 keV - 30 keV) has been continued by the Hakucho satellite (M.Oda, Y.Tanaka, ISAS group; Hayakawa, F.Makino, Nagoya Univ. group; S.Miyamoto, Osaka Univ. group), which was launched on February 21, 1979 and is still in operation (Kondo et al.1981; see Oda 1981 references therein). Ariel-6 has also been in operation over this period, but due to some anomalies in the satellite performance the data yield is not as much as was hoped. The main mission objectives of Hakucho are i) to monitor X-ray variables over a wide field of view and to investigate selected sources, and ii) to produce a status report of the X-ray sky to cooperate with astronomers of other disciplines. Among variable sources an emphasis is placed on the study of X-ray burst sources.

The HEAO-2 mission (EINSTEIN Observatory) (Giacconi et al. 1979) largely benefited by its imaging capability and increased sensitivity (up to 500 times that of previous observations) by the use of a focussing X-ray telescope for the first time in a satellite has opened a new era for X-ray astronomy, though the observable energy band is limited to a relatively narrow band (0.1 ∿ 3 keV). The Observatory makes use of two imaging instruments (Imaging Proportional Counter (IPC), High Resolution Imaging System (HRI)) and two spectrometers (Solid State Spectrometer (SSS), Focal Plane Crystal Spectrometer (FPCS)) at the telescope focus. The experiment was developed by a scientific consortium (R.Giacconi, E. Boldt, S.Holt, G.Clark, R.Novick, H.Gursky, H.Tananbaum and groups at Harvard-SAO, GSFC, MIT and Columbia) and more than 400 of guest observers were coordinated (F. Seward. SAO).

EINSTEIN had been actively in operation since it was launched on November 13, 1978 until some failures in the aspect control system started to constrain the observational programme in August 1980. EINSTEIN has conducted detailed observations of ∿ 300 known X-ray sources and has discovered thousands of new X-ray sources.

B. GALACTIC X-RAY BINARIES

It may be safely postulated by now that most, if not all, of bright galactic compact X-ray sources, the luminosity ranging $10^{36} \sim 10^{38}$ ergs/s, are binaries. They are hypothetically classified into three groups. The first, class-I, is X-ray pulsars which are characterized by their pulsation, periodical eclipse (for most of them) and hard spectrum. The model for this class is a binary consisting of a young massive star (Population I) and a strongly magnetized neutron star. The second class (class-II) sources are bright X-ray sources clustering loosely in the vicinity of the galactic center ($L < 30°$), which are characterized by no pulsation, no eclipse and soft spectrum in contrast to the class-I sources. There is no clear evidence that these are also binaries, but they are presumably considered to be a combination of a late-type dwarf (Population II) and a non-(or weakly) magnetized neutron star. It is not certain if Sco X-1, Cyg X-2 and 4U 0624+9 physically belong to the same class. The third class is a binary which contains a black hole.

I. X-ray Pulsars (Class-I).

Over the past years in-depth studies of timing and spectral properties of X-ray pulsars, 4U 0900-40 (Vela X-1), Cen X-3, Her X-1, 4U 0115+63, A0535+262, GX 1+4, LMC X-4 etc, have been performed. The Hakucho data (Nagase et al. 1981a) compiled with previous data on Vela X-1 reveal a clear turning from a spin-up (common phenomenon for most of the X-ray pulsars) to a spin-down trend of the neutron star and also exhibit the noise-like variation of the spin-period, both of which may provide a powerful tool for the study of the neutron star structure and its interaction with the accretion disk.

A recurrent slow pulsar, A0535+262, has been in the process of investigation (Nagase et al. 1981b) with the 1975 - 1978 data from Ariel-5 and SAS-3 and the 1980 data from Hakucho: the long span observation provides severe constrants on its orbital parameters which in turn may have strong bearings on the physics of neutron stars.(see, e.g., Rappaport et al. 1980 as for the phenomenology of pulsars.)

An absorption feature (∿ 40 keV) in the spectrum of Her X-1 (Truemper et al.

1978), which is interpreted as a cyclotron line providing a direct evidence for strong magnetic fields of neutron stars, has been reconfirmed by balloon experiments and by HEAO-1 (A-4) (Gruber et al. 1980). An absorption feature discovered by an A-4 observation near 20 keV in the 3.6 sec pulsed spectrum of 4U 0115+63 (Wheaton et al. 1979) may be the second case after Her X-1, which provides the evidence for the existence of strong magnetic fields.

Temporal and spectral behavior of several other pulsars have been investigated by the SAS-3, Ariel-5 and HEAO-1 (A-4) groups. These sources include newly discovered pulsars 2S 1417-624, LMC X-4: for the latter A-4 found a 30d period (Lang et al. 1981). LMC X-4 is known to exhibit an eclipse period of 1.408d: this may be the second case to Her X-1 where the pulsar period is longer than its binary period suggesting the existence of a precessing accretion disk.

II. Class-II Sources

The sources, often referred to as "Galactic Bulge Sources" (Lewin and Clark, 1979) while the word Galactic bulge should not be taken literally, contain the X-ray sources in globular clusters, the bright (but not highly variable) sources, the transient (often recurrent) soft ($kT \lesssim 5$ keV) sources, and the sources within a couple of degrees from the galactic center (GCX sources).

SAS-3 and Hakucho have performed extensive studies of the class-II sources (see, e.g., reviews by Lewin and Joss, 1981; Hayakawa, 1981; Oda, 1981 and references therein). Emphasis has been placed on the investigation of X-ray bursts. Preliminary burster catalogues have been produced and often revised. The number of well confirmed sources which burst or are known to have bursted is now 25. It is suggested that the X-ray burst is a common feature of all kinds of the class-II sources. Most of X-ray sources in globular clusters, if not all, generate bursts (under some, yet unknown conditions): they are NGC 1851, NGC 6441, NGC 6712, Terzan 1, Terzan 2, Terzan 5, MXB 1728-337. Several bright bulge souuces which are not in the globular cluster are known to generate bursts: some have been continuously burst active and some become active with long quiescent intervals. Transient sources which are known to outburst (probably recur) for weeks (Cen X-4, Aql X-1) were observed to generate typical bursts. Three GCX sources have been observed to burst sometimes. One may speculate, thus, that all class-II sources are potentially burst sources irrespective of their kinds (and the genetic process of the binary formation).

The impressive stability of the observed "black body" radius of the bursters at $\sim$ 10 km, regardless of a variety of properties of individual bursts from a single source and a number of different sources (van Paradijs 1978; references in Oda 1981), support a generally acceted picture of the thermonuclear flash on the neutron star surface: the concept is well represented by Joss's model (Joss 1978) among other theroretical works.

Profound studies of physical properties of bursters appear to lead to a variety of intriguing and challenging theoretical themes on the neutron star physics under the context of the thermonuclear flash model.

The rapid burster (see, e.g., review by Lewin and Joss, 1981), which is known to generate the type II bursts, exhibited a peculiar behavior during its outburst for August 8 - 23, 1979 (Inoue et al. 1980, see review by Oda 1980). The source generated the train of a new kind of type II bursts with long flat-topped profiles: the phenomenon leads to the suggestion of a reservoir of matter around a neutron star. (see, Oda and Tanaka 1981). Apart from the rapid burster the existence of the reservior is also demanded by findings of typical bursts in succession with short intervals. The phenomena are rare but common for a number of burst sources, and the intervals are orders of magnitude shorter to store a sufficient amount of the fuel on the neutron star surface to ignite a thermonuclear flash. (Murakami

https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

et al. 1980)

The programme of optical/X-ray simultaneous observations of bursts has been undertaken by Hakucho, ESO and US optical observers under the coordination of the MIT (Pedersen et al. 1981): The aim is to investigate physical circumstances of the burst emitter (neutron star) with the optical burst using the X-ray burst as the probe. The 1636-536 was chosen as a good target for this programme, and thus far ten cases have been obtained.

