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# BY DRACONIS IS A TRIPLE STAR SYSTEM

B. ZUCKERMAN,[1] RICHARD A. WEBB, E. E. BECKLIN,[1] IAN S. MCLEAN, AND MATTHEW A. MALKAN

UCLA Division of Astronomy and Astrophysics, Los Angeles, California 90095-1562
Electronic mail: ben@astro.ucla.edu

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## ABSTRACT

We have discovered that the nearby double-lined spectroscopic binary BY Draconis has a proper motion companion 17 arcsec to the northeast. Photometric measurements indicate that the companion is an M5 dwarf lying on the main sequence. Studies of this third component could prove valuable in determining the evolutionary state of the system. © *1997 American Astronomical Society.* [S0004-6256(97)01108-4]

## 1. INTRODUCTION

BY Draconis (HDE 234677=Gleise 719=PPM 36705) is the prototype of a class of late-type, flare stars characterized by periodic photometric variability due to star spots, rapid stellar rotation and emission lines of Ca II H and K. A large fraction ($>85\%$) of BY Dra stars are in short period binary orbits (Bopp *et al.* 1980) including BY Dra itself which is one of only nine known M dwarf, double-lined, spectroscopic binaries (Harlow 1996). We now show that the BY Dra system has a third component, an M5 V star (hereafter BY Dra C), located 17″ to the northeast of the primary. This well-studied system at a distance of 14.1 pc (Gliese 1969) has over 300 references listed in the SIMBAD database, so it is unclear why BY Dra C has not been previously identified given its $V$ magnitude of $\sim 16$.

## 2. OBSERVATIONS

BY Dra C was discovered in $J$, $H$, and $K$ images obtained with the IRCAM camera (McLean 1987) on the UKIRT in 1988 May. In 1989 July, we measured the IRCAM scale at $K$ to be 0.″624 per pixel. The scales at $J$ and $H$ differ by a few percent. Additional data were obtained in 1988 July with an InSb photometer (RC2) on the IRTF. We used a focal plane aperture of 3.5 arcsec (full width at half maximum power). The secondary mirror was chopped at 7 Hz between an infrared star and a reference position offset in declination by 20″ while the telescope was nodded every 10 s so that the star appeared first in one beam and then in the other. The $J$, $H$, $K$, and $L$ magnitudes listed in Table 1 are from the IRTF.

Although the chance that a background infrared source as bright as C would be found as close as 17″ to BY Dra is tiny, to be sure that there is a physical association, we measured the relative positions of BY Dra and C in 1995 June with the twin channel UCLA infrared "Gemini" camera (McLean *et al.* 1994) on the Lick Observatory 3 m telescope. So as not to badly saturate the detector, we used narrowband filters centered on an Fe II line at 1.64 $\mu$m and on an $H_2$ line at 2.122 $\mu$m. The pixel scales in the Fe II and $H_2$ images are about 0.″69 and 0.″67 per pixel, respectively (Casement 1996, private communication).

$I$-band images were obtained in 1988 May on the Shane 3 m telescope at Lick observatory with a $(800)^2$ CCD at 0.″72 per pixel resolution. $B$, $R$, and $I$ band images were also acquired in 1995 September on the Lick Nickel 1 m with a binned $(2048)^2$ CCD detector yielding a resolution of 0.″36 per pixel. The filters are those of the Johnson-Cousins photometric system as described in Bessel (1990) and the data were calibrated using standards of Landolt (1983). The $B$, $R$, and $I$ photometry from the 1995 September run is given in Table 1.

## 3. DISCUSSION

### *3.1 Proper Motion*

The proper motion of BY Dra listed in the PPM Star Catalog (Röser & Bastian 1991) is 0.″189 E & 0.″324 S per year with an uncertainty of 0.″004 per year in each direction. This large proper motion is easily discernable over relatively short time scales allowing confirmation of the common proper motion of BY Dra C. The best measurement of the proper motion of BY Dra C is provided by two $I$ band CCD images taken in 1988 May and 1995 September. Though the primary (BY Dra A+B) is heavily saturated in these images thus preventing an accurate measure of the separation to BY Dra C, the proper motion of C can be accurately determined by comparison to field objects. The fit residuals for each of the six field objects used were small, indicating that these field stars have little if any measurable proper motion of their own. The derived annual proper motion for BY Dra C from the $I$ band images is 0.″15±0.″02 E and 0.″33±0.″02 S, in reasonable agreement with the proper motion of the primary.

Proper motion can also be determined from the infrared images although the errors are larger. In 1995 June we mea-

[1]Visiting Astronomer at the Infrared Telescope Facility, which is operated by the University of Hawaii under contract to the National Aeronautics and Space Administration.

