3-D SPECTROSCOPY OF HH588.

E.R. Hovhannisyan, T.Yu. Magakian, T.A. Movsessian, E.H. Nikogossian,
Byurakan Astrophysical Observatory, Armenia (mail: helen@web.am)

Introduction.

Study of the bright-rimmed clouds [1] revealed some signatures of low-mass star-formation process in these objects. Such appearance as outflowing of the stellar matter in the form of Herbig-Haro objects and jets is a imprescriptible feature of star-formation.
In the bright-rimmed cloud BRC 37 [1] the HH588 flow was found, located at the distance 750 pc [2]. It has bipolar structure with well-defined two bow-shocks oriented in NE and SW direction and central part, which includes several more knots and tiny low-excited central emission object [3], close to the IRAS 21388+5622 source. More recent observations revealed two additional HH knots located on 1″.4 distance to the east from HH 588 NE [4], which also are the probable parts of the HH 588 complex. The most probable source of this flow is IRAS 21388+5622 which has a luminosity of 130 L [5] and is associated with the molecular outflow [2]. The aim of this work is an investigation of the kinematics and physical parameters for clarification the outflow components structure and belonging to one system. During several last years the observations of the young stellar objects are carried out in Byurakan Observatory using the multi-pupil spectrograph VAGR [6] with field of view 40″, attached on prime focus of the 2.6m telescope. A number of Herbig-haro objects, outflows and cometary nebulae were observed by this devise allowing to obtain about 1250 spectra.

Results and discussion.

On the Fig.1 the direct image with [SII] filter obtained by [3] is presented.

