Survey of Giants with Exoplanets

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1. Abstract

We have searched for giants with exoplanets since 2003. Almost 700 targets, mostly late-type giants, have been observed with Bohyunsan Observatory Echelle Spectrograph (BOES) at the 1.8 m telescope of Bohyunsan Optical Astronomy Observatory (BOAO) in Korea. We have so far discovered 35 exoplanet systems, some of which are one of the largest stars with an exoplanet. The most recent target we have observed and analyzed is HD 81817, which is known as a hybrid star. We show that HD 81817 is not accompanied by a white dwarf, but by a substellar companion of 27.6 M_{Jup}.

2. Introduction

- Over 16 years, we, K-EXO(Korea-EXOplanet group), have observed almost 700 targets and found 35 exoplanetary systems and over 20 candidate exoplanetary systems using radial velocity (RV) method. Table 1 shows our programs and output data since 2003. The current 'Search for Exoplanets around Northern circumpolar Stars II (SENS II)' program (Lee et al. 2015) are expected to discover more than 20 exoplanetary systems.

Table 1. K-EXO exoplanet survey programs

	Program	Duration	Sample	Exoplanets	Candidates
1	K giant	2003-2018	~50	11	1
2	F,M giant	2003-2019	~20	0	1
3	G giant	2005-?	188	2	~10
4	K dwarf	2008-2013	40	2	0
5	Binary	2010-2019	9	0	1
6	SENS I	2010-2018	~220	20	~10
7	SENS II	2017-2021	200	0	?
Total			700<	35	~23

3. Observation

Figure 1. BOAO in Mt. Bohyunsan, Youngcheon, Korea.

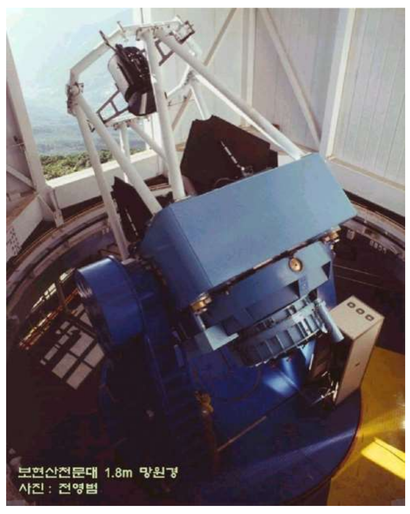
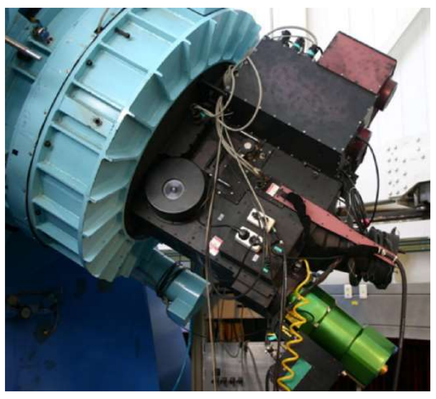


Figure 2. 1.8 m telescope at BOAO.

- We observed our targets using 1.8 m telescope which is Ritchey-Chretien reflector with f/8 (Figures 1 and 2). We used Bohyunsan Observatory Echelle Spectrograph (BOES, Kim et al. 2007) for our programs.



- The fiber-fed BOES covers a wide wavelength range from 3500 Å to 10 500 Å in one exposure.
- The BOES has resolving power (R) of 30k to 90k depends on the fiber diameter.
- For precise RV measurements, An Iodine (I2) cell and RVI2CELL code (Han et al. 2007) were used.
- We have monitored τ Ceti as a standard star since 2003. The long-term RV accuracy of BOES is ~ 7.6 m s^{-1}.

Figure 3. Cassegrain Interface Module of BOES attached to 1.8 m telescope.

4. Target - HD 81817, a hybrid star

- Hybrid stars have both emission features in UV or even in X-ray (Ayres 2005) and cool stellar winds features. They were first discovered in 1980 (Hartmann et al. 1980).
- HD 81817 was suggested as a hybrid star by Reimers (1984) based on the faint UV continuum from IUE spectra. Reimers suggested that the origin of these UV emission features are caused by a WD companion with a temperature of 20,000 K.
- We have observed HD 81817 since 2003 and have 84 high resolution (R = 90,000) spectra as part of our program that searches for exoplanets around K giants using radial velocity method.

4.1. RV measurements and analysis for HD 81817

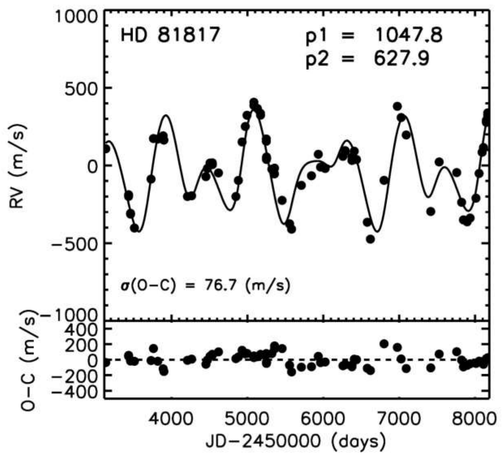


Figure 4. RV measurements for HD 81817. Solid line shows the Keplerian orbital fit.