TABLE 1. Triple star BY Draconis.

| Star | ΔRA | ΔDec | B | R | I | J | H | K | L | $M_I$ | $M_K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BY Dra (A+B) | – | – | – | – | – | 5.68 | 5.10 | 4.94 | 4.87 | – | 4.20 |
| BY Dra C | +11″9 | +11″8 | 17.32 | 14.29 | 12.34 | 10.50 | 9.89 | 9.57 | 9.25 | 11.61 | 8.83 |

Note. — The separations in RA & Dec are epoch 1995.5; C is located to the northeast of AB. The B, R and I magnitudes are on the Johnson-Cousins system defined by Bessel (1990) and calibrated using the standards of Landolt (1983). The V filter measurement was lost due to an equipment problem; V ≈ 15.75 is extrapolated from the other colors. The J, H, K & L magnitudes are on the IRTF photometric system and the J magnitudes are based on a red standard (Gliese 811.1). If a blue standard (an A-type star) is used, then the J magnitudes are fainter by 0.08 magnitudes. The photometric uncertainties are dominated by systematic errors which are estimated to be ~ 0.05 magnitudes in both the optical and the infrared. $M_I$ & $M_K$ are the absolute magnitudes in I & K respectively.

sured an offset from the primary to C of 11.″87 E and 11.″83 N with Gemini assuming the detector rows and columns lie EW-NS. This can be compared to the IRCAM images in 1988 May where, assuming a scale of 0.″624/pixel, we derive an offset of 11.″3±0.″2 E and 11.″8±0.″2 N. Using the published proper motion for the primary, this corresponds to an annual proper motion of C of 0.″11±0.″03 E and 0.″32 ±0.″03 S. This value agrees within the errors with the proper motion determined in the *I* band, but disagrees with the published R.A. proper motion of the primary by 2.5$\sigma$. However, these errors are statistical only and do not include any estimates of potential systematic errors. Some fraction of the discrepancy in R.A. could be a real difference in the proper motion between the primary and C. Given a favorable projection, the orbital motion of C could be more than 0.″03/year. This would completely account for the discrepancy between the PPM and our *I* images and would bring the infrared data to within 1.5$\sigma$. It will be interesting to see if this small proper motion difference plays out in the years to come. Together, all of our proper motion data leave little doubt that BY Dra C shares a common proper motion with the spectroscopic binary primary.

### *3.2 Classification and Age of BY Dra*

Evolutionary state may play a key role in distinguishing the class of BY Dra stars from other types of active flare stars such as RS CVn's and in understanding the physical mechanisms causing the BY Dra syndrome (Eker 1992). BY Dra stars and in particular the proto-type show several indicators normally suggestive of youth: rapid rotation, photometric variability due to star spots, high x-ray luminosity (Johnson 1983), strong chromospheric activity and an eccentric, yet short-period orbit. However, the relationship between these characteristics and age is confused by the mechanism causing the BY Dra syndrome, and attempts to estimate the age of BY Dra have been inconclusive. Models of Zahn & Bouchet (1989) show that binary orbits of ≲8 days should circularize very quickly and observational work of Duquennoy *et al.* (1992) show that by the age of the Pleiades (~$10^8$ yr), binaries with periods as long as 7 days have circularized. The highly eccentric orbit of BY Dra A+B ($e$ ~ 0.3) with a period of only ~6 days suggests that BY Dra may be quite young, though the exact timescales for circularization remain an issue of debate. The third component is too far separated to have a significant effect on the circularization of the spectroscopic system (Mazeh 1990). The assumption of youth is further supported by Vogt & Fekel (1979) who derive a radius for the dM0e primary of 1.4±0.5 $R_\odot$ and argue that it is a young star still contracting towards the main sequence. However, this measurement is dependent on an accurate determination of $v \sin i$, which may be distorted by larger than normal macroturbulence which might be expected in this chromospherically active star. A large but not unreasonable increase in the macroturbulence could put the derived radius of the primary in agreement with the canonical main-sequence value of ~0.7 $R_\odot$ (Lucke & Mayor 1980).

Our photometry of BY Dra C is given in Table 1. Based on Table 3 of Bessel (1991), BY Dra C appears in every respect to be a normal M5 dwarf star. Our discovery of component C, could prove valuable in sorting out the various theories relating to the age of BY Dra. The placement of BY Dra C on the theoretical isochrones of Stringfellow (1991) suggest a mass of ~0.13 $\mathscr{M}_\odot$ at an age of ~$3\times10^8$ y or older since the isochrones converge to the main sequence at a few $\times10^8$ y. The tracks also preclude the possibility that BY Dra C is a brown dwarf; a very young brown dwarf could match the luminosity of C but would be significantly redder in $I-K$ color. Future spectroscopic studies of BY Dra C should prove to be a more reliable indicator of the system age as C is not affected by tidal interaction and the "BY Dra syndrome" which may distort traditional indicators of youth in the primary system.

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