Revista Mexicana de Astronomía y Astrofísica
Universidad Nacional Autónoma de México
rmaa@astroscu.unam.mx
ISSN (Versión impresa): 0185-1101
MÉXICO

2006
M. C. Radiszcz / R. A. Méndez
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Revista Mexicana de Astronomía y Astrofísica, enero, volumen 25
Universidad Nacional Autónoma de México
Distrito Federal, México
pp. 45-46

RevMexAA (Serie de Conferencias), **25**, 45–46 (2006)

SUBSTELLAR BINARITY AMONG NEARBY WHITE DWARFS

M. C. Radiszcz[1] and R. A. Méndez[1]

RESUMEN

Usando una muestra de estrellas enanas blancas (WDs) de la vecindad solar, compiladas por Holberg et al. (2002), proponemos un estudio de posibles objetos sub-estelares asociados a ellas como binarias. Pequeños contrastes en bandas del cercano infrarrojo entre WDs y objetos sub-estelares nos ayudan a detectar emisiones térmicas provenientes de los objetos sub-estelares más calientes. Las observaciones se realizarán en Paranal. Para pares anchos se usará el sistema de óptica adaptativa VLT+NACO, mientras que para pares cerrados se usará interferometría. Este proyecto es parte de una tesis de doctorado y los datos se obtendrán haciendo uso del tiempo chileno reservado en dichos telescopios.

ABSTRACT

Using the sample of nearby white dwarfs (WDs) compiled by Holberg et al. (2002) we intend to study the sub-stellar binarity among WDs in the solar vicinity. A smaller contrast in near infrared bands between WDs and sub-stellar objects helps us to detect thermal emission from the hottest sub-stellar objects. Observations will be carried out in Paranal. For wider pairs, an adaptive optic system provided by VLT+NACO will be used, as well as interferometry for close companions. This project is part of a PhD thesis and the data will be collected during Chilean telescope time.

Key Words: **ASTROMETRY — BINARIES: CLOSE — STARS: LOW-MASS, BROWN DWARFS — STARS: LUMINOSITY FUNCTION — WHITE DWARFS**

1. INTRODUCTION

White dwarfs (WDs) correspond to the final evolutionary stage of MS stars with masses $\lesssim$ 8-9 $M_{\odot}$. These stars are not usually isolated, at least 50% are in binary systems and, in the last years, more than 140 giant planets have been found around FGKM solar type stars. Therefore, it is likely that some WD progenitors have a low mass companion or a giant planet. Our Sun will undergo changes while evolving to a WD, these changes will affect the Solar System completely. Thus, it is very interesting to study how the RGB and AGB phases of the primary star affect its companion.

The evolution of a main-sequence binary system depends on whether the primary star overflows its Roche lobe during its RGB or AGB phases. This overflow determines a critical initial orbital separation $a_{crit} \approx 5 - 50AU$. At this point, the primary fills its Roche lobe while evolving to RGB or AGB and mass transfer happens more likely producing a dynamically unstable system, when a common envelope phase is developed (Iben & Livio 1993). As a result, either the stars coalesce or the heated envelope is dissipated, leaving a WD-MS close binary system with circularized orbits. On the other hand, if the separation is greater than the critical value, the separation increases as the primary loses mass in its PNe phase.

The evolution of sub-stellar objects (brown dwarf [BD] or giant planet) embedded in the envelope of an AGB star was investigated by Livio & Soker (1984). They found that below a critical value for the mass of the secondary $\sim 0.02 M_{\odot}$, it will evaporate while it spirals-down around the AGB primary star. If the secondary exceeds the mass limit, it can accrete mass (up to ∼90 % of its final mass, according to Soker et al. 1984) from the envelope, becoming a low-mass star (time-scale $\sim 10^3$-10^4 yr). In this scenario, a short enough initial orbital separation result in either a short-period system with a separation of a few solar radius, or in a merge between the secondary and the core of the AGB star (Livio & Soker 1984). When the initial orbital separation is larger, and no common envelope is developed, the secondary increases its separation from the AGB star due to mass loss from the primary and the pair turns into a wider optical system.