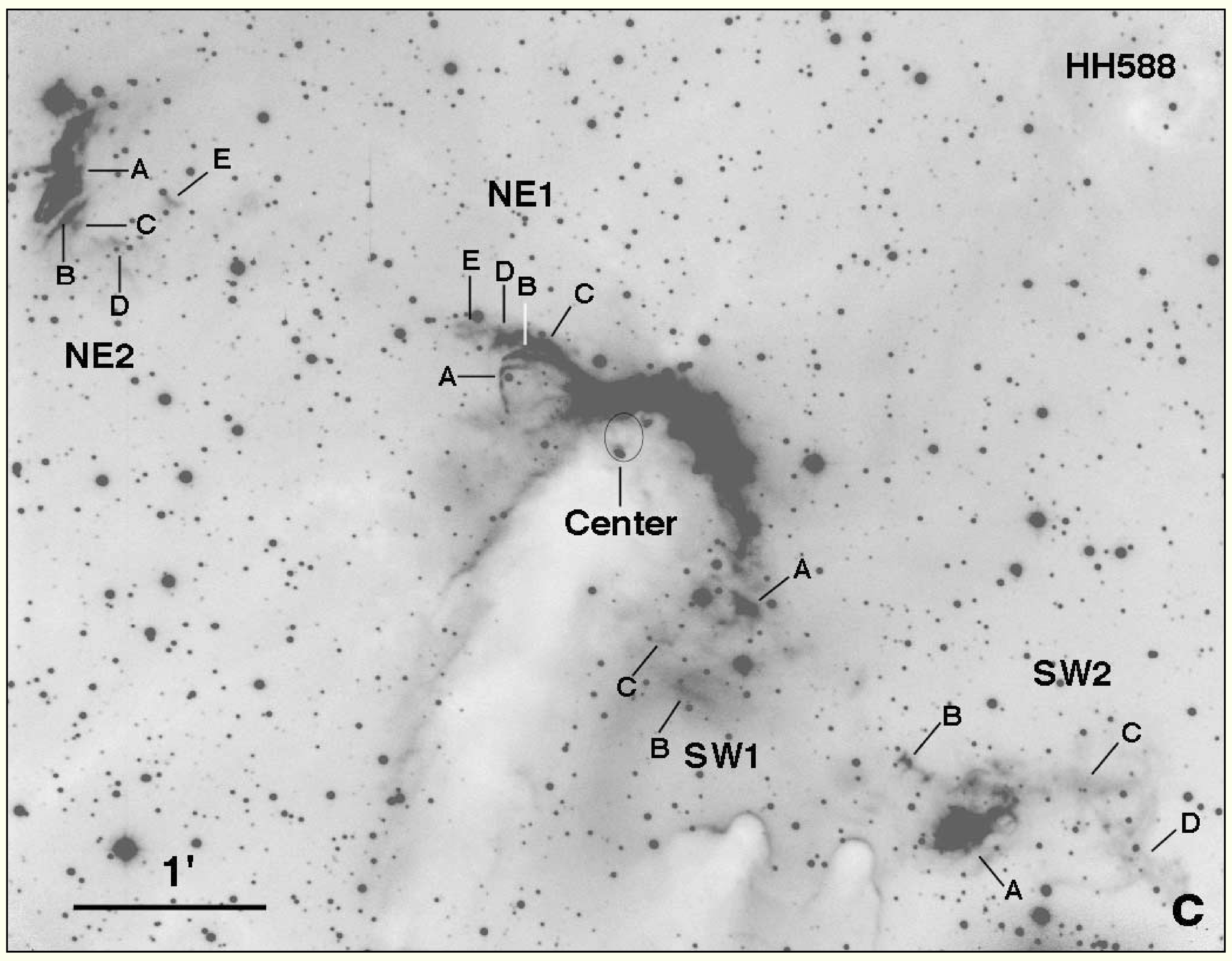
