P. G. MURDIN
Anglo Australian Observatory,
PO Box 296, Epping,
Australia 2121

R. F. HAYNES
CSIRO Division of Radiophysics,
PO Box 76, Epping,
Australia 2121

Received 3 April; accepted 10 May 1979.

1. Carpenter, G. F., Eyles, C. J., Skinner, G. K., Wilson, A. M & Willmore, A. P. *Mon. Not. R. astr. Soc.* **179,** 27P–34P (1977).
2. Doxsey, R. E., Apparao, K. M. V., Bradt, H. V., Dower, R. G. & Jernigan, J. G. *Nature* **269,** 112–116 (1977).
3. Bradt, H. V. *et al. Nature* **269,** 496–497 (1977).
4. Duldig, M. L. *et al. Mon. Not. R. astr. Soc.* **187,** 567–580 (1979).
5. Miyamoto, S. & Matsuoka, M. *Space. Sci. Rev.* **20,** 687–755 (1977).
6. Braes, L. L. E. & Miley, G. K. *IAU Symp.* No. 55, 86–97 (1973).
7. Whelan, J. A. J. *et al. Mon. Not. R. astr. Soc.* **181,** 259 (1977).

On the detection of jovian companions to white dwarfs

BRACEWELL[1] has recently proposed detection of planetary companions to nearby stars by means of a spinning IR interferometer. In particular, he notes that at far IR wavelengths, the emissivity ratio of the planet to the star increases by five orders of magnitude over equivalent values in the visible. I point out here that more than another three orders of magnitude in sensitivity is gained by choosing white dwarfs as the observational objects, which may permit detection of jovian or black dwarf companions by direct photometry from a space telescope with photon-limited, far IR detectors.

Compared with the Sun, a typical DA white dwarf has a surface area only $1\text{–}2\times10^{-4}$ as great, while its photospheric temperature is approximately double. Thus, at wavelengths in the Rayleigh–Jeans regime, an observer would detect 2,500–5,000 times fewer photons from a white dwarf than from a solar-type star at the same distance. The key assumptions to this proposal then are that planets of comparable or greater than jovian mass will (1) survive the parent star's red giant phase, and (2) presently contain internal energy sources similar to that of Jupiter. I discuss each of these assumptions in turn.

The most serious threat to a planet's survival is engulfment by the red giant photosphere. Viscous drag on the planet's orbital motion would then lead to a spiralling into the stellar core. The maximum luminosity[2] of a red giant with a $1.4\,M_\odot$ carbon–oxygen core (that is the Chandrasekhar limit) is $\sim5.2\times10^4\,L_\odot$. If the red giant's effective temperature is $\gtrsim$2,500 K, all planets with orbital semi-major axes >5.7 AU should remain outside the photosphere. For a $1.0\,M_\odot$ core, the equivalent value is 4.2 AU. Runaway atmospheric evaporation might also cause planetary destruction. However, Jupiter's atmosphere must be heated to temperatures far above 3,000 K ($GM_Jm_p/kR_J\sim$ 180,000 K) before significant quantities of atomic hydrogen will escape. Therefore, as long as a jovian planet remains outside the red giant photosphere, it will probably survive and perhaps even grow slightly from stellar wind accretion.

Both Jupiter and Saturn have internal energy sources. For Jupiter, this source provides more than half its observed thermal emission. Though gravitational contraction may be partially responsible, most astronomers favour an explanation relying on the radiation of primordial heat of formation. Graboske *et al.*[3] have calculated the initial contraction and subsequent evolution of a $0.0095\,M_\odot$ protoplanet and found that after a relatively short time ($O\{10^6\ \text{yr}\}$) spent along the Hayashi track, a rapid transition to the cooling curve of a very cold degenerate dwarf occurs. In this latter regime, $\log L/L_\odot$ scales as $-1.3\log t$. As the average age of a white dwarf (including its progenitor's lifetime) is somewhat greater than half that of the Galaxy, the present luminosity of a hypothetical jovian companion should remain at approximately half its value at $t=4.6\times10^9$ yr, the age of our Solar System. Thus, one expects relatively strong internal emission to be a general property of all planets of jovian mass or greater.

