DIVISION XI / 44 - SPACE AND HIGH ENERGY ASTROPHYSICS

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SPACE AND HIGH ENERGY ASTROPHYSICS

ASTROPHYSIQUE SPATIALE ET HAUTES ENERGIES

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I. THE INFRARED ASTRONOMICAL SATELLITE (IRAS)

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IRAS Highlights, July 1993 to June 1996

Between 1993 July 1 and 1996 June 30 there were 230 papers published in the major astronomical journals with IRAS data a major enough theme that the word IRAS appeared in the title. Some of the most notable advances from IRAS are selected below.

IRAS HIRES Galaxy Atlas

The Infrared Astronomical Satellite carried out a nearly complete survey of the infrared sky, and the survey data are important for the study of many astrophysical phenomena. However, many data sets at other wavelengths have higher resolutions than that of the co-added IRAS maps, and high resolution IRAS images are strongly desired both for their own information content and their usefulness in correlation studies. Cao et al. (1996) describe the port of IPAC's high resolution processor HIRES, designed to produce high resolution (~ 1') images from IRAS data using the Maximum Correlation Method (MCM), to the Intel Paragon, a massively parallel supercomputer, other software developments for mass production of HIRES images, and the IRAS Galaxy Atlas, a project to map the Galactic plane at 60 and 100 microns. The IRAS Galaxy Atlas is a major new resource for infrared galactic plane astronomy.

Protostars

Hurt et al. (1996) used high-resolution-processed (HIRES) IRAS images of the nearby Serpens star-forming cloud core at FWHM resolutions of ~ 30" - 1' to derive new flux values and the dust temperature, circumstellar mass, bolometric luminosity, and evolutionary status of each protostellar candidate in the Serpens core. Remarkably, they found that all five sources studied by Hurt, Barsony, & Wootten (FIRS 1, SMM 4, S68N, SMM 3, and SMM 2) share the defining characteristics of class 0 protostars, the short-lived (a few times 10^4 yr), earliest observable protostellar stage.

Lay et al. (1995) used single-dish submillimeter continuum observations to show that IRAS 4 in the NGC 1333 region of the L1450 molecular cloud is a 30" separation binary protostellar system. The components are designated as 4A and 4B, and are believed to be very young and deeply embedded. Observations with the CSO-JCMT Interferometer at lambda = 0.84 mm show that components 4A and 4B are both multiple systems; the visibility curve for IRAS 4A is well fitted by a 1."8 binary whose components are consistent in size and flux with dusty accretion disks. IRAS 4B appears to show even higher multiplicity, since it is not fitted well by either single or binary models.

I. Appenzeller (ed.), Reports on Astronomy, Vol. XXIIIA, 563–583.

Lay et al. conclude that IRAS 4 is a hierarchical quadruple, or higher order, embedded protostellar system.

Circumstellar Dust Disks

Since the discovery by IRAS that Vega possesses a dusty circumstellar disk there has been a vigorous search for, and study of, proto-planetary disks and planets around nearby stars. Weintraub et al. (1994) analyzed 1300, 870, and 800 micron single-element bolometer observations of Vega (alpha Lyr), Formalhaut (alpha PsA), epsilon Eri, tau^1 Eri, and Beta Leo and concluded that the dust disks around these stars are larger than the radio telescope beams with which they were observed; thus these disks may be many hundreds of AU in radius or larger, and previous derivations of some disk masses may have been underestimated because the submillimeter/millimeter chopping observations with chop throws less than 100" may have subtracted away some or most of the flux associated with their circumstellar disks. They find that it is possible that Vega has a disk that is at least 1000 AU in radius, with a possible gap at the orbital distance of alpha Lyr B.

IRAS/ISSA Survey of Bow Shocks Around Runaway Stars

Bow shocks around young massive stars are spectacular, in some cases they span one degree in the sky, and surprisingly they are mostly detected at infrared wavelengths. The IR bow shocks around nearby runaway OB stars were first discovered by Van Buren & McCray (1998). It has been recently, however, that a more systematic search for these objects and the study of their properties have been performed (Van Buren, Noriega-Crespo & Dgani 1995). The IR bow shocks arise when stars move supersonically through the ISM and their winds are contained by the ram pressure. The UV radiation from the OB stars warms up the dust that has been swept and trapped in the bow shock. It is the radiation from the dust that becomes observable at the IRAS band passes. Using the IRAS Infrared Sky Survey Atlas, the authors showed that a large fraction of OB stars (15% - 20%) have bow shock-like structures around them, the bow shocks are preferentially found around "high velocity" wind-blowing stars, and the bow shocks are aligned with the stars' proper motion vectors.

Wolf-Rayet Stars

In order to enhance efforts to locate Wolf-Rayet stars outside the current 2.0 kpc radius, Cohen (1995) has used IRAS to search for previously undetected dusty late type Wolf-Rayet Carbon (DWCL) stars. From the Atlas of Low Resolution IRAS Spectra data on all known Wolf-Rayet (WR) stars he established that DWCL stars have a well constrained LRS spectrum. However, efforts to enlarge the sample of known DWCL using the LRS to isolate IRAS sources with the same characteristic LRS shape were unsuccessful. Therefore, he used the 12, 25, 60 and 100 micron IRAS data from the Point Source Catalog (PSC) and Faint Source Survey (FSS) databases to determine if IRAS colors could provide an indicator of DWCL stars. The results from IRAS data on all known WR stars showed that whereas other classes of WR stars were not well separated by IRAS colors, DWCL stars were well isolated, and Cohen identified 219 IRAS sources from the PSC and FSS which fit the search criteria. By further extracting the LRS spectra, which were available for 132 of the sources, he identified 13 sources as potential DWCL stars.

Milky Way Kinematics

Levine (1995) has discovered 99 water masers in the Galactic Center Region from a VLA 22 GHz survey of IRAS sources selected from coadded images and from a preliminary version of the High Resolution Galactic Plane Catalog (S. Price, private communication). This increases the number of known water masers in the Galactic Center Region by a factor of 5, providing important kinematic information about the stars and gas in the inner galaxy and constraints on bar models for the Milky Way.

Normal Galaxies

There has been much recent debate on the relative importance of (a) the neutral and molecular gas phases, and (b) the population type of the heating stars, to the far-infrared emission of normal disk galaxies. Additional insight into these questions comes from detailed H I, CO and submillimeter studies of IRAS-bright galaxies, such as the study of Andreani et al. (1995) who used the IRAM 30 meter, SEST 15 meter, and Nancay radiotelescopes to gather 1 mm continuum emission, CO (J = 1 - 0) line, and 21 cm neutral hydrogen data for two samples of IRAS galaxies. They conclude that the atomic phase dominates in these galaxies, and the fraction of molecular gas increases with increasing FIR luminosity but does not show any obvious trend with other galaxy properties, in particular with the FIR surface brightness. The H_2 surface density derived from CO (1 - 0) emission is better correlated with the cold dust surface density than the H I surface density, but the correlation of H I with dust is not negligible, thus globally the cold dust emission is likely associated with both the molecular and atomic phases. They also found that FIR surface brightness shows a tight correlation with both the H_2 and dust surface densities and a weaker one with the H I surface density, suggesting that a large part of the far-infrared emission of these galaxies originates in the molecular medium. The gas-to-dust ratio ranges between 100 and 1000 and its average value is 230, close to the Galactic value, with a clear trend to decrease as the FIR surface density increases, which they explain as an enhancement of metallicity in galaxy discs having a higher star formation rate.

