Detection Limits for Unseen Companions to Barnard's Star from McCormick Observatory Archives

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Planet Searches

- van de Kamp (1963–1982) Sproul astrometric
  0.7 M_J in 12-yr, 0.5 M_J in 20-yr orbits
- Winglee, Dulk, & Bastian (1986) VLA
  detected neither Barnard's Star nor companion
- Marcy & Benitz (1989) Mt. Wilson radial velocity
  no planet > 11 M_J (mass sin *i*)
- Benedict *et al*. (1999) HST FSG astrometric
  Schroeder *et al*. (2000) HST WFPC-2 imaging
  no planet ~ M_J in 3-yr or shorter orbits
- Kürster *et al.* (2003) VLT radial velocity
  no planet > 0.12 M_J in 2.5-yr orbit or shorter

McCormick Observations & Reduction

- 26¼” Alvan Clark & Sons refractor
  - 20.75” mm^{-1} plate scale
  - 0.75° FOV
- Barnard’s Star + 12 reference stars
  - 919 exposures, April 1969–August 1998
  - Kodiak 103aG plates w/ Schott GG 495 filter
- PDS 1010GM Microdensitometer
- McCormick Parallax Reduction Program
  - iterative 3 plate-constant adjustment model (base)
  - significant secular acceleration & magnitude terms
- Lomb-Scargle periodograms of residuals (Press *et al*. 1996)

