V1331 Cyg - An outburst of results

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INTRODUCTION

FU Orionis objects are a class of young stars with large brightness outbursts in the optical. The outbursts lead to strong increase in luminosity due to enhanced accretion and dust removal by the accompanying wind. All FUors have large infrared excess emission from circumstellar dust, and some drive bipolar jets and outflows [1].

V1331 Cyg is a pre-outburst FUor candidate (Fig. 1) :

- At distance of ~ 550 pc
- At the border of the dark cloud LDN 981
- Is associated with an arc-like reflection nebula
- It has two nested rings of 9000 and 3300 AU radii respectively, encircled by an expanding CO ring [2].

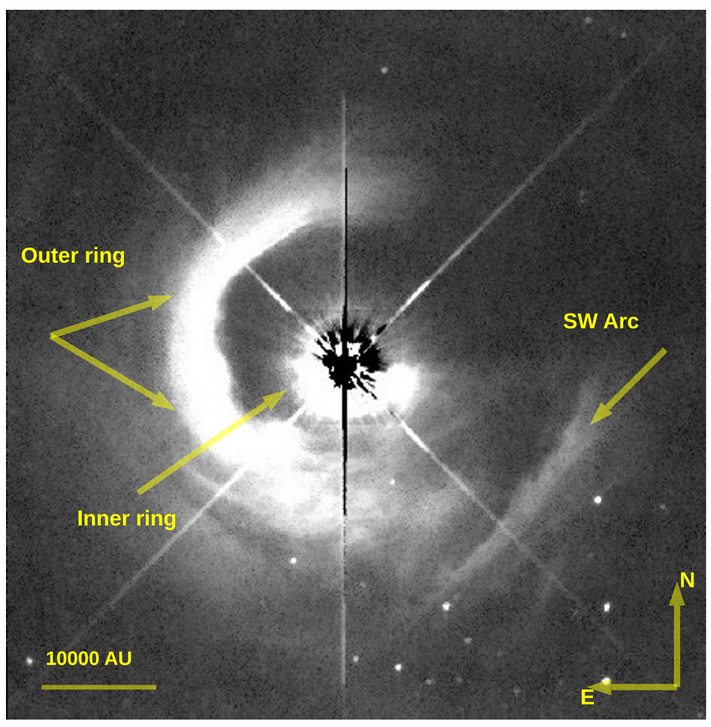

Fig.1: 2nd epoch F814W WFPC2 image of V1331 Cyg

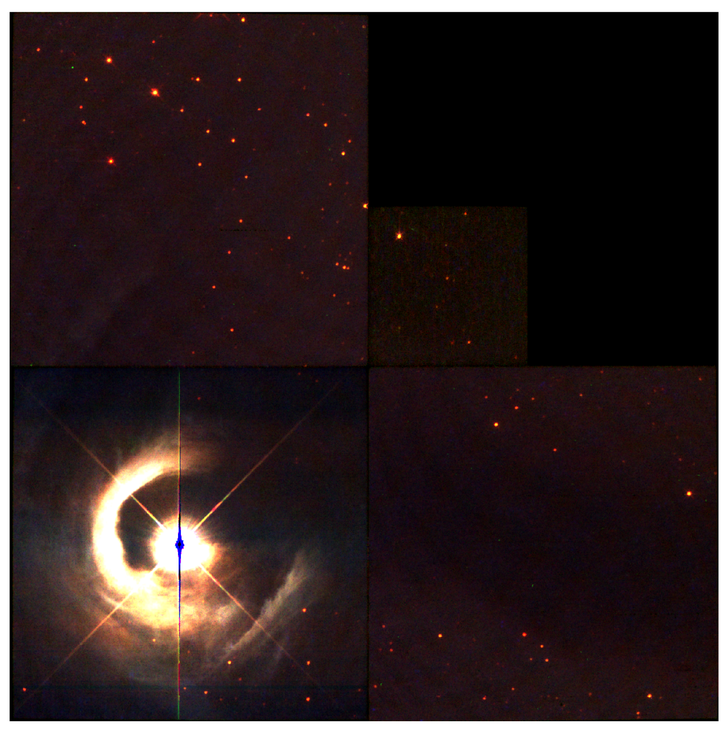

Fig.2: Full field image based on 2nd epoch frames

Are the nested rings expanding?

