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LOW MASS STELLAR AND SUBSTELLAR COMPANIONSHIP AMONG NEARBY WHITE DWARFS

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RESUMEN

Este trabajo es una búsqueda sistemática y profunda de objetos estelares y sub-estelares orbitando enanas blancas cercanas. El interés científico incluye desde comprobar predicciones específicas respecto a modelos de la fase de evolución de la envoltura común, así como dar restricciones a la evolución del sistemas planetarios en estados avanzados de su estrella (Livio & Soker 1984; Willes & Wu 2005). Además, queremos explorar la hipótesis sobre el origen de líneas metálicas en enanas blancas de hidrógeno, producidas por la acreción de material de asteroides o cometario destruido por efectos de marea. Esto podría estar relacionado a la presencia de un objeto sub-estelar no detectado que perturbó la órbita de estos asteroides o cometas (Debes & Sigurdsson 2002). Aquí presentamos resultados preliminares de este proyecto.

ABSTRACT

This work is a systematic, deep search for stellar and substellar objects orbiting nearby white dwarfs (WDs). The scientific interest spans testing specific predictions of common envelope evolutionary phase models, as well as providing constraints to planetary system evolution in advanced stages of its parent star (Livio & Soker 1984; Willes & Wu 2005). Additionally, we seek to explore the hypothesis about the origin of metal lines in hydrogen WDs, produced by the accretion of tidal disturbed asteroidal or cometary material. This could be linked to the presence of a undetected substellar object that perturbed the orbits of these asteroids or comets (Debes & Sigurdsson 2002). Here, we show preliminary results of this project.

Key Words: astrometry — binaries: close — stars: low-mass, brown dwarfs — white dwarfs

1. SAMPLE SELECTION AND OBSERVATIONS

Our targets were selected from the most complete known sample of WDs within 20 pc of the Sun, compiled by Holberg et al. (2002). Revisions and additional objects have been added (Kawka et al. 2004, 2006). From those WDs with $-80^\circ < \delta < 20^\circ$, we select objects with young cooling + main sequence ages (< 3 Gyr), metal lines detected at their atmospheres, and with any possible near-infrared (NIR) excess. Targets in this sample have high proper motion (> 0.1 arcsec), so it is possible to confirm substellar companion candidates by looking for common proper motion with the WD. We have obtained first epoch observations using VLT+NACO in Paranal Observatory in the J-band for 28 WDs. The frames obtained have a high-resolution (FWHM ~ 0.1 arcsec), and go very deep ($J_{\rm limit} \sim 23.5 - 24$ mags). We take advantage of the adaptive optic system by using the WD, which is brighter in the V-band, to correct the observations in the NIR. We obtained high contrast and resolution diffraction-limited images at the J-band, where detection of cooler objects is more favourable. Nevertheless, the small FOV ($\sim 28 \times 28$ arcsec^2) does not allow us to explore larger projected separation. Therefore, to achieve a more extended FOV, we have carried out additional observations with PANIC+Baade at Las Campanas Observatory. We obtained first epoch observation for 38 WDs, reaching a 5σ detection limit at $21<J<22$ mags ($\sim 5 - 10$ $M_{\rm Jup}$ orbiting a WD), and a FOV of $2{\times}2$ arcmin^2. We complemented our observation by obtaining high S/N ($\gtrsim 100$) NIR spectrum from SOFI+NTT in La Silla for WDs that exhibit IR-excess or metal lines in their atmospheres from the same sample. NIR spectroscopy is a very good way to study unresolved low mass stars and substellar objects around WDs. WDs have been traditionally identified and studied in the blue part of their spectrum, and therefore the presence of close low mass companions could have been missed. Any unresolved low mass star or substellar object should be detected if it is not too faint ($T_e \gtrsim 800$ K). WD with unresolved object will show IR-excess and characteristic molecular features associated to the atmosphere of the low mass and cool companion objects, such as H_2O, CH_4, CO, KI and NaI. We have added some

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WDs with IR-excess from the photometric sample derived by Wachter et al. (2003).

