REPORT ON A SYMPOSIUM ON X-RAY BINARIES

The symposium, which was jointly sponsored by the I.A.U. Commissions 42 and 44, was held at Goddard Space Flight Center, Greenbelt, Maryland, U.S.A. between October 20-22, 1975. It was attended by more than a hundred participants and covered observations of X-ray binaries not only in X-ray spectral range but also in optical, infrared and radio regions.

Except for the first session which covered the recent X-ray results, eight sessions were devoted to seven X-ray binary objects separately, the tenth session to other binary sources, and the last session to the present and future observational plans.

A. P. Willmore described the properties of five transient sources observed by Ariel 5 : A1524-62, A1118-61, A1742-28, A0535+26, A620.0. All these sources are confined to the galactic plane in the luminosity range of about 10^{37}–10^{38} ergs/sec.

H. Schnopper (ANS-SAO) and H. Kestenbaum (OSO-8 Columbia) have not detected, using Bragg spectroscopy, any narrow feature, which can be labeled as line features.

G. Clark discussed some of the results obtained from SAS-3, launched in May 1975 by the M. I. T. group. A soft source in Coma, identified to HD43 (hot white dwarf) may be the first observed object, called Ulsar by Chiu and Stothers, which lie between planetary nebulae and white dwarf phase. The observations fit a black body of a couple of thousand degrees Kelvin. They have observed in very low energy X-ray, at the flare time, SS Cyg, a white dwarf in a binary. X-ray nova A0535+26 was found to have a period of 103.8262 sec in the energy range 8-35 keV; the light curve varies with energy and has similarity with Vela X-1 and may be a binary.

The first panel on individual objects was devoted to Her X-1. J. Bahcall mentioned that 1.2 sec pulsation and $1^{d}.7$ periodity is reasonably understood but what is not well understood are : (*i*) the corotation of the system, (*ii*) 35^{d} periodicity, (*iii*) off state being not really off, (*iv*) low energy system, (*v*) cases of inactive states, and (*vi*) rate of change in period.

E. Boldt mentioned that Her X-1 has a simple spectrum of $E^{-1.05}$ between 1.5-25 keV, which can be explained by a magnetic field greater than 10^{12} gauss around a neutron star, as an optically thick medium becomes optically thin due to reduction in Thomson scattering cross-section in presence of strong magnetic field.

The optical off time for HZ Her is approaching and W. Liller pleaded to keep the object under watch for any variability.

In the Cen X-3 panel, H. Mauder mentioned that the optical counterpart is an early type (O9.5—B0.5) giant or mainsequence star, showing P-Cygni type profile, implying presence of wind. N. V. Vidal thought that the spectral type of the star may be changing and the radial velocity from emission line is not very certain. K. Pounds stated that evidence for accretion wake is reasonable in some cases. A value of $N_{HI} \simeq 4\times10^{21}$ cm^{-2} has been derived by Ryter from interstellar absorption, and may be variable due to stellar wind according to K. Pounds. Recent UHURU observations have given (E. J. Schreier) for Cen X-3 $\Delta P \simeq 0.0015$ sec/year, $\dot{P}/P \simeq -3\times10^{-4}$ per year (over 1971-72).

Opening the Cyg X-3 panel, R. H. Hjellming mentioned that the source, radio-wise, behaves like a nano-Quasar. G. Garmire stated that IR observations frequently do not show 4.8 hour period ; in X-ray one always observed it. However, when IR observations do not show 4.8 hour period, it matches well with the X-ray observations. The filling in of the IR minimum is not well understood at the moment ; may be it is due to some flaring activity as its return curve (K. O. Mason) is fairly stable in period, shape and amplitude and shows a line emission at about 6.7 keV, perhaps due to iron, of equivalent width 0.30 ± 0.05 keV. Data from Ariel 5 indicated (Goddard group) a periodicity of 17.0 ± 0.3 days, and a maximum on JD 24402371.5 ± 1. S. Shulman et al. failed to detect 6.7 keV line emission on 7 September 1974, though this was observed by the Goddard group a month later. G. Ricke reported observing time structure in 20—150 keV range, in times of less than a minute.

