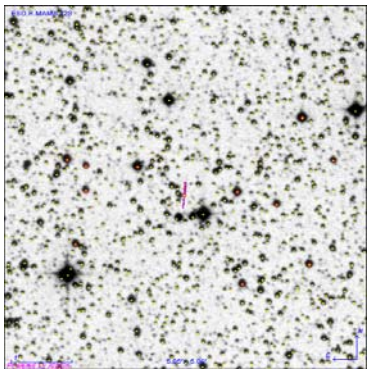
Possible Astrometric Perturbation of LHS 288
A Jupiter-Mass Planet?

Jennifer L. Bartlett (Hampden-Sydney College and University of Virginia), Philip A. Ianna (University of Virginia), Michael C. Begam (Steward Observatory)



LHS 288 AND REFERENCE FRAME

LHS 288 is identified by red arrow; purple dots mark its path from 1991 through 2007. Eleven reference stars used to measure its parallax and proper motion are marked by red diamonds. 2MASS sources appear as yellow points.

LHS 288 Photometry from Southern Parallax Program

- $V_C = 13.97 \pm 0.05$ mag
- $(R\text{-}I)_C = 2.00 \pm 0.04$ mag
- $(V\text{-}I)_C = 3.60 \pm 0.07$ mag

LHS 288 Spectroscopy

- Spectral type M 5.5 V per Bessell (1991)

What if a planet was present?

- Significant peaks in both all x- and y-residual periodograms at same frequency
- Similar peaks remain when nightly normal points used instead of individual observations
- Planetary masses for perturbations of LHS 288 calculated below

MASSES FOR POSSIBLE LHS 288 PLANET

Period (years)	Companion Mass ($M_\odot$)	Comment
1.5 …	7 ± 2	shortest period considered
3.4 ± 0.5	4 ± 1	corresponds to x-periodogram maxima
5 ± 1	2.8 ± 0.9	corresponds to local peak in all x-periodogram
7 ± 2	2.4 ± 0.8	baseline, corresponds to y-periodogram maxima

Mass Limits for Possible Planet

- Minimum detectable perturbation, $\alpha_{min} = 8$ mas or 0.3 μm
  Scaled from study of possible planets orbiting Barnard's Star (Bartlett 2007)
- Mass of LHS 288 0.10 $M_\odot$
  (Delfosse *et al*. 2000 with 2MASS photometry)
- Considered periods 1.5–6.8 years (baseline)

Previous Mass Limits for Possible Companions

- Speckle interferometry revealed no brown dwarfs (28–35 M_J) with similar orbital periods (3–8 years) per Leinert *et al*. (1997)
- Visual inspection of CTIOPI images revealed no low-mass stellar companions per Jao *et al*. (2003)

LHS 288 Astrometry from Southern Parallax Program

- $\alpha = 10^h\ 44^m\ 21.24^s$ $\delta = -61°\ 12'\ 35.6''$ [2000.0]
- $\pi_{rel} = 213 \pm 2$ mas → $d = 4.69 \pm 0.04$ pc
- $\mu = 1.6420 \pm 0.0006''\ yr^{-1}$ in $348.51 \pm 0.03°$
- 105 images in R_C on 18 nights between 1991 May and 1998 March
- Standard 3 plate constant model used—magnitude, coma, and color terms considered but found to be insignificant
- Mean error unit weight 0.54 μm (X) and 0.37 μm (Y)

FEATURES OF PERIODOGRAMS FOR ALL LHS 288 RESIDUALS

	Axis	Frequency ($years^{-1}$)	Period (years)	Power (mm^{-1})	Comments
right ascension (α) →	x			16.116	
	y	0.14762	6.7739	20.651	maximum power
	cps			33.135	
	x			31.895	local peak
declination (δ) →	y	0.18453	5.4192	16.688	adjacent to maximum
	cps			44.680	maximum power for all observations
	x			33.380	maximum power
combined power statistic →	y	0.29525	3.3870	14.581	local peak
	cps			44.070	maximum power for nightly residuals

NOTE.—False alarm probability < 1% for all points listed above.