Image Credit: LMO Archives

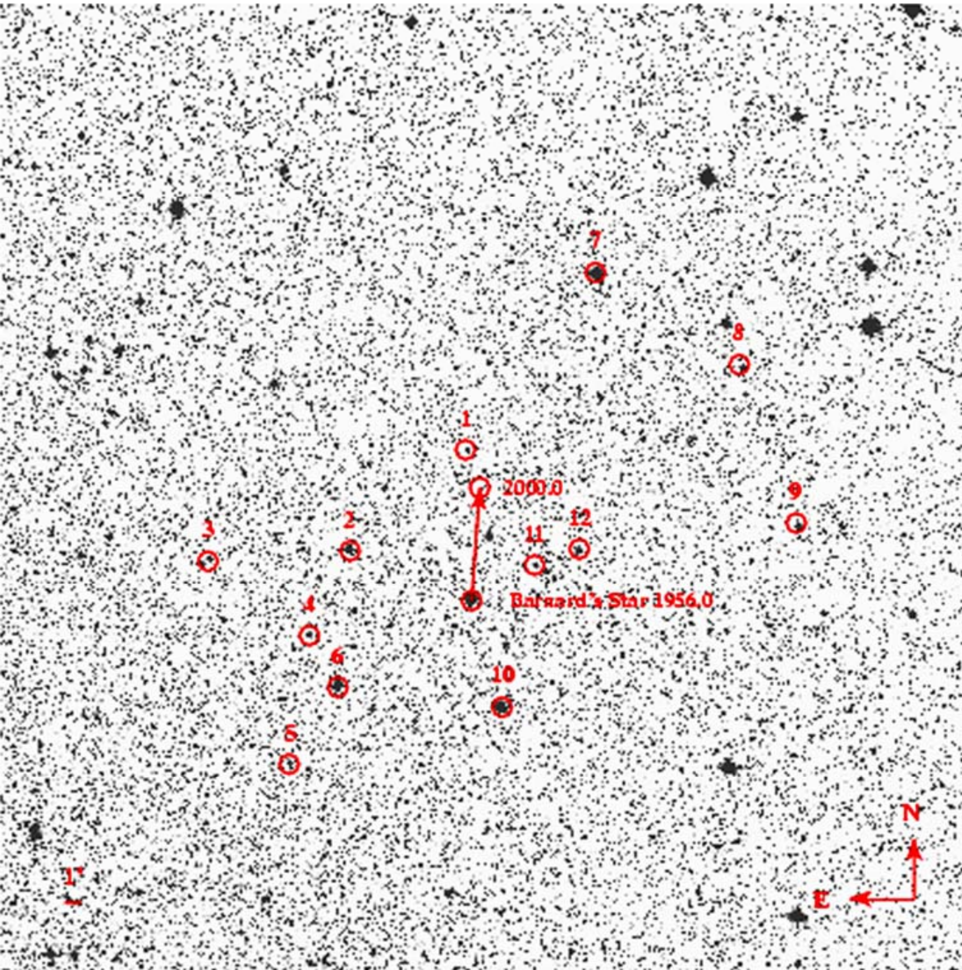


Image Credit: DSS/*SkyView* ©*AURA*

Results

- Relative Parallax

  π_{LMO} = 546 ± 1 mas

  π_{HST} = 544.2 ± 0.2 mas

- Relative Proper Motion

  μ_{LMO} = 10,361.3 ± 0.2 mas yr^{-1} in 355.905 ± 0.001°

  μ_{HST} = 10,370.0 ± 0.3 mas yr^{-1} in 355.6 ± 0.1°

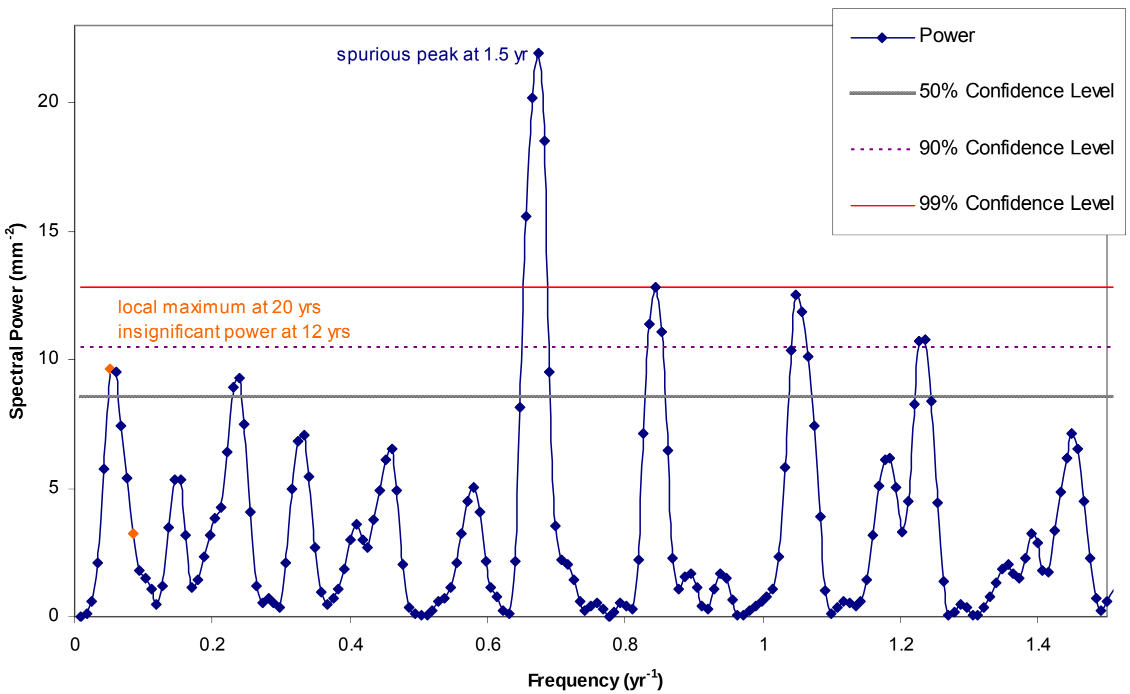
- Secular Acceleration

  $d\mu/dt_{LMO}$ = 1.25 ± 0.04 mas yr^{-2}

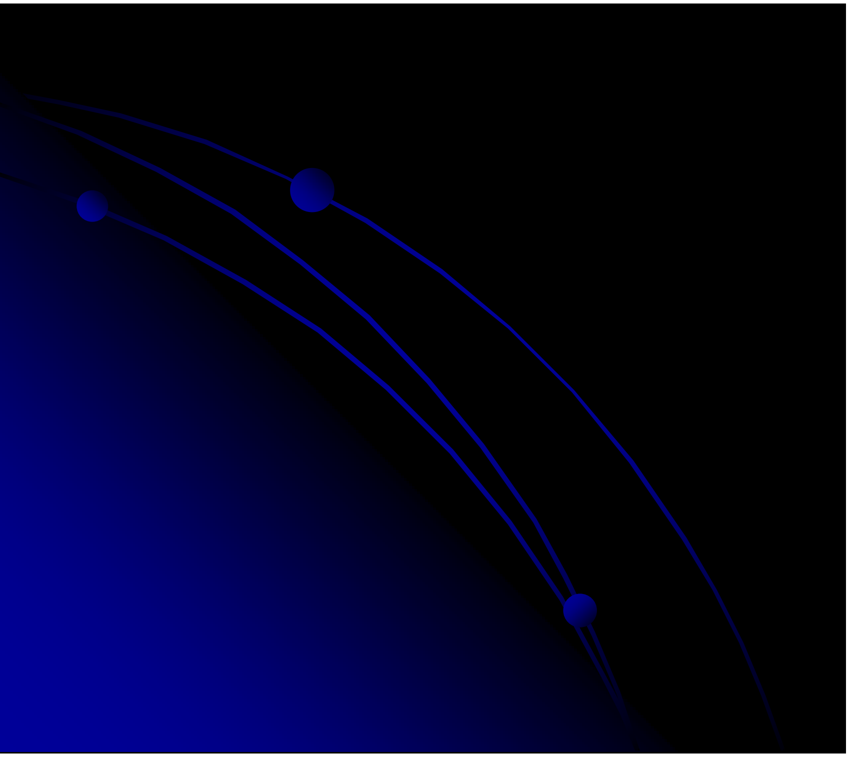
  $d\mu/dt_{HST}$ = 1.2 ± 0.4 mas yr^{-2}