In this way, it could be possible that sub-stellar object survive the post-main sequence phase of its primary. But, there is no direct evidence for this yet.

[1]Departamento de Astronomía, U. de Chile, Santiago, Chile.

2. DETECTING SUB-STELLAR OBJECTS AROUND NEARBY WDS

To detect a sub-stellar object around a WD, radial velocities can be the first method to be considered, since it gives good results in detecting close and massive planets around late type MS stars. However, the lack of metal lines and the strongly broadened lines in WDs makes impossible to measure radial velocities with the necessary precision (< 1 km s^{-1}).

There is also the possibility for the WD to be eclipsed by its sub-stellar companion. This could be easily detected by periodic photometric variability since the radius of the sub-stellar object could be about 10 times bigger than the WD radius. The probability for this event to happen is, however, very low ($< 1\%$). The last viable alternative is direct imaging of the sub-stellar companion.

Sub-stellar objects such as BDs have $T_{eff} \lesssim 1{,}700$ K. Consequently, there is an enormous contrast at optical wavelengths between the secondary with respect to a 10,000 K WD. Fortunately, the contrast is remarkably reduced when the WD-sub-stellar object system is observed in infrared bands (a few magnitudes).

Zuckermann and Becklin have been looking for BD among WDs at NIR bands. They discovered the only known companion to a WD with spectral type later than Burleigh et al. (2002) have also been observing around WDs to search for Jovian planets that survived the post main sequence phases of its primary in wide orbits. They have not achieve any success yet.

Once a sub-stellar object candidate is observed, it will be necessary to verify that it is indeed a companion. If the WD has a high proper motion, it is possible to verify the reality of the sub-stellar companion by studying whether both objects have a common proper motion. WDs up to 20 pc have high proper motion ($\gtrsim 0.1''$/yr), then possible sub-stellar companions, within this sample, could be confirmed by proper motion in a short time (∼1yr).

3. OBSERVATIONS

Most of the stars of our sample (Holberg's sample) have known proper motions, visual UBV photometry, and also available infrared JHK photometry from 2MASS and DENIS. With optical and infrared photometry, it is possible to determine whether there is any IR excess. Imaging of those objects will be carried out using the NACO instrument. NACO consists of an Adaptive Optics (AO) system (NAOS) and an Infra-Red ($1{-}5\mu m$) imager and spectrograph (CONICA) which is fed by NAOS. All these instruments are installed on UT4 in Paranal. This allows us to obtain NIR images with a spatial resolution provided from the AO system with a good sensitivity. It will allow us to resolve sub-stellar objects at angular separation from its WD primary near the diffraction limit of $0.04''$ in J-band (about 0.4 AU at 10 pc) and with magnitudes brighter than 24 in J-band. To make the AO system work, it is necessary to have a reference star closer than $55''$ as long as the target star is fainter than V=17. Otherwise, the target star (WD) can be used as reference star.

From evolutionary spectral models of isolated (not irradiated) EGPs and cool BDs developed by Burrows et al. (2003), we could be able to calculate the infrared JHK emission, therefore, synthetic JHK photometry is obtained. According to these models, it is possible to detect giant planets with masses $\gtrsim 5\ M_{Jup}$ and ages $\lesssim 1$ Gyr, for J $\lesssim 24$ mag. Sub-stellar objects could be detected in orbits $\gtrsim 1$ AU and confirmed by proper motion in a second epoch.

4. SUMMARY

Studying sub-stellar binarity around WDs provides important information about the evolution of these systems, whether sub-stellar object survive to the common envelope phase, whether there is mass accreted from the envelope to the secondary, and whether there are giant planets on wide orbital separations. Also, studying low mass binarity around WDs could be useful to understand the common envelope phases in close systems, as well as the effects on the luminosity function of WDs due to unresolved companions through a determination of the fraction of binaries. If sub-stellar or low-mass stellar objects are found among WDs, evolutionary models can be compared with observations. Finally, we will try to test mass transfer to the secondary from common envelope by estimating the $^{12}C/^{13}C$ abundance ratio in the secondary (see Sarna et al. 1995).

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