Method

- University of Virginia Southern Parallax Program
  - Used 1-m reflector at Siding Spring Observatory
  - Reduced observations using standard plate constant, central overlap solution
  - Described in detail by Begam, Ianna, & Patterson (2007); preliminary planet search results in Bartlett, Ianna, & Begam 2002
- Selected stars
  - Positions corrected for differential color refraction (DCR) when photometry available
  - Relative parallaxes and proper motions measured
  - Residuals to each observation analyzed
    - X- and Y-coordinates treated separately
    - Time-series analysis per Lomb-Scargle periodogram method (Press *et al*. 1992)
    - Frequencies searched up to 4x Nyquist frequency
    - Periodograms prepared using
      - Individual observations
      - Nightly normal points
      - Too few observations for annual normal points

TELESCOPE AT SIDING SPRING OBSERVATORY
(image source: Research School of Astronomy & Astrophysics)

REFLECTOR CHARACTERISTICS

Parameter	Description
Objective	1 meter (40 inches), f/8
CCD	GEC P88500 chip with 0.57" $pixel^{-1}$ GEC P8603 chip with 0.56" $pixel^{-1}$
Plate Scale	25.55" mm^{-1}
Filters	V, R, & I according to Cousins

For More Information jlb2j@virginia.edu
www.astro.virginia.edu/~jlb2j/research.htm

Results

- 13 stars tested for possible astrometric perturbations due to very low-mass companions
  - Selection criteria
    - Large parallax—half within 10 pc
    - Good parallax solution—error < 3 mas
    - Not known to be binaries
  - 12 Stars show no indication of companions
    White Dwarf LHS 34
    Red Dwarfs (M0.5–M5.5)
    LHS 271
    LHS 337
    LHS 532
    LHS 1134
    LHS 1565
    LHS 2310
    LHS 2739
    LHS 2813
    LHS 3064
    LHS 3242
    LHS 3418
  - **1 Star, LHS 288, shows possible signals that merit further analysis**

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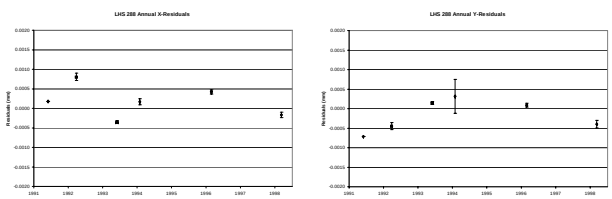
ACKNOWLEDGEMENTS

We acknowledge support from NSF grants AST 98-20711 and 05-07711, Georgia State University, the Space Interferometry Mission (SIM), F. H. Levinson Fund of the Peninsula Community Foundation, UVa, and Hampden-Sydney College in addition to support and generous observing time allocations from the Research School of Astronomy & Astrophysics, Australian National University.

CTIOPI was a NOAO Survey Program and continues as part of the SMARTS Consortium.

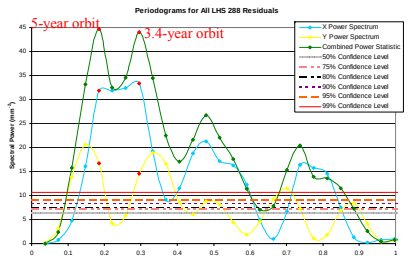
This research used data products from 2MASS, which is a joint project of the Univ. MA & IPAC/CalTech, funded by the NASA; NASA ADS Abstract System; SIMBAD database, operated at CDS, Strasbourg, France; Aladin; and, ESO MAMA imagery.



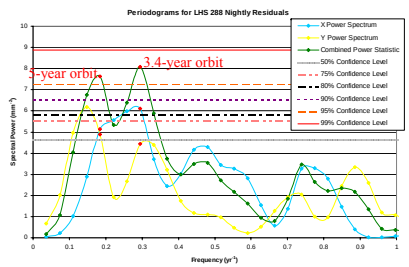
LHS 288 ANNUAL NORMAL POINTS

LHS 288—Possible planetary signal

- X-spectra maxima with period of ~3.4 years
- Y-spectra maxima with period of ~7 years
- X- and Y-peaks remain with reduced power for nightly residuals; false alarm probabilities < 15%
- Adding X- and Y-periodograms (combined power statistic) produces peaks at ~3.4 and ~5 years; false alarm probabilities < 5%
  - 5-year orbit maximum, all observations considered
  - 3.4-year orbit maximum, nightly observations



ALL LHS 288 OBSERVATIONS



LHS 288 NIGHTLY OBSERVATIONS

Significance Level vs. False Alarm Probability

- Higher power indicates stronger signal
- Significance level—likelihood peak identifies real "signal"
- False alarm probability—likelihood noise produced "signal"

What about LHS 288?

- Periodograms for LHS 288 are noisier than any others in this sample
- Signals detected may be spurious but require additional investigation
  Comparison with external data set or follow-up observations
- Signals persist after
  - Complete re-reduction from archival images
  - Confirming all observation times
  - Testing for additional plate constants
- LHS 288 lies in crowded region near galactic plane