3. Ultraviolet Astronomy

Stephen P. Maran

INTRODUCTION

During 1982-1984, progress in ultraviolet astronomy continued through extensive observations with the International Ultraviolet Explorer (IUE), continuing programs of sounding rocket and balloon flights, and through observations made from other orbital spacecraft, including the Space Shuttle and ASTRON. In addition, there was important progress in the design and development of facilities for future missions, including the Hubble Space Telescope.

INTERNATIONAL ULTRAVIOLET EXPLORER

As of November, 1984, a total of 554 proposals were received by NASA, ESA, and the UK Science and Engineering Research Council for observations during the 8th annual operating episode of IUE. These requests represent a proposed oversubscription of the available observing time by a factor of about 2.6; those requests that require observations during intervals of low orbital radiation environment represent an oversubscription of about a factor of 2.8. The IUE, clearly of continuing major scientific importance, is operating remarkably well considering its substantial orbital lifetime. Major recent IUE discoveries include the detection of the sulphur dimer in Comet IRAS-Araki-Alcock; this molecule was never previously detected in a celestial object or medium and appears to be a previously unsuspected cometary parent molecule for which it may be necessary to assign a presolar origin.

SOUNDING ROCKETS, SKYLAB, BALLOON EXPERIMENTS

Continuing analysis of data from the S183 experiment on Skylab resulted in new determinations of 2600 A isophotes in the Large Magellanic Cloud and of the integrated ultraviolet fluxes of stellar associations (A. Vuillemin), while 1430 A photographs obtained in a Goddard Space Flight Center sounding rocket experiment revealed what appears to be highly-organized large scale structure in the LMC that resembles forms predicted from the theory of detonation wave propagation in a rotating gaseous disk (A. M. Smith). New developments in ultraviolet sounding rocket astronomy include the completion and first flight of IMAPS, the Interstellar Medium Absorption Profile Spectrograph (E. Jenkins, Princeton University), an objective grating echelle spectrograph that attains spectral resolution R = 200,000 and incorporates an intensified CCD detector. IMAPS operates from 1100 A to the Lyman limit; its principal objective is to study the interstellar medium. Among balloon astronomy results, new photometric and imagery observations were obtained at 2000 A in a joint program of the Laboratoire d'Astronomie Spatiale (Marseille) and the Geneva Observatory. In the SCAP-2000 balloon program, isophotes of the LMC and other nearby galaxies were obtained; the hottest objects were reached down to magnitude 17. The 13-cm SCAP-2000 telescope, equipped with a Fabry-Perot device, will be reflown to make deep detections of sources of 1909 A C III intercombination line emission.

GALACTIKA

The 200 A-resolution scanning spectrometer "GALACTIKA" was built by the Laboratorie d'Astronomie Spatiale and the Crimean Observatory as a component of the France-USSR space program. It detected a systematic increase in background light at 1600 A and determined the functional dependence of brightness on galactic latitude, perhaps due to scattering by high-latitude galactic dust, although other sources have been considered. At apogee (220,000 km) of the highly elliptical orbit, GALACTIKA is beyond the geocorona; accurate corrections for terrestrial Lyman alpha can be made thanks to its varying contribution to observations made along the orbit.

SPACELAB

The FAUST 16-cm, f/1.2 telescope operating at 1500 A (joint project of the Space Science Laboratory, Berkeley and the Laboratoire d'Astronomie Spatiale) flew on Spacelab-1 in November, 1983. Besides Shuttle glow, high altitude airglow, arising well above Shuttle orbit, may have contributed significantly to an interfering background. However, useful photographs were obtained. A Space Shuttle reflight, in which FAUST will be fitted with an electronic detector in place of film, is anticipated on Earth Observation Mission-1, presently manifested for Fall, 1986. The Very Wide Field Camera of the Laboratorie d'Astronomie Spatiale, with a 66^{o} field at f/1.9 and operating at 1650 A, 1930 A, and 2530 A, also flew on Spacelab-1 and is to fly again; a large (1.2 X 2.4 Kpc), hot population stellar group was detected in the neutral hydrogen bridge between the Small and Large Magellanic Clouds.

