SPECTRAL STUDY OF THE OBJECT HH12

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Spectral studies of one of the brightest Herbig-Haro objects, HH12, using a multiaperture (multi-pupil) spectrograph are reported. We identify nine knots (densification nodes) in intensity diagrams. Hα emission mainly predominates in this object, except in two of the knots (C and M) which have a lower excitation level, given their high [SII] line intensity. The average electron temperature across the object is 6700 K. It is shown that the radial velocity of the object as a whole is low, i.e., its motion is mostly in the celestial plane. The excitation source for HH12 is also discussed.

Keywords: Herbig-Haro objects - individual: HH12

1. Introduction

The Herbig-Haro object HH12 lies in the region of the reflecting nebula NGC 1333, which is located near the dark cloud L 1450 that forms part of the molecular complex Perseus OB2 [1]. The main star illuminating the nebula NGC 1333 is BD+30°549, which is of class B9V. The distance to the molecular cloud has been estimated in various ways: one of the most plausible estimates is 350 pc [2], and an estimate of 220 pc based on photometry is also noteworthy. Many optical, IR, and radio observations (of which the most interesting are refs. 4-9) have shown that this nebula is extremely rich in deeply embedded IR sources, including some in class zero (first introduced in Ref. 10 and characterized by a small ratio of the bolometric and submillimeter luminosities, as well as by a low bolometric temperature [11] and considered to be the youngest population in clouds), Hα emission stars, collimated flows, and Herbig-Haro objects (HH objects). All of these data provide direct evidence that active star formation is under way.

The abundance of HH objects in the region of NGC 1333 makes identifying their sources much more complicated. While the sources of some HH flows have been determined uniquely (as an example, for the well collimated flow HH7-11, the source is undoubtedly the object SVS13 [4,5]), the sources of many other HH objects, including such large ones as HH12, have not yet been established reliably.

HH12, which was discovered by Herbig [12], is one of the brightest HH objects in the sky. It has a complicated,
patchy structure of size roughly 30"x50". As a whole, six major knots (densification nodes) can be identified in it in the visible range [8,13]. This object also has a strong structure in the IR and, while its image in the [FeII] emission at $\lambda = 1.64 \mu m$ [13] is similar to the image in the visible, the emission peaks for the $H_2$ 1-0 S(1) line at $\lambda = 2.122 \mu m$ [13-15] and the 1-0 Q(3) line at $\lambda = 2.424 \mu m$ [13] are shifted relative to their visible positions in several of the knots. In addition, yet another knot was observed in the northern portion of the object which had not been seen in the visible range. HH12 is essentially the same in the visible and infrared continua.

This article is an effort to answer questions about the structure and origin of HH12 by observing this object with a multaperture (multi-pupil) spectrograph.

2. Observations and data processing

The observations of HH12 were made on November 15, 2002 with the 2.6-m telescope at the Byurakan Observatory using the multiaperture (multi-pupil) spectrograph VAGR [16] mounted at the primary focus and a Loral CCD matrix with a 2058×2063 pixel format as the detector. The working field was 50"×40" with a scale of about 1.0"/pupil. In order to avoid overlap of the spectra a narrow band interference filter with a transmission bandpass of 6400-6800 Å was used. A grism with a dispersion of 2.1 Å/pixel was used as a dispersing element. The total exposure time for the object was 3600 s.

Initial processing of the resulting images was carried out using a special program package developed at the Special Astrophysical Observatory of the Russian Academy of Sciences [17]. The integrated spectroscopic data were processed further using the ADHOCw program package (http://www-obs.cnrs-mrs.fr/ADHOC/adhoc.html) developed at the Marseilles Observatory. This program automatically extracted individual spectra and performed wavelength calibrations. These data were used to construct charts of the line and continuum emission from the object (using the measured flux in each aperture), as well as to determine the radial velocities for the lines.

3. Results

The spectrum of HH12 is entirely typical of Herbig-Haro objects. In the range studied here, there is almost absent no continuum and Hα and the forbidden lines of ionized sulfur and nitrogen stand out. Figure 1 shows images of HH12 recovered from our spectral data in the Hα, [SII] $\lambda 6716$ Å and $\lambda 6713$ Å, and [NII] $\lambda 6583$ Å lines. We isolated nine knots in the observation region. The five brightest are designated as in Ref. 2 and the remaining four are labelled M, N, P, and Q in order of decreasing brightness. A high resolution image of HH12 [8] is shown in Fig. 2 for comparison with these charts. In that image, it can be seen that each of the large knots consists, in turn, of several smaller knots. The coordinates of the knots we found are listed in Table 1. Spectrophotometric data and the radial velocities are given in Table 2.

Table 2 and Fig. 1 show that Hα emission predominates from the object as a whole, except for knots C and M, where the emission in the [SII] lines is of essentially the same intensity and suggests a lower level of excitation. The [NII] lines in the spectrum of this object are mostly weaker than those of [SII] (the intensity ratio $I([SII])/I([NII]$