THE CRAB NEBULA'S JET

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Using deeply exposed Schmidt plates, van den Bergh (1970) discovered a peculiar jetlike feature extending about 100" beyond the Crab Nebula's northern boundary. The feature roughly coincided with a spur in the outer intensity contour map of the Crab's continuum emission (5200-6400A) made by Woltjer (1957) from plates taken by Baade with the 200 inch. However, little if any continuous synchroton emission is visible in the jet's region on Scargle's (1970) deep continuum photograph. More recent imaging of the jet by Chevalier and Gull (1975) and Wyckoff et al. (1976) using narrow passband interference-filters, show it slightly better than van den Bergh's plates, and indicate it is most visible in [O III] 5007A emission. Spectroscopy of the jet's southern portion by Davidson (1978, 1979) confirmed that the [O III] 4959A, 5007A lines are the brightest optical emissions in the jet and suggested a low radial velocity of about 100 km s^{-1}.

We have recently obtained a very deep image of the Crab Nebula using an [O III] interference-filter and the Carnegie Image Tube Direct camera attached to the 0.9m telescope at Kitt Peak. The image was digitally enhanced using a PDS microdensitometer and processed with a Comtal Display System at the GSFC. Figure 1 shows a "flattening" histogram transform for the [O III] image of the Crab, permitting simultaneous viewing of both the very bright and very faint [O III] emission features. Figure 2 is an enlargement of the nebula's northern region to show the jet in greater detail.

In our [O III] image, the jet appears as a wide ($\approx$45"), yet strikingly collimated filamentary feature extending about 75" above the main nebula's northern outer boundary. The jet appears brighter along its sharply defined and parallel eastern and western sides, suggesting a tube-like structure rather than a gaseous sheet or filled cylinder. At a resolution of 2", the jet's emission appears clumpy, consisting of several small discrete condensations. The feature's western side is especially straight and sharply defined in our image. At its northern end, the jet appears to terminate

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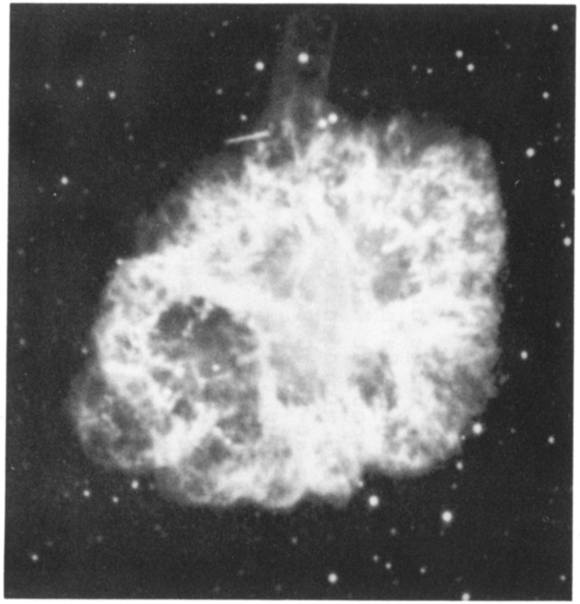

Fig. 1

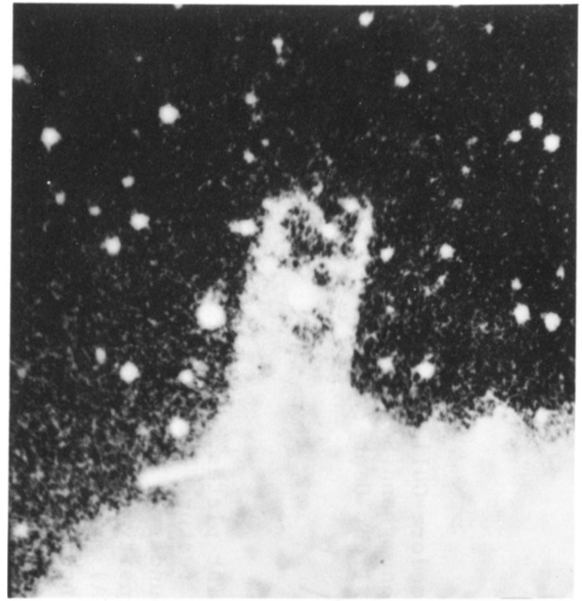

Fig. 2

Figure 1: Deep [O III] image of the Crab Nebula which has been digitally enhanced. The short E-W streak just east of the base of the jet was caused by the motion of the minor planet Holmia, accidentally recorded as it moved in front of the nebula.

Figure 2: Enlargement of the northern area of nebula showing the jet's structure in greater detail.

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abruptly and evenly. Despite its orderly morphology, however, the jet surprisingly does not project back to either the Crab's center of expansion or its pulsar. Instead, it is inclined to the northwest by about 15°.

No other jetlike or extended [O III] feature is visible on our photograph with a brightness exceeding about 1/4 that of the northern jet. Indeed, with the exception of the jet, the Crab Nebula has very well defined boundaries (see Figure 1). The remnant's maximum minor and major axes dimensions are 335" x 435" using the [O III] image and 315" x 420" using an Hα + [N II] photograph. Our measured [O III] dimensions are slightly larger than those quoted by van den Bergh probably due to deeper imaging as well as a 1.5% expansion from 1970-1981. At a distance of 2 kpc (Trimble 1973), our [O III] photograph indicates the Crab Nebula's physical dimensions are 3.2 pc x 4.2 pc.

The origin of the Crab Nebula's jet is unknown. Potential theories for its formation must provide answers as to why it is the only filamentary extension outside an otherwise well bounded nebula, and why it exhibits such an organized structure in a largely chaotic and amorphous appearing supernova remnant? Because of its appearance, it is not clear that the jet has undergone the same physical processes which shaped the rest of the Nebula. Also, though its structure suggests an energetic origin, one cannot even be sure that the jet is directly related to the AD 1054 event since it is not in radial alignment with either the Nebula's center of expansion or pulsar.

There are several possibilities for its origin. 1) the jet consists of some unusually high velocity material ejected by the 1054 explosion, 2) it is the result of a violent but separate event from the 1054 SN, 3) it represents some post-supernova input of energy by the Crab pulsar and/or plasma instabilities within the remnant, or 4) it could represent a tubular structure of material lost by the pre-supernova star during its red giant phase (Blandford et al. 1982). However, clearly more information regarding the jet's physical properties (e.g. proper motion, temperature and density estimates, and the presence of synchrotron radiation) must be obtained before we can understand the jet's structure and origin.

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