The first three flights of the Astro mission are manifested for March 6, 1986 (to coincide with the various Comet Halley flyby missions), Fall, 1986, and Summer, 1987. The instruments, Wisconsin Ultraviolet Photopolarimeter Experiment (A. Code, University of Wisconsin), Ultraviolet Imaging Telescope (T. Stecher, Goddard Space Flight Center), Hopkins Ultraviolet Telescope (A. Davidsen, The Johns Hopkins University) are already undergoing thermal vacuum tests and are scheduled for delivery at the Kennedy Space Center for integration into the Spacelab system by March, 1985. A prototype of the Ultraviolet Imaging Telescope was launched on a Black Brant sounding rocket in April, 1982 to photograph globular cluster M 5 and barred spiral galaxy M 83 at 1400 A and 2400 A. In M 5, an unusual ultraviolet-bright star was discovered and the initial helium abundance was determined from the horizontal branch stars. A starburst nucleus was found in M 83.

SPACE STATION ASTRON

The 80-cm UFT telescope, equipped with a ultraviolet spectrometer, provided spectra of stars, galaxies and the interstellar medium in the 1500 A - 3500 A region, at resolutions of 0.2 A - 28 A. In the low resolution mode, the spectrometer, with a single concave grating, is especially efficient for the detection of faint monochromatic emission from galaxies. UFT (Laboratoire d'Astronomie Spatiale and the Crimean Observatory) flew aboard the ASTRON Space Station as a component of the France-USSR space program.

HUBBLE SPACE TELESCOPE

The Hubble Space Telescope has been developed by NASA in preparation for a launch readiness date of June, 1986, with launch likely in the third quarter of 1986. The Optical Telescope Assembly and the five scientific instruments (Faint Object Camera, Faint Object Spectrograph, High Resolution Spectrograph, High Speed Photometer, Wide Field and Planetary Camera) have been delivered, as has the engineering model Fine Guidance Sensor. The instruments were provided respectively by ESA (D. Macchetto), the University of California at San Diego (R. Harms), Goddard Space Flight Center (J. Brandt), the University of Wisconsin (R. Bless), and the California Institute of Technology (J. Westphal). The Space Telescope Science Institute (Director, R. Giacconi) occupied its new quarters in Baltimore, Maryland; the Space Telescope European Coordinating Facility (Head, P. Benvenuti) began activity at the European Southern Observatory premises in Garching, and the Space Telescope Mission

Operations Control Center was inaugurated at Goddard Space Flight Center. Work is underway on the Guide Star Selection System catalog, which involves microdensitometry of survey plates, photometric and astrometric calibration. In the Fall of 1984, NASA issued an Announcement of Opportunity for astronomers to propose second-generation instruments that would be installed in-orbit to replace one or more instruments of the initial payload complement.

STARLAB, FUSE

Studies continued on the international 1-m telescope facility, Starlab. NASA is pursuing definition studies of the Far Ultraviolet Spectroscopic Explorer (FUSE) in response to the Field Committee recommendation that it be accorded highest priority among moderate-scale space astronomy missions. A joint ESA-NASA Scientific Working Group was established to refine common interests in this project.

SPARTAN

Spartan is a major new program to utilize the transportation capability of the Space Shuttle in order to enable short duration (40 hours), free-flying orbital astronomy experiments. Through Spartan, NASA hopes to virtually replicate the previous frequency of sounding rocket flights by the end of the decade. An ultraviolet spectroscopy payload to investigate Comet Halley during the near-perihelion phase in January, 1986 is under development as "Spartan Halley" at the Laboratory for Astronomy and Space Physics in Boulder, Colorado (C. Barth). The Spartan-3 payload (G. Carruthers, Naval Research Laboratory) consists of an electronographic Schmidt camera operating at 1230 A - 1600 A, with 11^{o} field of fiew; it is expected to photograph as many as 30 fields during its first orbital mission. Selection of additional ultraviolet astronomy Spartan payloads was underway in December, 1984.

UVX AND EUVE

The "Ultraviolet Experiment" (UVX) of the University of California at Berkeley (S. Bowyer) and The Johns Hopkins University (P. Feldman) consists of two ultraviolet spectrometers mounted in "Get Away Special" cans; a third can carries the battery and tape recorder. The objectives include definitive measurements of the cosmic ultraviolet background by the two university groups, which have previously differed in the results of sounding rocket measurements of this background. Another objective is to measure the spacecraft glow phenomenon and thus help establish that highly sensitive ultraviolet observations are viable from low earth orbit. Launch aboard the Space Shuttle may occur in 1985.

NASA is continuing work on the Extreme Ultraviolet Explorer (EUVE), with the prospect of mounting it on a leased space platform toward the end of the decade. Equipped with four telescopes, EUVE (S. Bowyer, University of California at Berkeley) will make a complete sky survey in the 100 A - 800 A region, and would also perform low resolution far-ultraviolet spectroscopy and support a guest observer program.

