OBSERVATIONS OF BIPOLAR MASS FLOW FROM SYMBIOTIC STARS

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ABSTRACT. Spectroscopic observations of high spatial and high spectral resolution indicate that mass flow from symbiotic stars generally exhibits a bipolar pattern. Besides the polar features moving at velocities up to several 100 km/s, equatorial structures of much lower expansion rate are present in some cases. Mostly, the high-velocity components appear to be highly collimated and hence can be considered as "jets". The jets probably originate from an accretion disk within a binary star where mass from a late-type giant is accreted by a compact companion.

1. INTRODUCTION

In recent years bipolar mass flow has been discovered to be associated with a large variety of stellar objects in both early or late stages of stellar evolution. Pre-main-sequence stars, such as T Tau or FU Ori stars, are now known as powering sources of highly collimated mass flow observed as jets or Herbig-Haro objects (see e.g. Mundt et al., 1987). Nova shells, if spatially resolvable (e.g. DQ Her or HR Del), exhibit a prolate ellipsoidal shape with polar blobs indicating that a bipolar geometry has been dominating the mass ejection (Solf, 1983b). Among the planetary nebulae most of them are known for strong deviations from an isotropic expansion leading to numerous types of axi-symmetric or bipolar shell structures. The recent discovery of highly collimated flow with a velocity of ~200 km/s in NGC 2392 (Gieseking et al., 1985) shows that the bipolar jet phenomenon is not uncommon even in evolved planetaries. Since in all these cases the bipolar mass flow seems to be related to some sort of mass accretion through a disk in the center region, it will not be surprising if some of the symbiotic stars known for mass ejection do present signatures of bipolarity as well.

2. OBSERVATIONAL METHOD

In order to detect bipolar mass flow from symbiotic stars (or other compact objects) long-slit coudé-spectroscopy of the lines of [O III] or [N II] was carried out at the 2.2-m-telescope on Calar Alto providing high spectral resolution (3-10 km/s) as well as high angular resolution

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(0.7-1.5 arc sec). Usually, the entrance slit was centered on the star and set to various position angles (p.a.). This method allows us to investigate the spatial distribution (along the actual direction of the slit) of spectroscopically resolved components of an emission line. If the components are sufficiently separated in the velocity space ($\Delta v \sim 10$ km/s), their apparent angular separation can be determined far below the seeing limit (down to typically 0.1 arcsec). Combining the results from the various p.a. of the slit, the spatial distribution of the different velocity components on the sky can be reconstructed (for details see Solf, 1984). In the cases of more extended nebulosities (e.g. R Aqr) a fine grid of different slit positions has been used in order to cover the entier nebular structure.

3. RESULTS

In the following, results obtained from R Aqr, V1016 Cyg, HM Sge, and CH Cyg will be summarized, each of them representing a different type of bipolar outflow. R Aqr is associated with extended nebulosities ejected several hundred years ago. V1016 Cyg and HM Sge underwent nova-like outbursts within the last two decades. CH Cyg ejected bipolar jet features in the course of brightening at radio wavelenghts three years ago.

3.1 R Aqr

The deduced velocity field of the nebulosity allows a clear-cut distinction between two (inner and outer) components. Each complex can be described as a bipolar, hour-glass-like, expanding thin shell resulting from a particular geometry of outflow presenting velocities increasing with the latitude angle of the flow vectors (Solf and Ulrich, 1985). Both shells are related to a common bipolar axis of symmetry (inclined by 72° with respect to the line of sight). The deduced ratio between the polar and equatorial expansion rates is about 6 suggesting a rather modest degree of collimation of the gas flow. The pronounced uniformity observed in the kinematic structure of each shell indicates that they must be attributed to no more than two major ejection events, 185 and 640 yr ago. Departures observed in some of the brighter nebular features ("jet") may be explained through local decelerating in the course of an interaction of the ejecta with the ambient material (at rest) rather than postulating additional episodic expulsions of high-velocity material.

3.2 V1016 Cyg

The emission lines of [O III] and [N II] observed in V1016 Cyg present two components separated by 44 and 51 km/s, respectively. The deduced maximum angular separation (p.a.$\sim 80^{\circ}$) for the [N II] components is 0.4 arc sec (Solf, 1983a). The data indicate a bipolar flow with 120 km/s velocity and a collimation angle of $\sim 20^{\circ}$ for an adopted distance of 2.2 kpc. (Larger distances would lead to higher velocities and higher collimation). The observations are compatible with the existence of an equatorial ring structure of lower expansion rate.

