# BROWN DWARFS IN BINARY SYSTEMS

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ABSTRACT. Searches for brown dwarf companions to known stars have revealed a number of tantalizing candidates.

## 1. INTRODUCTION

Until 1983, stars were the only objects that we knew with certainty were in orbit about stars other than the Sun. Then IRAS discovered clouds of particulate matter in orbit around Vega and many other nearby main-sequence stars. Even more recently, since 1987, various reports of potential brown dwarf and large planetary mass companions to nearby stars have appeared. (None of the pre-1987 claims have ever been confirmed.)

The purpose of this brief review is to summarize some of the recent searches for brown dwarf companions to nearby stars. The upper mass limit to brown dwarfs is about 0.08 $M_\odot$, which is also the lower mass limit to main-sequence stars. Below this mass, objects do not fuse protons into helium nuclei in their interiors. The lower mass limit to brown dwarfs, which is also the upper mass limit to large planets, is less well defined. One reasonably popular choice is 0.01 $M_\odot$ (or 10 $M_{Jupiter}$), because above this mass objects, i.e., brown dwarfs, can fuse deuterium nuclei into helium nuclei in their interiors. Models of brown dwarfs indicate that, following a short period of deuterium burning, they will have radii within a factor of 2 or so of that of Jupiter (e.g., Nelson et al. 1986).

## 2. INFRARED SEARCH TECHNIQUES

Most of the serious IR searches for brown dwarfs have involved either imaging with the new two-dimensional array cameras, or photometry of white dwarf stars. A list of the most ambitious of the array searches known to us is presented in Part IA of Table 1. The Rochester search has been described by Skrutskie et al. (1986) and the Arizona search by Rieke and Lebofsky was described briefly by Liebert and Probst (1987, page 490). The Rochester search revealed one low-luminosity object,



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Gliese 569B, which Forrest et al. (1988) interpret as a possible brown dwarf. Since brown dwarfs are expected to be cool and of low luminosity during most of their lifetimes (e.g., Nelson et al. 1986), and since Gℓ569B is neither especially cool nor of low luminosity, the brown dwarf interpretation rests on some very shaky theory of the evolution of low-mass stars and brown dwarfs. Gℓ569B is compared with some other very low luminosity stars in Table 2 and Figure 2 of Becklin and Zuckerman (1988) and considered in some detail by Zuckerman and Becklin (1989).

It is also possible to search for brown dwarfs near white dwarf stars with a photometric technique first exploited by Probst (1983a,b). Subsequent investigations by Kumar (1987), Zuckerman and Becklin (1987a,b, 1989), and Becklin and Zuckerman (1988), have probed down into the brown dwarf mass range. Two brown dwarf candidates have been found near a total of about 120 white dwarfs that have been searched to date.

The first candidate appeared as excess infrared emission from Giclas 29-38 (Zuckerman and Becklin 1987b). Although a reasonable case can be made for a brown dwarf source for this excess radiation (Greenstein 1988), it is not possible to rule out a swarm of dust particles or asteroid-like objects in orbit around G29-38 as the source of the IR excess. Recent observations by Tokunaga and Becklin (1988, private communication) with CGAS on the IRTF failed to reveal any sharp spectral features between 1.9 and 3.6 μm. As dust grains might carry a feature at 3.3 to 3.4 μm (see, e.g., the observations of Comet Halley reported by Knacke et al. 1986), and a cool brown dwarf might show deep atmospheric absorption features due to $H_2O$ (Berriman and Reid 1987), the CGAS data are a bit perplexing. Recent photometric data at 4.8 μm by Becklin, Tokunaga, and Zuckerman (1988, private communication), when combined with 10 μm data reported by Tokunaga et al. (1988), indicate that the IR excess at G29-38 can be well fitted from 2 to 10 μm by a black body of about 1200°K.

The second candidate brown dwarf, GD165B, was discovered to lie about 4" from the white dwarf GD165 (Becklin and Zuckerman 1988). If GD165B is a true companion to GD165, and not merely a very red background object (which seems improbable), then their separation is about 120 A.U. GD165B is certainly not a dust cloud, since it appears to be stellar and is well-resolved from GD165. Although, at about 2100°K, GD165B is cooler than any known dwarf star, it is not so cool that it can be classified unimpeachably as a brown dwarf. According to the cooling models of Nelson et al. (1986), GD165B is a brown dwarf with a mass that lies between 0.06 and 0.08 $M_\odot$. But the models of D'Antona and Mazzitelli (1985) would classify GD165B as a star at the very bottom of the main-sequence (mass about 0.08 $M_\odot$) rather than as a brown dwarf.