SPACE INTERFEROMETRY

A Workshop on Optical Interferometry in Space was held in Baltimore, Maryland in June, 1984. Among the presentations was a proposal for ultraviolet spectro-interferometry that could be accomplished from the Space Shuttle orbiter bay (S. Synott, Jet Propulsion Laboratory). Abstracts of the Workshop papers were published in the Bulletin of the American Astronomical Society, Vol. 16, No. 2.

SPACE SCHMIDT CAMERAS

A Working Group for Space Schmidt Surveys (Chairman, K. Henize, Johnson Space Center) has continued studies. The basic concept is that of a wide field, fast telescope with aperture approximately 1-m, for (1) surveying the sky in the far UV, (2) detecting very faint extended sources, and (3) objective prism or grating spectroscopy. F. Bertola, M. Golay, and R. West have submitted a statement of the Space Schmidt Concept to ESA for future mission planning. G. Carruthers and H. Heckathorn (Naval Research Laboratory) continue studies of electronographic cameras suitable in Space Schmidt cameras and the NRL group has modified an electronographic Schmidt camera to incorporate a microchannel intensifier stage for flight in the U.S. Air Force Space Test Program to study nebulae and the ultraviolet background.

ULTRAVIOLET ASTRONOMY FROM INTERPLANETARY PROBES

Far ultraviolet observations of stellar and interstellar sources continue from Voyager (A. Broadfoot, Lunar and Planetary Laboratory, Tucson, Arizona). Among the ultraviolet instrumentation to be launched on interplanetary probes to investigate Comet Halley in March, 1986 are an electronic camera for the Japanese probe "Planet A" and spectrometers on the USSR Vega probes.

https://doi.org/10.1017/S0251107X00006672 Published online by Cambridge University Press

4. Infrared Space Astronomy

Frank J. Low

I. INTRODUCTION

The years 1982 to 1984 have produced the greatest advances in Infrared Astronomy since its beginning. The InfraRed Astronomical Satellite (IRAS) was completed in 1982, launched on its 10 month mission in early 1983 to be followed only one year later by the first extensive release to the public of IRAS data, including the point source catalog of over 245,000 sources and an atlas of the sky in four wavelength bands from 10 to 100 um imaging the absolute sky brightness at 2 arcmin resolution. With its superfluid He cooled telescope system and sensitive IR detectors from the US, its 3-axis stabilized spacecraft from the Netherlands and its ground station in the United Kingdom, this satellite is viewed by many as the most successful example of international cooperation yet to occur in the exploration of Space. In addition, the technological advances and engineering achievements combined with the enormous scientific output from IRAS insure that in the coming years Astronomy will be marked by many new discoveries made around the world as the IRAS data products are analyzed, studied by various techniques and combined with results from other spectral regions; future space missions will build on this new technology and will carry forward the study of the universe even more effectively.

While these dramatic events were taking place in orbit, the more traditional methods of Infrared Space Astronomy were actively pursued using jet aircraft, stratospheric balloons and sounding rockets to reach above the obscuration and thermal background which limits such work from the ground-based observatories. Only a very brief summary of these developments can be given here in order to cover in more detail the results from IRAS.

II. NEAR SPACE ACTIVITIES

The tenth anniversary of NASA's Kuiper Airborne Observatory (KAO), an 85 cm IR telescope carried aloft in a four engine jet transport, was celebrated at the Ames Research Center in June 1984. Among the many new results described at the KAO Symposium and reported in the proceedings were the first measurements of Sub-mm (270 um) polarization of emitted radiation from very low temperature dust grains in the interstellar medium. This work opens up the possibility of studying in some detail the local magnetic fields in regions of active star formation since it is thought that the grain alignment producing the observed polarization is the direct result of the local magnetic field. Hildebrand et al (1984) report 1.7 +/- 0.5 % polarization at two locations within the most active parts of the Orion star-forming region. In addition to these very sensitive airborne measurements by the University of Chicago group using He three cooled bolometers, Harvey et al (1984) from the University of Texas showed that with very long integration times (3000 sec.) and conventional bolometers, sensitivity limits approaching those of the IRAS survey could be obtained at 50 and 100 um for compact extra-galactic sources such as OJ 287 and BL Lac. It is clear that such instruments can be expected to play a vital role in IRAS follow-up studies where it is necessary to extend either the spectral or spatial resolution or to extend the wavelength range in the study of specific objects. In this regard, both the Texas and the Chicago groups quickly confirmed and extended the IRAS observations of a far-IR excess from Vega reported by Aumann et al (1984).