The HST-WFPC2 imaging was done in 2000 and 2009. The first epoch images were obtained for F606W and F814W filters. The second epoch observations were deeper with one more filter, F450W introduced.

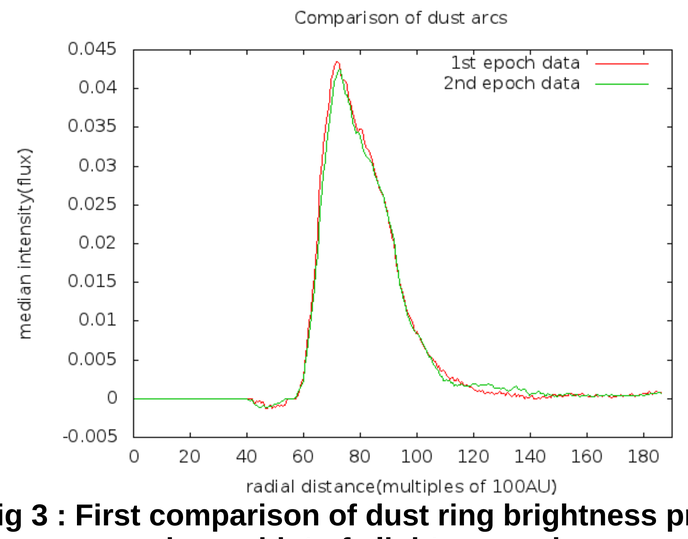

Fig 3 : First comparison of dust ring brightness profiles gives a hint of slight expansion.

Wind-driven expansion has an imprint on the colour profile of the ring, the study of which will be the next step to do.
There is a missing ring section to the NW not due to extinction by the dark cloud but represent a shadow (Fig. 6), originating close to the star. Our PSF - subtracted planetary camera frames disclosed a knot at ~0.4” from the star in the same direction.

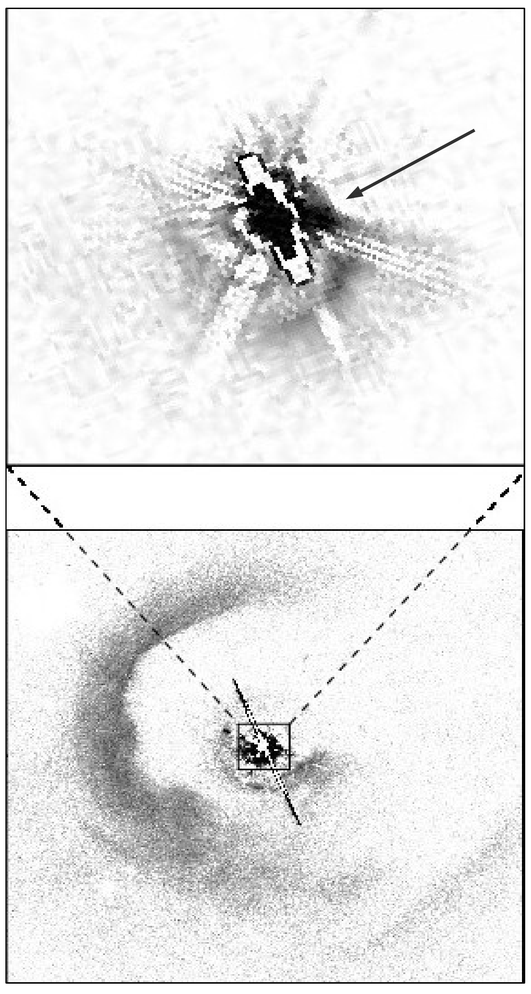

Fig 6 : HST PC image showing inner shadow details.

Also our analysis of archival Subaru coronagraphic H-band imaging reveals scattered light associated with this feature which was not seen before [4]. Both findings suggest increased height of the matter at distances of ~300 AU which casts the shadow. This might be related to planet formation in the circumstellar disk. The scattering knot is associated with two spiral arms which stretch further out.

Is there matter in the “gap” between the rings?

YES..!!

The UKIDSS JHK images show faint reddened stars in the gap (Fig. 4), confirming the presence of dense matter from probably both the protostellar environment and the molecular cloud.