III. Black Hole Candidates

The high state of Cyg X-1, which appeared during June $\sim$ July and November 1980 after a long pause since 1976, was observed by Hakucho. Simultaneous optical observation of Cyg X-1 during and after this high state (Kemp et al. 1981) yielded some constraints to the model of the binary system. Data from hard X-ray observation by the MIT balloon experiment (Ogawara et al. 1981) and HEAO-3 and also UV observation by IUE will be compiled to produce a more coherent picture of Cyg X-1 system. Some coordinated observation of Cir X-1 among X-ray, Optical, and IR was attempted.

The HEAO-1 (A-4) observation provides an interesting problem to the variability of Cyg X-1. The time variability of GX 339-4 (Friedman et al. 1979), which was suggested to be a black hole candidate, has been studied by Hakucho. A similarility of the nature of an aperiodic variability, which is, however, not the white noise, between GX 339-4 and Cyg X-1 is noted.

C. LOW LUMINOSITY COMPACT GALACTIC SOURCES

i) Sky surveys by SAS-3, Ariel-5, and HEAO-1 (A-3) added numerous identification of low luminosity nearby ($\sim$ 100 pc) souces (see, e.g., Boldt 1981) to those which had been known previously by rocket, ANS, OSO-8 and SAS-3 experiments. Almost every type of star in our Galaxy has been detected by EINSTEIN. The low luminosity sources, which ranges $10^{31} \sim 10^{33}$ ergs/s of luminosity, are not just fainter versions of the strong source (i.e. classical X-ray binaries), but are of great interest in its own right. These sources include Capella, most RS CVn type sources (Walter et al. 1978), AM Her and other cataclysmic variables (see, e.g. Griffith et al. 1979 ; also Cordova et al. 1981), white dwarf systems, white dwarf X-ray pulsars (H2252-035, 4U 1849-31), Sco X-1-like binaries, flare stars (e.g. Prox Cen, YZ CMi; Haisch et al. 1980) and other objects with a variety of physical phenomena.

EINSTEIN performed an extensive study of RS CVn stars and also surveyed known cataclysimic variables. EINSTEIN (SSS) has provided new data on emission lines from Capella (Holt et al. 1979) and RS CVn stars (Swank et al. 1981).

ii) One of the surprising discoveries by EINSTEIN is that normal stars in general constitute a pervasive class of low luminosity galactic X-ray sources (Vaiana et al. 1981). They include stars alsong the entire main sequence of all luminosity classes, pre-main sequence stars as well as very evolved stars. The data are consistent with models with magnetically dominated coronae (as in the case of sun), in contrast to previously presumed models of acoustically heated coronae.

Some of the most spectacular EINSTEIN pictures (IPC, HRI) of the X-ray sky have come from observations of star clusters and association. They were typically trapezium stars, O-stars in the Cyg OB 2 association with the luminosity 10^{33} erg/s (Harnden et al. 1979), 15 O-stars of the Carina OB 1 association embedded in a bright, diffuse X-ray nebula (Seward et al. 1979) and an X-ray survey of the central region of the Hyades cluster.

D. GALACTIC CENTER.

Apart from GCX-sources observed in the medium energy range, the X-ray images of the galactic center by EINSTEIN reveal a couple of weak sources within 20 arcmin of the galactic nucleus, together with a region of apparently diffuse emission, $\sim$ 20 arc arcmin in size. This is possibly the first sighting of the center of our galaxy with high angular resolution, though over a limited energy range where the X-rays are highly absorbed by intervening material. (Watson et al.1981)

E. SUPENOVA REMNANTS (SNR)

HEAO-1 (A-2) discovered a dozen new soft (1/4keV) X-ray sources associated with SNR's. One of the most spectacular discoveries with the sky mapping will be described in the next section F.

EINSTEIN has detected and mapped $\sim$ 40 SNR's in our galaxy and almost as many in the Magellanic Cloud. X-ray emission line spectra have been obtained by EINSTEIN (SSS) for many SNR's. These data support the study of the nature of the ejecta, the blast wave, the interaction of ejecta with the interstellar medium ---.

Cas A has been studied in detail by EINSTEIN (HRI, SSS) (Fabian et al. 1980, Becker et al. 1979): The distribution of material around the shell, the double structure of the shell and strong emission lines due to the enhanced abundance of elements over solar values have been investigated. Other shell-like remnants, Tycho and SN1006 (Pye et al. 1980, Becker et al. 1980), were also studied. Crab-like remnants with no shell-like appearance have been also studied (Becker and Helfand 1981). EINSTEIN (FPCS) observation of prominent lines from Puppis A (Winckler et al. 1981) provided badly needed high resolution spectroscopy data which will help determine the physical characteristics of the emitting gas.

EINSTEIN observations of the Crab pulsar and upperlimits for detection of pulsars in remnants have been used to evaluate the upper limits to the surface temperatures of neutron stars supposedly formed in the supernove explosion (Nomoto and Tsuruta, 1981): The cooling curves of the neutron star surface have a strong bearing on physics of the interior of neutron stars.

Another compact object associated with a SNR having yet X-ray manifestation is the star SS443, which is at the center of the remnant W50. The star is not only a compact X-ray source, but there are two associated diffuse X-ray sources (Seward et al. 1980).

The hard X-ray image of the Crab Nebula has been produced by balloon observations conducted under the ISAS-UCSD collaboration (Makishima et al. 1981). The image appears to suggest the cavity-like structure of the Nebula. The result, compiled with that by EINSTEIN (Giacconi and Tananbaum 1980), will help understanding physics of high energy plasma at the heart of the Nebula and its overall dynamics.

F. LARGE SCALE FEATURE

Soft X-ray (0.1 $\sim$ 0.3 keV) sky maps produced by rocket experiments (e.g. by Wisconsin group and by Leiden/Nagoya group) indicated the possible existence of a hot ($\sim 10^6$ K) bubble surrounding the solar system with a radius on the order of 100 pc. Following these experiments HEAO-1 (A-2) revealed a number of new large scale features including a very large hot "super bubble" in Cygnus (Cash et al. 1980), a giant ring some 20° in diameter tangent to the galactic plane in the general direction of Monoceros, and a bright extended, probably diffuse, region surrounding the general direction of the galactic center. The "super bubbles", which may encompass a tenth of the galactic disk and play a major role in the energetics of the interstellar medium, may be the result of the large number of supernovae.

https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

G. NORMAL GALAXIES

EINSTEIN (IPC, HRI) has performed complete X-ray survey of M31 (Van Speybrosck et al. 1979), SMC (Seward and Mitchell 1980) and LMC (Long et al. 1981). And a number of other normal galaxies have been also observed. Sixty-nine X-ray sources were detected in M31, having luminosities ranging from 10^{37} to 3 10^{38} ergs/s. Twenty-one of these bright sources lie in a compact inner bulge: The distribution is quite different from the "bulge" sources in our Milky Way. There is also a 10^{38} erg/s variable source coincident with the nucleus of M31.