In the past three years a variety of IR instruments were carried into the dry, almost transparent stratosphere by balloons launched in several different countries, including Japan, Italy and India as well as France and the USA. Among the results from these experiments were very long wavelength observations, >100 um, of the thermal emission from the galactic plane (De bernardi et al. 1984). Using He three cooled bolometers operating in two broad bands, 150 to 400 um and 350 to 3,000 um, they measured the large scale emission from the galactic plane over a large range of galactic longitude. When these results are combined with the IRAS data for the same regions at shorter wavelengths it will be possible to construct a more complete spectral energy distribution for a significant part of the galaxy.

Working in the much shorter wavelength range from 1 to 5 um, where it was predicted that the natural background from all known cosmic sources must reach a deep minimum, the Japanese group, led by Matsumoto from the University of Nagoya, began to use sounding rockets to make a series of extremely difficult measurements of the total sky brightness. Their initial results have recently been augmented by even more interesting findings soon to be published (1984).

III. IRAS

The information contained in this section is based on publications of the Joint IRAS Science Team; for more information refer to the catalogs which may be obtained from the various data centers in the USA, Netherlands and the United Kingdom or to the Explanatory Supplement edited by C. Beichman, G. Neugebauer, H. Habing, P. Clegg and T. Chester.

A. Design and performance-The following tables summarize important aspects of the design and inflight performance:

CRYOGENIC SYSTEM
- Cryogen- Superfluid He
- Bath Temp- 1.8K
- Main Tank Cap.- 500 l
- Lifetime- 300 days

TELESCOPE SYSTEM
- Type- f/9.6 Ritchey-Chretien
- Primary Dia.- 57 cm
- Optics Temp.- <5K
- Collecting Area- 2019 cm**2
- Construction- Beryllium

Total Mass- 809 kg (including 73 kg LHe)

FOCAL PLANE INSTRUMENTS

Survey Array- 62 discrete detectors with JFET TIA Amplifiers

Band (um)	Det. Material	# Working Detectors	Field of View (arcmin)	Av. Survey Sensitivity Pt.Sources (1 σ, Jy)	Ext.Sources* (1 σ, MJy/sr)
12	Si:As	16	0.75x4.5	0.07	0.02
25	Si:Sb	13	0.75x4.6	0.07	0.02
60	Ge:Ga	15	1.5x4.7	0.08	0.02
100	Ge:Ga	15	3.0x5.0	0.3	0.05

* For 30x30 arcmin Synthetic Beam

https://doi.org/10.1017/S0251107X00006672 Published online by Cambridge University Press

Chopped Photometric Channel

50	Ge:Ga	1	1.2 Dia.	0.7
100	Ge:Ga	1	1.2 Dia.	0.7

Low Resolution Spectrometer

Band (um)	Det. Material	# Working Detectors	Resolving Power
8-13	Si:Ga	3	14-35
11-23	Si:As	2	14-35

SPACECRAFT AND ORBIT

Type of Orbit- Sun Synchronous, Terminator
Altitude- 900 km
Inclination- 99 deg
Launch Date- 1983Jan26
Inertial Wheels- 3
Attitude Control- Sun Sensor, Gyros, Focal Plane Star Sensors
Pointing Accuracy- <10 arcsec.
Reconstructed Pointing- 2 arcsec
Survey Scan Rate- 3.85 arcmin/sec.

B. Survey Results-The following tables summarize the survey performance and list some of the results of general interest:

Sky Coverage		Reliability-	>99.8 %
HCON 1-	96 %	Completeness-	>97 %
HCON 2-	96 %		
HCON 3-	74 %		

Wavelength (um)	12	25	60	100
Limiting Flux Density (Jy)	0.4	0.5	0.6	1.0
b >50 deg. Density (sources/deg*2)	0.6	0.6	0.6	—
Photometric Uncertainty (%)	7	9	11	11

Contents of Point Source Catalog (<1 arcmin dia.)

