Pulsars : Problems & Progress
ASP Conference Series, Vol. 105, 1996
S. Johnston, M. A. Walker and M. Bailes, eds.

Search for the Optical Counterpart of PSR 1953+29

V.Boriakoff[1], G.Beskin[2], D. Dossa[3], F.Fauci[4], J.B.Oke[5], L.Tella[3]

[1] *National Research Council, US; Phillips Lab, Hanscom AFB, MA, US*

[2] *Special Astrophysical Observatory, Nyzhny Arkhyz, Russia*

[3] *Worcester Polytechnic Institute, Worcester, MA, US*

[4] *Istituto di Fisica, Università di Palermo, Palermo, Italy*

[5] *Dominion Astrophysical Obs., Victoria, B.C., Canada*

1. Observational Facts

1) PSR B1953+29, the first millisecond binary pulsar discovered, has a low mass companion with a long orbital period (see parameters in Table 1).
2) Shortly after its discovery the averaged pulse profile was observed to change shape in a discrete fashion: two different pulse profiles were alternating (Boriakoff *et al* 1986). Each pulse profile remained the same for typical times of days. This is reminiscent of the mode-changing behaviour of slower pulsars, however, normally such pulsars remain in one mode for only a few minutes.
3) Observations with a Cherenkov TeV Gamma-Ray detector have shown a large pulse-profile peak when the data is folded with the correct pulse period. Recent reprocessing of the original data shows the same peak (Bowden *et al* 1990).
4) Comparison with optical photographs revealed a bright star (20-th magnitude) located less than 1 arcsec from the pulsar positions determined with the VLA and from timing. A star of $\sim 0.2 M_\odot$ is expected to be a white dwarf, at the distance of 3.5-5kpc it would be invisible.
5) Optical spectral observations of the star with the 5-meter Palomar telescope showed a reddened spectrum without any emission or absorption lines. This is typical of very hot objects.
6) CCD images obtained with the Russian 6 meter optical telescope in the Caucasus were taken to pinpoint the location of the star with accuracies better than a small fraction of an arc second. Imperfections of the CCD star images (saturation, etc.), in particular for bright 15-18 magnitude stars, had to be taken into account to pinpoint the center of the observed image. A technique was developed for finding the center of the image with an accuracy better than 0.17 arcsec, a single pixel of the CCD image. Arcs of ellipses were fitted to cross-sections of the star image at different light intensity levels. Down to very low light levels no pulsation was found.

2. Interpretations

1) Joss & Rappaport (1983) modeled the evolution of the pulsar and its companion, and concluded that mass transfer was happening until recently, and the

https://doi.org/10.1017/S0252921100041786 Published online by Cambridge University Press

tail end of it may still be going on. This may be the cause of the pulse profile changes and the high level of gamma radiation.
2) Paczynski (1983) proposed a theoretical interpretation of the optical star: a low mass object that lost its outer envelope in the mass transfer that accelerated the pulsar to millisecond rotation periods. Because we would be seeing internal layers of the object after the mass loss a much higher brightness is expected.
3) A secure identification of the optical object will give us a much better insight into the evolutionary history of PSR B1953+29.

Table 1. Parameters of PSR B1953+29

		Ref.
RA 1950.0 Position (from timing)	19h 53m 26.7311s ± 0.0003s	3
DEC 1950.0 Position (from timing)	29° 00' 43.734" ± 0.004"	3
Period	6133166488.729 ps ± 0.009 ps	3
Period derivative	$(2.95\pm0.03)\times10^{-20}$ s.s^{-1}	3
Epoch of period	2446112.6435 JED	3
Projected semi-major axis $a_1 \sin i$	31.41269±0.00002 light s	3
Orbital eccentricity	$(330.4\pm0.3)\times10^{-6}$	3
Orbital period	117.349097±0.000003 d	3
Longitude of Periastron	29.51±0.09 deg	3
Time of Periastron	2446112.49±0.03 JED	3
Dispersion Measure	104.58±0.05 pc.cm^{-3}	2
Most probable companion mass	0.2 $M_\odot$	1
Distance	3.5 kpc	1
Distance	5.39 kpc	4

References

Boriakoff, V., Buccheri, R., Fauci, F., 1983, Nature, 304, 417, (Table Ref. 1)

Boriakoff, V., Buccheri, R., Fauci, F., Turner, K.C., 1986, Proceedings of the Third Cosmic-Physics National Conference, Saint-Vincent, 239.

Bowden, C.C.G., *et al*, 1990, High Energy Gamma-Ray Astronomy, AIP Conference Proceedings 220, Ann Arbor, 75.

Joss, P.C., Rappaport, S.A., 1983, Nature, 304, 419.

Paczynski, B., 1983, Nature, 304, 421.

Rawley, L.A., Taylor, J.H., Davis, M.M., 1986, Nature, 319, 383, (Table Ref. 2)

Rawley, L.A., Taylor, J.H., Davis, M.M., 1986, ApJ, 326, 947, (Table Ref. 3)

Taylor, J.H., Manchester, R.N., Lyne, A.G., 1993, ApJS, 88, 529, (Table Ref. 4)