High Redshift/High Luminosity IRAS Galaxies

Since the discovery of the extremely luminous object IRAS 10214 + 4724 at z = 2.36 in 1991 there has been a multitude of studies of this and similar objects and a variety of wavelengths, and the discussion of their nature has been linked closely to the ongoing debate about more local luminous far-infrared bright galaxies: are they powered by buried AGN, by circumnuclear starburst episodes, or both. Several studies have now demonstrated convincingly that F10214 + 4724 is gravitationally lensed (eg. Broadhurst & Lehar 1995; Eisenhardt et al. 1996) with lensing factors in the 10 - 20 range for the far-infrared flux. Barvainis demonstrated the similarity of F10214 + 4724 to the lensed Cloverleaf QSO at z = 2.5, also detected by IRAS, and argued that F10214 is also likely to be a buried QSO differing from the Cloverleaf mainly by orientation to the line of sight. Hines et al. (1995) detected a highly polarized continuum and broad emission line spectrum that is typical of QSOs in the hyperluminous infrared galaxy IRAS F15307 + 3252, and argued that viewed along the vantage point of the scatterers, F15307 + 3252 would appear to be indistinguishable from luminous optically selected QSOs. The detection of buried QSOs in the three most luminous infrared galaxies known (P09104 + 4109, F10214 + 4724, and F15307 + 3252) suggests that QSO activity is strongly related to the luminous infrared galaxy phenomenon, and the high redshift objects may provide important clues to the formation and evolution of galaxies and QSOs. Lonsdale et al. (1994) detected the OH megamaser in the prototypical luminous IR galaxy Arp 220 on VLBI scales, indicating that most of the emission originates on scales of < 10 pc. and suggesting that much of the far-infrared luminosity ultimately arises from a dense molecular torus.

AGN Unification Models

Currently popular unification models for active galactic nuclei propose that the different classes of AGN differ mostly due to obscuration and beaming effects caused by variations in orientation. A key test of such models is to find an observational parameter for which orientation should have little effect and study the dependence of this parameter on AGN class. One such parameter may be the mid- to far-infrared emission, expected to be mostly thermal dust emission little affected by extinction. IRAS was not sensitive enough to detect large numbers of AGN individually, so two studies have used IPAC's coaddition processor Superscanpi to add together IRAS data for multiple sources within a class. Heckman et al. (1994) and Hes et al. (1995) compared coadded IRAS data for matched samples of 3CR quasars and powerful radio galaxies, finding the detection rates to be consistent with quasars being more luminous in the FIR than radio galaxies. Assuming that all FIR emission represents isotropic thermal re-radiation from a circumnuclear dusty torus, this result is in conflict with the unified model for quasars and powerful radio galaxies. Hes et al. attempted to identify other processes that may influence FIR output. They find evidence for relativistic beaming on the FIR emission in those quasars that were known to be beamed from measurements at other wavelengths, as well as a trend for higher quasar 60 micron luminosities with increasing relative strength of the radio core. This suggests that lobe dominated steep-spectrum quasars also display some level of beaming in the FIR. By modeling the FIR radiation of powerful radio galaxies and quasars as the sum of isotropic thermal and aspect-dependent nonthermal radiation, the apparent inconsistency of the data with the unified model is relaxed.

Local Large Scale Structure

IRAS-selected catalogs of galaxies are of interest for determination of the local matter structure because unlike optically-selected galaxy catalogs IRAS surveyed the entire sky uniformly and is unaffected by extinction near the galactic plane. Interpretation of two large redshift surveys of IRAS galaxies has led to the suggestion that that a large class of CDM-related models for the formation of structure, with linear biasing, appears to be inconsistent with the IRAS distribution (eg. Sheth et al 1994). Other analyses find the IRAS data consistent with the linear theory power spectrum of a scale-invariant cold dark matter model with W = 0.2 (Tadros & Efstathiou 1995). Cole et al. (1995) find W Å 0.35 if galaxies trace mass, or a bias factor of about 2 if W = 1. Oliver et al. (1996) combined a new and deeper IRAS redshift survey with the other two redshift surveys and confirmed a conflict with the standard CDM model. In addition they compared the IRAS survey to the first CfA slice, and rule out any linear-bias model directly relating the two on scales of 5-20 h^{-1} Mpc. They argue that this result is expected since the CfA sample includes more elliptical galaxies which have different clustering properties from spirals, and find that if the CfA sample is restricted to spirals it traces the same structures as the IRAS galaxies, within the uncertainties.

II. INFRARED SPACE OBSERVATORY

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The main events during the reporting period were the successful launch of ESA's Infrared Space Observatory (ISO) and, following its in-orbit commissioning, the start of routine science operations.

ISO was given a perfect launch by an Ariane 44P vehicle with lift-off from Kourou occurring at 01:20 UT on 17 November 1995, in the first second of the launch window.

During the first 21 days after launch, the operational orbit was attained, the cryo-cover closing the cryostat on the ground was ejected, the spacecraft was shown to be in excellent condition, first light for all instruments was achieved, engineering checks were successfully made of all the four scientific instruments and the integrated ground segment was validated.

The following 56 days (from 8 December 1995 to 3 February 1996) were devoted to the "Performance Verification Phase", during which a detailed assessment of the in-flight performance of the scientific instruments was made, their core calibrations established and planned operating modes validated.

All subsystems of the spacecraft are performing above specifications. The cryogenic system is performing well and providing all the required temperatures. Current estimates are that ISO's in-orbit lifetime will be 24 ± 2 months, as compared to the requirement of 18 months. ISO's optical performance is excellent; images of point sources have been made with the IR camera, clearly showing the first six Airy diffraction rings. All nominal modes of the Attitude and Orbit Control system have been successfully verified. The pointing performance also exceeds the specifications substantially, with the short term jitter being about 0.5 arcs secs (2 sigma, half cone, over a period of 30 seconds of time) and with the blind pointing accuracy being around 3.5 arc secs (2 sigma, half cone). The specified values were 2.7 and 11.7, respectively.

The performance of the four scientific instruments is also very satisfactory. All instruments are operating functionally very well and as expected from ground-based tests. Particularly satisfying is that all the very delicate and complex cryo-mechanisms are fully operational.

The sensitivity of the instruments is affected to varying degrees by "glitches", i.e. impacts on the infrared detectors from high energy cosmic ray particles. Glitches primarily increase noise, but in some cases have necessitated modifications to instrument settings and recommendations for changes in observing strategy. ISOCAM's sensitivity is essentially identical to pre-launch expectations. ISOPHOT, SWS and LWS are more affected and their sensitivities are less than originally predicted. The operating conditions of the detectors and the data processing algorithms are being optimised to maximise the instruments' performance. All instruments are returning excellent quality scientific data with exciting astronomical results even coming out of the performance verification phase.

