

The Catholic University of America
Institute for Astrophysics and Computational Sciences
Department of Physics
Washington, DC 20064

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The following report covers the astrophysical research activities of the newly-formed Institute for Astrophysics and Computational Sciences (IACS). However, activities of non-Institute members in the Department of Physics at the Catholic University of America (CUA), who work closely with the Institute are also included. The period of this report covers from September 1996 through September 1997.

The IACS was established in October 1996 to a.) develop strong research and educational programs in the areas of astrophysics and computational sciences at CUA, and b.) promote closer cooperation between CUA and government agencies and with industry. This has been done to take advantage of CUA's proximity to major laboratories and its existing collaborations with government and private enterprise. The ultimate goal is to enhance research, educational, and employment opportunities for CUA faculty, research staff, and students over what is typically offered in the academic environment. The IACS operates in the Department of Physics at CUA.

1. PERSONNEL

The Ph.D. faculty and research staff that are directly affiliated with the Institute are, Fred Bruhweiler (Director), Al Boggess, Peter Chen, Mike Crenshaw, Mike DiSanti, Nat Gopalswamy, Steve Kraemer, C.-H. Lyu, Charles Proffitt, Mark Quigley, Rich Robinson, and Glenn Walgren. Other Ph.D. members of the Dept. of Physics working closely with the IACS include Pamela Clark, Lika Guhathakurta, Fred Lang, Vladimir Krasnopolsky, Richard Starr, and Neale Dello Rosso. Adjunct Professors of the IACS, or those working closely with it, include Yoji Kondo, Andrew Smith, and Carol Crannell.

Non-Ph.D. research and support staff, who work directly in the IACS, are Cherie Miskey, Brendan Smith, and Cecily Stewart, as well as the graduate students, Jack Gabel, Craig Harbuck, Charles Hall, Theo Hadjimichael, Ian Liska, Jose Ruiz, and Scott Weingarten. This is in addition to three students, who have earned their doctorates in Physics through the IACS under Dr. Bruhweiler's direction. These individuals are Dr. Allen Home for his work on the starburst irregular galaxy, NGC 4449, Dr. Colleen Hartman for her work on the interacting binary, V342 Vulpeculae, and Dr. Margaret Smith Neubig for her work on developing a population synthesis code that incorporates metallicity in reproducing UV starburst spectra.

2. RESEARCH ACTIVITIES

2.1 Galaxies and Extragalactic Astronomy

Bruhweiler along with Miskey, and Smith has been using Hubble Space Telescope imagery and spectra to study the nearby starburst/Seyfert 2 galaxy, NGC 1068. Observations

in narrow bandpass imagery indicate a rather uniform [O III]/H-beta ratio extending from the nucleus toward the NE in the ionization cone. There is no indication of shock ionization linked to the expanding radio lobes. Continuum imagery in the UV and optical indicate that approximately 50% of the scattered light of the obscured Seyfert 1 nucleus is scattered by what appears to be a single cloud complex close to the nucleus. Also, Bruhweiler is continuing to work with Smith Neubig, to use a new spectral population synthesis code to model UV HST and IUE spectra of starburst regions in external galaxies. This code uses a spectral library of IUE spectra of galactic and Magellanic stars to determine ages, slope of the IMF, and metallicity of the starbursts.

Bruhweiler is working with Kafatos and Ramos (George Mason U) in correlating the Extreme-UV variability of the BL Lacertae object, Mrk 421, with that seen at other wavelengths. EUVE observations of this TeV γ -ray source have been obtained on two separate occasions while this object was in outburst. Also, Bruhweiler and Boggess plan to use a significant portion of their guaranteed observing time associated with The Space Telescope Imaging Spectrograph aboard the HST to probe active galactic nuclei and starburst galaxies

Crenshaw continues to work on the intrinsic absorption lines in active galaxies. These lines are characterized by blueshifts relative to the nucleus (indicating outflow), high ionization (C IV and N V), and, in many cases, moderately broad widths ($100 - 300 \text{ km sec}^{-1}$). It is likely that the UV absorbers are related to the warm absorbers seen in X-rays, because they both occur in the same galaxies. However the nature of the relationship is unclear. One project that is nearing completion is on the C IV absorption in the GHRS spectra of NGC 3516, which shows four distinct kinematic components at high spectral resolution. Two of the components are narrow, and could arise from the interstellar medium or halo of the host galaxy. The two broad components are at radial velocities of -380 and -150 km s^{-1} relative to the systemic velocity, and likely arise from outflowing gas close to the nucleus. In the future, echelle spectra of several Seyfert 1 galaxies will be obtained with the Space Telescope Imaging Spectrograph (STIS) over the entire UV waveband, to determine the column densities and radial velocity structure of intrinsic absorption lines that span a wide range in ionization.

Kraemer and Crenshaw are working to explore the differences in physical conditions, reddening, and kinematics in the narrow-line regions (NLRs) of active galaxies. FOS UV and ground-based optical spectra of the Seyfert 1 galaxy NGC 5548 have been obtained to study the narrow emission lines over the $1200 - 10,000 \text{ \AA}$ region. The spectra were obtained when the broad emission line and continuum fluxes were at an historic low level, so that the contribution of the narrow-line region (NLR) to the emission lines can be easily determined. Multicomponent photoionization models were

generated to investigate the relative strength of the high ionization lines, compared to Seyfert 2 galaxies, and the weakness of the narrow Mg II λ 2800 line. The analysis indicates a high-ionization component of NLR gas that is very close to the nucleus, and optically thin to ionizing radiation. Plans are underway to study the physical conditions and velocity field as a function of position in extended NLRs, by obtaining long-slit UV and optical spectra with Kraemer's guaranteed time on STIS.

Kraemer and Crenshaw, along with Hutchings (DAO), Kaiser (Johns Hopkins), Weistrop (UNLV), Baum (STScI), Bowers (NASA/GSFC), Feinberg (NASA/GSFC), Green (NOAO), Gull (NASA/GSFC), Hartig (STScI), Hill (DAO), and Lindler (ACC), prepared a letter to ApJ on early observations with STIS of the nuclear region of NGC 4151. Direct images in [O II] and [O III], and slitless medium dispersion spectral images of the H β to [O III] region were obtained. A slitless UV spectral image was taken of the C IV 1550Å region. The letter presents radial velocities and line ratios of \sim 40 clouds resolved in the narrow-line region. The kinematics suggest outflow within a biconical region about the nucleus, centered on the radio axis, and viewed near the edge of the cones. A few high velocity clouds are seen which do not fit this simple picture. Line ratios indicate that the NLR gas is photoionized by the central continuum source and that there may be a density gradient in the NLR. These observations are being followed by an extensive STIS program on NGC 4151.