The three or more orders of magnitude gained in relative sensitivity by the choice of white dwarfs rather than solar-type stars suggest that planetary companions might be detected as an 'IR excess' if advanced detectors become available. Adopting sample parameters of $\lambda=40\ \mu\text{m}$, $\Delta\lambda=10\ \mu\text{m}$, $R_{\text{WD}}=0.013R_\odot$, $R_{\text{P}}=0.1R_\odot$, $T_{\text{WD}}=10^4$ K, $T_{\text{P}}=120$ K, and a distance of 10 pc, a collecting area of $10^4\ \text{cm}^2$ would receive ~180 photons s^{-1} from the white dwarf and ~20 photons s^{-1} from the planet. A hypothetical photon-limited detector above the Earth's atmosphere could reveal the excess planetary signal with a signal-to-noise ratio >10 in less than a minute. Confusion with the relic circumstellar dust shell of the red giant is unlikely because it should have been quickly swept away by the ram pressure associated with the white dwarf's motion through the interstellar medium. Zodiacal dust, however, may lead to serious background noise limitations[1] and increase detection times for a diffraction limited telescope by as much as a factor of 1,000 at low ecliptic latitudes.

One might also detect or set upper limits on the number of substellar, degenerate 'black dwarfs'[4] in the mass range 10^{-3} to $\sim0.06\,M_\odot$ associated with white dwarfs. Such objects may provide an important contribution to the mass density, both locally and in clusters of galaxies[5,6]. Their IR luminosity should scale at least linearly with mass. The advantage of a search in the immediate vicinity of a white dwarf is simply that one has a quite definite, highly localised position on the sky to measure. For a background-limited detection system, this allows one to maximise the signal-to-noise ratio until either the diffraction limit or the effective 'seeing' limit is reached.

There are over a dozen single white dwarfs known within 10 pc of the Sun[7]. A far IR survey of these stars from a space-borne telescope might quickly reveal whether solar system formation was a common event. A positive answer would give great impetus towards the construction of a more elaborate planet–detector, such as that proposed by Bracewell.

WILLIAM M. FAWLEY
Astronomy Department, University of Pennsylvania,
Philadelphia, Pennsylvania 19104

Received 12 February; accepted 23 April 1979.

1. Bracewell, R. N. *Nature* **274,** 780–781 (1978).
2. Paczynski, B. *Acta astr.* **21,** 417–435 (1970).
3. Graboske, H. C., Pollack, J. B., Grossman, A. S. & Olness, R. J. *Astrophys. J.* **199,** 265–281 (1975).
4. Kumar, S. S. *Astrophys. J.* **137,** 1121–1125 (1963).
5. Napier, W. McD. & Guthrie, B. N. G. *Mon. Not. R. astr. Soc.* **170,** 7–14 (1975).
6. Tarter, J. C. *Bull. Am. astr. Soc.* **8,** 517 (1976).
7. McCook, G. P. & Sion, E. M. *A Catalogue of Spectroscopically Identified White Dwarfs* (Villanova Univ. Obser., 1978).

Do comets provide material for the anomalous component of the cosmic rays?

MATTER from comets is proposed here to form a significant part of the source material for the 'anomalous component' of the cosmic rays. As a result it is concluded that certain molecular ions, such as CO^+, should be present at energies around 10 MeV per nucleon.

The spectra of the nucleonic component of cosmic radiation in the energy band 1–60 MeV per nucleon have produced a number of surprises. The most dramatic of these concerned the fluxes of oxygen and carbon. Jokipii[1] gave minimum flux values in the region 5 MeV per nucleon for hydrogen and helium which essentially divided the solar particles on the low energy side from the true cosmic radiation at the higher energies. The

0028–0836/79/0279—0622$01.00