Routine scientific operations started on 4 February 1996 as planned. ISO is operated for nearly 17 hours per day -the period when its orbit takes it outside the van Allen belts- makes an average of 45 observations per day for the worldwide astronomical community. Scheduling efficiency during these ~ 17 hours is routinely around 90% to 95%. Both processed and raw data from these observations are shipped on CD-ROMs to Observers.

A "Supplemental Call for Observing Proposals" for observations to be carried out in the period from December 1996 to December 1997 was issued in August 1996, with proposals being due in early October.

The first presentations of the initial scientific results of ISO were made during a workshop in the Netherlands at the end of May 1996. Subsequently, these (and other) results have been written up for an ISO-dedicated issue of Astronomy & Astrophysics. This contains around 90 papers and is due for publication in late October 1996. The reader is invited to consult this A&A issue to get the complete picture of the breath and depth of ISO's scientific achievements to date. A brief summary, based on early versions of some of these A&A papers, follows below.

General features of ISO's initial results include use of its wide photometric capabilities to address energy budgets, use of its varied spectral capabilities to examine the chemistry and physics in detail, and extensive application of its mapping abilities at all wavelengths.

Wide-ranging sets of sources are being observed across ISO's entire wavelength range of 2.5 to 240 microns, providing significant insights into the ways different objects emit energy as well as specifying their bolometric luminosity. Early examples of sources with extensive emission in the previously-inaccessible 200 micron region include the cold ChamA01 cloud and the galaxy NGC6090.

Spectacular spectra, covering up to 6 octaves of the electromagnetic spectrum, have been taken of many objects, ranging from NGC7027 to M82 and the Circinus galaxy. A rich variety of atomic, ionic, molecular and solid state spectral features are being studied in great detail, many for the first time.

Spectra at the shorter ISO wavelengths are providing many detections of H_2O, CO_2, CO, CH_3OH and CH_4 features in absorption allowing characterisation of the ice mantles on grains with unprecedented accuracy. Absorption features corresponding to solid $^{13}CO_2$ have also been detected.

Emission from the well-known "PAH" features at wavelengths of 3.3, 6.2, 7.7, 8.6 and 11.3 microns is widespread in ISO results. Practically everywhere in our galaxy, PAH's dominate the mid-IR spectrum, except in the most violent regions where they seem to be destroyed such as the centres of H II regions, parts of Cas A, the innermost Galactic centre. The integrated emission from all types of galaxies, including spirals, starbursts and Seyferts, shows PAH features. Distinct and complicated variations in the relative strengths of the features are seen, thereby providing a method for examining formation and destruction mechanisms, size and hydrogenation ratios.

Studies of thermal water vapour emission, believed to be a prime coolant of cold shocked regions, are prominent in ISO research. The Long Wavelength Spectrometer (LWS) surprisingly discovered water vapour in the young carbon-rich planetary nebulae, NGC 7027. Using both spectrometers, water has been seen in a wide variety of sources including the galactic centre, W Hya, NML Cyg, GL2591 and HH 54B. Both emission and absorption lines have been detected. Transitions are observed at so many different wavelengths that theoretical analyses can be applied to make secure inferences on physical conditions in the emitting regions.

ISO has detected emission from molecular hydrogen, including the long sought after S(0) pure rotational transition at a wavelength of 28 microns, in sources ranging from Jupiter and Saturn, through Cep A, out to M82, NGC6946 and Arp 220. A more direct method of determining the molecular hydrogen content of these objects is now available. The 56 micron line of HD has also been detected.

ISO's imaging capabilities have already been widely applied. Examples include ISOCAM's spectacular infrared images of the Whirlpool galaxy, M51, which was also ISO's "first light" object. Subtle differences are seen between the images at 7 and 15 microns. Longer wavelength images have been made by ISOPHOT. Other galaxies addressed to date include M101, NGC 6946 and the Antennae. Maps covering 0.75 by 0.75 degrees of the rho Oph cloud at wavelengths of 7 and 15 microns show a rich pattern of interactions in the complicated region, including, inter alia, regions opaque even to ISOCAM. Images of SNR's have been obtained with ISOPHOT. The circular variable filters in ISOCAM have been used for spectral imaging e.g. of the planetary nebula NGC6543, with very clear differences being found in the structure of the object at different wavelengths.

Already, just a few months into the routine operational phase of the mission, there is a rich harvest of exciting results. With new instruments, offering unprecedented combinations of wavelength coverage, sensitivity, and spatial and spectral resolutions in the infrared spectral region, ISO is well set to make significant impacts on nearly all areas of astronomy.

III. SUMMARY OF THE INITIAL RESULTS FROM THE INFRARED TELESCOPE IN SPACE (IRTS) MISSION

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The joint ISAS/NASA Infrared Telescope in Space (IRTS) was one of seven experiments on the first Space Flyer Unit (SFU-1) that was launched from Tanegashima Space Center in Japan on March 18, 1995 (Murakami H. et al. 1996). Four scientific instruments and a near-infrared star sensor used for telescope pointing reconstruction shared a common focal plane in the super-fluid helium-cooled telescope assembly. Science data-taking started on March 29, 1995 and continued until the liquid helium exhausted on April 24, 1995. The IRTS telescope scanned the sky along nearly great-circle tracks and covered approximately 7% of the sky over the course of the mission. The low operating temperature and relatively small primary mirror size favored a mission optimized for studies of diffuse regions. The four IRTS science instruments covered a wavelength range of 1 to almost 1000 microns. A brief description of each of the four instruments and a summary of their results to date follows. Detailed descriptions of all four science instruments can be found elsewhere (Noda M. et al. 1994, Roellig T.L. et al. 1994, Shibai H. et al. 1994, and Lange A.E. 1994).

The Near-Infrared Spectrometer (NIRS) on the IRTS operated from 1.4 to 4.0 microns with spatial and spectral resolutions of 8 x 8 arc-minutes and 0.12 microns respectively. The measured on-flight performance was almost exactly that predicted from laboratory tests (Noda M. et al. 1996.). Early analysis of the NIRS data have produced maps of the 3.3 micron emission feature over a roughly 10 x 10 degree area of the sky which shows that the intensity is well-correlated with both the IRAS 12 micron and 100 microns maps, indicating that the 3.3 micron band emitters are well-mixed with the classical sub-micron sized dust grains in the general interstellar medium (Tanaka M. et al. 1996). NIRS spectra were also obtained of the Zodiacal light emission, showing a close correlation with the solar spectrum at wavelengths from 1.4 to 3.2 microns and enhanced emission at longer wavelengths due to thermal emission (Matsumoto T. et al. 1996).