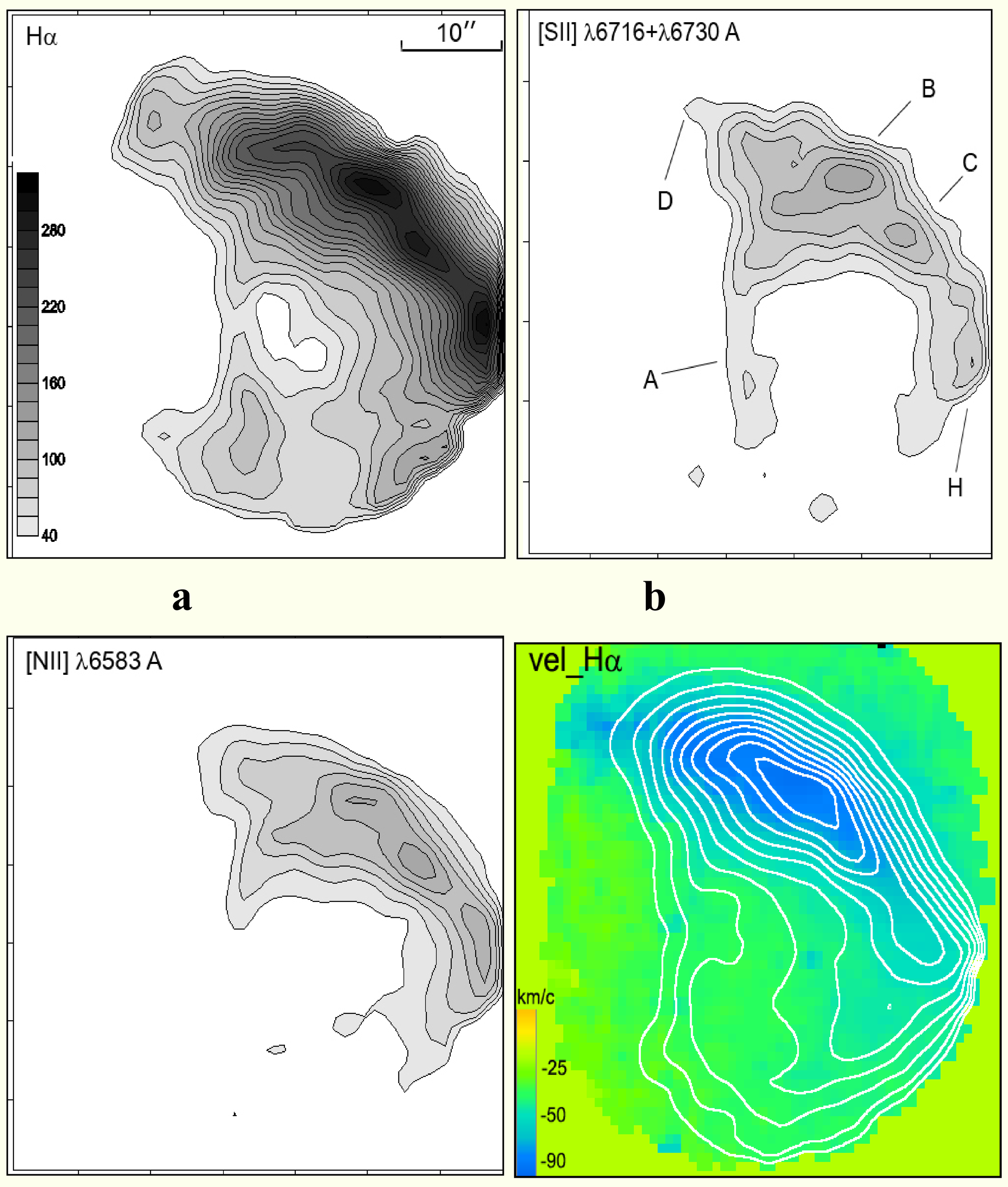