Probably 15 detected sources are associated with the SMC. The brightest source seen is a previously unknown SNR located in the central part. Aside from SMC X-1, there were no sources which might be identified with accretion powered sources with luminosities above 10^{37} erg/s.

Probably 75 detected sources are in LMC; at least 25 are SNR. If the rest is not also SNR, they represent a class of objects heretofore unrecognized in the galaxy. (As for different nature of the sources in SMC, LMC see Clark et al. 1979)

H. ACTIVE GALAXIES

A systematic study of high latitude sources in the Ariel 5 catalogue have shown that active galaxies are frequently prodigions X-ray emitters. The fast variability indicates that the energy is produced in a very small region ($\sim 10^{15}$ cm): The X-ray studies provide a unique insight into the physical processes associated with galactic nuclear activities.

EINSTEIN detected X-rays from virtually every type of galaxy with an active nucleus. The active galaxies include Seyfert galaxies (Kriss et al. 1980), Markarian galaxies (Hutter and Mufson 1981), BL Lac objects and QSO's. Some of the most interesting results have come from the analysis of the EINSTEIN images of the physical structure of Cen A (Shreier et al. 1979) and M 87 (Fabricant et al. 1980).

HEAO-1 (A-3) experiment confirmed the identifications of 19 Seyfert Type I galaxies, originally discovered by Uhuru and Ariel 5, with more precise location capability. Among several time variable Seyfert Type I galaxies observed by Ariel 5 and EINSTEIN, a particularly well observed source is NGC 4151. The spectrum of NGC 4151 obtained by EINSTEIN (SSS), compiled with the HEAO-1 (A-2) spectrum, led to an inference of the geometry of the source. The SAAO discovered an extreme Seyfert Type I galaxy as the probably optical counterpart of 3A0557-383: this new X-ray discovered Seyfert appears to be the most luminous known.

Another new class of active galaxy, high excitation emission line galaxies have been observed by HEAO-1 and Ariel-5: The X-ray variability of the source NGC 5506 has provided the first direct evidence that such galaxies also contain a "Quasar like" nucleus ($\sim 10^{15}$ cm).

The HEAO-1 (A-3) experiment confirmed four BL Lac objects and discoverd a new one, PKS 2155-304. HEAO-1 (A-2) experiment suggests that BL Lac objects often exhibit a flatter spectrum at higher energies (> 10 keV) (Worrall et al. 1981), while X-rays detected from many BL Lac objects show steep spectrum in the low energy region. For MKn 421 SAS-3 for the first fime discovered soft (< 1 keV) X-ray from a BL Lac object. Ariel 5 identidied MKn 421 with one of the fast transient sources.

Observations of QSO's by EINSTEIN have shown that virtually all of these objects are strong emitters (Zamorani et al. 1981). Surveys show a strong correlation between X-ray and radio emission for some sources. The luminosity of QSO's detected so far span a range from 10^{43} to 10^{47} ergs/s. The variability of X-ray flux from 3C273 was clearly established with the HEAO-1 (A-3) data.

https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

I. THE DIFFUSE X-RAY BACKGROUND

Deep surveys by EINSTEIN (Giacconi et al. 1979) have shown that a large fraction of the diffuse X-ray background may be due to previously unresolved discrete source. Many of these sources have been identified, and a significant fraction of them are distant QSO's.

Data from the all-sky survery carried out with the HEAO-1 (A-2) experiment have been used to define broad-band (2 - 60 keV) characteristics of the extragalactic X-ray sky. The overall flux in this band is dominated by an isotropic background (Marshall et al. 1980). Even when possible discrete source contributions are considered, the residual X-ray backgroung spectrum is compatible with emission form a hot intergalactic plasma (Fabian 1981). The controversial question of the origin of the diffuse X-ray background will require a future advanced mission for an answer.

J. CLUSTER OF GALAXIES

The HEAO-1 (A-3) experiment detected 11 clusters, for 8 of which sizes or size limits have been determined: they are consistent with a few optical sizes that have been reprorted to date. The luminosity functions and thermal spectra for clusters of galaxies have been well determined by A-2 (McKee at al. 1980).

The EINSTEIN observation have shown a variety of structures of nearby rich clusters of galaxies (Jones et al. 1979). The nature of the structure ranges from broad, highly clumped to smooth and centrally peaked. These observations are interpreted in terms of sequence of cluster evolutions. The clusters of the former nature are in early phases while the latter clusters are at a later evolutionary stage.

Early clusters, e.g. Abell 1367 (Bechtold et al. 1981) and Virgo Cluster (Forman et al. 1979), with diffuse emissions associated with individual cluster galaxies have been studied. The more evolved clusters with smaller core radii usually have a sharp peak around the centrally located cD galaxy. Massive halos are perhaps a common phenomenon. Another morphologically destinct class of clusters is characterized by a double structure, predicted as the intermediate stage of evolution by means of a model simulation of the evolution of cluster. (Forman et al. 1981, Henry et al.1981).

Emission lines were detected by EINSTEIN (SSS) from clusters of galaxies. The Perseus cluster has been analysed in detail (Mushotzky et al. 1981). HEAO-1 (A-4) detected a high energy (> 25 keV) tail in the spectrum of Perseus cluster (Primini et al. 1981). A rich cluster of galaxies in Ophiucus, which is the optical counterpart of the bright X-ray source 4U 1708-23, was discovered (Johnsten et al. 1980, Wakamatsu and Malkan 1981).

K. FUTURE EXPERIMENTS

Following X-ray satellite missions have been approved and are under preparation (see, Proceedings of the Uhuru Memorial Symposium, J. of Washington Academy of Sciences 1981 71 No2)

a) EXOSAT, the first X-ray astronomy mission form the ESA, will be launched in 1982. The experiment payload consists of the medium energy detector array for observing faint sources and precise location by means of lunar occultation, the low energy imaging telescope with geometric area of 90 cm^2 and focal length 109 cm and the gas scintillation proportional counter.

b) The Rosat mission, a German X-ray telescope, is due for launch before mid-1980s. The payload is a mirror telescope with a geometrical collection area of 1200 cm^2 and a focal length of 240 cm. In addition to the pointed observations the first X-ray sky survey with a imaging telescope is planned.

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c) Succeeding the Hakucho satellite, which continues to be in operation as of December 1981, the ASTRO-B and the ASTRO-C will be launched from Japan. The ASTRO-B will be launched in Feburuary 1983: One of its major instruments is a large area gas scintillation proportinal counter array with a total area of $\sim$1000 cm^2 for the temporal-spectral study of sources. The ASTRO-C is for the high sensitivity observation of variable sources with a large area proportional counter array: it will be launched on 1986/87.

The X-ray Timing Explorer, the Extreme Ultraviolet Explorer and the Advanced X-ray Astrophysics Facility (AXAF), all from NASA, are awaiting for approval. The AXAF is the advanced version of EINSTEIN, which is hoped to provide X-ray astronomy another break-through.

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5. Solar Space Research

C. de Jager

A. ANALYSIS OF DATA FROM SPACECRAFT LAUNCHED BEFORE 1979

I. OSO-8

The last spacecraft in NASA's Orbiting Solar Observatory programme OSO-8, was launched in June 1975 and has been operating until October 1978. It carried among other instruments a high resolution telescope and multichannel spectrometer built under the responsibility of the Laboratoire de Physique Stellaire et Planetaire in France. An extensive review of the results obtained with this instrument can be found in Bonnet (1981), from which we extract: the detection of chromospheric oscillations in Lα; the establishment of an active region model which represents correctly the profiles of Ca II H-K, Mg II h-k, H Lα and Lβ observations.

