A NEW MULTIPLE STELLAR SYSTEM IN THE SOLAR NEIGHBORHOOD
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ABSTRACT
Adaptive optics–corrected images obtained with the Coronagraphic Imager with Adaptive Optics instrument at the 8.2 m Subaru Telescope show the presence of two subarcsecond companions to the nearby \( (d = 19.3 \text{ pc}) \) young star GJ 900, which was previously classified as a single member of the IC 2391 supercluster. The two companions are redder than the primary and share the same proper motion. The projected separations of B and C from the primary are 10 and 14.5 AU, respectively. The estimated masses for the two new companions depend strongly on the age of the system. For the range of ages found in the literature for IC 2391 supercluster members (from 35 to 200 Myr), the expected masses range from 0.2 to 0.4 \( M_\odot \) for the B component and from 0.09 to 0.22 \( M_\odot \) for the C component. The determination of the dynamic mass of the faintest component of GJ 900 will yield the age of the system using theoretical evolutionary tracks. The apparent separations of the GJ 900 system components meet the observational criterion for an unstable Trapezium-type system, but this could be a projection effect. Further observations are needed to establish the nature of this interesting low-mass multiple system.

Key words: binaries: visual — stars: low mass, brown dwarfs — techniques: high angular resolution

1. INTRODUCTION
The star GJ 900 (BD +00\(^{°}\)5017, HIP 116384) is one of the nearest \((d = 19.3 \pm 0.6 \text{ pc}; \text{Perryman et al. 1997})\) cool (K7–M0) young stars known. It has been noted because of its high level of \( \text{H} \alpha \) and \( \text{Ca} \text{ ii} \ H \) and K emission (Stauffer & Hartmann 1986; Bopp 1987; Giampapa, Cram, & Wild 1989), as well as strong X-ray emission (Micela, Favata, & Sciortino 1997; Sterzik & Schmitt 1997), which indicate a young age. Montes et al. (2001) classify it as a member of the IC 2391 supercluster kinematic group. The IC 2391 cluster has a classical (isochrone fitting) age of 35 Myr, which has been recently revised to 53 Myr using lithium observations of very low mass (VLM) cluster members (Barrado y Navascués, Stauffer, & Putten 1999). On the other hand, Eggen (1991) found that IC 2391 supercluster stars have a bimodal age distribution (80 and 250 Myr).

The far-infrared fluxes of GJ 900 are normal for its spectral type (Mathioudakis & Doyle 1993), so there is no evidence of a large amount of warm dust in the system. Bopp (1987) reported 15 radial velocity measurements for GJ 900 obtained over a 3 yr baseline. There was no sign of radial velocity variability larger than the error bars (1 \( \sigma = 1 \text{ km s}^{-1} \)). Bopp also reported that GJ 900 \( V \)-band photometry was constant within 0.01 mag at \( V = 9.54 \). In addition, Bessell (1990) found \( V = 9.57 \). Hence, there is no evidence of large photometric variability despite its high level of chromospheric and coronal activity.

We included GJ 900 in an ongoing high-resolution imaging survey for brown dwarf companions to nearby young cool stars. The star was thought to be single, but our observations have revealed the presence of two VLM companions. The projected separations are such that GJ 900 could be a rare example of a young unstable Trapezium triple system. Monitoring of the orbital motion of this system is needed to determine the true separations of the components.

In § 2, we present our observations and data analysis. In § 3, we discuss the results and estimate masses for the components using theoretical models.

2. OBSERVATIONS AND DATA ANALYSIS
GJ 900 was observed in two observing runs (2002 August 7 and 2003 January 18) with the Coronagraphic Imager with Adaptive Optics (CIAO) attached to the 8.2 m Subaru Telescope (see Tamura et al. 2000 for a description of the instrument). We used an AO imaging mode with a pixel scale of 0.022 pixel\(^{-1} \) and a field of view of 22.3 arcsec\(^2 \). We did not use the coronograph. It was immediately apparent in the first inspection of the AO-corrected images (see Fig. 1) at the telescope that there were two companions to GJ 900.

In the first run, we took six images of 50 s, six images of 20 s, and 18 images of 3.3 s in the \( H \) band, and six images of 3.6 s in the \( K \) band. In the second run, we took 12 images of 3 s in the \( H \) band. The natural seeing in the second run was much worse than in the first one. Data reduction was performed using standard IRAF\(^1 \) routines which included bias subtraction, cosmic-ray correction, and flat-fielding. Differential magnitudes were calculated using the PHOT, PSF, and ALLSTAR routines in IRAF’s DAOPHOT package. The results are given in Table 1, together with relative astrometry of the triple system’s components. Error bars were estimated from the dispersion of the measurements obtained from individual images.

3. DISCUSSION
The baseline of our two epochs is 163 days. The proper motion of GJ 900 is 344 mas yr\(^{-1} \), so the star should have moved 155 mas (7 pixels) with respect to any background star. We would have detected such motion very easily in our images. Thus, we confirm that the two companions share the same proper motion as the primary. Moreover, there were not any other stars in the field of view of the CIAO.

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detector, and the two companions are redder in $H-K$ than the primary (Table 1).

