AM HERCULIS TYPE STARS - MAGNETIC BINARIES

W. Krzemiński
N. Copernicus Astronomical Center
Polish Academy of Sciences
Al. Ujazdowskie 4
00-478 Warszawa, Poland

A new class of close binary stars, proposed to be called polars, has been discovered during recent year; its prototype is AM Her. The three known polars, AM Her, AN UMa, and VV Pup, are polarization, spectrum, radial velocity, optical, and infrared variables of short periods of 3.1, 1.9, and 1.7 hours, respectively (Tapia 1977 a,b,c; Michalsky et al. 1977; Krzemiński and Serkowski 1977; Stockman et al. 1978; Herbig 1960; Cowley and Crampton 1977; Priedhorsky 1977; Greenstein et al. 1977; Berg and Duthie 1977; Szkody and Brownlee 1977; Olson 1977; Mumford 1977; Priedhorsky and Krzemiński 1978; Neugebauer et al. 1977). AM Her itself has been found to have strong soft X-ray emission in the 0.1 - 0.4 keV band (Hearn and Richardson 1977) and a hard X-ray spectrum (about half the observed 2 - 60 keV energy lies above 28 keV, Swank et al. 1977) both modulated with a 3.1 hour period. No X-ray emissions from the other systems have been detected so far.

AM Her-like objects exhibit wavelength and phase dependent strong circular and linear polarization. The linear polarization is characterized by a temporal pulse for 0.1 - 0.2 period. This linear polarization pulse is accompanied by either a change in sign or a local extremum of the circular polarization. During linear pulse the polarization position angle rotates slowly with a rate 100 - 120^{o}/period. In AM Her the linear pulse has not been always observed and seems to be associated with the overall brightness of the system. The flux of

https://doi.org/10.1017/S0252921100069426 Published online by Cambridge University Press

AM Her at wavelengths blueward of 4100 A shows almost no circular and linear polarization (Stockman et al. 1978).

All three polars exhibit small, rapid light variability analogous to that in common cataclysmic variables. Moreover, their brightness varies by $\sim$ 3 mags. between maximum ("high state") and minimum ("low state") and vice versa on a time scale of month to several months; prevailing is a high state. Their light curves exhibit very wide, $\sim$ 0.5 P, minima; in a low state and during transition to high state narrower secondary minima have been observed (AM Her, AN UMa). The optical flux from AM Her consists of a blue, unpolarized component which is feebly phase dependent, and a red, partially polarized component which shows primary and secondary minima. Its infrared light curve in the K (=2.2 μ) band closely mimics that in the X-rays, i.e. only secondary minima are present (Jameson 1977; Neugebauer et al. 1978). Multicolor photometry of AM Her suggests that the red component of the optical flux is closely related to the source of its circular polarization (Priedhorsky and Krzemiński 1978).

Spectroscopically, in high state, AM Her-type objects show strong emission spectrum of H, He I, and He II with rapidly varying profiles and large velocity variations (Bond and Tifft 1974; Crampton and Cowley 1977; Greenstein et al. 1977). Periods derived from radial velocities are identical to those determined from other observations (Herbig 1960; Priedhorsky 1977; Cowley and Crampton 1977; Tapia 1977b). There is no clear-cut universal correspondence in phases between the radial velocity and light curves for different systems.

To find out more polars among systems of similar physical properties (i.e. nova-like, ex-novae, dwarf novae, accretion disc objects, etc.) observations of circular polarization in the V and I band accompanied by multicolor photometry have been undertaken during spring and summer 1977. Survey of more that 50 stars yielded negative results: no more AM Her-like objects have been found (Tapia et al. 1977). It is expected that more such objects will be discovered by the HEAO-A satellite.

Most of the models for polars (eg., Chanmugam and Wagner 1977; Stockman et al. 1978; Kruszewski 1978) envisage the low-mass (i.e. $\mathfrak{M}_1 + \mathfrak{M}_2 \lesssim 1.5\,\mathfrak{M}_\odot$) close binary systems powered by the accretion of matter supplied by the Roche lobe filling secondary component to the primary which is a degenerate dwarf with the magnetic field

https://doi.org/10.1017/S0252921100069426 Published online by Cambridge University Press