The Mid-Infrared Spectrometer on the IRTS operated from 4.5 to 11.7 microns with spatial and spectral resolutions of 8 x 8 arc-minutes and 0.25 microns respectively. The measured on-flight performance was somewhat less than that predicted from laboratory tests, but did allow measurements with unprecedented sensitivity (Roellig T.L. et al. 1996). The first results from the MIRS include maps of the same region of the sky were obtained with the NIRS, showing that the 6.2, 7.7, 8.6, et 11.3 micron emission features are also well-correlated with the IRAS 100 micron emission (Onaka T. et al. 1996). In addition, the observed 7.7 and 8.6 micron features can account for at least 70% of the 12 micron excesses emission observed in the general interstellar medium by IRAS. Initial analysis of some of the point-sources observed by the MIRS indicates that they are clearly separated into five groups on a 5-8 micron 8-10 micron color-color diagram (Yamamura I. et al. 1996).

The Far-Infrared Line Mapper (FILM) on the IRTS operated at 68 and 157 microns with a spatial resolution of 8 x 13 arc-minutes. The measured on-flight performance was actually somewhat better than that predicted from laboratory measurements (Shibai H. et al. 1996). An initial map obtained in the Galactic Plane area near l = 50 degrees indicates an extended component to the C II emission above and beyond that observed from discrete sources (Makiuti S. et al. 1996). This extended component decreases rapidly as the galactic latitude increases.

The Far-Infrared Photometer (FIRP) on the IRTS employed Helium-3 refrigeration to cool four bolometer detectors operating at center wavelengths of 150, 250, 400, and 700 microns. The system employed dichroic beam-splitters so that the four wavelength channels simultaneously observed the same 0.5 degree beam on the sky. The cryogenic system operated flawlessly on orbit, although some intermittent noise was seen on different channels at various times (Hirao T. et al. 1996a). Initial results from observations near the Galactic Plane show a slight decrease in the 150-250 to 250-400 brightness ratios with increasing galactic latitude with $|b| < 3.5$ degrees (Hirao T. et al. 1996b).

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IV. RESULTS FROM NEAR-SPACE OBSERVATORIES

Kuiper Airborne Observatory (KAO)

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The Kuiper Airborne Observatory (KAO) concluded astronomy research flight operations in the fall of 1995, after 21 years of operations. The KAO carried a 91 cm gyrostabilized reflector to altitudes up to 13 km, providing regular access to the sky at far-infrared and submillimeter wavelengths. Although most observing flights were flown from the KAO home base at NASA Ames Research Center, numerous expeditions to other airfields permitted access to the southern sky and remote events such as occultations. This was especially true during the last ten years, in pursuit of IRAS follow-up, Halley's Comet, SN1987A, and the Comet Shoemaker-Levy 9 impacts into Jupiter.

Molecular Clouds and Star Formation

The repository of oxygen in dark molecular clouds is an outstanding question in interstellar chemistry. High-resolution (7 km/sec) spectra of the O I 63 um line toward DR 21 show a pronounced dip which is most likely explained as absorption by cold, atomic oxygen in a foreground molecular cloud. Most of the gas phase oxygen in this cloud must be in atomic form (Poglitsch et al. 1996).

Even higher far-infrared spectral resolution was achieved with heterodyne receivers. Boreiko & Betz (1996a) resolved the profile of the O I 63 um line in galactic molecular cloud (M 42) for the first time. At 0.3 km/sec resolution, the line profile shows the effect of optical depth broadening. This result with C II 158 um data yields a gas kinetic temperature of 175-220 K for the M 42 photodissociation region (PDR). This in turn applied to earlier observations of the two isotopes 12C II and 13C II yields an isotopic ratio near 58 for M 42 (Boreiko & Betz 1996b).

Far-infrared photometry and high resolution mapping of young stars have been used to place much stronger limits on the nature of circumstellar dust distributions, and in many cases obviate the need to assume the presence of compact circumstellar disks (Natta et al. 1993, Di Francesco 1994). Similar observations of massive star forming regions like G05.89-0.4 (Harvey et al. 1994), DR 21 (Colome et al. 1995) and W3 (Campbell et al. 1995) have been used to infer the density gradient of the dust surrounding compact H II regions, with the result that such gradients are highly variable from source to source and probably unrelated to simple theoretical predictions.

Extensive far-infrared polarimetry of the Orion Nebula has shown a smoothly varying magnetic field that is drawn into an hourglass shape centered on BN/KL. At the bar SE of BN/KL the polarization nearly vanishes as can be explained if the field becomes highly inclined in that region (Hildebrand 1996). In contrast to expectations based on near-IR observations of dark clouds, the polarized flux increases with optical depth to at least Av = 200 (Schleuning et al. 1996).

The peculiar luminous star MWC 349 was known to have very strong maser enhanced atomic hydrogen recombination lines in the radio. Millimeter-wavelength line profiles are double-peaked, and the two spectral components had been shown to be spatially distinct, bracketing the central star (Martin-Pintado 1989). This suggested the possibility of detectable higher-level H lines in the far infrared formed at smaller radii in the putative edge-on disk, enhanced by laser amplification. Three far-infrared H line wavelengths, 15-alpha, 12-alpha and 10-alpha, were observed from the KAO. The 15-alpha line was clearly detected at over 4 sigma, and the other two may be present at the 2 or 3 sigma level (Strelnitski et al 1996). Ordinary spontaneous H-line emission would not have been detected at these wavelengths. With conservative assumptions for the unresolved line profile and emitting region parameters, Strelnitski et al. estimate a brightness temperature of at least ten million degrees, and a laser amplification factor of at least 1000.

Interstellar Medium

Observations of a half-dozen far-infrared ionic fine structure lines in 16 galactic H II regions were used to trace the radial dependence of metals relative to hydrogen, over galactocentric distances from 0.01 to 10 kpc. The observed far-infrared line fluxes require only modest or negligible corrections for extinction, scaled from the depth of the 10 micron silicate feature. The N, Ne and S relative abundances can be described as decreasing at about 0.08 dex/kpc. However, the radial dependance is equally well or better represented by a step fit, with the break at 6 kpc (Simpson et al. 1995). Simpson et al. suggest this may be a consequence of radial mixing by the central bar.

In similar work, Afflerbach, Churchwell, & Werner (1996) used the KAO to obtain fine structure line intensities of O III, S III, and N III toward a selection of 18 ultracompact H II regions. High resolution radio continuum images were used to to identify the hydrogen column coincident with the FIR line emission region. Data from the literature were also used for a total of 35 sources spanning 0 to 12 kpc in galactocentric radius. It was found that O/H, S/H, and N/H all have rather strong and similar galactocentric gradients with slopes of about - 0.07 dex/kpc. The abundances and their slope are found to be entirely consistent with the average temperature gradient of ultracompact H II regions with galactocentric radius found independently. The ratios O III/S III and N III/O III indicate an increase in excitation with increasing galactocentric radius, consistent with the decrease in stellar atmosphere line blanketing produced by the observed abundance gradient.