S. P. Maran traced the history of the discovery (3 August 1975) of the transient source A0620—00, in the special panel to discuss it. Now the source is called Nova Monocerotics 1975 and it should not be confused with MX0650-07 (discovered 20 September 1975) and Nova Cygni 1975. X-ray observations (Ariel 5) revealed flare ups at late-stage far after the peak; optical emission decreased more slowly than X-ray. S. Holt et al. attempted to classify the transient sources into two groups :

	Group I	Group II
Spectrum	$\alpha >$ Crab	$\alpha >$ Crab
Time Scale	$t_{on} > 1$ month	$t_{on} < 1$ month
Intensity at maximum	> Crab	< Crab
Mean time between source appearance	$\tau > 0.1$	$\tau < 10^{-3}$
Peak luminosity	$L > 10^{38}$ ergs/sec	$< 10^{37}$ ergs/sec.

Cen X-2, Cen X-4, 1543-47, 1524-61, 1524-61, 1742-28, and 0620-00 fall in the first group and 1735-28, 1118-61, and 0535+26 in the second. In passing, Holt mentioned that Aql X-1 (3U 1908 + 00) increased, in June 1975, in intensity by two orders of magnitude. H. Bradt and T. Motisky (M.I.T.) observed the source by SAS-3 beginning 8 August 1975 in 0.15 - 50 keV range. They found dramatic softening of the source on August 8, a gradual hardening from August 9-14, and a softening from August 20 to September 17. In the far UV, it shows a small amplitude variation (Wu) ; interstellar extinction places it $\sim$ 1 kpc away and a blackbody of 28000 K fits the spectrum between 1500-3000Å. R. Wolfson discovered the optical counterpart on16 August 1975 having M_v=11.2±0.1. In 1917 Harvard College Observatory plate collection showed that M_v=12.00 with a decline of 0.011 mag/day (W. Liller); it may be a recurrent nova with ΔT (years) = 58 and $\Delta m = 8^{m}.5$. However, Liller felt the distance of the object to be 11.0 $^{+2.8}_{-2.3}$ kpc. T. Snow, D. York and T. Gull found, from high dispersion spectral analysis, that the flux distribution of optical counterpart resembles an O-star with a possible UV excess; the distance based on interstellar Na D lines is between 1-3 kpc. The fact that no stellar lines are seen is inconsistent with O-star spectra. J . Dolan found no stellar polarization and deduced a distance of 1 kpc. F. Owen observed at 1400 MHz (also at 1418, 1420, and 2695) a quick drop in intensity between August 15—22. K. Brecher and P. Morrison proposed a theoretical model in which they divided the transient sources into two classes: 1. pulsating X-ray source showing hard X-ray and 2. unpulsed soft spectrum sources; the first one powered by sporadic infall of matter onto rapidly rotating magnetized collapsed objects and the class (2) by shock heating.

In the Cyg X-1 X-ray panel, E. Boldt listed some of the properties reasonably understood and questions which still need to be answered. D. M. Eardley tried to explain the powerlaw spectrum by Inverse Compton Scattering of a soft photon flux in a very hot accretion disk with slope of the spectrum varying when source conditions vary. Ariel-5 Goddard monitor revealed a 5.6 day modulation in the 3-6 keV range between October 1974 to July 1975; these observations imply the X-ray emission from the compact member of HDE 226868. The balloon observations of J. L. Matteson et al. show that the steep spectrum at E $<$ 10 keV during the "radio quiet" phase can extend to 200 keV; during some one hour periods, the intensity remained constant to 20 percent and during other periods it varied a factor of 2 in 5 min and a factor of 10 in an hour. These intensity changes were accompanied by complex spectral variations. P. Murdin discussed the absorption dips in 2-7 keV X-ray flux and concluded: (1) the dips occur near to superior conjunction, when the B supergiant lies between Earth and the unseen companion; (2) significant scatter about the line joining the two stars, i.e., about ± 35°; (3) the angle subtended by the absorbing material at X varies from 1° to 32°; and (4) the column density varies by at least two powers of ten. UHURU observations in the range 2.1—16.4 keV have shown that the cross-correlation function is symmetrical when plotted against time delays in steps of 0.192 sec (M. Weisskopf).