Crenshaw continues his work with the International AGN Watch. The goal of the collaboration is to probe the size and structure of the broad emission-line region and the nature of the continuum source in active galaxies through intensive monitoring campaigns. Current efforts are concentrating on multi-wavelength (optical to X-ray) campaigns, to discriminate between models (e.g., accretion disk and reprocessing models) for the central continuum source, and UV and optical profile variability, to probe the kinematics of the broad-line region.

2.2 Interstellar Medium

Bruhweiler is continuing work with Holberg (Univ. Arizona) and Barstow (Leicester) to use the Extreme Ultraviolet Explorer, IUE, and HST to study the physical processes both in the photospheres of hot white dwarfs, and in the local ISM. Bruhweiler and Lyu are also continuing their theoretical calculations in modeling the time dependent ionization in the Local ISM. Previous results has shown that the observed ionization of He is due to a recent supernova event producing the nearby Loop I radio loop. Work is now including the prediction of a time-dependent X-ray spectrum as well as the abundances of the heavier abundant ions in the interstellar gas. Modeling by Gabel and Bruhweiler has attempted to explain the observed gas morphology and distribution of young stars within 500 pc of the Sun by an old supershell structure. Preliminary results are to be presented at the Jan '98 AAS Meeting.

Crenshaw, together with Wu (CSC), Hamilton (U. of Colorado), Fesen (Dartmouth), Leventhal (U. of Maryland), and Sarazin (U. of Virginia), published a far-ultraviolet spec-

trum (1150 – 1600 Å) of a hot subdwarf star behind the remnant of SN 1006, obtained with the FOS on HST. The high-quality spectrum is used to test previous identifications of the strong absorption features discovered by IUE. These features have FWHM = 4000 (\pm 300) km s $^{-1}$ and are *not* at the rest wavelengths of known interstellar lines, as opposed to the broader (\sim 8000 km s $^{-1}$ FWHM) Fe II lines from the remnant centered at zero km s $^{-1}$ in near-UV FOS spectra. The authors confirm that the broad absorption features are principally due to redshifted Si II, Si III and Si IV lines, which are centered at a radial velocity of 5100 (\pm 200) km s $^{-1}$. In separate papers, Wu and Hamilton present two possible explanations for the asymmetry of the Si II λ 1260.4 line.

2.3 Stellar Astronomy

Bruhweiler in collaboration with Schultz (STScI/CSC) has been using HST instruments to search for sub-stellar objects around nearby stars and study the circumstellar disk of Beta Pictoris. Two observations using the barred aperture of the Faint Object Spectrograph indicate what appears to be a brown dwarf around the nearest star to the Sun, Proxima Centauri. These results are to appear in the January '98 Astronomical Journal. Bruhweiler and Lyu, in a separate study, using high resolution HST data have determined the temperature structure in the gaseous infall seen in the inner circumstellar disk of Beta Pic. The resulting profile indicates a double shock structure in the inner disk. A new model is proposed that does not require infalling cometary bodies to explain the variable infall seen in the spectrum of β Pic. This work is being prepared for publication.

Kondo pursued the study of the evolutionary processes in interacting binary stars involving gas flows within and out of the binary systems, and continued his participation in multi-wavelength observations of active galactic nuclear and X-ray binaries.

The X-ray Timing Explorer (XTE) data for "Studies of Long-Period Variability in Neutron-Star HMXB System," a collaboration of Lang, Crannell, Heindl, Gruber, and Rothschild (UCSD), were received in July. The spectra for LMC X-4 and SMC X-1 have been calculated and variations in the intensity of the 6.5-keV Fe line, the hydrogen column density, and the spectral index are being investigated. Preliminary results are suggestive of variations, and we reported our results at the 8th Astrophysics Conference— "Some Like it Hot" at the University of Maryland in October.

Proffitt with Leckrone (NASA/GSFC), Walgren, Brandt (U Colo) and Brage (Univ of Lund) has continued to work on HST/GHRS spectra of the chemically peculiar stars χ Lupi and HR 7775. This work includes extensive non-LTE and radiative force calculations for mercury and other heavy elements, and has lead to improved understanding of the causes of line profile anomalies observed in these stars.

Proffitt is also engaged in a study of the B III resonance line in early B stars, using HST/GHRS and IUE data. The goal of this work is to determine boron abundances for a large number of such stars, and to measure the boron isotope ratio in two of the most slowly rotating such stars.

Robinson and Carpenter (NASA) continued their investigations of the chromospheres and winds of oxygen-rich cool stars and carbon stars. Analysis of ultraviolet spectra taken with the GHRS/HST of the M-supergiant Alpha Ori reveals that its chromosphere is characterized by a supersonic turbulence, with a mean velocity (Doppler FWHM) on the order of 35 km s^{-1} , and that that turbulence is anisotropically distributed along the radial and/or tangential directions. The chromospheric emissions are formed relatively low in the wind, before significant acceleration has occurred, but self-absorptions seen over the Fe II and Mg II emissions allow the acceleration of the wind to be followed from zero up to about 7 km s^{-1} . Carpenter *et al.* (1997) report similar dynamics in the carbon star TX Psc, but find that the ionization fraction of iron (Fe II/Fe I) in the outer layers of the carbon star are lower than in the oxygen-rich stars.

Robinson, Airapetian, Maran, and Carpenter used time series observations of the RS CVn binary HR 1099 to determine the turbulence versus height relation in the chromosphere, transition region, and up into the corona of the primary star. The extent of the corona of the primary is estimated to be no more than 2.3 stellar radii, while the coronal loops producing the high temperature emissions are inferred to be much smaller and to have an electron density $\sim 10^{10} \text{ cm}^{-3}$. The relative importance of MHD turbulence and microflares to the heating of the atmosphere is discussed.