Galactic Center

Maps in the far-infrared O III, N III and O I lines of the "sickle" feature and of the arched filaments in the Radio Arc add evidence to the concept that these structures are H II/PDR regions at the surfaces of molecular clouds which are excited by hot stars. Ionization by shocks or other kinetic processes are ruled out. However, the large linewidths observed in some regions may be related to the interaction of the plasma with the strong magnetic fields in the Galactic Center (Timmermann et al. 1996).

Polarization maps of the far-infrared continuum from two parts of the Radio Arc were obtained, showing strong and predominantly uniform polarization in both fields. Applying the standard interpretation of the measured polarization vectors in terms of the projected magnetic field geometry, it appears that the magnetic field is oriented along the thermal, arched radio filaments, and is perpendicular to the linear, nonthermal filaments of the Radio Arc. In both cases, it is surprising that the field direction within the emitting dust clouds appears to be perpendicular to the supposed large-scale poloidal field indicated by radio measurements for the intercloud medium. As yet there is no accepted explanation for the high polarization, the low dispersion, or the orthogonal fields (Morris & Serabyn 1996).

A new instrument, the Kuiper Widefield Infrared Camera, was used to obtain the first high-resolution (8") large-scale (13' x 25') images of the Galactic Center area. Fabry-Perot filters defined narrow passbands at 31.5 and 38 um in the thermal continuum. These far-IR continuum images clearly reproduce all of the thermal radio continuum features: the thermal arches, the sickle, pistol, and mini-spiral. The corresponding far-IR features are identified as warm dust at the photodissociated surfaces of UV exposed molecular clouds. The excellent correspondence between the far-IR appearance and the thermal radio arches suggests that the illuminating stars are within the arches themselves -not external to the features. The remarkable, curving arc geometry of the arches remains somewhat difficult to explain.

Within about 4 pc of Sgr A*, the high S/N ratio in these images permits modest image reconstruction to an effective resolution of 5" or better. This shows for the first time, the complete circumnuclear ring and mini-spiral complex in one image. The far-IR western arc is external to its radio counterpart, and internal to the molecular ring. Together with general fall-off in dust temperature with distance from Sgr A*, this indicates that the far-IR emission arises from warm dust in photodissociation regions at the inner surface of the molecular ring, confirming a central source for the heating. A self consistent model has been constructed explaining all of the major morphological features. The northern arm, and eastern arm/bar features are streamers of material out of the plane of the ring that flow on parabolic orbits into the center from regions outside of the molecular ring. These streamers are heated by the central source as well (Latvakoski et al. 1996).

Extragalactic Astronomy

The far infrared luminosity of galaxies is often used as a tracer of the star formation rate. High angular resolution far infrared mapping from the KAO, however, has shown that galactic energetics are not quite so simple. Smith et al. (1994) observed two early type galaxies, NGC 4736 and NGC 3627, and found that in these galaxies the bulges provide an important source of heating of the far-IR emitting dust. More recently, Smith & Harvey (1996) have compiled an extensive set of similar KAO observations of a number of galaxies and found that heating by young and old stars can be clearly separated as a function of galaxy type, as well as examined correlations between the far-IR, CO, optical/UV, and other galactic characteristics.

Maps of nearby galaxies in the 158 micron C II line have revealed that, on larger scales, emission from the diffuse interstellar medium contributes a major fraction of the total C II luminosity of a galaxy (Madden et al. 1995). The pressure in the atomic medium derived from the C II line varies substantially between individual galaxies (Geis et al. 1996). Observations of the interacting galaxies NGC 4038/4039 (the Antennae) in the 158 micron C II and 88 micron O III lines show that the collision has triggered a starburst which is confined to the interaction zone (Nikola et al. 1996). C II and O I observations of low-metallicity galaxies such as the LMC and IC 10 have shown that the photon-dominated regions in these systems can extend over much larger fractions of the interstellar medium than in "normal" galaxies (Poglitsch et al. 1995; Israel et al. 1996; Madden et al. 1996). This leads to a reduced CO (1 - 0) intensity which, in the past, has mistakenly been interpreted as a lack of molecular gas in such galaxies.

KAO HIFOGS (High Efficiency Faint Object Grating Spectrometer) observations of the inner 1 kpc diameter region of the bright Seyfert galaxy NGC 1068 have revealed two new coronal lines of Ne VI 7.642 um and Mg V 5.608 um. These are thought to originate in the high excitation region close to the central engine. Ground-based measurements of the Ne II 12.8 um line agree with model calculations for the coronal line region (CLR). The KAO Ne VI line is, however, 20 times brighter than expected, indicating a much higher abundance of neon in the CLR than previously thought. This provides further circumstantial evidence that the coronal line region is distinct from the starburst region. The HIFOGS spectra of NGC 1068 also reveal a very strong Ar II 6.985 um line arising from the PDR/starburst region. Normal argon abundance for the PDRs at the center of this Seyfert's nucleus is deduced from small-beam ground-based measurements of the Ar III 8.991 um line. Simple scaling of the small-beam model to the KAO beam shows that the KAO Ar II line is more than a 100 times stronger than predicted: the PDRs must fill a much larger fraction of the starburst volume than previously imagined (Greenhouse et al. 1996). While high spectral resolution measurements of the coronal lines will be made by ISO/SWS, high spatial resolution studies of the CLR awaits the next generation of instruments on SOFIA (see "Future Projects" below).

Stellar Astronomy

Low-resolution infrared spectra of selected bright non-variable stars have been assembled into a set of celestial flux standards for calibration of spaceborne, airborne and groundbased spectroscopy to 30 microns wavelength. Kurucz stellar models for alpha CMa and alpha Lyr out to 15 microns provide the absolute standard fluxes. Measurements of spectral ratios at 2% accuracy incorporating data from the KAO, groundbased observatories and IRAS were used to establish a dozen stars as standards (Cohen et al. 1995, 1996). The calibrated spectra cover a wide range of spectral types, thus offering a grid for estimating spectra of intermediate classes of normal stars: A0 through M1, luminosity classes III-V, without dust shells or unusual tidal distortions.

Planetary Astronomy

Three stellar occultations by small bodies -one by the comet Chiron and two by Neptune's largest satellite, Triton- were observed by the KAO during 1993-95, on deployments to Chile, Brazil, and Hawaii. The Chiron occultation was observed simultaneously with high-speed visible and IR array detectors (Elliot et al. 1995). Several extended features were detected, with different degrees of certainty, including jet-like features, a possibly bound coma, and material in the orbit plane. The particle radii in at least one of the jet-like features are larger than 0.25 microns. The radius of the nucleus lies between 83 and 156 km.

For the Triton events -from a combination of KAO and ground-based data (Elliot et al. 1993, Olkin et al. 1995, Olkin 1996)- there was a lack of spikes in the occultation light curves, implying no turbulence with an RMS density variation greater than 0.1% and a scale greater than 4 km in the microbar pressure level of Triton's atmosphere. Isothermal and non-isothermal models were fit to the occultation light curves and evidence for asymmetry in the scale height of Triton's atmosphere was found. From the highest signal-to-noise light curve, the immersion density scale height is 17.8 km and the emersion density scale height is 20.8 km, a 4 sigma difference. If interpreted as a temperature difference, the region probed during immersion is approximately 7 K colder than that probed during emersion. The temperature gradient predicted by models based on Voyager data (Krasnopolsky et al. 1993; Strobel et al. 1996) is not present in the highest signal-to-noise ratio data. The occultation data place a limit on the thermal gradient of less than 0.08 K/km at 1400 km radius. The lack of extinction signature in the occultation light curves is consistent with the Voyager results as most chords did not probe below 30 km.