2. DATA ANALYSIS AND RESULTS

For PANIC data reduction, we use the IRAF pipeline *gopanic*, with very good results. We check for any significant optical distortion that may have been left uncorrected. For NACO data reduction, we use the pipeline jitter provided by ECLIPSE. We find a very little "*pincushion*" distortion, but it is not significant enough (< 0.05 pix for a typical 7 arcsec of offset) to introduce problems in the reduced images and astrometric solutions.

From 38 first epoch objects observed with PANIC, only 11 have at least 1 year baseline second epoch observation. These objects don't show common proper motion companions. For most of the objects, 1 year of baseline is enough to detect common proper motion over 3σ dispersion from the fainter objects detected on the frames (fainter objects exhibit larger residual RMS). We have been granted observation time for this purpose.

For the NACO frames, we have second epoch observations for 9 promising targets. These data have been reduced and preliminarily analyzed. Some of these objects have faint candidates around 1 arcsec from the WD. To properly study objects closer than 1 arcsec, it is necessary to execute a good PSF subtraction. IRAF daophot PSF models were not completely satisfactory. The best result could be obtained using a look-up table PSF model, based on a very similar WD (ideally the same WD without close companion) observed with the same instrument configuration. Residuals after the PSF subtraction could be either real objects, optical effects or simply a PSF fitting which does not exactly reproduce the central object. To improve the PSF subtraction we observed the second epoch objects on two different rotation angles for the FOV. In this way we were able to discard some false detections produced by the NACO optical system (see a PSF subtracted image in Figure 1). Despite the poor PSF subtraction within 1 arcsec from the WD, it was possible to detect objects with a contrast of $\triangle J \sim 10$ mags, located just ~ 1 arcsec off the target. It could be there only one possible common proper motion companion, but it is not clear yet whether this object is real or not. It is necessary a most careful analysis with the PSF subtraction to confirm this detection.

The spectroscopic data were reduced with IRAF. They were calibrated in wavelength with arcs and/or sky lines. We use a early type B8V-A0V as standard to calibrate in flux. For an absolute flux calibration we use the 2MASS JHK photometry with uncertainties less than 5% in most of the cases. We use WD models from Bergeron et al. (2001) and Finley et al. (1997) calibrated in flux in the optical to subtract the WD spectral distribution. We use model with parameters of log(g) and effective temperature obtained from the literature for our targets. The results were very well, but no signatures from an unresolved substellar object with $T_e \gtrsim 800$ K was detected. Until now, we have not had a confirmed detection of massive extra-giant planets and brown dwarf among WDs. But a more detailed and complete analysis is needed to get a most definitive conclusion. Although our sample has statistical limitation, at least we can say that substellar objects more massive than 10 $M_{\rm Jup}$ look like not to be common among WDs (< 5%). This result is consistent with Farihi et al. (2005), who found that brown dwarf companion fraction is < 0.5% for WD.

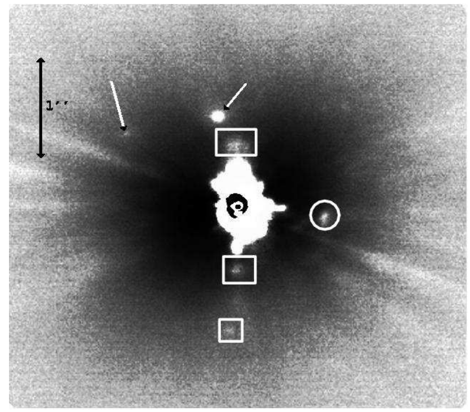

Fig. 1. Residuals from one of our targets after of the PSF subtraction. Some residuals correspond to real objects (arrows); others are due to optical effects or imperfect fitting of the PSF model (circles, squares).

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