The optical panel on Cyg X-1 reviewed the properties of HDE 226868. According to C. T. Bolton, it is a perfectly normal O9.7 I abp var. star except for the variable λ4686 He II emission; the velocity curve is normal, He 4686 emission is in antiphase with hydrogen absorption velocity curve (ruling out 3rd body model), $M_1/M_2 \sim 1.6$, and Roche lobe appears to be nearly filled. However, because of radiation pressure, Roche lobe approach may not be correct. The secondary may be a B0-B4 V star. The spectra is riddled by 1 or 2 percent intensity lines throughout the 2000Å range around λ4026. Bolton has determined a period of 5.59972 days from velocity curve, which he thinks is better determined than the light curve. E. N. Walker observed the star in blue light between 1972-75 and noted dramatic changes in late 1974-early 1975 compared to 1972-74; he has obtained P=5.6026±0.0003 from mean light curve and found a phase shift of 0.08 between 1972-74 data and 1975 data. W. Liller has found that in 1903, P=5.600 d, and brightness amplitude (A)=$0^{m}.035$, during 1944-45, $P=5^{d}.600$, A=0.052 and in 1974, P=5.60118±0.00004, A=0.008. G. E. McClusky and Y. Kondo discussed the effect of radiation pressure on the equipotential surfaces in X-ray binaries, and C. Wu found E (B-V)= 1.02 assuming a B0 Ib star within 10° of Cyg X-1. In the U-band, J. F. Dolan found polarization angle to be correlated with polarization, with polarization variation all around the orbit; this implies that we are observing λ-dependent scattering, i.e., Rayleigh scattering due to atoms; may be there are gas streams.

In his remark in the panel for HD 153919 (3U1700—37), T. B. Hutchings mentioned that even though it is the brightest binary source, it has been neglected as it is in the southern hemisphere. At $\sim$ 0.5 phase, it shows X-ray attenuation and its low energy cut off is the strongest among the binaries. It has a very large mass ratio with the primary being an extreme Of star, the hottest among the X-ray binary primary stars. Optical spectroscopy suggests spherically symmetric stellar wind with no evidence of accretion disc. Hα emission may change with phase but this is not confirmed. Loss of mass by the primary due to stellar wind, according to Hutchings, is $dM/dt \simeq 10^{-5}\ M_\odot$. Other parameters for the system are :

$$P = 3.4126 \pm 0.0003 \text{ days, Sep}/R_{\text{primary}} \sim 1.4$$

$$V_0 = -65 \pm 2 \text{ km/sec, f}(M) = 0.0027,$$

$$M_1 = 27 \pm 5\ M_\odot,\ M_2 = 1.3 \pm 0.2 M_\odot,$$

$$V = 20 \pm 3 \text{ km/sec.,}\ V_{\text{rot}} = 300 \text{ km/sec,}\ i = 90° \pm 5°,$$

$$K_1 = 20 \pm 2 \text{ km/sec.}\ \ K_2 = 400 \pm 70 \text{ km/sec.}$$

Light curve $\Delta M \sim 0^{m}.05$, distance $\simeq$1200 pc, M_v=6.5. As the absorption is patchy in this direction, one should take a narrow field in deriving reddening distance. Bolton has derived 2 kpc from a narrow field. A. K. Durpee and J. Lester have found on high dispersion spectrograms emission and absorption features variable in intensity and velocity, a feature around 5303Å may be due to Fe XIV. The broad emission has never been visible when X-ray was not visible; the doubling of the line has been confirmed by Conti and Cowley. *Copernicus* X-ray data (K. O. Mason) reveals that (1) intensity variation is energy independent and (2) energy hardness varies with orbital period. Skylab shows (Y. Kondo et al.) spectral type O6.5 Ief and P Cygni type profile for N IV 1718. Though luminosity and spectral type of the object appears to be that of O supergiant, efforts need to be made to see the secondary features and the eclipse duration.

Opening the panel on 3U0900-40 (HD77481, Vela X-1), N. V. Vidal mentioned that besides the 8.95 days period, 283 sec modulation has been found by the SAS group. One may be able to determine apsidal motion and $\dot{\omega}$ from X-ray, which are more accurate than derived from visual observations. The mass of the optical component is $\sim 20 M_{\odot}$ and its luminosity high for the mass. He 4686 line has been an enigma in X-ray binaries but it has not been observed in this except for a small feature as reported by Hutchings. Its distance has been estimated about 2 kpc and may go down to 1·2 kpc. In infrared, it is not different to other hot stars. Kamp et al. have found a varying circular polarization in the wings of Hβ and have deduced a magnetic field about 10,000 gauss but others have not concurred with this result. 1.8 $M_{\odot}$ and 20 $M_{\odot}$ are the most likely masses, though the former appears a little high for a neutron star. C. T. Bolton estimated the distance, from reddening measurements, between 1-2 kpc, and C. C. Wu found E (B-V)=0.73 assuming B0Ib star. K. Pounds found a big dip around 0.3 phase and around 0.6 phase in the X-ray data; a flare of duration of a day was also observed around MJD 42634 and may be due to temporary blow up of Roche lobe. J. E. McClintock et al. gave for HD 77581, $M \gg 20 M_{\odot}$, $R \sim 32 R_{\odot}$ and for Vela X-1, $M \gg 1.7 M_{\odot}$, whereas van Paradijs et al. gave $M_x = 1.61 \pm 0.22 M_{\odot}$, and $M_{opt} = 21.2 \pm 2.4 M_{\odot}$.