B $\gtrsim 10^8$ gauss. Because the magnetic field effectively channels the accretion flow, then accretional X-ray emission is produced, and cyclotron radiation is likely to be the dominant source of the optical and infrared light. Since field falls like the inverse cube of the primary's radius, r^{-3}, and the wavelength of cyclotron radiation, $\lambda_c(\mu) = 1.074/B_8$, where B_8 is the field in units of 10^8 gauss, an appreciable part of the flux in the optical region originates in the vicinity of the magnetic pole (-s) of the white dwarf. Primary is assumed to be an oblique rotator with the simple dipole field; this dipole may be displaced from the stellar center. Rotation of the primary is phase-locked into a synchronous orbit with the secondary. Modulation of the optical, infrared, and X-ray radiation and polarization is caused by rotation of the white dwarf, leading to wide light and X-ray minima. Linearly polarized light, created near one of the primary's magnetic poles, is emitted perpendicular to the magnetic field in a angular fanlike beam, while circularly polarized light propagates parallel to the field (Stockman 1978). Variations of the circular polarization result from changing orientation of the magnetic field lines with respect to the line of sight with additional distortions induced by one or two eclipses. The optical emission lines originate outside the Alfven radius around the magnetic primary. The phase relation between light and X-ray minima and binary conjunction depends thus on the polar direction of the white dwarf magnetic field.

It is a pleasure to acknowledge a support from the U.S. National Science Foundation, through the M. Sklodowska-Curie Fund, under Grant No. INT-76-80588.

REFERENCES:

Berg, R.A., and Duthie, J.G. 1977, Ap. J., 211, 859.

Bond, H.E., and Tifft, W.G. 1974, Pub. A.S.P., 86, 981.

Chanmugam, G., and Wagner, R.L. 1977, Ap. J. (Letters), 213, L13.

Cowley, A.P., and Crampton, D. 1977, Ap.J. (Letters), 212, L121.

Crampton, D., and Cowley, A.P. 1977, Pub. A.S.P., 89, 374.

Greenstein, J.L., Sargent, W.L.W., Boroson, T.A., and Boksenberg, A. 1977, preprint.

Hearn, D.R., and Richardson, J.A. 1977, Ap. J. (Letters), 213, L115.

Herbig, G.H. 1960, Ap. J., 132, 76.

Jameson, R.F. 1977, IAU Circ., No 3095.

Kruszewski, A. 1978, in Nonstationary Evolution of Close Binaries, 2nd Symposium of the Multilateral Cooperation between the Academies of Sciences of Socialist Countries, Warsaw, 20-25 June 1977, Anna Zytkow, ed.

Krzemiński, W., and Serkowski, K. 1977, Ap. J. (Letters), 216, L45.

Michalsky, J.J., Stokes, G.M., and Stokes, R.A. 1977, Ap. J.(Letters), 216, L35.

Mumford, G.S. 1977, Sky and Telescope, 54, 194.

Neugebauer, G., Werner, M.W., Priedhorsky, W.C., and Krzemiński, W. 1977, in preparation.

Olson, E.C. 1977, Ap. J., 215, 166.

Priedhorsky, W.C. 1977, Ap. J. (Letters), 212, L117.

Priedhorsky, W.C., and Krzemiński, W. 1978, Ap. J., 219.

Stockman, H.S. 1978, Ap. J., in press.

Stockman, H.S., Schmidt, G.D., Angel, J.R.P., Liebert, J., Tapia, S. and Beaver, E.A. 1978, Ap. J., in press.

Swank, J., Lampton, M., Boldt, E., Holt, S., and Serlemitsos, P. 1977, Ap. J. (Letters), 216, L71.

Szkody, P., and Brownlee, D.E. 1977, Ap. J. (Letters), 212, L113.

Tapia, S. 1977a, Ap. J. (Letters), 212, L125.
1977b, IAU Circ., No. 3049.
1977c, IAU Circ., No. 3054.

Tapia, S., Krzemiński, W., and Priedhorsky, W.C. 1977, preprint.

D I S C U S S I O N of paper by KRZEMIŃSKI:

GEYER: I might be wrong, but it may be that the variability of AN Uma was found at Bamberg or Sonneberg.

KRZEMIŃSKI: Light variability of AN UMa had been discovered in 1963 by C. Hoffmeister who thought that this was an RR Lyrae type object. AN UMa was subsequently studied by L. Meinunger and W. Wenzel who found long term variability. All this work has been done at the Sonneberg Observatory.

PRINGLE: I find it hard to believe that in these systems the white dwarf rotates synchronously with the binary period. It should be spun up by the accretion of material from the secondary. The magnetic coupling does not seem strong enough to ensure synchronous rotation.

KRZEMIŃSKI: You are right that accretion of mass onto the magnetic white dwarf should quickly spin up the white dwarf unless there exists an opposing torque to maintain synchronism. I did not calculate the magnetic coupling between component stars. However, new data on circular polarization with 30 sec. time resolution obtained in the summer of 1977 by S. Tapia, W. Priedhorsky and myself, do not show periodicities on a time scale of minutes or more.

https://doi.org/10.1017/S0252921100069426 Published online by Cambridge University Press