Long baseline interferometric observations of HD 195019: no K dwarf companion detected

C.D. Kovacs (Michigan Science Centre, Battle Creek), R. Massetrem (PAS, Caltech), A. P. Bodey, R. L. Atkinson (Thomson Science Center, Caltech), K.A. Fisher (UC, Berkeley), R.P. Butler (GEM, UW), G.W. Marcy (UC, Berkeley), S.V. Vogt (UCSD/Keck Observatory)

Abstract

Radial velocity measurements of the G3V IV star HD 195019 revealed the presence of an orbiting companion with m sin(i) = 3.5 Jupiter masses and a period of 18 days (Fischer et al. 1995). A subsequent search for an astrometric wobble using Hipparcos data suggested that the companion may be a K dwarf star with a mass of 0.7 Msun in a nearly pole-on orbit (Han et al. 2001). Here we present new visibility measurements obtained at the Palomar Testbed Interferometer which rule out any companion in an orbit consistent with the spectroscopic data and having more than 1% of the flux of the primary star in the near-infrared K band. This upper flux limit corresponds to an upper mass limit of 0.25 Msun for the companion.

Introduction

Among the numerous low mass companions so far detected by radial velocity (RV) measurements of nearby main sequence stars, 70 exhibit an m sin(i) < 10 Jupiter masses, less than 13 Jupiter masses, the lower limit for deuterium burning. Depending on the unknown inclination angle of the system, those objects may be planets, brown dwarfs or stars. Han, Black, & Gaiaward (2001) hereafter HBG searched the Hipparcos Intermediate Astrometric Data (IAD) for astrometric wobbles in 80 of the stars suspected from radial velocity measurements to host planetary-mass companions. They reported that most of these systems showed wobble consistent with companions of brown dwarf or even stellar mass, in very low inclination orbits. These conclusions have been challenged by Piskunov (2001), who analyzed their orbit-fitting procedure in the presence of noise at the level of the Hipparcos IAD and found that most of the HBG orbits were not statistically significant, and that their model fitting technique is biased toward producing orbits with low inclinations. These conclusions have been further challenged by further analysis of low-inclination astrometric binaries.

The candidate with the largest astrometrically-determined companion mass to HD 195019, with m sin(i) = 3.4 Jupiter masses and an astrometric mass of 713 Jupiter masses. If the companion were on the Main Sequence, such a large mass would make it a star with a near-infrared K-band flux ~15% as bright as the primary. The semimajor axis of its orbit, which would be viewed essentially pole-on, would be 4 milliarcsec. Such a system would be very detectable with the Palomar Testbed Interferometer (Colavita et al. 1999), which measures the fringe visibility in the K band along one of two baselines of length ~100 m. We have combined PTI observations with new radial velocity (RV) measurements to place a stringent upper limit on the near-infrared brightness of the companion, and thereby infer an upper limit on its mass. A companion as massive as that inferred by HBG is excluded.

Observations

The near-infrared interferometric measurements were made at the Palomar Testbed Interferometer (PTI, Colavita et al. 1999), which measures the visibility along a pair of ~100 m baselines, with a fringe spacing of ~4 mas in the K band. A total of 71 scans were obtained on HD 195019 over 8 nights between 2001 May and September. Each scan consisted of a measurement of the visibility while the central fringe was tracked for a period of 125 sec. The scatter in the visibility measurements taken during 25-second subintervals provided an estimate of the uncertainty.

The visibility measured by the interferometer for a perfect point source falls below unity because of imperfections in the optics and the tracking of the fringe. The actual point-source response, or system visibility, was measured using observations of calibrator stars chosen to have small and well-determined angular sizes and to lie within ~10 deg of the target. The calibration stars chosen were HD 19406, HD 192425, and HD 194012, for which the adopted angular sizes were 0.05, 0.42, and 0.41 mas, respectively.

A total of 38 measurements were made of the radial velocity of HD 195019 at the Keck and Lick Observatories between 1998 August 2 and 2001 October 1. The 28 Keck measurements were made using the HIRES spectrometer (Vogt et al. 1994) with R = 87,000, and produced a mean estimated uncertainty of 5.5 m/sec, while the 60 Lick measurements were made using the 0.6 m Coude Auxiliary Telescope (CAT) and the 3 m Shane telescope with the Hamilton spectrograph (Vogt 1987). Using these measurements, we derived mean values and uncertainties from the distributions, which are plotted in Figure 2. The distribution for the brightness ratio R is bimodal, with positive and negative peaks. If we fitted the positive peak alone we would conclude that the companion is weakly detected, with R = 0.065 ± 0.002. However, we observe that the distribution of the PA of the ascending node, which is the only parameter other than R which depends on the flux from the companion, exhibits no peak. This argues that the "detection" of the light from the companion is not real. Instead, we conservatively derive an upper limit on R by observing that 99% of the fits converged to R < 0.01. This corresponds to an absolute K-band magnitude MK = 2.5, which is consistent with the Near-Infrared Photometric System (NIRPS) measurements of Baraffe et al. (1998). We derive a precise velocity measurement. The average of our 30 measurements is 0.0 ± 0.2 m/sec, with a scatter of 0.3 m/sec. In the original publication, this was reported as 0.0 ± 0.2 m/sec with a scatter of 0.3 m/sec. We derive a precise velocity measurement.

Results

We first compare the measured visiblities with an optimized model based on the occultations of HDG, namely that the companion is in a nearly pole-on orbit with a semimajor axis of 4 milliarcsec. The resulting visibility is plotted in Figure 1. The distribution for the brightness ratio R is bimodal, with positive and negative peaks. If we fitted the positive peak alone we would conclude that the companion is weakly detected, with R = 0.065 ± 0.002. However, we observe that the distribution of the PA of the ascending node, which is the only parameter other than R which depends on the flux from the companion, exhibits no peak. This argues that the "detection" of the light from the companion is not real. Instead, we conservatively derive an upper limit on R by observing that 99% of the fits converged to R < 0.01. This corresponds to an absolute K-band magnitude MK = 2.5, which is consistent with the Near-Infrared Photometric System (NIRPS) measurements of Baraffe et al. (1998). We derive an upper limit on R by observing that 99% of the fits converged to R < 0.01. This corresponds to an absolute K-band magnitude MK = 2.5, which is consistent with the Near-Infrared Photometric System (NIRPS) measurements of Baraffe et al. (1998). We derive an upper limit on R by observing that 99% of the fits converged to R < 0.01. This corresponds to an absolute K-band magnitude MK = 2.5, which is consistent with the Near-Infrared Photometric System (NIRPS) measurements of Baraffe et al. (1998). We derive an upper limit on R by observing that 99% of the fits converged to R < 0.01. This corresponds to an absolute K-band magnitude MK = 2.5, which is consistent with the Near-Infrared Photometric System (NIRPS) measurements of Baraffe et al. (1998).