CLASS	DEFINITION	# IN CAT.	# OF ASSOC.
"STARS"	F (12 um) > F (25 um)	134,092	46,000
"GALCIR"	F (60 um) > F (25 um)	58,295	10,000
"CIRRUS"	100 um only	33,146	—
"OTHER"	None of the above	23,782	—
TOTAL		245,839	71,000
b 50 deg		12,418	
OTHER TYPES			15,000

As indicated in the table above most of the point sources that are brighter at 12 um than at 25 um are stars and positional associations with visible stars have been made for a large number of such sources. At 6Ø um a very different population of objects dominates the sky at high galactic latitudes, positional association with cataloged galaxies show that these sources are mostly extragalactic; it appears that about 2Ø,ØØØ extragalactic objects have been detected and cataloged. Yet another population dominates the sky at 1ØØ um, the interstellar cirrus; the point source processor could not discriminate between compact features of the cirrus clouds and discrete sources at the resolution of IRAS. In addition to positions, flux densities and associations with previously cataloged sources, the IRAS catalog contains information on the measurement accuracy and on the reliability of sources and in many cases indications of variability. It should be noted that an important astronomical class of infrared point sources, asteroids, have been removed from the catalog and constitute another large data base which is still being prepared for release. At this time the catalog of small extended sources, objects with sizes between 1 and 8 arcmin, is also undergoing further processing and analysis at JPL.

C. Early Scientific Results From IRAS

1. The Cosmic Background-Because of its capacity to measure the total photocurrent from each of the IR detectors in the four wavelength bands and because it was possible, through a special calibration procedure, to determine the inflight values of the electronic offset voltages for each of the channels, accurate data was obtained from IRAS on the absolute sky brightness throughout the mission. As reported by Hauser et al (1984), thermal emission from the cloud of interplanetary dust through which the earth travels on its orbit around the Sun dominates the sky away from the galactic plane at 12, 25 and 6Ø um (the data given in the tables above reflect the final calibrations and differ somewhat from those published by Hauser et al 1984). It was discovered, however, that the 1ØØ um diffuse background is composed of at least two parts, the much weaker zodiacal emission and a galactic component which is present over the entire sky. The distribution over the sky of this bright, and as yet unexplained, galactic component will be accurately determined by subtraction of the zodiacal emission based on empirically determined models (Good 1984).

2. Solar System Results-One of the most surprising features of the extended emission was the existence of three narrow bands of emission seen in all four wavelengths extending around the sky close to and almost parallel with the ecliptic plane. These so called "zodiacal dust bands" described by Low et al (1984) have been identified with material ejected into specific orbits as the result of multiple collisions between certain families of main belt asteroids.

The discovery of a number of comets, including IRAS-Araki-Alcock 1983d (Walker et al 1984) and pointed observations of several others, provided the first far-IR observations of these primitive objects with their large envelopes of dust and debris. The amount of dust and the sizes of the dust tails greatly exceeded expectations based on optical studies; this explains in part why so many Comets were found in such a short period.

The systematic survey of large numbers of named and unnamed asteroids--perhaps as many as 1Ø,ØØØ--has provided a large and rich data

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base for detailed analysis once the preliminary data reduction has been completed.

3. The Vega Far-IR Excess--As part of their photometry program to provide absolute calibration data for IRAS, Aumann and Gillett discovered that alpha Lyrae (Vega) showed a large, unexpected excess at 60 and 100 um. In their paper, Aumann et al (1984) give the results of special high angular resolution scans which provided data on the size of the 85 K shell of orbiting material, the first direct observational evidence of solid material in orbit around stars other than the Sun. Subsequently, similar phenomena were reported for alpha Pisces and beta Pictor, with indications of perhaps 50 more stars with similar types of far-IR excess. Ground-based photography of beta Pictor has confirmed that the distribution of material is similar in size and shape to that expected for the solid material in a pre-planetary envelope.

4. Absolute Photometric Calibration-Because it was possible to make repeated pointed observations of stars and asteroids to produce photometry accurate to a few percent with IRAS, a new absolute calibration has been developed for each of the four wavelength bands. The results given by Neugebauer et al (1984) extend the ground-based calibration of Rieke et al (1984) at 10 um and 20 um to 25, 60 and 100 um with accuracy adequate for most astrophysical purposes. Detailed studies of the thermal models required to fit the observations of bright asteroids is one immediate consequence of this development.

5. Low Mass Protostars-Surveys of nearby molecular clouds such as those in Taurus, Ophiucus and Chamaeleon show numerous cold unresolved sources with a wide range of temperatures and luminosities (Wesselius et al 1984; Baud et al 1984; Beichman et al 1984). Recently, Beichman has reported objects which have such low luminosities, only 0.1 L(sun), that it is difficult to escape the conclusion that they must be extremely primitive and of very low mass. Thus it appears that the census of infrared stars in dense molecular clouds produced by IRAS includes almost the complete range of masses, luminosities and temperatures expected for the various stages of star formation.