Several quiet and active prominences have been observed with OSO-8.

II. Intercosmos

Solar spectroscopic data were analysed in a cooperative programme between the Moscow group (Institute for Spectroscopy, and the Lebedev Institute), and the Wroclaw Astronomical Observatory. The analysis concentrated on the study of high-resolution spectra in the range 0,175 - 0,19 nm. Models of the differential emission measure distribution were calculated for large flares observed in October-November 1970. The models show two maxima in the distribution of the differential emission measure : one in the range of $10 - 20 \times 10^6$ K and the second at temperatures of $30 - 100 \times 10^6$K. Results are published in Hudson (ed.; 1981). Intercosmos -16 high resolution spectra were studied in the region of Mg XI and Mg XII resonance lines. The electron density in the emitting regions was estimated from the intensity ratios of the resonance, intercombination and forbidden Mg XI lines. The density in the Mg XI emitting volume of a coronal active region appears to be higher when the region is hotter. Papers on this subject have been submitted to Solar Physics.

III. Solar Wind Studies

Solar particles and solar wind properties are being measured by instruments on board of Helios 1 and 2 (both are heliocentric with periapsis at 0,3 AU and apoapsis at 0.98 AU) and on board of the International Sun Earth Explorers (ISEE 1, 2 & 3). Based on these missions, publications have appeared on solar wind properties and solar particle acceleration and propagation in the corona. A recent selection can be found in the Proceedings of the 17th International Cosmic Ray Conference, Paris, July 1981.

B. SATELLITES LAUNCHED DURING THE REPORT PERIOD

I. The Solar Maximum Mission (SMM)

The most important event in the reporting period was undoubtedly the launch and operation of the Solar Maximum Mission (launch date February 14, 1980). The spacecraft and its instrumentation are described in a series of papers in Solar Physics 65, 1980.

The SMM contains the following scientific instruments.

- Gamma-Ray Spectrometer (Forrest et al., 1980)
- Hard X-ray Imaging Spectrometer (Van Beek et al., 1980)

https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

- Soft X-ray Polychromator (Acton et al., 1980)
- UV spectrometer and Polarimeter (Woodgate et al., 1980)
- Coronagraph / Polarimeter (MacQueen et al., 1980)
- Solar Constant Monitoring Package (R.C. Wilson, 1980)

Unfortunately the attitude control system of the spacecraft broke down after only nine months of operation. Owing to the fact that the solar maximum of 1979-1980 was the second highest on record since 1610 a large amount of new data could be acquired. Preliminary results are published in Hudson (1981), pp 247-287. Results appeared also in a special volume of Astrophys.J.Letters 244, L113-189, 1981.

Here, we briefly list the most important findings: the magnetic field strength above a sunspot in the transition region is about half that of the photospheric value; oscillations occur in the transition region above sunspots; impulsive flare bursts in (hard) X-rays coincide in time with those observed in ultraviolet lines as well as in microwaves; large outstreaming motions are found preceding the occurrence of flares; "footpoints" of flares observed in hard X-rays and microwaves may occur simultaneously (within one or two seconds) at separations as far as 10^5 km apart; the diffuse (soft) X-ray emitting area of flares appear after the (hard) kernels, are slightly hotter, and may derive their content of energetic electrons from the kernels, where they apparently originate. The discovery of X- and UV-line precursors to flares, and giant X-ray emitting loops after large flares is another new result of SMM. A further result is the discovery of a series of γ-ray line emissions during important flares, indicating high-energy acceleration processes. SMM also discovered a relation between variations in the solar "constant" and sunspot development. The elaboration of the SMM data will still take several years, and may yet reveal several discoveries, still hidden in the available material.

II. Prognoz 8

This spacecraft, launched December 25, 1980, carries among other payloads a solar X-ray photometer developed by the Ondrejov Observatory. The photometer measures in six energy bands (2-4, 4-8, 10-20, 40-80, an 80-160 KeV) with a time resolution of 10 seconds.

III. Hinotori

Hinotori (ASTRO), the Japanese astronomy satellite launched by the Institute of Space and Aeronautical Science of the University of Tokyo, has been continuously operating since February 26, 1981 to perform extensive observations of solar flares in X-rays and γ-rays. Hinotori carries five instruments; they are (1) hard X-ray imaging telescope in the energy range of 10-60 keV (SXT), (2) Bragg spectrometers for 1,7-2, 0 Å (SOX), (3) soft X-ray spectrometer for 2-20 keV (FLM), (4) hard X-ray spectrometer for 17-340 keV(HXM), and (5) γ-ray spectrometer for 240-7000 keV (SGR). All the instruments monitor the full sun.

The hard X-ray image is obtained by the rotating modulation collimator technique; computer processings of the data give two-dimensional images with about 10" resolution. The SOX, consisting of two flat SiO_2 crystals and scintillation counters, makes use of the spacecraft rotation for scanning two wavelength bands: 1,81-1, 90 Å and 1,7-2,0 Å every 6 to 10 seconds with a resolution of 0,2 mÅ and 2 mÅ, respectively. The SOX has the capability to detect line polarization. Observations by FLM, HXM and SGR cover the flare spectra in a wide spectral range from 2 keV to 7 MeV almost simultaneously; the temporal resolutions are 125ms(HXM), 2s(SGR), and 4s(SGR). The 2-20 keV region is measured by the gas scintillation proportional counter which is capable to resolve line emission from the continuum. The gamma-ray line emissions can also be resolved. The spacecraft has the capability to record the initial 20 minutes of each flare.

The following preliminary results have been obtained.

In the early operation, by July 31, 1981, Hinotori observed 261 flares including 13 X-class events. The SXT has observed many events in the energy band of 12-30 keV (efficiency peak above 20 keV); several large events have been analyzed to reveal very compact sources for these hard X-ray bursts. With the exception of a few events most have linear dimensions less than the FWHM(30") of the collimator triangular response.

The SOX has obtained a large number of high resolution spectra which include emission lines from Fe XIX to Fe XXVI, $K\alpha$ and $K\beta$ (1,75Å). The $L\alpha$ and satellites of Fe XXVI have been well resolved; their ratios give the electron temperatures considerably higher (3-10 million degrees) than the electron temperatures derived from the Fe XXV pair. A steady increase of the mean temperature from about 15×10^6K to 30×10^6K has been found in the rising phase of the impulsive flares. In the differential emission measure derived from the line intensities for these events a pronounced peak of the emission measure has been found to appear above 20×10^6K and shift progressively to higher temperatures and then return to the lower temperatures. This time behaviour is considered to represent the heating and cooling in the flare. Line broadening of about 250 kms^{-1} has been seen before the increase of the temperature. In the initial phases of some flares blue enhanced line profiles and Doppler-shifted complex profiles have also been found.

The soft X-ray spectra in the range of 2-10 keV obtained by the FLM have given evidence for gradual heating of the flare plasma in the rising phase of small flares; in these spectra the emission lines from the He-like and H-like ions of Ar, Ca, Ti, Fe and Ni appear and become enhanced successively in this order, along with the increase of the continuum slope.