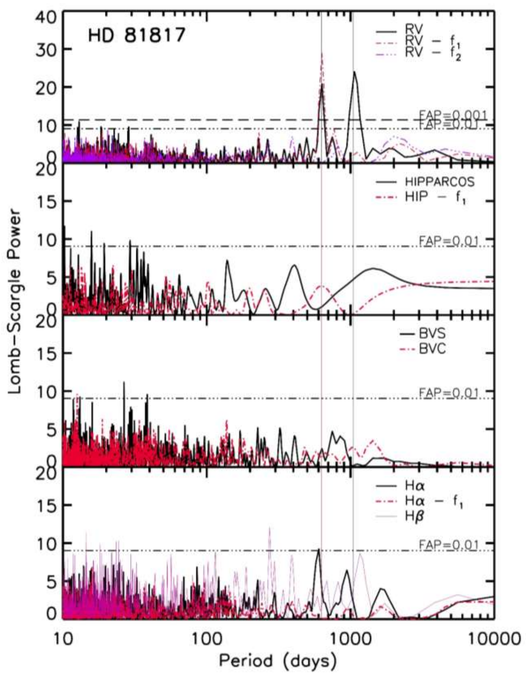


Figure 5. Lomb-Scargle periodogram of RV measurements, HIPPARCOS, bisectors and Hα and Hβ EW measurements (from top to bottom) for HD 81817. Vertical solid lines are the periods of 1047.8 days and 627.9 days.

- We found two significant periods in RV variations of HD 81817, FAP of the period of 1047.8 days is about 9 x 10^{-11} and that of 627.9 days is about 2.5 x 10^{-9} (Figure 4 and top panel of Figure 5).
- Lomb-Scargle periodograms of photometric and bisectors variations do not show any significant period (second and third panels of Figure 5). On the other hand, variations of Hα EW shows a significant period around 600 days with a FAP of 0.01 (bottom panel of Figure 5).
- There are no significant periods of variations in other parameters similar to that of RV period of 1047.8 days.
- Hα EW variations of the period 600 days may be related to the secondary period of RV variations, 627.9 days.
- We conclude that the period of 1047.8 days in RV variations is caused by a substellar companion with a minimum mass of 27.6 M_{Jup}, a semi-major axis of 3.3 AU, and an eccentricity of 0.17, assuming the stellar mass of 4.3 $M_{\odot}$. This mass puts HD 81817b in the brown dwarf desert.

4.2. White dwarf companion in HD 81817?

- According to our RV measurements, the observed amplitudes of two RV variation periods were around 200 m s^{-1}, significantly lower than those of Doppler effect of a typical WD companion which will produce a few kilometer scale RV variations.
- We consider the possibility of a very low inclination. Assuming a 0.7 $M_{\odot}$ WD companion, the inclination of this system should be about 2° or less to be compatible with the amplitudes of our RV measurements. In this case, however, the real rotational velocity of HD 81817 will be 130 km s^{-1}. For the spectral type (K3 III) and radius (83.8 R⊙) of HD 81817, such high rotational velocity is unlikely because these spectral type stars have much lower rotational velocities, typically less than 10 km s^{-1}.
- We reanalyzed the IUE spectra and found that the apparent UV continuum can be explained by superposition of many unresolved emission lines stemming from extended chromosphere or stellar wind.
- Therefore, we conclude that HD 81817 is not accompanied by a WD, and UV features are likely to be caused by extended chromosphere or stellar wind.

6. Summary

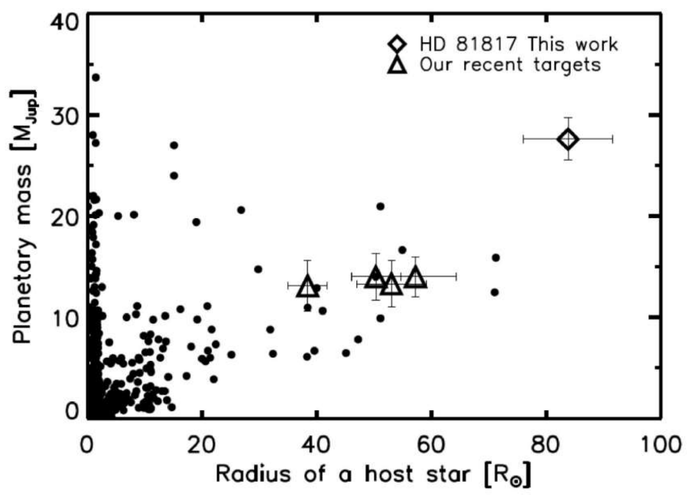


Figure 6. Distribution of the mass of planetary companions versus stellar radii of some of the exoplanetary systems we found (triangles and a diamond).

- K-EXO have actively searched for exoplanetary systems over 16 years using BOES at BOAO. We found 35 exoplanetary systems and more than 20 candidate exoplanetary systems so far. Most of our targets are late-type giants. Host stars of some of the exoplanetary systems we have found have largest radii than other planet-host stars. Our surveys will help us understand the late-stage evolution of the exoplanetary systems.
- Our survey also allows us to understand the pulsational, rotational, surface activities, and binary nature of the late-type giant stars.

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