



KINEMATIC OF THE SYMBIOTIC SYSTEM R AQR

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ABSTRACT

We present here the results of the kinematical analysis of the symbiotic system R Aqr. We obtained high dispersion spectra with the MES spectrograph on the 2.1 m telescope of San Pedro Mártir (MEZCAL). The used filter were H α + [NII], ($\lambda_c = 6575\text{\AA}$, $\Delta\lambda = 90\text{\AA}$). We analyse the $\lambda\lambda 6583$ line principally. When the observations are compared with previous ones by Solf (1992) we detected an important change in the magnitude of the velocities and we conclude that this is a probe for precession in the observed jet. We are working also in a 3-D kinematic model for the object using the measured velocities and the state of the model is presented.

BACKGROUND

R Aqr is a symbiotic system formed by a Mira variable (with a pulsation period of 287 days: Mattei & Allen, 1979) and a white dwarf. It has two bipolar and co-axial shells with kinematical ages: 185 and 650 years (Solf & Ulrich, 1985). A high collimated structure (jet) is observed in this object, with bright "knots" along the jet that evolve in position, brightness and size. It was first detected in the late 70's (Wallerstein & Greenstein, 1980).

UV observations reveal the nature of this jet-like structure (Nichols & Slavin, 2009). They show that the shape of the emission lines is consistent with an eject model of a bow shock, supporting the existence of an accretion disk as the origin of the ejected material.

OBSERVATIONS

We observed R Aqr with the MES spectrograph at San Pedro Mártir Observatory (Meaburn, et al. 2003). We obtained high resolution spectra in the H α + [NII] region. The observations were obtained on September 24 and 25, 2010, using the 150 μm slit and a 2 x 2 binning. The two pixels represent 4.9 km/s in the spectral direction and 0.602 arcsec in the spatial direction. In this paper we discuss the results of this observations. In figure 1 we draw over an H α image of R Aqr, some of the slit positions that were observed. Almost all of them were positioned to pass through two or three "knots" avoiding the central source, due to its high brightness. Only one of the slits (number 3) pass through the center.

For spectral calibration we used the ThAr lamp and for the spectral reduction the MIDAS package.

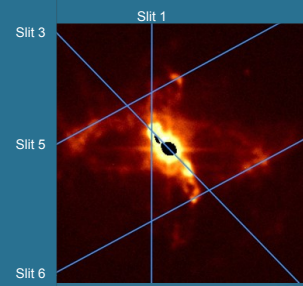


Figure 1. Slit positions observed on R Aqr

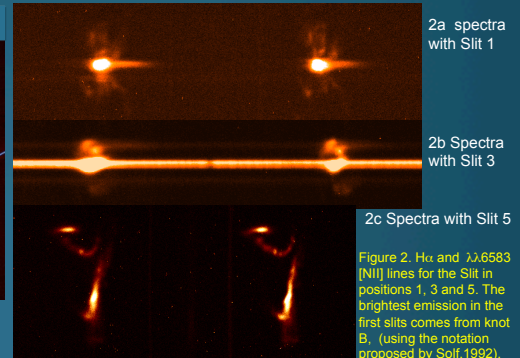


Figure 2. H α and $\lambda\lambda 6583$ [NII] lines for the slit in positions 1, 3 and 5. The brightest emission in the first slits comes from knot B, (using the notation proposed by Solf, 1992).