Smith and Robinson investigated the X-ray properties of the classical Be Star γ Cas using observation taken with the RXTE satellite. The X-ray time history was found to be dominated by short term bursts which were identified as the result of flaring activity near the stellar surface. The frequency and intensity of the flaring activity was also found to be rotationally modulated and inversely correlated with variations in the UV continuum near 1400 \AA , as deduced from contemporaneous HST/GHRS observations. The current interpretation is that both the X-rays and UV continuum variations arise from localized magnetic complexes near the surface of the star.

Along with Bohm-Vitense, Evans and Carpenter, Robinson utilized the GHRS/HST to determine the mass of several Cepheids and to test theoretical models using differing amounts of convective overshoot and to assess the impact of the new opacities used in those models.

2.4 Solar Physics and Sun-Earth Connection

A complete determination of the relative visibilities and the degree of over resolution for observations obtained with the Owens Valley Solar Radio Array has now been completed for all of the solar flares observed from mid 1992 through mid 1994 by Schmahl and Crannell who were assisted during the summer by a particularly able undergraduate student, Ms. Chelsea Wald, a sophomore at Columbia University. The results obtained to date are presented on the web page <http://fourier.gsfc.nasa.gov/objec.html>. Our future plans include parametric mapping selected flares in the same data base.

The High Energy Solar Spectroscopic Imager (HESSI) has been selected for a Small Explorer mission to be launched in the year 2000 to study solar flares. HESSI will

provide the first hard X-ray imaging spectroscopy, the first high-resolution spectroscopy of solar gamma-ray lines, the first imaging above 100 keV, and the first imaging of solar gamma-ray lines. Crannell is a HESSI Co-Investigator, and Lang is a Research Associate working on grid characterization. Clark, in collaboration with Trombka has analyzed observations of the sun and/or sky made with X-ray spectrometers being flown on the NEAR (Near Earth Asteroid Rendezvous) mission spacecraft as part of the calibration process. The spacecraft is now in cruise mode on its way to its late 1998 encounter with the asteroid 433 Eros. A differentially filtered set of sky-pointing proportional counters operating in the 1 to 10 keV region with 25 square centimeter windows and five degree fields of view have provided estimates of the amplitude and variation in charged particle induced background. One solar monitor is a Si PIN detector, the other also a proportional counter with a graded shield filter and effective thirty degree field of view. Both M- and C-Flares have been detected by the solar monitors. Output from both detectors generally agrees with predicted output from detectors as a function of solar activity. As part of the PIDDP and NEAR programs, Clark has been involved in development of standardized designs, calibration procedures, and test protocols for the next generation of solid state remote and in-situ X-ray detectors.

Gopalswamy and Shibasaki (Japan) are investigating the peculiar radio enhancement in coronal holes. In collaboration with SOHO scientists, they are trying to identify the height in the solar atmosphere where the brightening occurs. The radio enhancement may be an indication of heating taking place in the upper chromosphere and lower transition region. An important aspect of the radio enhancement is the presence of bright points, similar to the polar plume bases in the polar coronal holes. These may also indicate activity that is peculiar to the coronal holes. Detailed model calculations are also being carried out to account for the radio enhancement.

Gopalswamy is continuing his study of the transient microwave brightenings (TMBs) in solar active regions. Non-thermal electrons of very low energy ($\sim 10 \text{ keV}$) emit gyrosynchrotron radiation during transient energy release episodes from the periphery of sunspot umbra. The released energy is extremely small ($\sim 10^{22} \text{ ergs s}^{-1}$) very similar to Parker's nano-flares. The X-ray signatures of these TMBs are also being investigated using Yohkoh data. More radio observations are being accumulated from the Nobeyama Radioheliograph and the Very Large Array.

Gopalswamy, Hanaoka (Japan) and Lemen (Lockheed Martin) are investigating the manifestations of the geoeffective solar disturbances near the solar surface in collaboration with SOHO and Yohkoh scientists. It is found that almost every filament eruption is associated with a change over a large volume of the corona surrounding the filament. These coronal changes may be the signatures of coronal mass ejections at the lowest heights from the solar surface. Filament eruptions are considered from active regions and quiet regions. Microwave observations of filaments have the advantage of being free from the effects terrestrial atmosphere and hence it is possible to track them to large distances in the corona. By combining radio, X-ray and white light observa-

tions, a detailed picture of the onset phase of coronal mass ejections could be obtained.

Gopalswamy is investigating the relationship between coronal mass ejections near the Sun and the magnetic clouds in the solar wind in an attempt to clarify which substructure of a coronal mass ejection evolves into a magnetic cloud. This question is also connected to the inter-relationship between flares, CMEs and coronal and interplanetary shocks. In collaboration with WIND and SOHO scientists (Kaiser, Lepping, Gurman and Howard) an attempt is made to bring together what is known in the near-Earth and near-Sun regimes for a better understanding of the geo-effective solar disturbances.

Guhathakurta's research has been directed towards the synthesis of a number of multi wavelength observations, ranging from the radio to the extreme ultraviolet, for the purpose of exploring the Sun-Earth connection and the distinguishing properties of the source regions of the slow, moderate and high speed solar wind. She has been involved in multi-spectral photometric solar data analysis, image processing, and physical interpretation with the goal of characterizing the large scale magnetic field of the solar corona, the large and small scale density and temperature structures of the solar corona and then apply these high quality observational constraints towards solar wind modeling to understand the coronal heating process.

Guhathakurta has been the project scientist (1/1/93-current) for the Spartan 201 white light coronagraph which is preparing for its fourth flight in November 1997. Following are some important results that came from the Spartan 201 white light coronagraph and other simultaneous observations: 1) For the first time polar plumes were established as large-scale coherent structures that extended into the inner heliosphere (Science News, August, 15, 1995, page 89) which resulted in a renewed research interest in these structures and their contribution in the coronal heating and solar wind outflow processes. 2) For the first time solar wind model, using the white-light density constraints was able to show that the proton temperature in the inner corona is much hotter than the electron temperature which was later verified by observations from SOHO UVCS. 3) Spartan 201-03 WLC observations of the corona for the first time set a value (not an upper limit) in the coronal hole density estimate which matched Ulysses in situ particle observations at 2.3 AU. This result has tremendous implications for solar wind modeling showing that the solar wind accelerates much closer to the Sun (5 solar radii) than had been thought before. 4) The steady-state 2-D, MHD behavior of the corona and the heliosphere was modeled using constraints from Spartan, SOHO and Ulysses observations which for the first time agreed with observations both at the corona and at 1 AU.