The γ-ray spectrometer(SGR) has detected significant emissions of following lines (shown in MeV) at least in two events: 0,51($e^+ + e^-$), 0,84(^{56}Fe),1,37(^{24}Mg), 1,64(^{14}N or ^{20}Ne), 2,22(D), 4,44 (^{12}C), 6,14(^{16}O). Unidentified emission has been seen at 1,0 MeV. In the limb event (April 27) the 2,2 MeV line was less intense by an order of magnitude than the 4,4 MeV line. This supports the photospheric origin of the 2,2 MeV line. The continuum spectra extending to 7MeV have been observed. The spectra tend to show a break near 1 MeV.

C. OBSERVATIONS BY ROCKET- AND BALLOON PAYLOADS

I. The Transition Region Camera (TRC)

The TRC is a small (10 cm) Cassegrain rocket-borne telescope built by the Laboratoire de Physique Stellaire et Planetaire du C.N.R.S. It is equipped with a filter wheel and a film cassette. Sequences of images at various wavelengths can be obtained through the rotation of the filter wheel and for various exposure times. This instrument has been launched twice on a NASA Black Brant rocket on July 3, 1979 and September 23, 1980, jointly with other solar instruments built by the Lockheed Palo Alto Research Laboratory (LPARL). The TRC has provided the best solar pictures ever obtained so far from above the earth atmosphere. The pictures correspond to $L\alpha$ 121,6 nm (Bonnet et al, 1980) and to the temperature minimum continuum, 160 nm (Bonnet et al, 1982).

The $L\alpha$ pictures show a large variety of chromospheric features, in particular, magnetic loops of varying sizes and extension both in the chromospheric network and in the corona. These loops appear either as emission (bright) or absorption (dark) features. Optically thin coronal loops have been used to infer the density and temperature of neutral hydrogen in the corona. Temperatures of around 10^5 degrees K and densities of 5.10^5 cm^{-3} neutral hydrogen atoms have been found (Bonnet et Tsiropoula, 1982).

By contrast, the U.V. continuum pictures display very sharp features of point like appearance (bright points), and circular surface wave patterns revealed here for the first time. The bright points have an excess brightness of 100 to 200 K over the average background. They seem to be located at the edges of granules.

Two more flights of the TRC are scheduled in 1982. An enlarged version of this instrument is in preparation at L.P.S.P. and L.P.A.R.L.. It is intended to fly first on a rocket and possibly later onboard the Space Shuttle.

II. The Rocket Launchings

For the investigation of solar X-ray emission within the Intercosmos programme the "Vertical-8" and "V-9" rockets were launched on 26 September, 1979 and 28 August, 1981, respectively. The instrumentation was designed at the Lebedev Phusical Institute (USSR), the Space Research Center at Warszawa (Poland) and the Ondrejov Observatory (CSSR) and included wideband photometers for the region 0.4-1.5 nm, Bragg-spectrometers with flat and bent crystal spectrometers for the region 0,6-1,0 nm, pinhole cameras, and two grazing incidence mirror telescopes forthe band 0,5-1,5 nm (spatial resolution: ca. 20"). The apparatus mounted on a 2-axis pointing system, was installed in a special vehicle. At an altitude of 100 km at ascent this vehicle was separated from the rocket landed with a parachute system. The maximum altitude achieved was about 500 km; the pointing accuracy was about 10 arc sec. By these experimetns X-ray photographs of the Sun were obtained in the ranges 0,8-2,2 and 0,6-2,0 nm. Simulaneously, high-resolution spectra around lines of Si XIV, XIII; A1XII; ;gXII, XI were obtined by the traditional scanning method. The fluxes in the same lines were also measured continuously, with a time resolution of about 0,04 s. The results were investigated with a view to obtain the distribution of temperature and density in the Active Region McMath 16288.

D. PROJECTS UNDER DEVELOPMENT

I. International Solar Polar Mission

The ESA/NASA International Solar Polar Mission (ISPM) will be the first spacecraft to explore the heliosphere, within a few astronomical units from the sun, over the full range of heliographic latitudes. Its main objectives are to study the large-scale structure of the heliosphere, the solar wind, solar energetic particles and X-ray flares, galactic cosmic rays and inter-planetary dust as a function of heliolatitude (Wenzel, 1980). Since NASA decided to cancel its spacecraft, no solar imaging instrumentation will be carried on this mission. The launch of the ESA spacecraft is scheduled for May 1986 or earlier, if possible. The passages over the solar poles would occur in 1989-90.

II. ESA-NASA Cooperation on Spacelab 1

Part of the payload for this flight (scheduled for mid-1983) is a package of solar irradiance measuring instruments consisting of

- two absolute radiometers to measure the total irradiance, one built by the "Institut Royal Metéorologique de Belgique", Brussels and the Space Science Department of ESA, Noordwijk and the other by Jet Propulsion Laboratory, Pasadena, California.
- a spectrometer that covers the range 170 - 3200 nm, built by Service d'Aeronomie du CNRS, Verrieres-le-Buisson; Institut d'Aeronomie, Brussels; Landessternwarte, Heidelberg and Hamburgersternwarte.

To improve the accuracy of absolute values of the solar irradiance, the instrument performance will be determined before, during and after the flight. It is foreseen to refly the instrument package on future Spacelab missions, at intervals of about half to one year, to observe long term changes of the solar irradiance .

III. Solar Optical Telescope (SOT)

The next major solar physics space facility currently selected by NASA is the Solar Optical Telescope, a 1,25-meter diameter telescope for the optical and UV which will fly on the Shuttle starting in 1987, to perform high spatial resolution studies of the solar atmosphere and magnetic fields. SOT will have a resolution of better than 0,2 arc seconds. Two investigations have been selected: a) A combined Filtergraph Spectrograph which will include a tunable filtergraph-polarimeter for the visible and a visible and UV spectrograph; this will use large CCD arrays as detectors, and b) A visible and near UV photographic filtergraph which will have a somewhat larger field of view, extremely high resolution film, and short exposure times to try to test the ultimate performance of the SOT optics.

IV. Soviet Solar Satellite

The Institute for Cosmical Research in Moscow is preparing a three-axis stabilized spacecraft with solar instrumentation, to be launched in 1982 or 1983. Main instruments are solar high-resolution spectrometers, polarimeters and UV and X-ray imaging equipment.

V. RASOLBA

A balloon-borne telescope and spectrometer, with 30 cm aperture, prepared by Laboratoire de Physique Stellaire et Planetaire at Verrieres, France will operate between 2000 and 3000 Å and is devoted to high-resolution spectroscopy of the photosphere, chromosphere and active regions. A CCD Hα camera will allow the choise of targets on the disc. The scientific objectives will concentrate on the heating mechanisms in the solar outer atmosphere.

E. SOME PROJECTS UNDER CONSIDERATION

I. DISCO

DISCO is a proposal under consideration in the European Space Agency. It would be a 550 kg satellite orbiting the L1 Lagrangian point of the Sun-Earth system (0,01 AU from the Earth on the Earth-Sun line). It would be spin-stabilized with its spin-axis maintained in a sunward direction. Its primary scientific objectives may be described best by the "solar seismology". It would be the logical continuation of the early observations of solar oscillations from mountain altitudes (Clavery et al., 1979). Velocity oscillation observations with a precision of a few mm s^{-1} may be achieved from space measurements and would constrain the solar models to a better defined convection zone (Berthomieu et al., 1980). They would give access to the gravity modes which will probe the composition and rotation of the interior of the Sun from the upper layers down to the central core. DISCO will also refine the observation of changes of solar irradiance associated with solar activity observed by Willson (1981) on the Solar Maximum Mission, and the spectral observations of similar variations made by Fröhlich (1980) from a balloon. The solar brightness oscillations observed by Deubner (1981) in reflected light by Uranus and Jupiter may be improved and the phase of the luminosity variations and velocity oscillations obtained.

