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

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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. 1999). A subsequent search for 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 m sin(*i*) less than 13 Jupiter masses, the lower limit for deuterium burning. Depending on the unknown inclination angle *i* of the system, those objects may be planets, brown dwarfs or stars.

Han, Black, & Gatewood (2001; hereafter HBG) searched the Hipparcos Intermediate Astrometric Data (IAD) for astrometric wobble in 30 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 Pourbaix (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 the their model-fitting technique is biased toward producing orbits with small *i*. Only four systems were found to be deserving of further consideration as possible low-inclination astrometric binaries.

The candidate with the largest astrometrically-determined companion mass is 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 a K 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 clearly 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 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 calibrator stars chosen were HD 190406, HD 192425, and HD 194012, for which the adopted angular sizes were 0.55, 0.42, and 0.41 mas, respectively.

A total of 88 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 Auxilliary Telescope (CAT) and the 3 m Shane telescope with the Hamilton spectrograph (Vogt 1987). The average of their estimated uncertainties is 7.1 m/sec.

The observing and data reduction methods are described in Butler et al. (1996) and Fischer et al. (1999). Briefly, the starlight is passed through an iodine cell which imposes a grid of sharp reference lines on its spectrum. The iodine-gridded spectrum is compared to a model spectrum made by multiplying an ungridded stellar "template" spectrum by a laboratory iodine spectrum, and convolving the result with a model for the spectrometer point-spread function, to derive a precise velocity measurement.

Results

We first compare the measured visibilities with an optimized model based on the conclusions of HBG, namely that the companion is in a nearly pole-on orbit with a semimajor axis of 4 milliarcsec and is 15% as bright as the primary in the K band. The model has only two free parameters: the angular diameter of the primary star and the position angle Ω of the ascending node. The diameter of the companion was set to 0.3 mas, which is consistent with the assumption that it is a K dwarf star; the visibility is not very sensitive to this choice because the diameter is much smaller than the interferometer's fringe spacing. The remaining parameters were set according to a fit to the RV data. The model fit to the visibility data, shown in Figure 1, is clearly ruled out, with X^2 per DOF = 35.2.

To derive an upper limit on the brightness of the companion, we fitted the visibility and RV data simultaneously, assuming a nearly pole-on orbit with a semimajor axis of 4 mas. The fits were made to 1000 synthetic data sets made by adding Gaussian noise to the best model for the real data. Each fit produced a set of parameter values. We derive the best-fit values and their

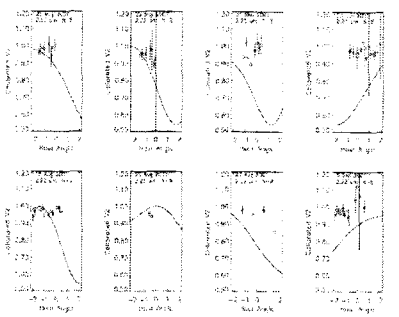

Figure 1: The visibility data measured at PTI (points) are not consistent with the model (curves) in which the companion is a K dwarf star 15% as bright as the primary, as expected from the astrometric orbit of HBG.

uncertainties from the distributions, which are plotted in Figure 2. The distribution for the brightness ratio R is bimodal, with positive and (nonphysical) negative peaks. If we fitted the positive peak alone we would conclude that the companion is weakly detected, with R=0.004 +/- .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 when compared to the Main Sequence models of Baraffe et al. (1998) indicates an upper limit on the mass of 0.25 M_{sun}.

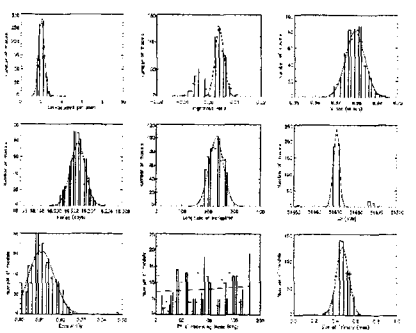

Figure 2: Distributions of the model parameters derived from fits to 1000 sets of synthetic visibility and RV data. The curves are Gaussians used to derive mean values and uncertainties.