Presently Guhathakurta is involved in developing suitable mathematical tools for tomographic inversion of (single spacecraft or solar rotation tomography and multiple spacecraft) quasi-stationary white light observations of the solar corona from Skylab, SMM, Spartan, Mk III K-coronameter and SOHO to obtain both a necessary and sufficient three-dimensional density model of the solar corona. The results of this ongoing interpretive model can be and are being used as

a planning tool for the Solar Stereo Mission and would be instrumental in the analysis and interpretation of data from this mission. She is also a co-I on NSF funded eclipse expeditions with the goal of taking quantitative observations of the solar corona. She is currently a member of the science definition team of NASA towards defining the scientific goals for the Solar Stereo mission. She has been a participant in the science definition team of NASA proposed Solar Probe mission. She is currently involved in a study to estimate solar coronal brightness as seen from the vantage point of the Solar Probe and to relate these estimates to typical instrument sensitivities which would be extremely important for designing imaging remote sensing instruments.

Starr is the Principal Investigator for the X-Ray Spectrometer (XRS) experiment which will be launched in March 1998 on the Clark spacecraft. Clark is one of two Small Spacecraft Technology Initiative (SSTI) missions (Lewis is the other) which are designed to prove the new NASA paradigm of "faster, better, cheaper." The XRS will detect X-ray emissions from solar flares and other astrophysical sources.

2.5 Planetary Astronomy

Krasnopolsky *et al.* provided high-resolution spectroscopy of Mars at 3.7 and 8 μm . They obtained D/H on Mars using HDO lines and established upper limits to H_2O_2 , H_2CO , and HCl of few parts per billion (ppb). They found some indication of a possible presence of CH_4 at a level of tens ppb. They also obtained oxygen and carbon isotope ratios in CO_2 on Mars from the above observations and discussed implications of these ratios to atmospheric evolution. They showed that these ratios are determined by the present water ice amount, the regolith-atmosphere-polar-cap reservoir of CO_2 , the carbonate abundance, the initial abundance of CO_2 , and losses of H_2O and CO_2 to space.

Krasnopolsky has proposed an improved concept for photochemical mapping of Mars. He suggested to support the Mars Global Surveyor observations of H_2O and temperature profiles with ground-based telescope mapping of ozone and its temperature, both above 20 km on Mars. This combination will provide a complete set of data for photochemical modeling of Mars' atmosphere.

Krasnopolsky, in cooperation with Mumma and DiSanti, made mapping observations of ozone and temperature above 20 km on Mars using CSHELL spectrograph at IRTF. Analysis is in progress. Krasnopolsky, Mumma, and Gladstone observed Mars near 1216 \AA with the Goddard high-resolution spectrograph at HST. The observation was aimed to detect D Lyman-alpha and to measure a D/H escape ratio. This ratio should differ from D/H in the lower atmosphere and is important for Mars' evolution. Analysis is in progress.

2.6 Planetary Science

In preparation for the NEAR encounter with 433 Eros, where no ground truth will be available, work is being done with available lunar data to establish the quantitative relationship between iron as detected by spectral reflectance and gamma-ray spectrometers (with McFadden). The one micron feature in the reflectance data results primarily from iron

found in orthopyroxene and to a much lesser extent in olivine. Gamma-ray spectral output in the 6 to 8 meV region correlates well with bulk iron content of the soil, regardless of iron mineralogy. Variations within the major terrains, such as farside highlands, on the Gamma-ray derived map are well-correlated with mapped geological features, and are largely non-existent on the spectral reflectance derived map. The discrepancy between the 'global' iron maps derived from recent Clementine orbital spectral data and the Apollo orbital Gamma-ray data is the result of the presence of iron in olivine or metallic form. The Clementine derived map, recently published as the latest global iron map is, in actuality, largely a pyroxene map. We are now in a position to understand such discrepancies we will undoubtedly encounter at the asteroid. Available data on potential asteroid compositions for S Class asteroids were used as input to X-ray spectral production models to help in the design of hardware and software for the NEAR mission (Clark and Trombka).

The latest two issues of the Mercury Messenger summarize the data now available on the atmosphere and surface of Mercury from the latest ground-based observations (Clark). Recent striking results include detection of material at the poles and in the unimaged hemisphere with unusual radar and/or spectral signatures, further refinement of distribution models for atmospheric components, and detection of anomalies in atmospheric K distribution that could be correlated with surface features. These data were used as input to X-ray spectral models to determine the capability of the X-ray detectors being developed for a proposed Discovery mission, the Mercury Messenger (Clark and Trombka). Clark participated in planning X-ray and Gamma-ray instruments on the Mercury Messenger, a Mercury orbital mission proposed by APL for the latest round of Discovery Class missions. Her inputs included preliminary developmental work, through experience with the NEAR spectrometers, and modeling to provide constraints on proposed design of differentially filtered Si PIN X-ray detectors.

Starr is participating scientist on the Mars Surveyor 2001 Gamma-Ray Spectrometer (GRS) experiment which is currently in the design stage. MS 2001 will launch in February 2001 and orbit Mars for two Earth years. The GRS will provide elemental maps of the planet's surface.

Starr is working on three flight programs that are in various stages of development. The Near Earth Asteroid Rendezvous (NEAR) mission was launched in February 1996 and is on its way to rendezvous with and orbit the asteroid 433 Eros. He is working with the team responsible for the X-ray/Gamma-Ray Spectrometer (XGRS) experiment which will provide elemental maps of the asteroid's surface. NEAR is the first of NASA's Discovery missions.

2.7 Cometary Studies

DiSanti and Dello Russo continue to work with Mumma (NASA) and others in the investigation of parent volatiles in the bright comets, Hyakutake and Hale-Bopp. During the past year, they have used extensively the high resolution spectrograph, CSHELL, at the NASA Infrared Telescope Facility (IRTF) atop Mauna Kea. These observations have resulted in the discovery of methane (CH₄) and ethane (C₂H₆)

in comets, plus verify or establish the presence of several other crucial molecules including methyl alcohol and water. Present efforts are aimed at determining the production rates and basic cometary chemistry.