II. Grazing Incidence Solar Telescope (GRIST)

GRIST would be a spacelab-borne telescope-spectrometer to be flown in conjunction with the second flight of SOT, and was the subject of an earlier study of ESA. It would operate between 7 nm and about 120 nm. Focal plane instruments are presently under study in various European institutes. The objectives of GRIST, its technological and scientific possibilities and constraints are described in a special issue of Space Science Reviews edited by Huber (1981).

III. Solar Corona Explorer

A proposal under consideration in NASA. The objectives are the continuous study of coronal structures and their developments, with a view to arrive at an understanding of their origin and evolution.

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6. Gamma-Ray Astronomy
L.E. Peterson

In the past few years gamma-ray astronomy has made significant discoveries, and has moved from an exploratory phase to a developing phase. Results from the High Energy Astronomical Observatories (HEAO-1 and HEAO-3), Cos-B, and balloons have shown that many galactic and extragalactic X-ray sources have time variable spectra extending into the few MeV range. Variable annihilation radiation has been found from the galactic center, and Cos-B has resolved $\sim$ 25 sources emitting in the > 30 MeV regime, as well as confirming a general emission in the galactic plane. The most remarkable progress has, however, occurred in the study of solar γ-ray lines from the Solar Maximum Mission (SMM) and of the gamma-ray burst phenomena. Observations of the latter were from simple detectors placed on such spacecraft as the Vela series, Pioneer Venus Orbiter, Venera 11 and 12, ISEE-3, and Prognoz-7.

Many of the recent results are summarized in the published Proceedings of a number of conferences devoted to the entire subject (Cowsik and Wills, Ed., 1980; H.S.W. Massey, et al. Eds. 1981), as well as those on specialized aspects (Hurley,Ed., 1981). In the following, recent results are reviewed,based on technique and/or observation classifications. These include a) continuum emissions, $\gtrsim$ 20 keV which extend into the MeV range, b) gamma-ray line spectroscopy, including the sun, c) observations of the γ-ray burst phenomena, and d) high-energy ($\geq$ 30 MeV) astronomy. Finally, future plans and observational possibilities are indicated.

A. CONTINUUM OBSERVATIONS (E $\gtrsim$ 20 keV)

Although well over a thousand galactic and extragalactic sources have been discovered and studied from the HEAO-1 and HEAO-2 (Einstein Observatory), most have soft spectra, KT $\lesssim$ 3 keV, and therefore do not have fluxes extending beyond $\sim$ 20 keV Sources of certain classes have "hard" spectra, characterized by a power law $\frac{dN}{dE} \sim E^{-\gamma}$ph/cm^2-sec-MeV, with $1 < \gamma \lesssim 3$, and therefore may be dedectable in the 100 keV range or beyond.

I. Galactic Sources

X-ray pulsators in binary systems are believed to be accreting neutron stars with a remnant magnetic field $\sim 10^{12}$ gauss. Gas flow from a main sequence companion star becomes ionized, is guided to the magnetic poles of the rotating neutron star, where it acquires energy on the order of 100 MeV/nucleon before being shocked into a high temperature plasma with T $\sim 10^8$ K. A general property of these pulsators, whose periods range from 0.7 to > 100 sec., is a hard ($\gamma \sim 1$) spectra below 30 keV, and a steepening of at least one index at higher energies. Nineteen of these objects have been observed in the hard X-ray range (Wang and Welter, 1981).

The most extensively studied member of this class is Her X-1. Trümper et al. (1978) have observed a feature at $\sim$ 45 keV, which may be due to cyclotron resonance transitions in the a $\sim 10^{12}$gauss field. Gruber et al. (1980) have confirmed these features and provided details on the variation of pulse shape with rotation and orbital phase. Tueller et al. 1981 have measured these features with a high resolution Ge detector and these data have shown the feature is not a narrow emission or absorption line. Wheaton et al. (1979) have shown the transient X-ray pulsator 4U0115+63 also has features likely due to cyclotron effects.

The black hole candidate in a binary system, Cyg X-1, has a complex time variable spectra extending to over 200 keV (Nolan 1981a). The composite spectrum is thought to be due to soft X-rays originating in an accretion disc near the

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Schwarzchild radius, and Compton-scattering in an outer high temperature ($T \sim 10^9$ K) disc (Sunyaev & Trümper, 1979). Nolan et al. (1981b) has also determined the average spectrum to $\sim$ 2 MeV. Only minimal observations now exist on other X-ray black-hole candidates, GX339-04 and Cir X-1 (Nolan, 1980; Samini et al., 1979, Sadeh et al., 1979); however they are known to have $\sim$ 1 sec. variability at a few keV. The radio pulsars PSR 0531-22 (Crab) and PSR 0833-45 (Vela), having periods at $\sim$ 33 and $\sim$ 89 ms respectively, have been detected in $\sim$ 50 MeV γ-rays (Bennett, et al., 1977). Only upper limits exist for Vela pulsations $<$ 10 MeV (Knight et al., 1980). Both pulsed and continuous emission from the Crab Nebula region have been extensively observed in the X-ray range since the beginning of X-ray astronomy. Recently the entire pulsed emission spectra has been characterized with a 3 component power law (Kundt and Krotscheck, 1980) and spectral variations with phase have been detected in both soft and hard X-rays (Pravdo & Serlemitsos, 1980; Knight, et al., 1980).

II. Extragalactic Sources

The extragalactic sources thus far detected at the higher energies ($E \gtrsim 20$ kev) are characterized by hard, non-thermal spectra, variability, and high luminosity, and are from galaxies with active nuclei. These include Seyfert's, Bl Lac objects, QSO's and certain radio galaxies. Some of these have been detected into the 100 keV range; in most cases the major luminosity is in hard X-rays.

Dean and Ramsden (1981) have recently reviewed the data on extragalactic gamma-rays. The emission is often explained in term of direct radiation by Comptonization from an accretion disc surrounding a massive black-hole (Meszaros and Silk, 1977); or by synchrotron-self-Compton emission (SSC) from relativistic electrons, also produced by a massive black hole or other compact source (Jones, O'Dell and Stien, 1974; Mushotzky, 1977).

The QSO 3C273 has been observed in 2-60 keV X-rays and at 13-120 keV (Primini et al., 1979) with HEAO-1 and in high-energy γ-rays (50-500 MeV), with Cos-B (Swanenberg et al., 1978). The total spectrum to 60 keV can be described by a power law spectral index $\gamma \sim -1.6$ and requires a steepening to connect with the Cos-B data. The variability observed in soft X-rays also energies. Although other QSO's have been observed at lower X-ray energies, none of these have yet been detected $E \geq 20$ keV.