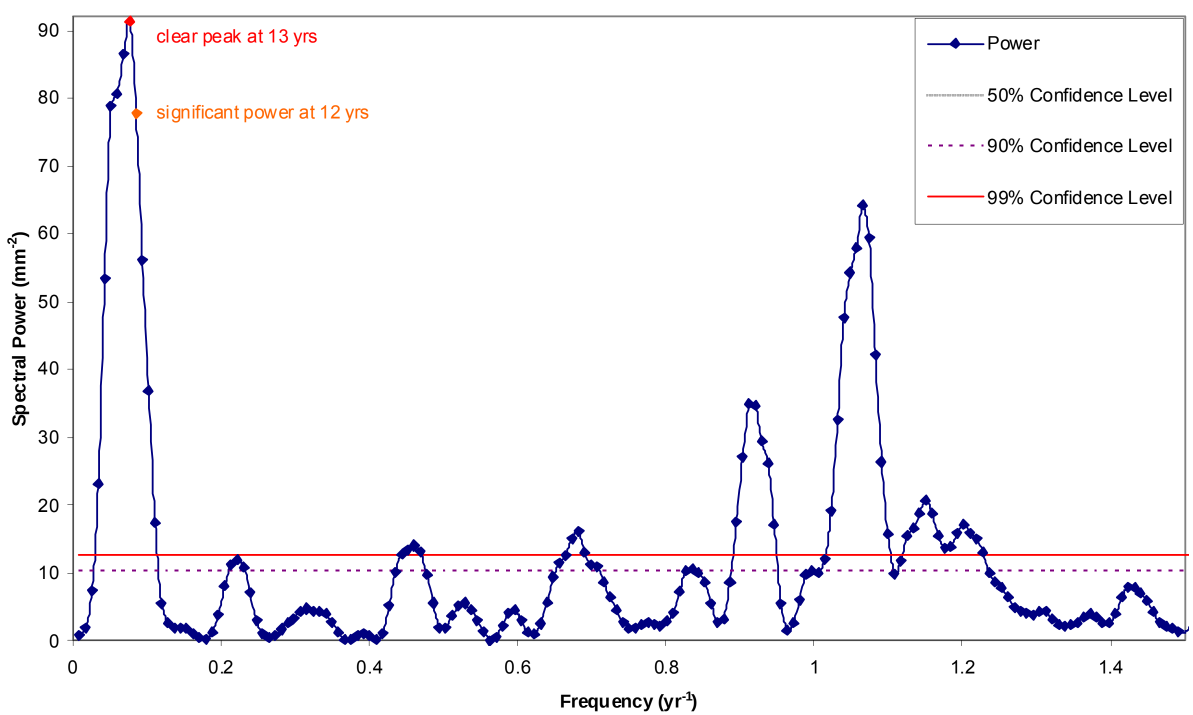
Benedict *et al*. 1999 (HST)

**Periodogram for All Barnard's Star X-Residuals
(McCormick Photographic Plates)**



**Periodogram for All X Residuals
(12-year orbit, 2-planet perturbation tripled)**





Mass Limits

- No significant perturbation appears in periodograms for residuals
- Modeled orbits described by van de Kamp (1982)
  - Added noise as represented by residuals
  - Increased separation until 12-yr period emerged
  - Detected perturbation 3x greater than described α_{min} = 0.021" ± 0.004"
  - Should be able to detect planets > 2.2 ± 0.5 M_J

Secular Acceleration of Barnard's Star

Source	Secular Acceleration ($mas\ yr^{-2}$)		
Predicted, 1983.77	1.285	±	0.006
McCormick, 1969–1998	1.25	±	0.04
HST FGS, 1993–1996 (Benedict *et al*. 1999)	1.2	±	0.4

For details, please visit our poster 406.13 today in Stars, Cool Dwarfs, Brown Dwarfs III

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Abstract

Interest in Barnard's Star has continued since 1916 because of its high proper motion, nearness to the Sun, and planetary claims. In 1963, van de Kamp announced the astrometric detection of a planet orbiting this star. In his final 1982 analysis, he described 2 planets with 0.7 and 0.5 $M_{Jupiter}$ in 12- and 20-year orbits using ~20,000 exposures collected at Sproul Observatory between 1938 and 1981. Since his first assertion, at least 14 studies have attempted to confirm their presence.

Although several techniques have been employed to detect van de Kamp's planets, no other program has been successful; most lacked sensitivity to low-mass objects in long-period orbits. Benedict *et al*. (1999) eliminated planets slightly less massive than Jupiter in 3-year orbits with HST; their observations cover a fraction of the shorter orbital period calculated by van de Kamp. The California and Carnegie Planet Search appears to exclude Jupiter-mass planets in orbits as long as 8 years.

McCormick Observatory houses more than 900 photographic plates taken of Barnard's Star between 1968 and 1998 with the 26.25" refractor. Using these, we measured a relative parallax, proper motion, and secular acceleration for Barnard's Star comparable with those obtained using more modern techniques. Lomb-Scargle periodograms (Press *et al*. 1996) of the residuals indicate that no planet exits more massive than 2.2 ± 0.5 $M_{Jupiter}$ in a 12-year orbit. Our baseline is more than twice the period of van de Kamp's inner planet, which is necessary to separate proper motion from orbital motion. Although we can neither confirm nor deny the planets he described, we have demonstrated that photographic plate archives contain material sufficiently sensitive to detect giant planets orbiting nearby stars.