## 3. OPTICAL AND RADIO TECHNIQUES

The search techniques listed in Part II of Table 1 are sensitive to much lower mass objects than are the infrared methods. Indeed, at present, techniques IIC and IID are about the only methods capable of detecting planets with Earth-like masses. Eclipses of white dwarfs by orbiting brown dwarfs are, potentially, yet another detection technique. However, a recent exciting report of just such an eclipsing system (I.A.U. Telegram No. 4648) apparently will be retracted (R. Rubin and B. Zuckerman 1988, private communication).

The most secure detection of an object with a mass in the brown dwarf range (Fruchter et al. 1988) was achieved with technique IID. However, very likely, this brown dwarf (mass $\gtrsim 20\ M_{Jupiter}$) was originally a bona fide low-mass star that is now being destroyed by its nearby pulsar primary. Technique IIB has revealed only one potential brown dwarf candidate to date. Reported at this Joint Discussion by Dr. Latham, the mass of the unseen companion to a G-type primary star is $\gtrsim 10\ M_{Jupiter}$. The actual mass of the companion depends on the unknown inclination angle of the orbit. A back-of-the-envelope calculation indicates a 1% chance that the orbit is sufficiently unfavorably inclined that the mass of the companion is greater than $0.08\ M_{\odot}$, i.e., stellar. Since Dr. Latham and collaborators have examined thousands of stars, we should not be surprised if the companion is, indeed, stellar.

## 4. SUMMARY

In spite of many searches utilizing various techniques, at this moment there is only one object known whose mass unquestionably lies in the domain of brown dwarfs. This object, the companion to an eclipsing millisecond pulsar, is most unusual and, very probably, began its life as an ordinary star. Other plausible candidates have been identified during the past year and the field is ripe for new discoveries.

## References


Becklin, E.E. and Zuckerman, B. 1988, Nature, in press, December 1988.

Berriman, G., and Reid, N. 1987, M.N.R.A.S., 227, 315.

D'Antona, F., and Mazzitelli, I. 1985, Ap. J., 296, 502.

Forrest, W.J., Skrutskie, M.F., and Shure, M. 1988, Ap. J., 330, L119.

Fruchter, A.S., Stinebring, D.R., and Taylor, J.H. 1988, Nature, 333, 237.

Greenstein, J.L. 1988, A.J., 95, 1494.

Knacke, R.F., Brooke, T.Y., and Joyce, R.R. 1986, Ap. J., 310, L49.

Kumar, C.K. 1987, A. J., 94, 158.

Liebert, J., and Probst, R.G. 1987, Ann. Rev. Astr. Ap., 25, 473.

Nelson, L.A., Rappaport, S.A., and Joss, P.C. 1986, Ap. J., 311, 226.

Probst, R.G. 1983a, Ap. J., 224, 237.

________ 1983b, Ap. J. Suppl., 53, 335.

Skrutskie, M.F., Forrest, W.J., and Shure, M. 1986, in Astrophysics of Brown Dwarfs, ed. M.C. Kafatos, R.S. Harrington, S.P. Maran (Cambridge, Cambridge University Press), p. 82.

Tokunaga, A.T. et al. 1988, Ap. J., 332, L71.

Zuckerman, B., and Becklin, E.E. 1987a, Ap. J., 319, L99.

________ 1987b, Nature, 330, 138.

________ 1989, in preparation for Ap. J.


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Table 1

Searches for Brown Dwarfs as Companions to Known Stars

## I. INFRARED TECHNIQUES

### A. TWO-DIMENSIONAL IMAGING CAMERAS (Mostly Main-Sequence Stars)

| Camera/ Telescope | Approximate Number of Stars Searched | Brightness Limit at 2.2 μm |
|---|---|---|
| Rochester/IRTF | 60 | 15 mag |
| Arizona/90" | 50 | 15.5 |
| NOAO/1.3 and 2.1 m | 40 | 16 |
| IRCAM/UKIRT | 10 | 17 |

### B. PHOTOMETRICALLY (All White Dwarfs)

| Telescope | Approximate Number of Stars Searched | Brightness Limit at 2.2 μm |
|---|---|---|
| IRTF (and a few UKIRT) | 120 | 16 mag |

## II. OPTICAL AND RADIO TECHNIQUES

| Technique | Number of Stars Searched |
|---|---|
| A. Classical Astrometry | Many |
| B. Radial Velocity Variations | Dozens |
| C. Variations in Optical Periods of ZZ Ceti White Dwarfs | A Handful |
| D. Variations in Radio Periods of Pulsars | Many |

Notes to Table 1:

For the infrared techniques IA and IB, the outer search radius at each star is typically 100 to a few hundred or even a few thousand A.U.
For A the inner radius is a few tens to a few hundred A.U.
For B the inner radius is that of the white dwarf primary.
Techniques IIC and IID are sensitive to companions with Earth-like and even smaller masses.