The near-infrared magnitudes of GJ 900 (combined flux of the whole system) are $J = 6.865 \pm 0.021$, $H = 6.245 \pm 0.007$, and $K = 6.008 \pm 0.014$ in the Telescopio Carlos Sánchez system (Alonso, Arribas, & Martínez-Roger 1994). Using these photometric data and the differential photometry obtained from our AO observations, we derive $H = 6.52$ for GJ 900 A, $H = 8.30$ for GJ 900 B, and $H = 9.07$ for GJ 900 C. The distance modulus is $m - M = 1.46 \pm 0.03$, and thus the absolute magnitudes are $H = 5.06, 6.84$, and $7.61$ for GJ 900 A, B, and C, respectively. In order to estimate the masses of the components, we need to know the age of the system. Montes et al. (2001)

![Fig. 1.—CIAO discovery image of the GJ 900 triple system obtained in $H$ band on 2002 August 7. North is up, and east is to the left. The angular separation between A and B is 0\textdegree 51, and the separation between A and C is 0\textdegree 76. GJ 900 is a low-mass Trapezium-type triple-system candidate.]

| Epoch          | Components | $\Delta H$   | $\Delta K$   | Separation (arcsec) | P.A.  |
|---------------|------------|--------------|--------------|---------------------|-------|
| 2002 Aug 7.....| A-B        | 1.78 ± 0.02  | 1.61 ± 0.03  | 0.51 ± 0.01         | 324.5 ± 0.1 |
| 2002 Aug 7.....| A-C        | 2.55 ± 0.03  | 2.38 ± 0.04  | 0.76 ± 0.01         | 344.0 ± 0.1 |
| 2003 Jan 18....| A-B        | 1.70 ± 0.04  | ...          | 0.52 ± 0.02         | 327.4 ± 0.1 |
| 2003 Jan 18....| A-C        | 2.31 ± 0.06  | ...          | 0.74 ± 0.02         | 343.9 ± 0.1 |
have argued that it belongs to the IC 2391 supercluster on the basis of its space motion. IC 2391 cluster’s classical age is ~35 Myr. However, the age of IC 2391 has recently been revised to 53 Myr using the lithium-depletion boundary method (Barrado y Navascués et al. 1999).

For an age of 35 Myr, we derive the following masses from the absolute $H$-band magnitudes and models tailored for GJ 900 provided by I. Baraffe (using the input physics described in Baraffe et al. 1998): 0.60, 0.20, and 0.09 $M_\odot$ for GJ 900 A, B, and C, respectively. For an age of 50 Myr, we infer masses of 0.61, 0.22, and 0.14 $M_\odot$ using the same models. As expected, the mass of the lowest mass component is the most sensitive to the age of the system. Older ages, such as those proposed by Eggen (1991), lead to higher masses for the C component. In the referee report for this paper, John Stauffer has argued that GJ 900 A has an age of about 100 Myr or older based on its position in the $V$ versus $V-I$ color-magnitude diagram, after correcting the flux for binarity and after comparison with low-mass members of the IC 2391, IC 2602, and Pleiades open clusters. The correction for the presence of the companions at visual wavelengths remains speculative until optical data are acquired for each of them. Such a study is beyond the scope of this paper. For an age of 100 Myr, the masses of B and C would be 0.36 and 0.21 $M_\odot$, respectively.

Determination of dynamical masses in the future will yield an improved age for the system using evolutionary models. In order to get a rough estimate of what to expect for the orbital period, we assume an age of 50 Myr and a total mass for the system of 0.97 $M_\odot$. For a distance of 19.3 pc, the projected separation between A and B is 10 AU and between A and C is 14.5 AU. Thus, we estimate orbital periods of ~34 yr for GJ 900 B and ~56 yr for GJ 900 C.

A hint of orbital motion may already be present in the difference between the position angles measured in the two different epochs of CIAO observations (Table 1). Component B has moved 2°9 in 0.45 yr, while component B has not moved more than 0°2. If the orbits are circular, the orbital periods would be ~56 yr for B and ≥810 yr for C. These periods are longer than our previous estimate, but we should bear in mind that most binary orbits are quite eccentric, and the components spend a larger fraction of the time near periapsis. We will have to cover a significant fraction of the orbits to derive reliable orbital parameters.

### 3.1. Is GJ 900 a Trapezium-like Multiple System?

Trapezium-like multiple systems have been defined as physical systems with at least three components in which the largest separation is less than 3 times the smallest separation (Abt & Corbally 2000). The apparent configuration of the GJ 900 system meets this criterion because the largest separation is 1.45 times the smallest one.

The Abastumani Catalogue of Trapezium-type multiple systems includes 637 objects. The masses of all these objects are several times that of the Sun, and the ages are typically younger than 50 Myr (Abt & Corbally 2000; Allen & Poveda 1975; Harrington 1992; Salukvadze 1999, 2000) because they are thought to be unstable. Because of its present configuration, it appears that GJ 900 could be the first example of a subsolar-mass Trapezium-type multiple system. Its survival would indicate an age younger than ~40 Myr or a peculiar orbital stability (resonances).

If GJ 900 is significantly older than 40 Myr, it is likely to be stable and hence not a true Trapezium system. There is about a 10% chance that GJ 900 looks like a Trapezium-type system because of a chance projection (Ambartsumian 1954). Astrometric monitoring of the orbital motion is required to determine the inclination of the orbit with respect to the line of sight. In a few years we should be able to tell whether GJ 900 is a Trapezium-like system, to estimate dynamical masses for the components, and to derive an age for the system.

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