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Dr. Nicholas White, Code 668
Lab for High Energy Astrophysics
NASA/GSFC
Greenbelt, MD 20771

Dear Dr. White:

This is the final report on the ASCA project, "Determining the Composition of the Vela Pulsar's Jet," funded under NASA grant NAG 5 2557.

The pulsar jet is significant in explaining how the Vela pulsar's rotational energy is transported outward to the rest of the SNR, since direct radiation from the pulsar only accounts for a small percentage of the total power. Our previous ROSAT observations presented the first evidence that the pulsar is driving a narrow, collimated, and remarkably symmetrical jet into the SNR (Markwardt, C. and Ögelman, H., 1995, *Nature*, **375**, p. 40) which we interpret to be from a "cocoon" of hot gas surrounding the jet itself. We obtained an ASCA exposure of the jet in order to determine whether the spectrum is thermal or power-law continuum.

The jet cocoon is detected with ASCA at approximately 2–3$\times 10^{-3}$ ct s^{-1}. The X-ray spectrum of the jet is remarkably similar to the surrounding supernova remnant spectrum and extends to X-ray energies of at least 7 keV, with a total flux of approximately 2×10^{-13} erg s^{-1} cm^{-2} $arcmin^{-2}$. The only strong emission line is from He-like Neon at $\sim$ 0.9 keV; otherwise the spectrum is quite smooth. The spectrum cannot be fit by any one standard plasma emission model, so we used models with two-components. The lower energy component is thermal and has a temperature of 0.29 ± 0.03 keV; the higher energy portion can either be fit by a thermal component of temperature $\sim$4 keV or a power law with photon index $\sim$2.0.

If the observed spectrum is of a "traditional" jet cocoon, then we estimate the speed of the jet to be at least 800 km s^{-1}, depending on the angle of inclination of the jet axis to our line of sight. The mechanical power driving the jet is $\geq 10^{36}$ erg s^{-1} which is comparable to the pulsar's spin-down luminosity of 7×10^{36} erg s^{-1}. and the mass flow rate at the head is $\geq 10^{-6} M_{\odot}$ yr^{-1}. We conclude that the jet must be entraining material all along its length in order to generate such a large mass flow rate.

The results of this observation will appear shortly in *The Astrophysical Journal, Letters*, in an article entitled, "The ASCA Spectrum of the Vela Pulsar Jet."

We have also presented the results at two international conferences. In January 1996, I gave a talk titled, "ASCA X-ray Observations of the Vela Pulsar Jet" in the IAU Colloquium 160, *Pulsars: Problems and Progress* in Sydney, Australia, whose proceedings have recently appeared. My student Craig Markwardt presented a synopsis of the ASCA and ROSAT observations of the Vela jet at the NATO ASI *The Many Lives of Neutron Stars* in October 1996, in Lipari, Italy.

Finally, we are continuing the observational effort to understand the jet. We have an accepted ASCA observing program to finish the X-ray coverage of the jet, which should allow us to test for spectral variability along the jet's length. Similar putative pulsar jets, such as the structure observed around PSR 1509–58, appear to show thermal emission at the "tip" of the jet, with more non-thermal emission in the intermediate region between the pulsar and the tip. We should be able to show whether the Vela jet shows the same behavior with the upcoming ASCA observations. Furthermore, we have complementary observations with the ROSAT HRI and in the radio band which are all contributing to the solution of the jet mystery.

Yours truly,

H. B. Ögelman

Hakkı Ögelman