Fig.1

Here we discuss the largest objects of this region, namely NE1, NE2 and SW2.

NE1.

In the Fig.2 the emission maps of this object in the lines Hα, [NII]λ 6583Å, [SII] λλ6716Å+6731Å, restored from the multi-pupil spectra, are presented. The scale of the relative intensities shown in Fig. 2a applies to all three panels (the same is valid for other figures also).



a b c d

Fig.2

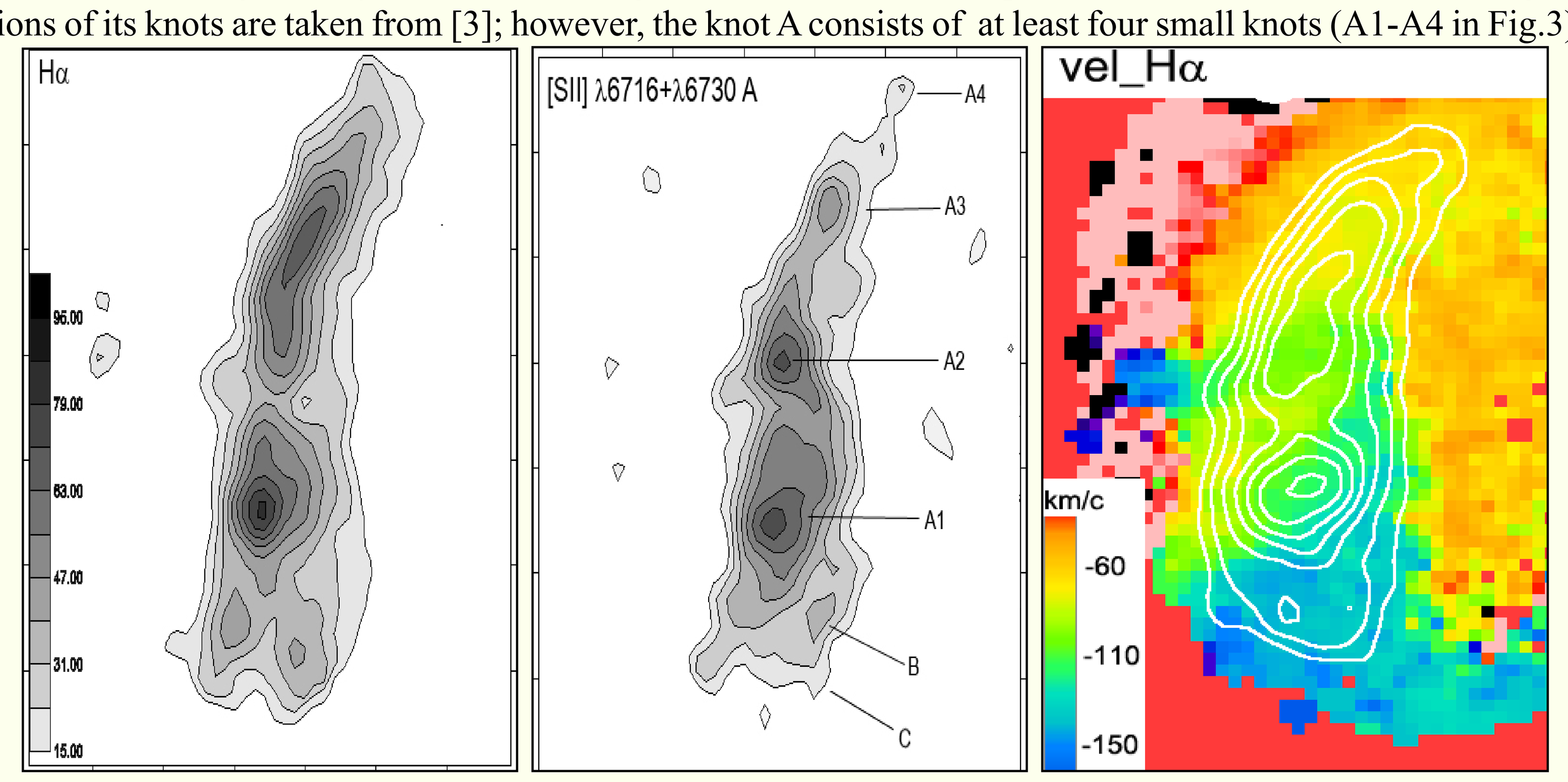
In the [SII] lines the object is similar to the direct image [3]. The knots designations are from [3]; however, the knot H is just a part of bright rim. Knots B, C, D probably represent the part of the flow outgoing from the source, knot A is well defined only in the [SII] map. We compute the lines ratios for this object. Hα/[SII] and Hα/[NII] ratios gradually decrease along the jet with exception of the knot D. The [SII] lines ratio along the jet is nearly constant and lower than in bright rim. We computed also the radial velocities of Hα line from the high resolution spectra (fig.2d). This object is well-discerned on the nebular background by its velocity, which tends to rise in absolute value toward the direction of the flow. Again the velocity of the knot D is a slightly lower. One can explain this effect by the deceleration of the flow by more dense surrounding matter. As can be seen from the fig.2d the velocity of knots A and H is the similar to background; they probably belong to bright rim.