The Type 1 Seyfert galaxy, NGC 4151, has been most extensively studied, and fluxes have been reported to $\sim$ 6 MeV, although these latter measurements are controversial (cf. Dean and Ramsden, 1981). Clearly, however, HEAO-1 has detected 4151 to $\sim$ 2 MeV (Baity et al., 1980) with evidence of $\sim$ factor of two variability on a time scale of months (Meegan and Haymes, 1979). The spectra of other Seyferts have been determined and have a power law index typically -1.67 extending into the hard X-ray region (Mushotzky et al., 1980). In particular, MKN 509, (Dil et al., 1981), has been measured to have a hard X-ray spectrum to 73 keV and NGC 1275 in the Perseus cluster has been measured to over 200 keV, both with an index ~ -1.5 (Rothschild et al., 1981; Primini, et al., 1981).

The strong radio source Cen A has been extensively observed (Dean and Ramsden, 1981). Recent data over the 2 keV - 2.3 MeV range has shown the lower energy spectral index is ~ -1.65, breaking to ~ 2.0 at 140 keV. The source is also 50% variable over a 6 month period (Baity et al., 1981). Although only upper limits have been observed from Cen A in the 30-200 MeV range (Bignami, et al. 1979) a possible detection has been reported at $E > 300$ MeV (Grindley, et al. 1975).

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Although the principal X-ray emission from cluster sources such as Virgo (Lea et al., 1981) and Perseus (Primini, et al., 1981) is soft (KT $\lesssim$ 6 keV), these sources also have a hard component which has been determined to $\sim$ 200 keV. This emission may be from either compact active galaxies in the cluster, or from Compton scattering by relativistic electrons on photons in the intercluster medium.

B. NUCLEAR GAMMA-RAY SPECTROSCOPY

Mono-energetic γ-ray lines have long been predicted to originate from solar flares and from cosmic sources due to such processes as radioactivity in supernovae remnants, novae, or the interstellar medium; capture and inelastic scattering of energetic protons and neutrons; and position-electron annihilation phenomena (Ramaty & Lingenfelter, 1979). Many of these phenomena have now been measured in certain source locations, and significant upper limits to other predicted processes are available. Cyclotron line emission, which is a phenomena of electromagnetic rather than nuclear origin has been discovered in the binary X-ray systems Her X-1 and 4U0115+63, as discussed here previously. This feature also has apparently been observed in γ-ray bursts.

1. Solar Flares

The initial observation of extra-terrestial γ-ray lines was in the great solar flare of 4 Aug. 1972. Features were seen at 0.51 MeV due to positron annihilation; 2.2 MeV due to neutron capture on hydrogen forming deuterium; and at 4.4 and 6.13 MeV due to de-excitation of $^*C^{12}$ and $^*O^{16}$, respectively (Chupp et al., 1973). Since then the 2.2 and 4.4 MeV lines were observed by HEAO-1 in the white light flare of 11 July 1978 (Hudson et al., 1980) and in a number of flares by SMM (Chupp et al., 1981; Ryan et al., 1981). All these are accompanied by a strong X- and γ-ray continuum extending to $\sim$ 7 MeV.

The width of the 2.2 MeV line has been determined to be less than $\sim$ 3 keV in the flare of 9 Nov. 1979 from the Ge spectrometer on HEAO-3 (Prince et al., 1982). The narrow width of this line, and its delay of 1-2 min. from the prompt 4.4 and 6.13 MeV lines, are consistent with neutron production in the lower chromospheric region of the flare and thermalization followed by capture in the photosphere. The NaI spectrometer on the SMM has, in addition to the 7 June 1980 event, observed several more flares producing γ-ray lines. Analysis (Ramaty and Lingenfelter, 1981) shows that the nuclei must be accelerated near the flash phase of the flare, that the γ-rays are produced by accelerated particles trapped at the Sun, and that the total nucleonic energy deposited in the photosphere is only a small fraction of the total flare energy.

2. Galactic Center Region

Gamma-ray emission near 0.511 MeV, positively detected in a balloon observation by Leventhal et al. (1978) has been confirmed and studied further using the Ge spectrometer on HEAO-3 (Riegler, et al., 1981). The emission is confined to a region small compared to the 30^o FWHM of the detector, has a line-width less than $\sim$ 3 keV at 0.511 MeV and had a strength of $\sim 1.8 \times 10^{-3}$ ph/cm^2-sec in Sept. 1979, consistant with that of Leventhal. Most remarkable, however, was the decrease in intensity to 0.65×10^{-3} six months later. This observation requires that the annihilation source be a discrete object near the galactic center, less than 1 light year across, and that the region be a relatively high density, partially ionized gas of $T < 10^5$ K (Ramaty and Lingenfelter, 1981). Because of the large number of hard X-ray sources within a few degrees of the galactic center (Levine et al., 1980) the relation of these sources with the 0.511 emission region, if any, is unclear, as is the association with other structures near the galactic center (Ramaty and Lingenfelter, 1981).

Other possible γ-ray line emissions in the galactic plane due to the integrated effects of supernovae production (nucleosynthesis) and cosmic-rays interacting in the interstellar medium (Ramaty and Lingenfelter, 1979) have not been observed. Significant upper limits on such lines as Al^{26}(1.809 MeV),Co^{60} (0.847, 1.238 MeV), Ti^{44} (.068, .078, 1.156 MeV) are forthcoming from HEAO-3. Earlier reported fluxes at 4.4 MeV from the galactic plane (Haymes, et al. 1975) seem not to have been confirmed (Mattheson et al., 1980).

3. Extragalactic Sources

Only upper limits on γ-ray lines are available at the $\sim 10^{-3}$ ph/cm^2-sec flux level for a few sources, notably active galactic nuclei. For example the 3σ limit on 0.511 emission from Cen A is 1.2×10^{-3} ph/cm^2-sec. (Hall et al., 1975). Gamma-ray lines at $\sim$ 1.6 and at $\sim$ 4.4 MeV has also been reported by Hall, et al., (1975) for this source; however, these results are unconfirmed.

C. GAMMA-RAY BURSTS

Since the discovery in 1969 of short ($\sim$ 1-10 sec.), intense ($> 10^{-5}$ ergs/cm^2 sec) bursts of cosmic origin in the 50 keV $\lesssim E \lesssim$ 1 MeV range, over 100 of these events have been observed, some with intensities as weak as 3×10^{-6} ergs/sec. By the end of 1978 a series of interplanetary spacecraft including the Pioneer Venus Orbiter, Venera 11 and 12, ISEE-3, and HELIOS-2 were launched and formed, together with near-earth spacecraft, an interplanetary triangulation timing network. The specialized instruments permitted the location of some bursts on the celestial sphere to arc-minute accuracy. Hurley (1980) has reviewed the observational situation and provided a catalog of the 62 confirmed events detected through mid 1978. Through 1980 about 40 confirmed additional events have been discovered (Vedrenne, 1981) by the interplanetary network, and even more from the Venera 11 and 12 (Mazets, et al., 1979a; 1981).

1. Ln N - Ln S

The interpretation of the Ln N-Ln S curve for burst distribution has proven difficult (Vedrenne 1981). Observational data sets by different instruments fail to agree either in shape or the normalization of the event sets. For example, the most complete set of data (Mazets et al., 1980; 1981), seems fully a factor of three above the Vela and Imp-7 results in the range $2 \times 10^{-5} < S < 2 \times 10^{-4}$ ergs/cm^2 Furthermore, the shape of this curve is dependent on assumptions regarding the astrophysical model selected (Jennings and White, 1980). At present, comparison of observed and predicted distributions seems to favor a galactic origin for most of the bursts.

