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A Search for Hot Subdwarf Companions to Rapidly-Rotating Early B Stars

Geraldine J. Peters[1], Douglas R. Gies[2], Luqian Wang[2] and Erika D. Grundstrom[3]

[1]Space Sciences Center & Dept. of Physics & Astronomy, University of Southern California, 835 W. 37th St., Los Angeles, CA 90089-1341, USA
email: gjpeters@mucen.usc.edu

[2]CHARA & Dept. of Physics & Astronomy, Georgia State University, Atlanta, GA 30302-5060, USA

[3]Dept. of Physics & Astronomy, Vanderbilt University, Nashville, TN 37206, USA

Abstract. We continue to search for O-type subdwarf companions in binary systems containing Be primaries. We were not able to confirm an sdO object in π Aqr and HR 2142, even though optical and UV observations suggest their presence. Some possible reasons are enumerated.

Keywords. (stars:) binaries: close, stars: emission-line, Be, (stars:) subdwarfs, (stars:) circumstellar matter, stars: individual (π Aqr, HR 2142)

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1. Motivation and method

The rapid rotation seen in some early B stars appears to be the result of angular momentum gain during a prior episode of binary mass transfer where the mass donor is now a sdO object or neutron star. *But just how common is this scenario?* An sdO companion has now been confirmed in three well-known Be stars: ϕ Per (Gies *et al.* 1998), FY CMa (Peters *et al.* 2008), and 59 Cyg (Peters *et al.* 2013). We continue to search for sdO companions by performing a similar analysis of *IUE* HIRES and optical Hα spectra of other bright binary Be stars for which there is evidence that the secondary might be an O subdwarf. Our most recent efforts focus on π Aqr and HR 2142. The method is fully described in Peters *et al.* (2008). Our first task is to find a good set of orbital elements. We look for the signature of the suspected sdO object by cross-correlating the *IUE* spectra with either a template generated from the NLTE model atmospheres of Lanz & Hubeny (2003) or a standard sdO object. We then employ a Doppler tomography algorithm (Bagnuolo *et al.* 1994) to reconstruct the spectrum of the secondary.

2. π Aquarii

π Aqr (B 1 III-IVe, $P = 84.1$ d) is a well known bright Be star that temporarily lost its circumstellar (CS) disk in the mid-1990s. We employed Hα spectra from the Coudé Feed Telescope at the Kitt Peak National Observatory(KPNO), the Be Star Spectra Database (http://basebe.obspm.fr/basebe/), and 22 images from *IUE* to determine good orbital parameters for the primary. Zharikov *et al.* (2013) found that excess Hα emission is located on the side of the disk facing the secondary. Since this is seen in other sdO objects, we searched for a hot companion in the FUV using cross-correlation templates for BD+28 4211 ($T = 82$ kK), BD+75 325 ($T = 53$ kK), and HD 49798 ($T = 48$ kK), but did not find a signature of the secondary.

3. HR 2142

HR 2142 (B 1.5 IV-Vnne, $P = 80.86$ d) has been known as a binary since the early 1970s (Peters 1972, 1983) but the spectrum of the secondary has never been detected. The system displays a two-component shell phase centered on the inferior conjunction of the secondary. The shell lines are red-shifted prior to conjunction, but violet-shifted afterwards. The behavior of the CS material has suggested that HR 2142 is an Algol-type interacting binary undergoing mass transfer (Peters & Gies 2002, Peters 2001, 1983). Several researchers have searched for the secondary in the IR without success, which has led to the suspicion that it is an O subdwarf. We determined a new radial velocity curve for the primary in HR 2142 based upon the combination of 50 measurements from Peters (1983), 87 measurements from the *IUE* cross-correlation functions, 129 measurements of the Hα wings from the KPNO spectra, and BeSS spectra. With a good set of orbital elements for the primary in hand, we searched for an sdO object using our cross-correlation technique, but could not confirm the presence of an O-type subdwarf.

4. Why are there no detections?

Using the same method and software that we employed to detect the subdwarfs in ϕ Per, FY CMa, and 59 Cyg, we did not find an sdO secondary in the π Aqr and HR 2142 systems, even though the behavior of the CS structures in them suggests that they are similar binaries. Possibly the subdwarfs are cooler or smaller and contribute less than 4% of the light in the FUV, which is about the limit of our ability to detect an sdO object. The lines of the secondary may be broad, or the object immersed in a dense wind. The shell lines in HR 2142 could be the result of a density enhancement due to a shock interface where the wind from the subdwarf collides with the primary's massive CS disk. Another possibility is that the secondary creates a one-armed spiral wake in the disk similar to that predicted for forming planets in a protoplanetary disk (Bate *et al.* 2003, Ogilvie & Lubow 2002). This scenario will be discussed in a forthcoming paper.

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