The nebula around P Cygni with LBT/LUCI-AO

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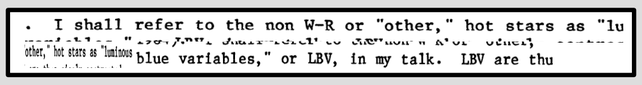
Luminous Blue Variables – the basics

1984 Peter Conti introduced the term LBV:


. I shall refer to the non W-R or "other," hot stars as "lu
other," hot stars as "luminous blue variables," or LBV, in my talk. LBV are thu

<u>Evolutionary state:</u> LBVs are **evolved massive stars**. Observations and theoretical stellar evolution models that include rotation (Maeder et al. 2005) find LBVs with initial mass as low as $\mathbf{M_{ini} \sim 22\ M_{\odot}}$ (see Fig. 1). LBVs can be close to the Eddington limit, what enhancing their mass loss and drives instablility and eruptions.

LBVs show very **characteristic photometric** & **spectral variabilities:**

<u>S Dor variability</u> or **<u>S Dor cycle:</u>**
Changing the **spectral type** from O-B to A-F and back the V magnitude changes (faint in hot, bright in cool phase) as does the B-V color ↔ LBV moves accross the HRD (Fig. 1). In the cool phase the wind is optically thick.

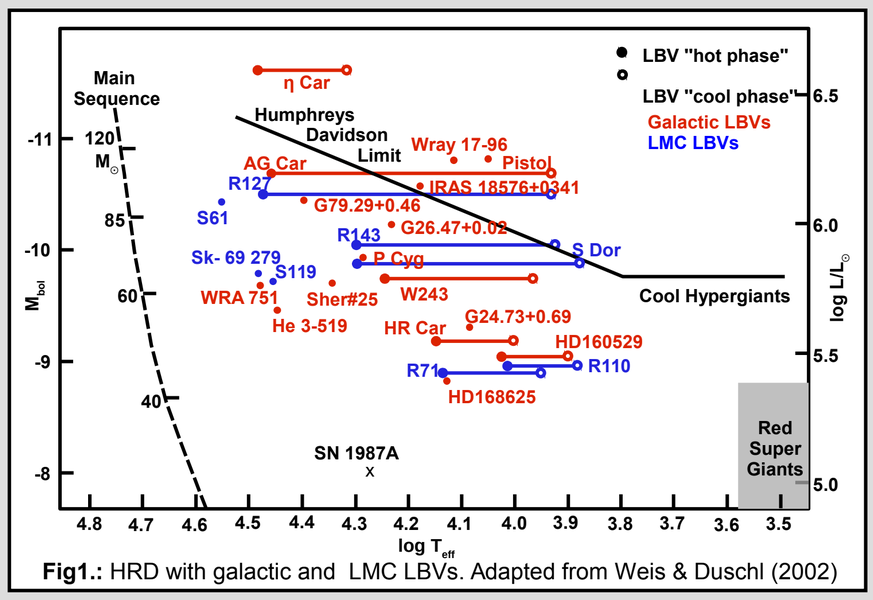


Fig1.: HRD with galactic and LMC LBVs. Adapted from Weis & Duschl (2002)

<u>Giant eruption:</u>
More violet variations are the **giant eruptions,** here the brightness rises spontaneously by **several magnitudes, and** larger amounts of **mass** can be **ejected** within a few years. Some **LBV giant eruptions** have been **mistaken** for **supernovae**. Best known examples are η Car, SN1961V, NGC 2403-V12 and **P Cygni** (see Fig. 2)**.**

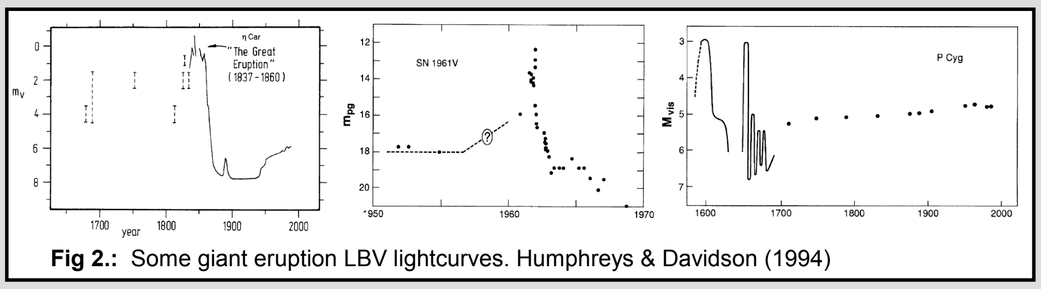


Fig 2.: Some giant eruption LBV lightcurves. Humphreys & Davidson (1994)

<u>LBV nebulae:</u>
High mass loss by **wind** and/or a **giant eruption** forms **small (~2pc) circumstellar nebulae**. A **large fraction** (~70%) are **bipolar** (Weis 2011).