Four comets were observed with the Extreme Ultraviolet Explorer by Krasnopolsky, Mumma, Abbott and others. Along with the ROSAT observations, this led to a discovery of X-ray emission from comets which exceeds the expected level by three orders of magnitude. To identify the X-ray excitation process, Krasnopolsky calculated intensities for six processes of X-ray excitation in cometary dust and eight processes in gas. He concluded that only charge transfer of solar wind heavy ions (proposed by T. E. Cravens) and scattering of solar X-rays by very small (10^{-19} g) dust particles could contribute significantly to the cometary X-ray emission. Observations of comet Hale-Bopp revealed a spatial distribution of X-rays in the comet. He 584 Å was observed in the comet. Helium appears in the comet due to charge exchange of solar-wind alpha-particles with cometary neutrals, the process which is essentially similar to that excites X-ray. The first sensitive upper limit to Ne was established in comets which corresponds to a depletion of Ne relative to the solar abundance by more than factors 25 and 200 for cometary gas and gas plus dust, respectively. This means that the comet was formed or experienced temperatures higher than 25 K. Measurements of X-ray production rates in four comets, study of correlations of these rates with gas and dust production rates, behavior of sunward offsets of brightness centers from nuclei, and the detection of helium - all these facts favor the charge transfer as a dominant process for X-ray excitation in comets (Krasnopolsky, Mumma, and Abbott).

3. INSTRUMENTAL DEVELOPMENT

Chen, in collaboration with Smith(NASA), Bowers (NASA), and Oliverson(NASA), continued work on the development of extremely lightweight telescopes for lunar and space astronomy missions. Accomplishments include the successful fabrication of a composite replica 0.6 m f/1 mirror with mass 908 g (areal density 1.9 kg m⁻²), vacuum and cryogenic testing of composite optics, demonstration of active optics control, and demonstration of the complete suppression of fiber print through and bond line problems encountered by previous workers. Some aspects of this work may be applied to the NGST and future telescopes on the moon. Chen presented an invited paper at the Joint Discussion No.22 of the IAU in Japan describing this work.

4. EDUCATIONAL OUTREACH & OTHER ACTIVITIES

Clark worked with high school teachers on X-ray production and background determination and published an article of general interest (1996) on the launch of the NEAR mission. Clark has also been editing a newsletter for the planetary community interested in Mercury for the last ten years.

Crannell was at the Thomas Jefferson National Accelerator Facility and the College of William and Mary during 1997 January through June working with the Jefferson Lab Education Group on their program for middle school stu-

dents: Becoming Enthusiastic About Math and Science (BEAMS) and with faculty in the School of Education at the College on developing evaluation techniques for the BEAMS program. The possibility of introducing a program, SUN-BEAMS patterned after BEAMS, is now being explored at Goddard. Other members of the IACS, Bruhweiler, Home, Quigley have regularly visited elementary and intermediate schools to lecture and assist teachers in astronomy and physics presentations.

Gopalswamy is a member of the Organizing Committee of IAU Commission 10 for 1997 - 2000.

Guhathakurta received Certificate of Appreciation for the significant contribution made to the 1996 summer institute in engineering and computer applications (SIECA) program at Goddard Space Flight Center from Bowie State University.

Kondo served as President of IAU Division V (Variable Stars), which comprises IAU Commissions 27 (Variable Stars) and 42 (Close Binary Stars). Kondo also served as an editor for the scientific journals, *PASP*, *Comments on Astrophysics*, *Earth-Space Research*, and *Astrophysics & Space Science*. He also serves as the official IAU representative to the International Astronautics federation (IAF).

Kondo also served as NASA Project Scientist for the International Ultraviolet Explorer (IUE), which was turned off on 1996 September 30. Efforts continued to complete the IUE Final Archive by the end of the fiscal year 1997. The IUE has operated productively since 1978 January; by the end of 1996, 3435 refereed articles have been published from IUE observations. Kondo served also as Project Scientist for the Extreme-Ultraviolet Explorer (EUVE), which was launched in 1992.

