BOW SHOCK MODELS OF HERBIG-HARO OBJECTS

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ABSTRACT. It has recently been found that models of a radiating bow shock can explain qualitatively the strange emission line profiles observed in some Herbig-Haro (H-H) objects. It is also possible to compare directly the emission line intensity maps predicted from these models with CCD images of H-H objects. Such a comparison between our models and observations of HH 46/47 is presented, showing that the condensation HH 47A may tentatively be identified with a bow shock formed at the "head" of a jet.

1. INTRODUCTION

There now is relatively strong evidence that the emission line spectra of some H-H objects are formed in the recombination region behind a bow shock. Models of a bow shock formed around a "bullet" moving supersonically with respect to the surrounding medium predict emission line profiles (Raga and Böhm 1985, 1986) which are qualitatively similar to long-slit spectra obtained for HH 1 (Böhm and Solf 1985, see also Choe *et al.* 1985) and HH 32 (Solf *et al.* 1986). Hartmann and Raymond (1984) have also shown that a bow shock model successfully explains the emission line ratios observed in HH 1.

Given this quite convincing spectroscopic agreement between theory and observations, one would expect that bow shock models should also successfully predict the emission line intensity maps obtained from narrow-band CCD imaging of H-H objects. We have calculated such intensity maps from our bow shock models (Raga 1986). In this paper we attempt to compare our predictions with narrow-band images of H-H objects.

2. THE PREDICTED AND OBSERVED INTENSITY MAPS

We have developed bow shock models from which predictions of the emission line spectrum, line profiles, and spatial distribution of the emission can be obtained. If the size assumed for the seeing disk is small relative to the size of the bow shock, the emission line intensity maps predicted from these models show an arc-like shape (Raga 1986). We have also calculated line-ratio maps, which provide another possible observational test for our models.

A quite striking similarity is found between the Hα images of HH 34 obtained by Reipurth *et al.* (1986) and by Bührke and Mundt (1987) and the predictions from our models (Raga 1986). The observations of HH 34 show an intensity distribution which agrees quite well with the bow shock model predictions, but also shows a few low contrast in-

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homogenieties ("condensations") which could in principle be due to the presence of other shocks, a time-dependent behaviour of the recombining gas, or the presence of inhomogenieties in the pre-shock gas. In other H-H objects with smaller angular diameter (for example, HH 32) the situation is less favourable, and comparisons of narrow band images of these objects with predictions from our models are inconclusive.

3. THE CASE OF HH 46/47

We have obtained narrow-band CCD images of the H-H object HH 46/47. This object morphologically appears to be jet-like, and proper motion studies (Schwartz *et al.* 1984) indicate that HH 47A might be the "head" of this jet. In figures 1 and 2 we show a comparison between a [S II] λ 6717 image of HH 47A (fig. 1) and the corresponding prediction from a model of a 72 km/s bow shock moving at an angle $\phi = 60°$ with respect to the plane of the sky (fig. 2). Although the predicted and observed images are qualitatively similar, a bow shock identification for HH 47A should be considered only tentative. Line ratio maps and high resolution spectroscopy should provide information needed for a more careful interpretation of this H-H object.

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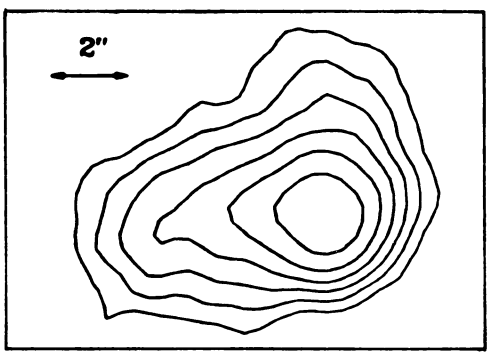

Figure 1 - [S II] λ 6717 image of HH 47A obtained with the CTIO 0.91 m telescope.

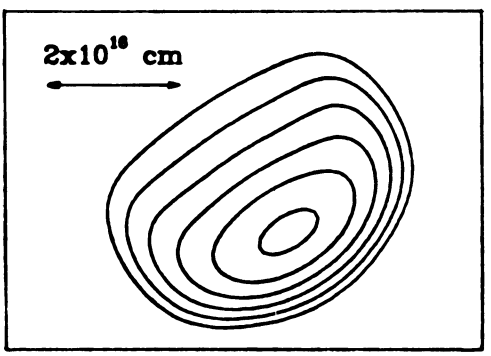

Figure 2 - [S II] λ 6717 image predicted from a 72 km/s model of a bow shock moving at an angle $\phi = 60°$ with respect to the plane of the sky.

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