AD-A273 546

JMENTATION PAGE

Form Approved
OMB No. 0704-0188

(2)

2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
30 Sep 93	Annual - 1 Oct 92 - 30 Sep 93

4. TITLE AND SUBTITLE

CHROMOSPHERIC ACTIVITY IN AGOL BINARIES

5. FUNDING NUMBERS

F4962u-92-J-0024
2311
AS
61102F

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

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110 Duncan Avenue, Suite B115
Bolling AFB DC 20332-0001
Dr Radoski

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release
distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The PI continued her study of magnetic activity on the cool components in short-period Algol-type binaries. The rapid rotators typically display enhanced magnetic activity, variations in the brightness of the cool secondary, and changes in the orbital period of the binary which can be linked to changes in the polarity of the magnetic field of the cool star. The PI has compiled observational evidence of magnetic activity in 15 Algol binaries and found that there is a 12 ck of information on the cool stars in these binaries. The systems chosen had orbital periods typically less than 6 days since short-period rapid rotators are more likely to display magnetic activity than their long-period counterparts. The survey showed that although six of the chosen boundaries displayed evidence of variations in the brightness of the secondary, Persei is the only Algol binary for which there was strong evidence of starspot activity.

14. SUBJECT TERMS

15. NUMBER OF PAGES
4

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
(U)	(U)	(U)	(UL)

Annual Technical Report for AFOSR Grant F49620-92-J-0024

Principal Investigator: Mercedes T. Richards, University of Virginia

Project Title: Chromospheric Activity in Algol Binaries

Project Period: 10-01-91 to 09-30-94

Report Period: 10-01-92 to 09-30-93

Current Date: September 27, 1993

I. Summary of Scientific Progress

During the past year, the P.I. continued her study of magnetic activity on the cool components in short-period ($P < 6$ days) Algol-type binaries. These rapid rotators typically display enhanced magnetic activity in the form of Ca II H and K emission, hydrogen Balmer line emission, x-ray and radio flares, variations in the brightness of the cool secondary, and changes on the order of $\sim 10^{-5}P$ in the orbital period of the binary which can be linked to changes in the polarity of the magnetic field of the cool star. This activity is similar to that of the doubly magnetically active RS CVn binaries (Richards 1990 and references therein). The P.I. has compiled observational evidence of magnetic activity in 15 Algol binaries and found that there is a paucity of information on the cool stars in these binaries (Richards 1992a; Richards and Albright 1993a,b). The systems chosen had orbital periods typically less than 6 days since short-period rapid rotators are more likely to display magnetic activity than their long-period counterparts. The properties examined included changes in the orbital period of the binary, possible detections of Ca II H and K emission and hydrogen Balmer line emission, the x-ray luminosity determined from x-ray flares, detections of radio emission, and evidence of variations in the brightness of the cool secondary which are linked to motions of starspots on the cool secondary star (starspot activity). The survey showed that although six of the chosen binaries displayed evidence of variations in the brightness of the secondary, β Persei is the only Algol binary for which there was strong evidence of starspot activity. In this case, the evidence was found by the P.I. (Richards 1990) from a study of the only complete 1.2 μm light curves of that system that were obtained from 1960 to 1963.

The P.I.'s work on magnetic activity in the Algols was recently described in a new book titled "The Realm of Interacting Binary Stars," 1993, edited by J. Sahade, G. E. McCluskey, and Y. Kondo (Dordrecht: Kluwer). The need for new infrared photometry of the Algols was emphasized in this book, as has been done by the P.I. for several years. The limiting factors are the large amounts of observing time required on an infrared photometer or spectrograph (Richards and Albright 1993b). Moreover, any evidence of magnetic activity would appear as weak features in the light curve or spectrum.