PUBLICATIONS

- Bohm-Vitense, E., Evans, N. R., Carpenter, K., Beck-Winchatz, B., and **Robinson, R. D.**, 1997, "The Mass of the Classical Cepheid S Muscae," *ApJ*, 477, 916.
- Brage, T., Wahlgren, G. M., Johansson, S. G., Leckrone, D. S., and **Proffitt, C. R.**, 1997, "Theoretical Oscillator Strengths for Sr II and Y III, with Application to Abundances in the HgMn-Type Star χ Lupi," *ApJ*, in press.
- Brandt, J. ... **Bruhweiler, F.**, *et al.* 1997, "Observations of 3C273 with the Goddard High Resolution Spectrograph. II," *AJ*, 114, 554.
- Brandt, J., ... **Bruhweiler, F.**, *et al.*, 1996, "High Signal-to-Noise Ratio Observations of Weak Interstellar Absorption Lines Toward Xi Ophiuchi with the Goddard High Resolution Spectrograph aboard the Hubble Space Telescope," *AJ*, 112, 1128
- Carpenter, K.G., **Robinson, R. D.**, 1997, "GHRS Observations of Cool, Low-Gravity Stars. III. Plasma Flows and Turbulence in the Outer Atmosphere of alpha Orionis (M2 Iab)," *ApJ*, 479, 970.
- Carpenter, K.G., **Robinson, R.D.**, Johnson, H.R., Ericksson, K., Gustavsson, B., Querci, F. and Querci, M. 1997 "HST Spectroscopy of the Carbon Star TX Psc," *ApJ*, 468, 457.
- Chen, P.C.**, **Y. Kondo**, and R. J. Oliverson, 1997, "Advanced Technology Lunar Astronomy Mission: The Moon As An Immense Optical Bench in Vacuum," presented in IAU JD 22 in Kyoyo, Japan August 1997. To appear in *Highlights of Astronomy*.
- Chen, P.C.**, T. T. Saha, A. M. Smith, and R. Romeo, 1997, "Progress in Very Lightweight Optics Using Graphite Fiber Composite Material," *Opt. Eng.* in press.
- Cheng, K-P, **Bruhweiler, F.**, and Neff, J., 1997, "Detection of Beta Pictoris-like Gaseous Infall in 2 Andromedae," *ApJ*, 481, 866.
- Clark, P.E.** 1997, (Editor), *Mercury: Planet of Fire and Ice, The Atmosphere and The Surface*, Mercury Messenger, Editions 8 and 9, Lunar and Planetary Institute, Houston, TX.
- Clark, P.E.**, 1996, "Counting Down: The last one hundred hours before the launch of the NASA Mission NEAR," *OUTLOOK*, The Magazine of St. Joseph College, 1996-2, West Hartford, CT.
- Clark, P.E.** and J. Trombka, 1997, "X-ray fluorescence experiments for future Mercury orbital missions," *PLAN AND SPACE SCI*, 45, 1, 57-65.
- Clark, P.E.**, 1997, "Future exploration of the Moon and Mercury with remote X-ray measurements," *ADVANCES IN SPACE RESEARCH*, 19, 10, 1539-1549.
- Clark, P.E.** and J. Trombka, 1997, "Remote X-ray spectrometry for NEAR and future missions: Dealing with solar source variation and data analysis," *JGR*, 102, E7, 16361.
- Clark, P.E.**, S.R. Floyd, J.I. Trombka, "The Effectiveness of the Proportional Counter with Specially Designed Filter as a Solar X-ray Monitor on the NEAR Mission," *IEEE Trans in Nuclear Science*, in press.
- Clark, P.E.** and L. A. McFadden, 1997, "Mapping Iron Distribution in the Lunar Crust, Part 1: Establishing the Relationship between Chemical and Mineralogical Iron Abundances and Albedo," *LUN AND PLAN SCI XXVIII*, 237.
- Crenshaw, D.M.** 1997, "Intrinsic Absorption and Emission Lines in Seyfert Galaxies," in *Emission Lines in Active Galaxies: New Methods and Techniques*, ed. B.M. Peterson, F.-Z. Cheng, and A.S. Wilson (San Francisco: Astronomical Society of the Pacific), 113, 240.
- Dello Russo, N.M.**, **DiSanti, M.J.**, *et al.* 1997, "Water in Comet Hale-Bopp," *IAUC* 6604.
- Dello Russo, N.M.**, Mumma, M., **DiSanti, M.J.**, Magee-Sauer, R., Novak, R., & Rettig, T. 1997, "OCS and CN in Comet Hale-Bopp," *IAUC* 6682.
- DiSanti, M.J.**, Mumma, M., **Dello Russo, N.**, *et al.* 1997, "Parent Volatiles in Comet Hyakutake," *IAUC* 6374.
- Dobrzycka, D., L. Strachan, M. P. Miralles, J. L. Kohl, L. D. Gardner, P. L. Smith, S. R. Cranmer, **M. Guhathakurta**, R. Fisher, "Comparison of SPARTAN and UVCS/SOHO Observations," *Proceedings to the 10th Cambridge Workshop on 'Cool Stars, Stellar Systems and the Sun'*, 1997, in press.
- Evans, N. R., Bohm-Vitense, E., Carpenter, K., Beck-Winchatz, B., and **Robinson, R. D.**, 1997, "The Mass of the Classical Cepheid V350 Sgr," *PASP*, 110, 789.
- Gaither, C. C. III, E. J. Schmahl, **C. J. Crannell**, B. R. Dennis, **F. L. Lang**, L. E. Orwig, C. N. Hartman, and G. J. Hurford, 1996, "Quantitative characterization of the