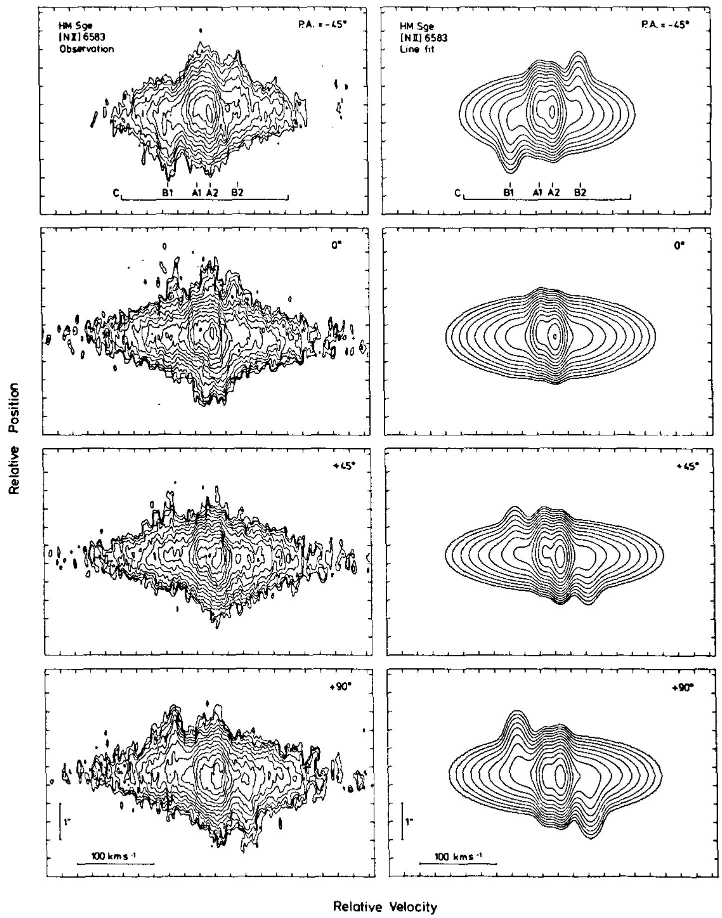

Fig. 1. (Left): Contour diagrams (in a position-velocity representation) of the spatially resolved [N II]λ6583 line of HM Sge observed at various slit position angles. (Right): Two-dimensional gaussian line fits to the observed lines using five distinct components (A1,A2,B1,B2,C)

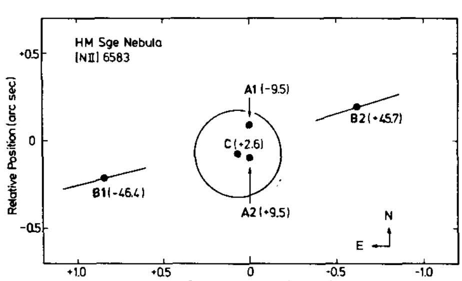

Fig. 2. Map of the relative positions (1983) of the five resolved nebular components of HM Sge as reconstructed from the [N II] line spectra. Relative radial velocities are quoted in parentheses

3.3 HM Sge

The observed [N II] lines (Fig. 1) exhibit four resolved narrow line components (A1,A2,B1,B2) being superimposed on a broad fifth component (C). The data show that the inner components A1, A2 are separated by 19 km/s in velocity and 0.2 arc sec along p.a. 0°, whereas the outer components B1, B2 are separated by 91 km/s and 1.5 arc sec along p.a. 105°, respectively (Solf, 1984). The derived distribution of the five components on the sky is shown in Fig. 2. The resulting expansion velocities depend on the distance of HM Sge (values beteen 0.4 and 2 kpc are found in the literature). For d = 0.4 kpc one obtains a bipolar expansion velocity of 200 km/s for components B1, B2 and a collimation angle of ≤6° for the flow. At 2 kpc the corresponding values are 900 km/s and ~1°. In any case, the bipolar flow is highly collimated and of remarkably high velocity. Hence components B1, B2 must be considered as jet features which have been ejected during the 1975 outburst of HM Sge. The low-velocity components A1, A2 are likely to represent an equatorial structure, either slowly expanding (25 km/s) blobs or a rotating (10 km/s) ring. The broad component C might be due to an unresolved (spheroidal or ellipsoidal) shell expanding at intermediate velocities (~60 km/s). Both the geometry and kinematics of the nebular components seem to be less compatible with an single star model of symbiotics, but are in good agreement with predictions of a binary star model assuming that mass loss from a giant is accreted through a disk around a compact companion.

3.4 CH Cyg

High-resolution observations of the [O III] 5007 line of CH Cyg in September 1986 have revealed a compact nebular feature located 1.1 arc sec northwest of the star (Solf, 1987). The feature has been identified with a component of the radio jet ejected in 1984 (Taylor et al. 1986). The data confirm the high tangential velocity (>800 km/s) of the outflow. The deduced low radial velocity difference beteen the jet feature and the star suggests that the jet is moving nearly perpendicular to the line of sight. The observed width of the [O III] line indicates a high collimation of the flow (<7°). The jet probably originates from an accretion disk seen nearly edge-on around the hot compact companion of the M6 giant in an eclipsing binary of highly excentric orbit.

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