As part of a new observing campaign to obtain infrared light curves, the P.I. and Ph.D. student Mr. G. E. Albright applied for time to use the infrared photometers on the 1.3m telescope at Kitt Peak National Observatory in Tucson, Arizona, and the 1.5m Carlos Sanchez Telescope at Tenerife in the Canary Islands. They had hoped to start observing

in Spring 1993 but the KPNO telescope was oversubscribed for the Spring session, and the Otto detector used with the infrared photometer was later permanently discontinued. The Carlos Sanchez Telescope was shut down for unplanned maintenance until Fall 1993, but they will observe with this telescope for the first time during 10 nights February 1994. They expect to obtain infrared light curves of up to 15 short period Algols beginning with β Per, TX UMa, RW Tau, δ Lib, and U CrB. This work is part of Mr. Albright's Ph.D. thesis research. Dr. R. M. Robb, University of Victoria, Canada, is also collaborating with the P.I. on a project to monitor I-band (8800 Å) photometry of short-period Algols to detect starspot activity in these systems. This project began in July 1993.

Spectroscopic evidence of magnetic activity has been difficult to find. In the RS CVn binaries, whose stellar components have comparable brightnesses, the usual magnetic indicators are the Hα and Ca II H and K lines. In this latter case, there is normally no mass transfer in the system and so all of the Hα emission is linked to chromospheric activity. However in Algol binaries, both Hα emission and absorption are associated with the dominant mass transfer process, and not to chromospheric activity. The P.I. showed that although the relative contribution of chromospheric activity to the Hα line was small ($\sim$ 10%), the structure of the magnetic field of the secondary could influence the gas flows in the binary (Richards and Albright 1993a).

The P.I. has continued her investigation of the relative spectroscopic contribution of the chromosphere of the cool Algol secondaries. In the study of β Persei, the P.I. (Richards 1992b; 1993) assumed that the chromospheric Hα emission from the K2 IV secondary would be insignificant compared to that from the circumstellar material associated with the B8 V primary. However, some of the Hα "difference profiles" profiles seen during primary eclipse could have been produced by either a transient accretion disk or a chromospheric flare (Richards 1992b), even though the disk explanation is more likely. Since October 1992, the P.I. and Albright have obtained over 1500 Hα spectra of nine short-period Algols at positions around the entire orbit of each system (Richards and Albright 1993c, Albright and Richards 1993b). The observations were made at the National Solar observatory (NSO) and Kitt Peak National Observatory (KPNO) in Tucson, Arizona. To date, they have not found any convincing evidence of flares at this wavelength. In addition, they obtained some spectra of the Ca II H and K lines but found no evidence of emission, indicative of magnetic activity. In July, Dr. B. W. Bopp, University of Toledo, assisted in a pilot campaign to examine the Ca II infrared triplet (8500 – 8700 Å). As with the photometry, the relative contribution of the cool secondary is at its highest in the infrared part of the spectrum, and we expect to find evidence of emission or excess absorption in the Ca II lines at these wavelengths.

The P.I. and Albright have applied for time to use the 0.9m Coudé Feed Telescope at KPNO to observe the Ca II infrared triplet at high dispersion and high signal-to-noise ($\sim$ 400) in a selected group of short-period Algols. These Ca II lines are very sensitive to magnetic activity and are absent or weak in the spectrum of the non-magnetically active hotter primary companion in Algol binaries. This survey will indicate the relative contribution of the magnetic field of the secondary. In addition, the P.I., Albright, and Dr. E. F. Guinan, Villanova University, have submitted a proposal to the NASA IUE Guest Observer Program to obtain ultraviolet spectra of 8 Algol-type binaries. A complementary proposal was submitted to KPNO to obtain "Simultaneous Balmer-line and IUE

Spectroscopy of Short-Period Algols." The IUE spectra should arise primarily from the mass transfer process, but the Hα spectra could also arise from the chromosphere of the secondary. The relationship between the IUE and Hα spectra should therefore shed light on the relative contribution of the chromosphere.

Finally, the sources of Hα emission can also be distinguished by using the technique of Doppler Tomography (or imaging). The P.I. and former undergraduate student Mr. R. Jones used this technique and found that the source of the Hα emission in one system, β Per, was concentrated near the inner Lagrangian point between the two stars (Jones and Richards 1992). However, if the data are separated into symmetric halves or quarters and analyzed separately, the Doppler images show several sources of the Hα emission. The strongest source is found along the gas stream between the two stars which is due to the mass transfer process. Weaker sources are in a disk around the mass gaining star, and in a region close to the cool secondary (Richards, Jones, and Swain 1993). Dr. S. Jankov of the Institut D'Astrophysique Spatiale, University of Paris XI, France, has applied for a Hubble Postdoctoral Fellowship to work with the P.I. to study magnetic activity in interacting binary stars. Dr. Jankov has extensive experience with tomographic imaging of late-type single and binary stars.