- x-ray imaging capability of rotating modulation collimators with laser light," *Applied Optics*, Vol. 35, No. 34, 6714-6726.
- Gibson, S.E., Bagenal, F., Biesecker, D., **Guhathakurta, M.**, Hoeksema, T., and Thompson, B., 1997, "Modeling a solar minimum streamer structure from whole sun month," *Proc. of the Fifth SOHO Workshop held in Oslo, Norway, June 19-22*, in press.
- Goldsten, J. O., R. L. McNutt, Jr., R. E. Gold, S. A. Gary, E. Fiore, S. E. Schneider, J. R. Hayes, J. I. Trombka and S. R. Floyd, W. V. Boynton and S. Bailey, J. Bruckner, S. W. Squyres, L. G. Evans, P. E. Clark and **R. Starr**, 1997, "The X-ray/Gamma-ray Spectrometer on the Near Earth Asteroid Rendezvous Mission," *Space Sci. Rev.*, in press.
- Gopalswamy, N.**, M. R. Kundu, Y. Hanaoka, S. Enome, and J. R. Lemen, "Detection of Large-Scale Radio Structure and Plasma Flow during a Solar Bright Point Flare," *ApJL*, 457, L117.
- Gopalswamy, N.**, J.-P. Raulin, M. R. Kundu, J. Hildebrandt, A. Kruger and A. Hofmann, "Observation and Model calculations of Sunspot Ring structure at 8.46 GHz," *Astron. Astrophys.*, 316, L25, 1996.
- Gopalswamy, N.**, M. R. Kundu, Y. Hanaoka, S. Enome, J. R. Lemen, and M. Akioka, "Yohkoh/SXT observations of a coronal mass ejection near the solar surface," *New Astron. J.*, 207, 1996.
- Gopalswamy, N.**, M. L. Kaiser, R. P. Lepping, S. W. Kahler, K. Ogilvie, D. Berdichevsky, T. Kondo, T. Isobe and M. Akioka, "Origin of Coronal and Interplanetary Shocks: A new Look with WIND Spacecraft Data," *Journal of Geophysical Research* in press, 1997.
- Gopalswamy, N.**, M. R. Kundu, P. K. Manoharan, A. Raoult, N. Nitta, and P. Zarka, "X-Ray and Radio Studies of a Coronal Eruption: Shock Wave, Plasmoid, and Coronal Mass Ejection," *ApJ* 486, 1036, 1997.
- Gopalswamy, N.**, M. R. Kundu, A. Lara, Y. Hanaoka, S. Enome, J. R. Lemen, M. Akioka, 1996, "Three Part Structure of a CME Revealed by X-ray and Microwave Observations," in the *Proceedings of Yohkoh Conference on 'Observations of Magnetic Reconnection in the Solar Atmosphere'*, ed: R. D. Bentley and J. T. Mariska, ASP conf series vol. 111, p. 373.
- Gopalswamy, N.**, J. Zhang, M. R. Kundu, and E. J. Schmahl and J. R. Lemen, 1997, "Time Structure in Transient Microwave Brightenings: Evidence for Nonthermal Radio Emission," *ApJL*, in press.
- Gopalswamy, N.**, Y. Hanaoka and J. R. Lemen, 1997, "Radio and X-ray Investigations of Erupting Prominences," *Proc. IAU Colloquium 167, PASP Conf. Series*, (eds.) D. Webb, D. Rust and B. Schmieder, in press.
- Gopalswamy, N.**, C. E. DeForest, B. Bromage, and G. Del Zanna, 1997, "Multiwavelength Observations of a Coronal Hole," in the *Proc. 18th National Solar Observatory/Sacramento Peak Workshop*, (eds.) K. S. Balasubramaniam, J. W. Harvey and D. M. Rabin, in press.
- Gopalswamy, N.**, B. J. Thompson, and K. Shibasaki, 1997, "Comparison of Microwave and SOHO Synoptic Maps of the Sun During the Whole Sun Month, 1996," in the *Proc. 18th National Solar Observatory/Sacramento Peak Workshop*, (eds.) K. S. Balasubramaniam, J. W. Harvey and D. M. Rabin, in press.
- Guhathakurta, M.**, Holzer, T.E. and MacQueen, R.M., 1996, "The large scale density structure of the solar corona and the heliospheric current sheet," *ApJ*, 458, 817.
- Guhathakurta, M.**, Fisher, R.R., and Strong, K., 1996, "Temperature structure of the high-latitude corona," *Ap. J. Lett.*, 471, L69.
- Guhathakurta, M.** and Fisher, R.R., 1996, "Importance of white-light observations of the extended corona, *Robotic Exploration Close to the Sun: Scientific Basis*," *AIP Conference Proceedings*, 385, 121.
- Guhathakurta, M.**, Biesecker, D., Gibson, S. and Fisher, R., 1997, "Polar coronal hole density and its solar wind consequences using LASCO observations," *Proc. of the Fifth SOHO Workshop held in Oslo, Norway, June 19-22*, in press.
- Guhathakurta, M.**, 1997, "Evolutionary patterns of large-scale coronal structures and their solar wind consequences," *Proceedings of 18th NSO/Sacramento Peak Summer Workshop on Synoptic solar physics, Sunspot, New Mexico, September 9-12, 1997*, in press.
- Guhathakurta, M.**, Sittler, E.C., Fisher, R., Biesecker, D., Strachan, L., Thompson, B. and McComas, D., "Semi-empirical 2D MHD model of the solar corona and interplanetary medium using Skylab, SOHO and Ulysses observations," *Proceedings of 31 Eslab Symposium on correlated phenomena at the Sun, in the Heliosphere and in Geospace, 22-25 September, 1997 Estec Noordwijk, The Netherlands*, in press.
- Hamilton, A.J.S., Fesen, R.A., Wu, C.-C., **Crenshaw, D.M.**, and Sarazin, C.L. 1997, "Interpretation of UV Absorption Lines in SN 1006," *ApJ*, 481, 838.
- Hutchings, J.B., **Crenshaw, D.M.**, Kaiser, M.E., Kraemer, S.B., Weistrop, D., Baum, S., Bowers, C.W., Feinberg, L.D., Green, R.F., Gull, T.R., Hartig, G.F., Hill, G., and Lindler, D.J. 1997, "Gas Cloud Kinematics near the Nucleus of NGC 4151," *ApJ*, in press.
- Kafatos, M., and **Y. Kondo**, 1996, editors, "Examining the Big Bang and Diffuse Background," *Kluwer Academic Publishers*.
- Ko, Y-K, L. Fisk, J. Geiss, G. Gloeckler, **M. Guhathakurta**, "An empirical study of the electron temperature and heavy ion velocities in the south polar coronal hole," *Sol. Phy.*, 171, 345.
- Koenen, M., J. Bruckner, U. Fabian, H. Kruse, H. Wanke, A. N. F. Schroeder, **R. Starr**, L. G. Evans, J. I. Trombka, D. M. Drake, P. A. J. Engler, and J. Dempsey, 1996, "Analysis of Radiation Damaged HPGe Detectors with a New Algorithm," *IEEE Trans. Nucl. Sci.* 43, 1570.
- Kondo, Y.** 1996, "Mass Flow In And Out Of Close Binaries," *Revista Mexicana de Astronomia y Astrofisica*, 5, 5.
- Kondo, Y.** 1996, "Concluding Remarks at the La Plata Symposium," *Revista Mexicana de Astronomia y Astrofisica*, 5, 129.
- Kondo, Y.** "Major Unsolved Problems of Cosmology," *Examining the Big Bang and Diffuse Background*, ed. Kafatos and Kondo, 399. **Kondo, Y.** 1997, "Evolutionary Pro-