During July, 1994 the KAO was deployed to Melbourne, Australia for observations of the Comet Shoemaker-Levy 9 impacts into Jupiter. Flights out of Melbourne were scheduled for observations of six impact events, with long airborne observing periods of each new impact site. High-resolution time-resolved spectra at around 7.7 microns of two of the early major impacts contained bright, rapidly changing water vapor emission lines and numerous methane emission lines. The water vapor lines peaked about impact + 14 minutes, and lasted until about impact + 30 minutes. Water vapor excitation temperatures of 1000 to 1200 K are inferred, and a water mass equivalent to a sphere of ice 180 m in diameter (Bjoraker et al 1996). Similar results were seen with the HIFOGS instrument from two other impacts and their aftermath, over a broader wavelength range (4.9 - 14.5 microns).

These spectra also clearly showed the brief flare of water vapor at 1000 K, with inferred masses of the observed water approximately that of a 90 meter sphere of pure water ice (Sprague et al. 1996). In addition, a longer-lasting acetylene feature was seen at 13.7 microns. The results from both instruments are consistent with the observed spectral features originating very high in Jupiter's atmosphere, and with the observed water vapor the result of impactor-derived oxygen recombining with Jovian hydrogen. Both experimenter teams conclude that the water vapor could not have been dredged up from the lower Jovian atmosphere, and the observed quantity represents a fraction, perhaps only ~0.1, of the original water content of the impactors.

Spectra of both hemispheres of Mercury in the 5 to 10 micron spectral range were obtained from the KAO using HIFOGS. These spectra, the first ever obtained from 5 to 7.5 microns, showed unexpectedly strong spectral radiance near 5 microns, presently unexplained. One hemisphere exhibited spectral features also seen in plagioclase feldspar (F. Witteborn, pers. comm.).

Balloon-Borne Astronomy Programs

The Infrared Astronomy Group of the Tata Institute of Fundamental Research continued its studies of Star Formation using its 1m balloon-borne far-infrared telescope. The earlier two detector photometer was replaced by a new 12 detector array (2 x 6) of Silicon bolometers observing the same part of the sky simultaneously in two bands centred on 135 and 180 microns. The detectors are cooled to 0.3 K using a closed cycle liquid He3 cryostat. Three successful flights have been carried out with this photometer. Both the sensitivity and mapping efficiency have improved with the use of this photometer. Signals from the different detectors have been combined to produce 1 arcminute resolution maps using a Maximum Entropy Deconvolution procedure.

The aim of the program is to obtain high resolution maps of star forming regions at wavelengths longer than the IRAS bands.Several IRAS "cold sources" (09227 - 5146, 20286 + 4105, 10049 - 5657, 14416 - 5937, 01195 + 6136, 05327 - 0457), Compact H II regions(18507 + 0121, 20178 + 4046, 20255 + 3712, 19181 + 1349, 01195 + 6136), outflow sources(NGC 281W, S187, Lynd 1287, HH 67, NGC 2023), molecular clouds and a large complex around RCW 106 have been observed. Using the data from two bands, maps of dust temperature and optical depth will be obtained. These are being used to study several aspects of star formation -role of environment, density structure of the young star surrounding, mass disribution of stars, stellar clustering etc. Besides photometric studies, it is proposed to undertake mapping in selected far-IR lines in future.

Using balloon-borne telescopes equipped with Fabry-Perot spectrometers a joint group from ISAS (Institute of Space and Astronautical Science), Japan, and the University of Arizona, continued its program of making large scale maps of the far-infared C II 157 micron line emission from the galactic plane. When compared with 100 micron dust emission observed by IRAS, the C II line emission appears well correlated with the dust emission except for a 10 degree region centered on the galactic center where emission from the gas is much weaker than that from the dust (Low et al. 1993).

PRONAOS

PRONAOS is a 2 meter diameter balloon-borne telescope for submillimeter astronomy built in France by CNES (Toulouse). The telescope accomodates two focal-plane instruments: a multiband photometer and a heterodyne spectrometer.

PRONAOS was first launched in September, 1994, but encountered flight problems. The second flight was successfully launched 22 September 1996 from NASA's National Scientific Balloon Facility in Fort Sumner, NM. It reached an altitude of 40 km altitude for a flight duration of 27 hours. Observations with the multiband photometer were very successful.

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V. FUTURE PROGRAMS

Stratospheric Observatory for Infrared Astronomy (SOFIA)

SOFIA will be a 2.5 meter ambient temperature telescope mounted in a specially modified Boeing 747 aircraft, which will replace the now retired Kuiper Airborne Observatory. SOFIA is scheduled to begin research flight operations by the end of the year 2001. It will have capabilities throughout the spectrum from 0.3 microns to 1.3 mm wavelength. The planned flight program of 160 8 hour flights per year would support approximately 20 science instruments and 60 principal investigator teams annually. In addition, SOFIA will have a strong educational outreach program. SOFIA will be sponsored by NASA, with participation by the German space agency, DARA.

Submillimeter-Wave Astronomy Satellite (SWAS)

SWAS is one of NASA's Small Explorer Class satellites, consisting of a 55 cm ambient temperature telescope with passively cooled detectors, to search for single lines of H_2O, O_2, C I, and ^{13}CO in molecular clouds and to qualify several critical submillimeter wave receiver and spectrometer elements to be used on later missions. The launch date is 1997.

Wide-Field Infrared Explorer (WIRE)

The WIRE experiment is a deep point-source survey down to the confusion limit at 12 and 25 microns wavelength. The instrument consists of a 28 cm telescope with two Si:As IBC arrays (128 x 128 pixels) at its focal plane. During a 4 month mission life WIRE will cover 110 square degrees of the sky and will detect about 90,000 starburst galaxies with median redshifts of 0.5.

The Near Infrared Camera and Multi-Object Spectrometer for the Hubble Telescope (NICMOS)

NICMOS is a second generation NASA instrument for the Hubble Space Telescope (HST) that is designed to provide imaging and spectroscopic observations at wavelengths between 0.8 and

3 microns. NICMOS contains cryogenically-cooled cameras and spectrometers to cover a wide range of scientific objectives and has an expected lifetime of greater than five years. It is scheduled to be placed in the HST in February, 1997.

Space Infrared Telescope Facility (SIRTF)

SIRTF, one of NASA's Great Observatories, is a 0.85 meter diameter cryogenically-cooled telescope which will be located in a solar orbit for a period of at least 2.5 years. SIRTF's three focal plane instruments will permit imaging over the infrared spectrum from 2 to 160 microns and high and low resolution spectroscopy from 5 to 40 microns. It will be operated as a facility for the entire astronomical community. SIRTF entered Phase B in November, 1996, and is scheduled for launch in 2002.