In the last but one session devoted to "Other Possible X-ray Binaries", H. Gursky reviewed the galactic sources which do not follow the "normal" pattern of the X-ray sources. He discussed the low luminosity sources (luminosity lower by one or two orders compared to "normal"), like X-Per globular cluster sources, which may be related to a black hole in the center of the cluster and transient sources in which the X-ray emission increases suddenly at least 2 or 3 orders of magnitude and declines gradually over weeks or months. A. P. Cowley et al. have found that Sco X-1 is a single lined binary with a period of $0^d.787$ with $M_x \backsim 1.4 M_{\odot}$ and $M_{sec} \backsim 1 M_{\odot}$. A. F. Davidsen, R. Malina and S. Bowyer have found that the optical candidate for GX1+4 (3U 1728-29) is a strong infrared object and is an M giant star at a distance of abour 10 kpc if $M_v \simeq 0.5$. S. I lovarsky reported simultaneous X-ray and optical observations of Cyg X-2 ; the results indicate a period of 13.6 days and it was found that the optical intensity decreased in 1975 relative to 1974, whereas in X-ray it was the reverse.

The workshop ended with a session on the present plans and future prospects. Emphasis was laid on simultaneous observations in X-ray, optical, IR and radio regions.

The symposium, though crowded, was a very useful contribution to this fast developing field.

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REPORT ON THE COLLOQUIUM ON THE PHYSICS OF Ap STARS

This IAU Colloquium No. 32 was held at the University of Vienna between September 8-11, 1975. The meeting was organized according to themes of current research interest, each theme being extensively reviewed by invited papers with new results being reported in short contributed papers. In addition, three "open discussions" were held on "hot" topics, viz., diffusion versus magnetic accretion theories, the Hg-Mn star problem and blanketing-backwarming effects.

The Ap stars are among the most complex and problematical objects in stellar astrophysics. Constituting about 20 per cent of the main-sequence stars with effective temperatures in the range 8000-16000°K, they may be divided into two broad groups-those with appreciable surface magnetic fields and those without. Each group exhibits a remarkable variety of chemical peculiarities. The non-magnetic Ap stars include those which are helium rich, helium deficient, enhanced in Hg and Mn or generally enhanced in metallic spectral line strengths. The magnetic Ap stars exhibit enhanced spectral lines of Si, Sr, Cr, He, C etc. The magnetic Ap stars are typically variable in field strength, in brightness and in the strengths and radial velocities of certain spectral lines. These variations are described most successfully by oblique-rotator models, wherein the stellar magnetic and rotational axes are inclined with respect to each other and with respect to our line of sight. In addition, the sources of line and continuous absorption are distributed in a patchy manner over the surface of the oblique rotator, although whether this reflects real chemical inhomogenity or local variations in physical conditions of excitation, line broadening, etc., is still debated. The non-magnetic metallic-line A stars (Am Stars) and Hg-Mn stars are usually members of binary systems and are intrinsically slow rotators. The magnetic Ap stars also are usualy sharp-lined but their spectroscopic binary frequency is lower than normal. There are a number of major issues in Ap star research and discussion at the colloquium quickly focused on these and upon new observations which provide leverage for the resolution of major questions. This discussion is summarized below.

The Origin of Magnetic Fields :

Two competing hypotheses were discussed by L. Mestel (U. K.) : (1) relic or primeval magnetic fields "frozen" into the stellar envelope and photosphere with a mixture of poloidal and toroidal components producing dynamical stability, and (2) fields being maintained by stellar rotational dynamo. The primeval fields, advocated by Mestel, could either arise in the interstellar medium from which the star formed or in a dynamo generated as the star went through its Hayashi phase pre-main-sequence contraction (models for which were discussed by M. Schessler, G.F.R.). The dynamo models are advocated primarily by physicists from the U.S.S.R. The major difficulty with the dynamo is the lack of observed correlations between rotational period and field strength and the absence of significant (> 1000 gauss) fields in the most rapidly rotating Ap stars, as discussed by J. Landstreet (Canada). An important test for the relic field theory will be an observational confirmation of the segregation of field obliquity (angle between