Observation.

Observations were carried out in November 2002 and January 2005 in Byurakan. As a detector 2063X2058 Loral CCD was used, which provides 40″ field of view with 1″ per micro-lense sampling. We used VAGR spectrograph in high and low resolution modes with 2.1 Å/pix and 0.5 Å/pix dispersion respectively. To avoid overlapping of the spectra the interference filters with about 100 Å width for high resolution mode and 400 Å for low resolution mode were used. First mode allows to observe separately Hα and [SII] spectral regions; in the second mode all these emissions were observed simultaneously. For data reduction the ADHOCw software developed in Marseille observatory was used to build 3D data cube. From these data cubes the maps of physical parameters were restored. Here we are describing the most interesting results.

NE2.

Fig.4 presents the intensities maps of the emission lines for this object in the same way as Fig.2.
NE2 is an elongated object; its non-homogenous structure is more pronounced in [SII] lines. The designations of its knots are taken from [3]; however, the knot A consists of at least four small knots (A1-A4 in Fig.3).



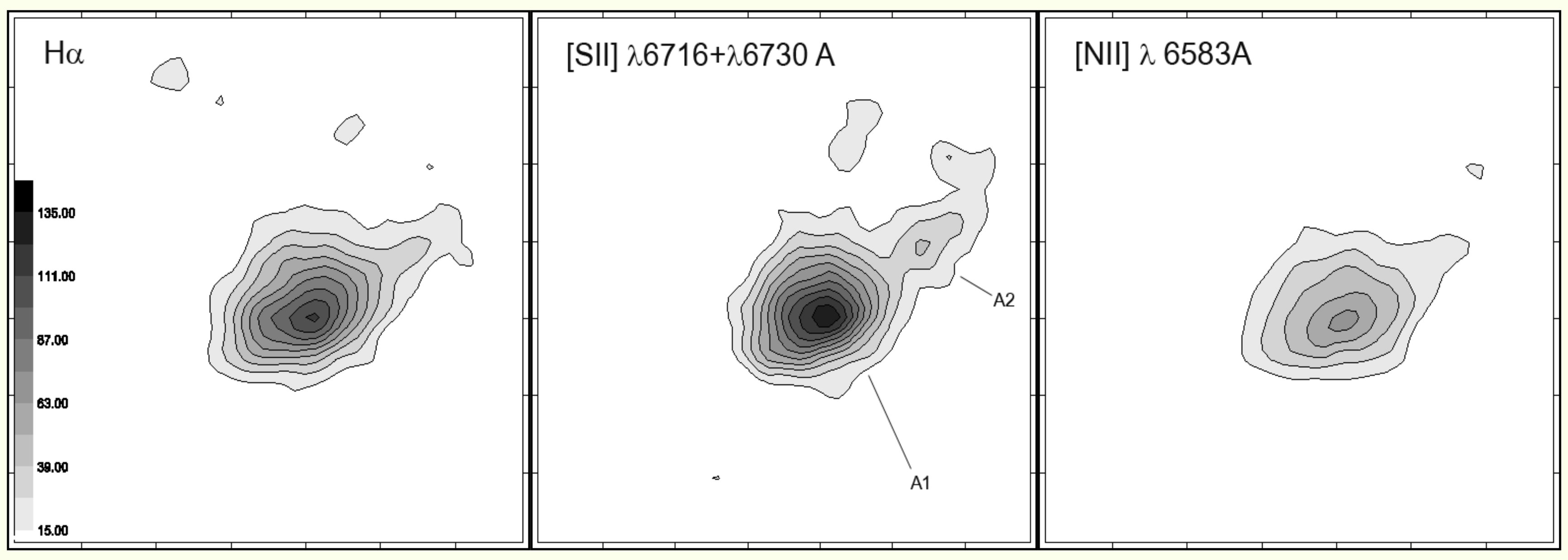
a b c

Fig.3

The comparison of our maps with the images from [3] shows some discrepancy in the region of knots B and C: the pronounced border between knots A and B in [3] is fuzzy in our maps, moreover, the knot B is south-elongated and blends to knot C.
The dependence of the lines ratios on distance from the source shows that the more excited region is more distant from the source. The average value of Hα/[SII] ratio in the object is equal to 2.8, Hα/[NII] is 1.2, [SII] lines ratio is almost constant in whole object and equal to 1.
We present also the velocity maps (Fig.3b) for two emission lines. The deceleration effect in the outer part of bow shock is well-pronounced. It is clear that the matter of the outer lobe of the outflow interacts with the surrounding medium, creating the region of the increased excitation.