Far Infrared and Submillimeter Space Telescope (FIRST)

FIRST is a cornerstone mission of the ESA long term science program. It is a large (3 meter) diameter passively cooled telescope equipped with a combination of photometer/camera and very high resolution spectrometers for far-infrared and submillimeter wavelength. FIRST is planned for launch in 2006.

VI. ULTRAVIOLET AND OPTICAL ASTRONOMY FROM SPACE

W. Wamsteker, A. Code & S. Bowyer

Introduction

In the area of UV/Optical Astronomy from space, the past period has been one of excitement as well as one with disappointments on the different fronts needed to maintain the necessary access to space.

- On the negative side, space astronomy faced an important loss with the decision to discontinue the operations of the International Ultraviolet Explorer (IUE) on 30 September 1996. The agencies which until that moment had continuously supported the science operations of IUE for 18.5 years were forced, by budgetary constraints, to terminate the operations of this extraordinarily successful Ultraviolet Observatory, which has contributed in a totally unforeseen way to the development of the understanding of many phenomena in all branches of Astrophysics.
- An important milestone was accomplished with the successful first servicing mission of the Hubble Space Telescope (HST). The successful installation of the COSTAR optical bench to correct for the spherical aberration in the HST Telescope system has allowed the HST to fulfill the great expectations the community had for this mission.
- The continued (until 1998) support for the Extreme Ultraviolet Explorer (EUVE) from its funding agency allowed this successful mission to continue to explore and study many objects in the wavelength range below 76 nm.
- The reflight of the ASTRO payload (ASTRO-2) with its Ultraviolet Imaging Telescope (UIT), the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE) and the Hopkins Ultraviolet Telescope (HUT) have supplied access to the Ultraviolet domain even though the flight duration was only short.
- Further development of the results obtained from the extremely successful HIPPARCOS mission which stopped operations in 1993, are reported by Commission 24 and 8 (http://astro.estec.esa.nl/SA- general/Projects/Hipparcos/ hipparcos.html).

Below we will highlight some of the accomplishments of these missions for Space Astrophysics. This report does not pretend to be complete nor exhaustive and only some of the major impact areas of these missions on Astronomy are addressed. References will only be given to general reviews which will allow direct connection with the original results where the highlighted results are found. Also some more general conference publications are given to guide, those interested, to more specific references. A rather extensive review of recent results in Space Astrophysics can be found in (27th ESLAB Symposium, 1994). In these years the trend to use the existing space observatories in combination with each other, or in coordination with ground observatories to acquire more complete astrophysical information, continued to grow and a significant fraction of the space observations at many different wavelengths are now assisted by active coordination support from the space observatories in their observation schedule preparations.

International Ultraviolet Explorer (IUE)

The IUE Project (http://www.vilspa.esa.es/iue/iue.html) is a 45 cm telescope in geosynchronous orbit for ultraviolet spectroscopy from 115 nm to 320 nm. IUE is an international collaboration between NASA, ESA and the United Kingdom and has been in continued operation since launch on 28 January 1978. From October 1st 1995 all science operations with IUE were done under full control of the ESA IUE Observatory in Spain ("hybrid" IUE Operations). This operational scheme was foreseen to continue for two years after which the science operations would be terminated. The severe budgetary constraints suffered by all participating Agencies changed conditions, and only one year of the 19th and final episode of IUE observing could be accomplished. IUE Science Operations were discontinued on 30 September 1996 in presence of the President of the IAU. Thus terminating 18.5 years of extremely successful functioning of this important general user UV facility, for which the only replacement foreseen in the programs of the major space agencies, is the SPEKTRUM-UV mission (to be launched not before the turn of the century). The experience of 18 years has clearly shown that the access to the UV domain is equally essential for progress in astrophysics as access to the optical or radio domain, which are maintained through the continuous availability of ground observatories. The scientific output of the IUE remains very high, with, to date, more than 3,400 papers published in the refereed literature based on IUE data. The IUE science program extends from interplanetary plasma interactions, comets and planets, stellar winds, conditions in the interstellar medium, nova outbursts, supernovae, extragalactic star formation, the size determination of black holes in active galaxies, to the search for transparent sightlines at high redshifts. The IUE Data Archive remains the heaviest used archive in astronomy. With a total of 550,000 data delivered in archival form, and a total final data content in the archive of nearly 114,000 spectra, each IUE spectrum has already been used nearly 6 times.

Some highlights include:

- The Supernova 1993J could fortunately be observed, due to the quick response of the IUE, through its rapid decrease and the high ionization lines observed, were associated with the radiation from the shock outbreak a few hours after the explosion. Temperatures were found to decrease very rapidly. A high resolution spectrum showed that the supernovae occurred on the near side of its parent galaxy M81.
- The observations of Nova Cas 1993 allowed for the first time the detailed study of the evolution of the UV spectrum during the dust formation stage of a nova.
- The RIASS (ROSAT-IUE All Sky Survey) Coronathon program has acquired simultaneous UV, EUV and X-ray observations of some 50 cool stars in a magnitude limited sample (Ayres et al. 1995). These results have supplied important new information on the roles of stellar wind in the dynamo action as well as on the different dynamo modes which affect coronal heating in late-type stars.

- A complete coverage of the collision of Comet Shoemaker-Levy with the Jovian atmosphere has been obtained and supplied unique information on the physical processes associated with the atmospheric impacts.
- The reverberation studies measuring the delays in the response of the emission lines to continuum variations in active galaxies have been extended to six Seyfert I galaxies extending over the 3 orders of magnitude in luminosity by the Active Galaxy Watch consortium (the AGN-Watch), involving more than 100 astronomers (Alloin 1994). Many of these campaigns were coordinated with other space missions (ROSAT, XTE, HST, ASCA, GINGA) as well as many ground-based observatories. All line delays were found to be considerably shorter than expected (Peterson, 1994).
- The coordinated studies made on BL Lac objects have allowed strong constraining parameters on the possible models for the continuum emission from the jet sources.
- The discovery of transparent sightlines to three high redshift QSO's.

Hubble Space Telescope (HST)

This 2.4 m telescope in low earth orbit, which is a joint project operated by NASA and ESA, has four Instruments: the Goddard High Resolution Spectrograph (GHRS); the Faint Object Spectrograph (FOS); the Faint Object Camera (FOC) and the Wide-Field Planetary Imaging Camera 2 (WFPIC-2). The replacement of the High-Speed-Photometer was required to be able to introduce the COSTAR unit in the telescope instrument bay. The performance of these corrective optics was exceptional and the resulting image quality of the telescope was excellent. This has allowed full utilization of diffraction limited imaging with HST after the servicing mission. The results (Science with the Hubble Space Telescope, 1996) and (Ap.J. Letters 454, 1996) have really opened completely new windows on the observable Universe at all distance scales (http://www.stsci.edu/).