2. Spectra and Time Variations

The rather more sophisticated instruments on the spacecraft of the interplanetary network have allowed the detailed study of the time structure of many bursts and permitted attempts at classification (Barat et al., 1981; Mazets et al., 1981). Bursts are now observed with durations from $\sim$ 0.1-100 sec.; many events have numerous peaks; some of these are highly structured with individual pulses as short as 2 ms. Apparently a two-peaked recurrent structure with individual peaks spaced 2-3 sec. is common. Only one burst, the unique 5 March 1979 (Mazets, et al.,1979b) event shows a distinct periodicity of $8.0 \pm .02$ sec.

Although the time-averaged spectra are generally consistent with the exponential form $\frac{dN}{dE} \sim e^{-E}/Eo$ (Eo $\sim$ 150 keV), considerable spectral variations and structure have now been observed (Vedrenne, 1981; Barat, et al. 1981; Mazets et al., 1981).

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Knight et al. (1980) have noted spectral evolution and detected fluxes to over 2 MeV in the events of 20 Oct. 1977, and 10 Nov. 1977.

Gamma-ray emission and absorption features have now been reported from many bursts, mostly by Mazets and co-workers (Mazets & Golenentski, 1981; Mazets et al., 1981). The principal emission lines are in the 400-460 keV range, while the absorption features lie in the 30-60 keV range. The emission lines are interpreted as red shifted ($Z \sim .2$) positron annihilation and the absorption features are thought to be cyclotron absorption in strong ($\sim 10^{12}$G.) magnetic field. Both of these results strongly suggest a magnetized neutron star as the burst source. The event of 19 Nov. 1978 was also observed by the Ge detector on ISEE-3 (Teegarden & Cline, 1980) to have features not only at 400 keV, but also at 740 keV. The latter may be interpreted as red-shifted ($Z \sim 0.25$) 847 keV emission from the first excited state of Fe^{56}.

3. Locations

About 6 events have now been located with enough precision ($\sim 1'$) for deep optical searches; perhaps another 6 are localized to within $\sim 0.5^0$ (Vedrenne, 1981). The unique 5 Mar. 1979 event, which was characterized by a very fast-rising, intense ($\sim 2 \times 10^{-3}$ ergs/cm^2-sec), main burst with a 420 keV line feature, followed by an ~ 8 sec. periodicity, has been localized to a 6" x 30" error box (Evans et al., 1980; Vedrenne et al., 1980). This lies within the supernova remnant N49 in the LMC, which at a distance of 55 kpc, requires a luminosity of 3×10^{44}ergs/sec., about 10^5-10^6 more than that of a typical galactic source.

Searches at other locations are beginning to reveal interesting optical and X-ray counterparts. The error box for the event of 19 Nov. 1978 (Cline et al., 1981) may contain weak X-ray emission detected by Einstein as well as a weak radio source (Vedrenne, 1981) and it appears to be the site of an optical burst in 1928 (Schaefer 1981).

D. HIGH ENERGY (> 30 MeV) ASTRONOMY

1. Cos-B Catalogue

The Cos-B satellite, constructed and operated by the Caravane collaboration†, was launched in Aug. 1975 and has continued to operate successfully. The spark chamber operates between $\sim$ 30-500 MeV, and has an area of ~ 600 cm^2.

Since the publication of the first catalog of γ-ray sources (Hermsen et al., 1977), a more systematic survey has been completed, and a new 2nd catalog issued (Hermsen 1980; Swanenberg et al., 1981). This catalog contains 25 detected sources, mostly clustered in the galactic plane, having intensities > 100 MeV typically of $> 10^{-6}$ ph/cm^2-sec, and positional error circles $\sim 1^0$ radius.

At present, only 4 of these sources are identified with known radio, optical, or X-ray sources. The identification with radio pulsar PSR 0531 + 21 (Crab) and PSR 0833-45 (Vela) is through their timing signatures. Positional coincidence associates 2CG289+64 with 3C273, and 2CG353+16, with the ρ-Oph cloud complex. Most Cos-B error circles fail to associate with known galactic objects such as strong X-ray sources, radio pulsars, galactic structures, etc. More detailed and systematic searches on a few sources have turned up only suggested candidates (Caraveo, 1981).

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https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

2. Diffuse Galactic Emission

As initially discovered by OSO-3, and studied in detail by SAS-2 (Fichtel et al. 1978), a γ-ray map of the galaxy, after correcting for known point sources, reveals diffuse emission in a "ridge" along the galactic plane (Mayer-Hasselwander et al., 1980). This has a typical latitude scale height of $\sim 3^{\circ}$, with structure in longitude associated with spiral arms and perhaps with more local phenomena, such as HI distributions, clouds, etc. Bignami (1981) has reviewed the interpretations of this emission in terms of a true diffuse component, due to a cosmic-ray distribution interacting in the interstellar medium, or a collection of sources unresolved by the Cos-B point-spread angular response function. The matter is at present not solved. The total emission of the galaxy is $> 2 \times 10^{38}$ ergs/sec in > 100 MeV photons; only about 5% of this is in the low-latitude sources of the 2nd Cos-B catalog.

3. Identified Sources

The Crab and Vela radio pulsar have been observed by Cos-B (Bennett et al., 1977) at their periods of 33 and 89 ms, respectively. There are many interesting comparisons and contrasts between these objects, the only radio pulsar s yet detected in γ-rays, despite intensive searches. Both have a nearly similar double-pulse structure in γ-rays. The Crab shows a similar double pulse structure at all observed wavelengths; radio, optical and X-ray, while Vela has only a single radio pulse, a very weak (relative to the Crab) optical double-pulse, and no confirmed X-ray pulse.

The QSO 3C273 is the only detected extragalactic source at E > 30 MeV (Swanenberg, 1978). As discussed earlier, the spectrum must exhibit a steepening or break in a power-law form between $\sim$ 30 keV and 30 MeV.

The other source is tentatively associated with the dark molecular cloud near ρ-Ophiuchus (Wills et al., 1980; Bignami and Morfill, 1980). This source may be due to enhanced γ-ray production by a uniform (throughout the galaxy) cosmic-ray flux interacting in the locally increased density region (Issa and Ti-pei, 1981); a contrary view (Morfill et al., 1980) is that an enhanced cosmic-ray density trapped in the cloud is required.

E. FUTURE PROSPECTS

The future of γ-ray astronomy depends largely on dedicated observatory class space missions significant instruments on other missions, or on improved capability for specific balloon measurements (Fichtel, 1981).

The Gamma-Ray Observatory, to be launched by NASA in 1988, contains a set of 4 complementary instruments extending from $\sim$ 50 keV to over 10 GeV. The Franco-Soviet spark chamber Gamma-1 is expected to be launched in 1988. The Vela spacecraft, Pioneer Venus Orbiter, Venera 11 and 12 and Helios-2 will continue as an interplanetary burst network for some time. To that will be added additional instruments on future Venera missions, and on the single remaining spacecraft of the International Solar Polar Mission (ISPM). NASA's X-ray Timing Explorer (XTE) may contain an instrument providing coverage of the extended X-ray spectrum to $\sim$ 250 keV.

Finally, limited observations at high resolution for cosmic γ-ray line spectroscopy will be obtained using cooled Ge counters of large area on enhanced balloon programs being planned both in the U.S., and in Europe.

https://doi.org/10.1017/S0251107X0000506X Published online by Cambridge University Press

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