6. Evolved Stars and Supernova Remnants-Circumstellar dust shells are formed by the mass loss mechanisms which play important roles in the evolution of stars as they return much of their mass to the interstellar medium; they are seen as excesses in the color-color diagrams of IRAS sources (Rowan-Robinson et al 1984). As in the case of proto-stars or the pre-planetary systems around nearby stars mentioned above, thermal reradiation of energy from solid particulate matter around stars is a signature that is well imprinted on many of the objects in the IRAS catalog. In these cases, such as the OH/IR stars studied by Olnon et al (1984), it is the final stages rather than the birth of stars and planets that are observed.

The most dramatic form of stars returning their mass to the interstellar medium is the supernova. Marsden et al (1984) reported on the IRAS observations of the Crab Nebula which show a small but significant far-IR excess attributed to dust within the nebula, probably but not necessarily formed from the material ejected by the supernova. Pointed observations of several supernova remnants were made as part of the additional observation program and should provide a better insight into the role of dust in the development of these nebulae as they expand into the surrounding interstellar medium.

7. The Interstellar Medium-Once the solid material formed in the various out-flow processes reaches interstellar space it forms a dilute but optically detectable medium. IRAS has shown a dramatic picture of the intricate patterns of the so called interstellar cirrus clouds. Low et al (1984) reported on the optical depths and temperatures of prominent examples of very high latitude clouds; surprisingly high color temperatures of 30 K at 60 and 100 um were found suggesting that small graphite grains are the chief constituents of these particular clouds and that evidence for variations in temperature from one cloud to another requires a range of material properties. More recently it has been noted by Gautier and Beichman that some clouds have very hot emission, several hundred degrees. If this is the result of grains heated by the normal interstellar radiation field they must have properties very different from the colder grains. Leger et al (1984) have suggested models in which extremely small graphite grains are raised to high temperatures by the absorption of individual energetic quanta. The study of grain properties and the structure of the clouds and their evolution will yield new insights as this work progresses.

8. Galactic Structure-Because even the most dense interstellar clouds are optically thin at long IR wavelengths and because so much of the galaxies energy is radiated in the thermal IR, it was expected that the IRAS survey would reveal details of the structure of the galaxy not seen before. This has been the case. The structure of the inner galaxy, already mapped to some extent by balloon instruments, was revealed in much greater detail and depth. Perhaps the most surprising feature of the galaxy is the central bulge as seen in the distribution of stars bright at both 12 and 25 um. These luminous stars must be short lived which means that they are constantly replaced on a much shorter time scale than expected.

9. Close Galaxies-IRAS has provided quite detailed views of neighboring galaxies such as the Magellanic Clouds and the Andromeda Nebula (Habing et al 1984). Both Magellanic Clouds are found to be quite active sites of star formation and will require much detailed study. On the other hand, when compared to our galaxy M31 seems almost quiescent with its total IR luminosity only 3 % of its total (our galaxy must have a ratio of IR/Optical output of about unity). Clearly the IR emission from spiral galaxies is in general higher than in eliptical galaxies because the star formation rate is much higher and because there is much more dust. Given the new IR results on such a large sample of galaxies out to the distance of the major clusters there is much more to be learned in this area.

10. Active Galaxies and Quasars-With the discovery of extremely luminous galaxies emitting almost exclusively in the IR, such as ARP 220 (Soifer et al 1984) and NGC 6240, it became clear that the space density of these objects is much higher than for quasars which, though of similar energy output emit a much broader non-thermal spectrum (Neugebauer et al 1984). Houck and co-workers (1984) found that many of the 60 um sources with the characteristics of extragalactic sources could not be readily identified on Palomar plates; subsequent studies with more sensitive CCD cameras show that these "unidentified" sources are optically faint systems with very high ratios of IR/Optical luminosity (>50) and very high total luminosity.

It was noted by Lonsdale and others that a high percentage of IR galaxies are morphologically disturbed as the result of interactions between galaxies. A sample of Seyfert galaxies, with their quasar like nuclei and high IR luminosities, were studied by de Grijp et al (1984) who conclude that their nuclear activity is more readily detected by their relatively warm IR spectral energy distributions than by their UV excesses; they predict a very large increase in the number of such objects available for study when the catalog is searched more thoroughly and that many of these will have luminosities as high as quasars. Thus models for the primary energy source in IR galaxies may differ little from those for quasars except for the almost universal presence of extremely high levels of "star burst" activity.

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