Some highlights:

- The first results have been obtained in the projects to determine the Hubble constant based on the study of Cepheids in the Virgo and Fornax Clusters of Galaxies, the Leo-I group, as well as for individual galaxies such as NGC 7331.
- An important program to study the faintest objects in the Universe at four wavelengths (30, 45, 60.6 and 81.4 nm) has been completed in a high galactic latitude field (the Hubble Deep Field).
- Many active galaxies have been found with their jets traced to the resolution limits of HST. For M87 optical proper motions have been discovered indicating Doppler boosting to 2.5c.
- In low redshift objects, absorption lines corresponding to the Lyman forest have been found.
- New extensive gravitational lenses have been found associated with clusters of galaxies.
- The expansion of the SN1987A shell has been measured to be 2,300-3,000 km/sec in good agreement with the observed width of the emission lines.
- The D/H value for the local interstellar medium was found for the direction of Capella to be (D/H) = 1.60 +/- 0.09 x 10^{-5}.
- Strong evidence was found from the velocity field near the centers of galaxies for the presence of mass concentration only consistent with the presence of massive black holes in the centers of M87, NGC 4261, NGC 4570 and others.
- Strong overabundance of O/C (3-5 times Solar) was found in absorbing clouds at high redshift.

Extreme Ultraviolet Explorer (EUVE)

The Extreme Ultraviolet Explorer (EUVE) of NASA (http://www.cea.berkeley.edu/), a grazing incidence telescope for the range from 7-76 nm in LEO, was launched in June, 1992. In the period through June, 1996, over 250 articles have been published reporting on results from this satellite. The Second Catalog of EUVE sources (Bowyer et al., 1996) contained more than 700 sources. The†scientific results obtained include work in the fields of extragalactic astronomy, neutron stars, stellar atmospheres (both early and late type stars), white dwarfs, cataclysmic variable, and the interstellar medium. Some highlights include:

- He II was detected in the ISM and an order of magnitude difference in pressure was found between the local cloud, surrounding the Sun, and the hot material beyond this cloud.
- The EUV thermal emission detected from Geminga was found to be more than an order of magnitude less than the extrapolated X-ray emission.
- Absorption by metals was found in many hot white dwarfs, even those white dwarfs that appear, from optical data alone, to have pure hydrogen atmospheres.
- EUV-selected white dwarfs were found to delineate a new class of ultra- massive hydrogen rich degenerate objects. These objects lie so close to the Chandrasekhar mass and are so numerous that new evolutionary scenarios may be needed to explain their existence.
- The EUV flux short of 91.2 nm in the spectra the B stars, Epsilon Canis Majoris and Beta Canis Majoris, was more than an order of magnitude higher than expected from current model atmosphere theories.
- The discovery of a "cool" (500,000 K to 1 million K) component to the intracluster gas in the Virgo and Coma clusters of galaxies. This gas cannot be the product of a cooling flow from the hot X-ray producing gas and its high cooling rate requires rapid replenishment.

ASTRO-2

NASA's ASTRO-2 Spacelab mission was flown on Shuttle mission STS-67, for the second time in March 1995 (First flight was in December 1990). The instrument package consisted of the following three independent telescopes systems: the Ultraviolet Imaging Telescope (UIT:http: //fondue.gsfc.nasa.gov/UIT/ UIT_HomePage.html) for imaging in the Ultraviolet domain around 150 nm (Science with the Hubble Space Telescope, 1996), the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE: http://jerry.sal. wisc. edu/WUPPE) for the range from 150 nm to 1000 nm and the Hopkins Ultraviolet Telescope (HUT http://praxis.pha.jhu.edu/hut.html) for spectroscopy in the range from 82.5 to 185 nm (Smith et al., 1996).

Highlights from the results of the ASTRO-2 mission:

- The albedos of the planets Venus, Mars and Jupiter were measured in the range 200-320 nm.
- Observed linear polarimetric differences between of the satellite Io on two different orbital phases have been interpreted as arising due to the rotational effect of two polarized regions which are either associated with the volcanic site Pele or Hephaestus Patera and Viracocha Patera.
- Spectropolarimetry has been obtained from 150 nm to 1000 nm for 35 galactic objects in which the polarization appears to be dominated by the interstellar component. The extrapolation of the empirical Serkowski formula based only on visual data does not provide a reliable representation of the UV polarization. This may indicate that the small and large grain alignment mechanisms may be independent and so could provide a new diagnostic tool for the interstellar medium.
- Three novae have been observed and appear to have intrinsic polarization, with changes across emission lines, indicating that the ejecta were quite aspherical.

- The envelope alignment in Be stars was found to be persisting over two orders of magnitude in radius.
- Detection of primordial He II 30.4 nm absorption at a redshift of z = 2.4.

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VII. X-RAY AND GAMMA-RAY SPACE ASTRONOMY

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Perhaps the most universally appreciated X-ray work is that associated with the direct evidence for black holes at the centers of active galactic nuclei. Observations of M87 with the Hubble Space Telescope showed that Keplerian velocities of gas close to the galactic nucleus implied central densities for which a black hole is the most conservative assumption -- but this gas is millions of Schwartzschild radii from the black hole. Even more impressive evidence was the VLBI radio water maser observations of the Seyfert 2 galaxy NGC 4258, this time at thousands of Schwartzschild radii. But the most direct evidence, from only tens of radii, comes from the X-ray spectroscopy of Seyfert galaxy MCG-6-30-15 with ASCA, where the profile of the Fe K line cannot be reasonably explained in any other way (Tanaka et al. 1995). Similar effects have now been observed in several other Seyferts.

Another long-anticipated result is direct evidence for the acceleration of cosmic rays to very high energies within supernova remnant shocks. ASCA provided this evidence in clearly nonthermal (and with radio correlations, probably GeV) electrons in SN1006 (Koyama et al. 1995) and Cas A (Holt et al. 1994).

A totally unexpected result was the detection of X-rays from comets with ROSAT.

The initial discovery of iron in the X-ray spectra of clusters of galaxies some twenty years ago first suggested that emission came from the galaxies themselves, since the gas between the galaxies was assumed to be the primordial material from which the galaxies were formed. Subsequent imaging measurements from Einstein demonstrated that the emission arose in the intracluster gas, not in the galaxies, so that the gas must have somehow been removed from the galaxies. ROSAT imaging observations a few years ago suggested that gas is stripped out of galaxies tidally in close encounters, but the large (> half solar abundance) iron emission still suggested the iron arose from Type I SN (here we refer to low mass progenitors, not the amount of H emission). For the first time, the X-ray spectometers from ASCA have been able to measure the abundances of virtually all even-Z constituents from O to Fe in several clusters, and they find, instead, that the relative abundances match those expected from massive stellar progenitors (Loewenstein and Mushotzky 1996).

Other important results are the continuing gamma-ray burst enigma, the lack of annihilation lines in contemporary measurements of both AGN and burst sources (they had been reported regularly until the latest, most sensitive measurements), evidence for beaming from AGN jets in the EGRET blazars, and kilohertz quasi-periodic oscillations (QPO) measured with RXTE.

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