PV DIAGRAMS

In figures 2a, 2b and 2c, we present the H α + 6583 [NII] lines obtained for the slit positions: 1, 3 and 5, respectively. The PV diagram obtained for the H α line in the Slit 1 spectra is shown in figure 3a. The brighter emission comes from knot B, according to Solf notation. In figure 3b, the Solf (1992) observations for [NII] line is compared with our observations, we can observed the clear variation in the velocity profile of the line. The line profile predicted for a region ("knot") with a gaussian velocity distribution, is simetric (see figure 6), the observed profiles are highly asymmetrical indicating that we are observing a bow shock, according with the model where the collimated ejected mas interac with previously ejected material from the AGB. Hartigan et al. (1987), predicted the line profile for models of a bow shock at different angles with the line of sight. Comparing Solf observations and ours with Hartigan profiles, we conclude that we are observing from an angle between 150° and 180°, while the 1987 Solf observations correspond to an angle between 15 and 30 degrees, proving with this the precession of the jet

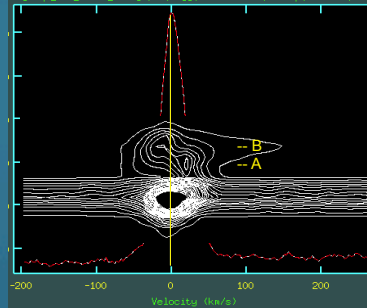


Figure 4. Velocity profile and contour plot of the 6583 [NII] line observed with Slit 3. Is notorious the red wing observed also in this line, in contrast with Solf observations (figure 4d y g in his paper)

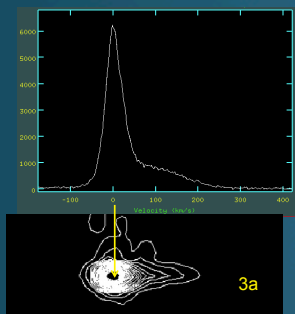


Figure 3: 3a. PV diagram for the H α line observed with the slit in position 1. In the upper profile we can see that the red wing of the line extends until 200 km/s.

In 3b we present, the PV diagrams from Solf (1992, figures 4d y g in his paper) for his 1987 and 1982 observations. The clear variation of the profile indicate the existence of a precessing jet.

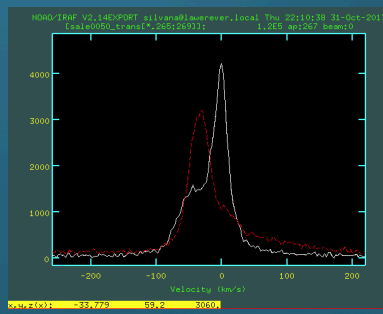
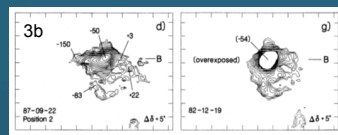


Figure 5. Profile of the $\lambda\lambda 6583$ [NII] line observed through the Slit 3 at the position of the A (in white) and B (in red) knots. The velocity of the centroid of each line differ by 34 km/sec.

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3D-KINEMATICAL MODEL

According to the determined parameters for R Aqr, we constructed a kinematical model for this object, using the SHAPE modelation tool (Steffen et al. 2009). We proposed a bipolar thin nebulae expanding with constant velocity, a precessing jet with the alignment near to observed in R Aqr, and a series of bright "knots" along the jet. In Figure 6 we present the model and the spectra obtained from the slit at position near our Slit1. The wide of the line is reproduced but not the asymmetry observed. The asymmetrical profile could be explained as a bow shock (ref) that is observed at an angle near 150°, i.e. from behind. In contrast to the blue wing observed by Solf in 1987. Such profile could be explained with a bow shock observed from an angle between 150 and 180 degrees, according with the models for a bow shock from Hartigan (1987).

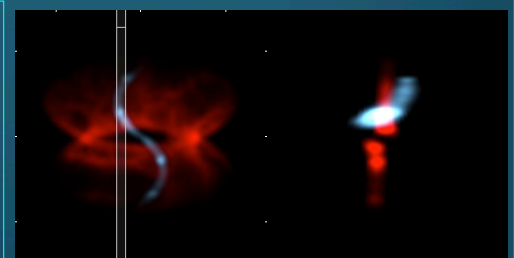


Figure 6. Left. First approximation with SHAPE for modeling the R Aqr jet and nebulae. We have a bipolar nebula and the jet with the observed knots. Right: PV diagram for the slit position shown.