Undergraduates Ms. L. Bowles and Ms. M. Lugo assisted the P.I. this Summer in a study of the shape of the Hα line profile due to chromospheric activity and mass transfer, and identified the observatories (public and private) which own infrared photometers and spectrographs. Ms. M. Swain, graduate student, helped with the Doppler imaging.

General References

Jones, R. D., and Richards, M. T. 1992, *Bull. Am. Astron. Soc.*, **24**, 768

Richards, M. T. 1990, *Astrophys. J.*, **350**, 372

Richards, M. T. 1992b, *Astrophys. J.*, **387**, 329

Richards, M. T., Jones, R. D., and Swain, M. 1993, in preparation

II. Publications by AFOSR-Sponsored Principal Investigators

Publications in Peer-reviewed Professional Journals

1. Richards, M. T. and Albright, G. E. 1993a, "Evidence of magnetic activity in short-period Algol binaries," *Astrophysical Journal Supplement*, **88**, 199 – 204
2. Richards, M. T. 1993, "Circumstellar material in Algol: A study of the Balmer line profiles," *Astrophysical Journal Supplement*, **86**, 255 – 291
3. Albright, G. E. and Richards, M. T. 1993a, "Circumstellar material in TX Ursae Majoris," *Astrophysical Journal*, **414**, 830 – 845

Other Publications

4. Richards, M. T. 1992a, "Magnetic activity in Algol-type binaries," in *Cool Stars, Stellar Systems and the Sun*, ed. M. Giampapa and J. Bookbinder, ASP Conference Series **26**, 367 – 369

5. Richards, M. T. and Albright, G. E. 1993b, "Facilities for Infrared Photometry and Spectroscopy of Short-Period Algols," in Optical Astronomy From The Earth and Moon, ed. D. Pyper Smith and R. Angione, ASP Conference Series (San Francisco: ASP), in press (4 pages)
6. Richards, M. T. and Albright, G. E. 1993c, "Full-Orbit Spectroscopy of Nine Short-Period Algols," in Interacting Binary Stars, ed. A. Shafter, ASP Conference Series (San Francisco: ASP), in press (4 pages)
7. Albright, G. E. and Richards, M. T. 1993b, "Evidence of Mass Transfer in TX UMa," in Interacting Binary Stars, ed. A. Shafter, ASP Conference Series (San Francisco: ASP), in press (4 pages)

III. Observing awards

National Solar Observatory (NSO), National Optical Astronomical Observatories (NOAO), observing award of 7 nights on the 1.5m McMath telescope to study "Full-orbit Hα spectroscopy of short-period Algol-type binaries" (with G. E. Albright) in October 1992.

National Solar Observatory observing award of 24 nights on the 1.5m McMath telescope to study "Full-orbit Hα spectroscopy of short-period Algol-type binaries" (with Albright) in March and April 1993.

Kitt Peak National Observatory (KPNO, NOAO) observing award of 12 nights on the 0.9m Coudé Feed to study "Balmer-line and Ca II spectroscopy of Short-period Algols," (with Albright) in April and May 1993.

Teide Observatory, Astrophysical Institute of the Canaries (CAT) observing award of 10 nights to use the infrared photometry proposal on the 1.5m Carlos Sanchez telescope in Tenerife, Spain, to study "Starspot activity on Algol secondaries" (with Albright) in February 1994.

Pending:

Kitt Peak National Observatory proposal to observe with the 0.9m Coudé Feed to study "Simultaneous Balmer-line and IUE Spectroscopy of Short-period Algols," submitted September 1993.

NASA International Ultraviolet Explorer (IUE) proposal to observe with the IUE satellite SWP and LWP high dispersion cameras to study the "Dynamics and Physical Properties of Accretion Regions in Algols," submitted September 1993.

IV. Number of Additional researchers working with the P.I.

Faculty: 4 (including P.I.)
Postdocs: 0
Graduate Students: 2
Other (Undergraduate students): 3

V. Professional Honors

The P.I. was promoted to Associate Professor, with tenure, at the University of Virginia in September 1993.