- cesses in Close Binaries,” ‘Symposium on Supercomputing – New Horizon of Computational Science’.
- Krasnopolsky, V. A.**, 1997, “Excitation of X-rays in comet Hyakutake (C/1996 B2),” *J. Geophys. Res.*, in press.
- Krasnopolsky, V. A.** 1997, “X-ray emission from comet Hyakutake exceeds expectations.” *Phys. World* 10, 21.
- Krasnopolsky, V. A.** 1997, “Photochemical mapping of Mars,” *J. Geophys. Res.* 102, 13313.
- Krasnopolsky, V. A.** 1997, “On the nature of soft X-ray radiation in comets,” *Icarus* 128, 368.
- Krasnopolsky, V. A.**, G. L. Bjoraker, M. J. Mumma, and D. E. Jennings 1997, “High-resolution spectroscopy of Mars at 3.7 and 8 μ m: A sensitive search for H_2O_2 , H_2CO , HCl , and CH_4 , and detection of HDO,” *J. Geophys. Res.* 102, 6525.
- Krasnopolsky, V. A.**, M. J. Mumma, M. J. Abbott, B. C. Flynn, K. J. Meech, D. K. Yeomans, P. D. Feldman, and C. B. Cosmovici 1997, “Detection of soft X-rays and a sensitive search for noble gases in comet Hale-Bopp (C/1995 O1),” *Science*, 277, 1488.
- Krasnopolsky, V. A.**, M. J. Mumma, G. L. Bjoraker, and D. E. Jennings 1996. “Oxygen and carbon isotope ratios in Martian carbon dioxide: Measurements and implications for atmospheric evolution,” *Icarus* 124, 553.
- Lara, A., **N. Gopalswamy**, M. R. Kundu, R. Perez-Enriquez, H. Koshiishi and S. Enome, 1997, “A Multiwavelength Study of Active Region Development,” *Solar Phys.* in press.
- Laros, J. G., W. V. Boynton, K. C. Hurley, C. Kouveliotou, M. L. McCollough, G. J. Fishman, C. A. Meegan, D. M. Palmer, T. L. Cline, **R. D. Starr**, J. I. Trombka, M. Boer, M. Niel, and A. E. Metzger, 1997, “Gamma-Ray Burst Arrival Time Localizations: Simultaneous Observations by Mars Observer, Compton Gamma Ray Observatory, and Ulysses,” *Astrophys. J. (Supp.)* 110, 157.
- Marilli, E., ... **Bruhweiler, F.**, *et al.*, 1997, “Searching for Chromospheric Lyman-alpha Emission in A-F Stars from IUE High Resolution Spectra,” *Astron. Astrophys.*, 317, 521.
- Marshall, H. L., Carone, T.E., Peterson, B.M., Clavel, J., **Crenshaw, D.M.**, Korista, K.T., Kriss, G.A., Krolik, J.H., Malkan, M. A., Morris, S., O’Brien, P.T., and Reichert, G.A. 1997, “The Variability and Spectrum of NGC 5548 in the Extreme Ultraviolet,” *ApJ*, 479, 222.
- Michalitsianos, A., Dolan, A., Kazanas, D., **Bruhweiler, F.**, *et al.*, 1997, “Ly-alpha Absorption-Line Systems in the Gravitational Lens Q0957+561,” *ApJ*, 474, 598.
- Mumma, M. J., **V. A. Krasnopolsky**, and M. J. Abbott 1997, “Soft X-rays from four comets observed with EUVE,” *Astrophys. J. Lett.*, in press.
- Proffitt, C. R.**, 1997, “The Importance of Helium and Metals Diffusion in Stars,” in *Fundamental Stellar Properties: The Interaction between Observation and Theory: Proceedings of the 189th Symposium of the International Astronomical Union, 1997 (July)* eds. T. R. Bedding, A. J. Booth, and J. Davis, Kluwer Academic Publishers: Dordrecht, p 355.
- Robinson, R. D.**, Airapetian V. S., Maran, S. P. and Carpenter, K. 1996, “Observing Stellar Coronae with the Goddard High Resolution Spectrograph. II. The RS CVn Binary System HR 1099,” *ApJ*, 469, 872.
- Rodriguez-Pascual, P.M., Alloin, D., Clavel, J., **Crenshaw, D.M.**, Horne, K., Kriss, G.A., Krolik, J.H., Malkan, M.A., Netzer, H., O’Brien, P.T., Peterson, B.M., Reichert, G.A., Wamsteker, W., *et al.* 1997, “Steps Toward Determination of the Size and Structure of the Broad-Line Region in Active Galactic Nuclei. IX. Ultraviolet Observations of Fairall 9,” *ApJS*, 110, 9.
- Ramos, E., Kafatos, M., Fuscione, A., **Bruhweiler, F.**, *et al.*, 1997, “Contemporaneous IUE, EUVE, and High-Energy Observations of 3C273,” *ApJ*, 482, 167.
- Sawant, H. S., R. R. Rosa, J. R. Cecatto, and **N. Gopalswamy**, 1997, *Solar Phys.*, 177, 155.
- Schultz, A., ... **Bruhweiler, F.**, *et al.*, “First Observations using the STIS Aboard the HST: Observations of the Brown Dwarf Gl 229B,” *ApJ Letters*, in press.
- Schultz, A., Hart, H., Hershey, F., **Bruhweiler, F.**, *et al.* 1997, “A Possible Proper Motion Companion to Proxima Centauri,” *AJ*, in press.
- Schultz, A., ... **Bruhweiler, F.**, *et al.* 1997, “HST/FOS Imagery of Wolf 424 AB: Is this Binary a Double Brown Dwarf?,” *PASP*, accepted.
- Smith Neubig, M. and **Bruhweiler, F.**, 1997, “UV Spectral Classification of O and B Stars in the Small Magellanic Cloud,” *AJ*, in press
- Starr, R.**, M. Acuna, B. Dennis, U. Desai, L. Orwig, J. Trombka, D. Douglass, J. Houser, P. Panetta, T. Plummer, J. Scheifele, P. Uribe, 1996, “The X-Ray Spectrometer for the Clark Mission,” *Acta Astronautica* 39, 293.
- Stecher, T. P., R.H. Cornett, **P.C. Chen**, and 19 co-authors, 1997, “The Ultraviolet Imaging Telescope: Instrument and Data Characteristics,” *PASP* 109, 584.
- Trombka, J. I., W. V. Boynton, J. Bruckner, S. W. Squyres, P. E. Clark, **R. Starr**, L. G. Evans, S. R. Floyd, E. Fiore, R. E. Gold, J. O. Goldsten, R. L. McNutt, Jr., and S. H. Bailey, 1997, “Compositional Mapping with the NEAR X-ray/Gamma-ray Spectrometer,” *J. Geophys. Res.*, in press.
- Von Montigny, C., Aller, H., Aller, M., **Bruhweiler, F.**, *et al.*, 1997, “Multiwavelength Observations of 3C273 in 1993-1995,” *ApJ*, 483, 161.
- Wanders, I., Peterson, B.M., Alloin, D., Clavel, J., **Crenshaw, D.M.**, Edelson, R.A., Horne, K., Kriss, G.A., Krolik, J.H., Malkan, M.A., Netzer, H., O’Brien, P.T., Reichert, G.A., Wamsteker, W., *et al.* 1997, “Steps Toward Determination of the Size and Structure of the Broad-Line Region in Active Galactic Nuclei. XI. Intensive Monitoring of the Ultraviolet Spectrum of NGC 7469,” *ApJ*, in press.
- Wu, C.-C., **Crenshaw, D.M.**, Fesen, R.A., and Hamilton, A.J.S. 1997, “Far-UV Spectra of Absorption Lines in the Remnant of SN 1006,” *ApJ*, 477, L53.
- Zhang, J., **N. Gopalswamy**, M. R. Kundu, E. J. Schmahl and J. R. Lemen, 1997, “Spatial Structure of Coronal Magnetic Loops Revealed by Transient Microwave Brightenings,” *Solar Phys.*, in press.