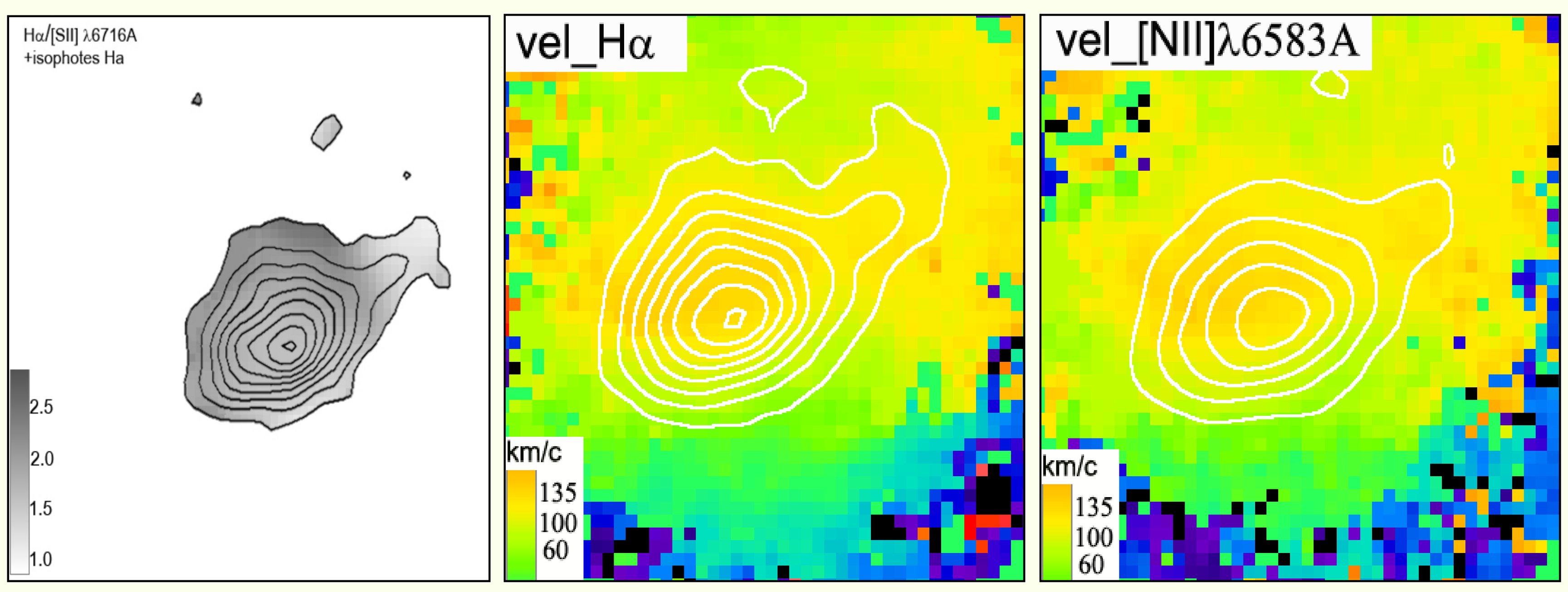
SW2.

The south-western part of HH588 is the probable counterpart of NE2 object. lightly elongated to the west. It is presented in the fig.4. We see that the object is elongated across the flow direction and its shape well agrees with image from [3]. We marked out two concentrations as parts A1 and A2.



a b c

Fig.4



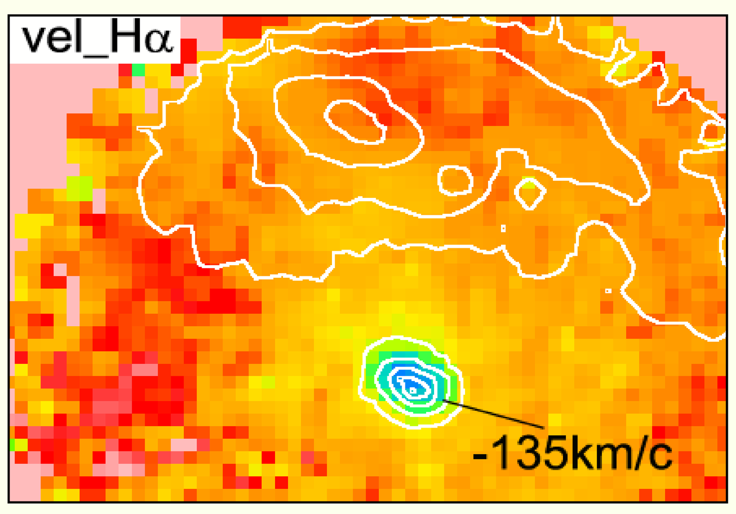
a b c

Fig.5

Radial velocity maps (Fig.5 b, c) show the prominent deceleration in south-western direction (from 120 to 60 km/s); however, the lines ratios (Fig. 5a) show the decrease of excitation in the direction away from the source, which is somewhat unusual. We do not have yet a good explanation for this behavior.

Center

Finally, we present the velocity maps of the probable central source area (fig.1). It has a large negative velocity. The source probably is somewhat extended, and on 2MASS maps a small IR cometary nebula actually can bee seen at its place.



Conclusion.

In this work the bright components of HH588 flow are analyzed, using the maps of emission lines and radial velocities. The bipolar nature of this outflow is obvious from their radial velocities. The unusual feature of this flow is its inclusion in the bright-rimmed cloud; thus, it can belong to so-called irradiated jets. It is worth to mention that all HH-objects studied here show a deceleration in the regions of interaction with the interstellarmedium.
We plan to continue the investigations of this region in future.

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References:

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