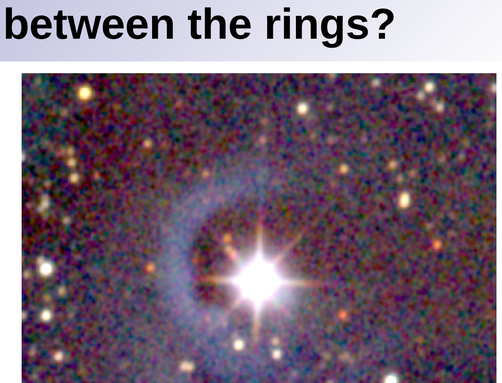

Fig 4 : UKIDSS image showing reddened stars

Is V1331 Cyg the driving source of the outflow?

Herschel and SCUBA data confirm that V1331 Cyg is the most luminous object in the surroundings, ONLY possible young stellar candidate responsible for the outflow (Fig. 5).

Pole-on view of the outflow disk.!!

- Narrow-band imaging in the Hα and [SII] line revealed a bipolar outflow, presumed to have a substantial inclination [3].
- Spitzer IRAC 4.5 micron image shows emission due to shocked H_2 [6] (Fig. 5), which does not resemble a bow shock, rather suggests a close to pole on view.
- High resolution IR spectroscopy of OH emission also suggests almost pole on inclination [5].
- The revised outflow length might be as large as ~10 pc.

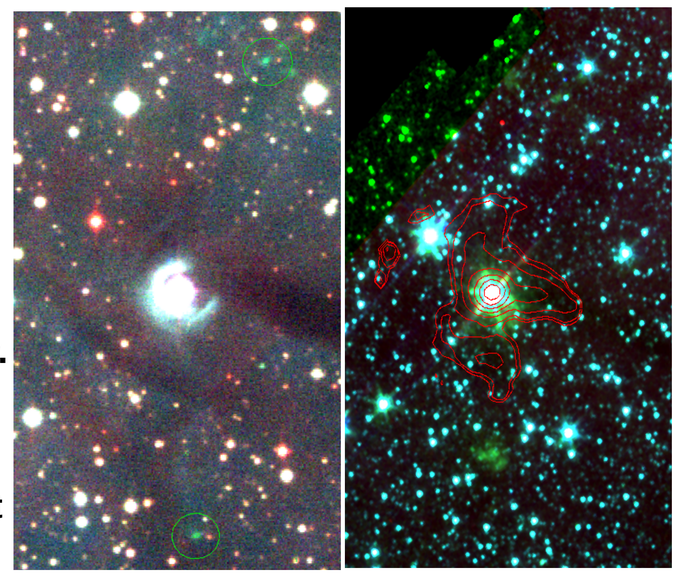

Fig.5: TLS (left) and IRAC (right) images showing a bipolar Herbig-Haro (HH) flow

Recent spectroscopy of the HH flow

The plot shows the superimposed HHO spectra (northern-blueshifted, southern-redshifted) obtained with the 2-m Tautenburg telescope.

- The velocity difference of Hα and [SII] lines is ~150 km/s.
- Both, the azimuthal brightness distribution of the inner rings, and the radial velocity measurements provide consistent information on the geometry of the outflow cavities.

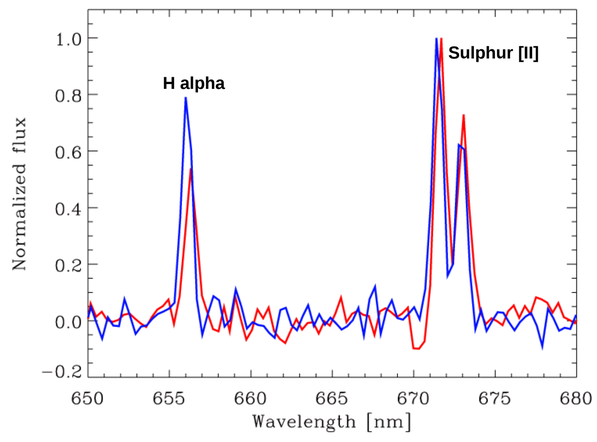

Fig 7 : Spectra of HHO taken at TLS.

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