<u>LBV – THE definition :</u>
LBVs are characterized by **variability, high mass loss** and **eruptions** <u>but</u> temporarily may appear as **'well behaved'** normal supergiants! **No unique** classification scheme exists identify a LBV !

One needs to see an S Dor cycle or a giant eruption to **know its a LBV !!!**

The LBV P Cygni

- one of the few known **giant eruption LBVs**, the only other in our galaxy beside η Car.
- lightcurve (Fig.2 right) show several maxima in the between 1600-1700.
- Van Genderen 2001 classifies it currently as a weakly active LBV.
- two distinct nebulae, a large 0.5 x1.2pc and a small clumpy shell 0.1-0.2pc

P Cygni data – LBT LUCI AO images

P Cygni was observed during the LUCI-AO commissioning run in October 2016 with images in [FeII] and Brγ. The bright central star was avoided using four partially overlapping positions around the star, that we mosaiced by manually alignment. The diffraction spikes are removed using the smallest pixel value. Finally a PSF model was created and subtracted to remove the flanks of the central star. The images have a pixel scale of 0.015"/pixel, a FWHM ~ 3.5 pixel and resolve scales down to ~ 85 AU.

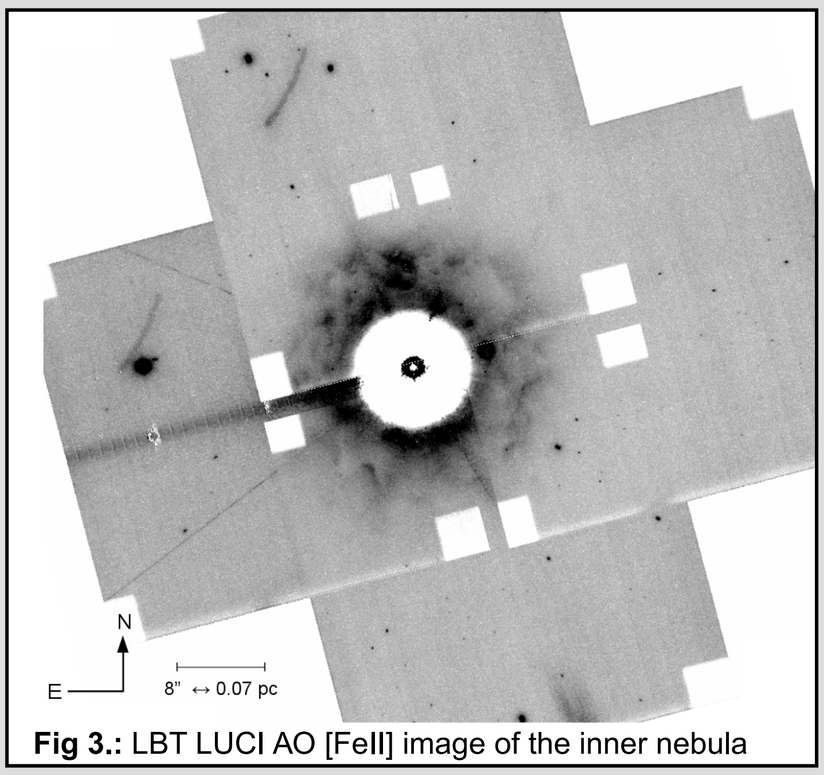


Fig 3.: LBT LUCI AO [FeII] image of the inner nebula

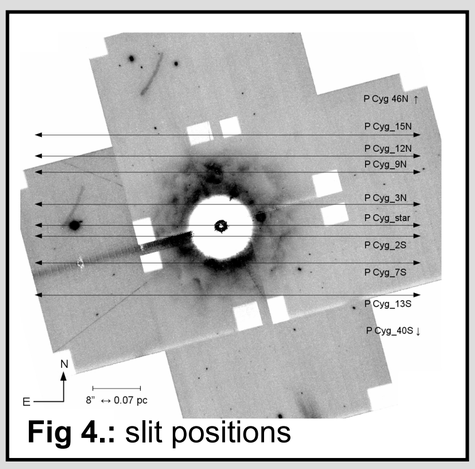


Fig 4.: slit positions

P Cygni data – KPNO high-res. Echelle Spectra

For a kinematic analysis high resolution long-slit Echelle spectra were taken at the 4m telescope at Kitt Peak. With a post-slit Hα filter we selected the spectral region that included Hα, and the [NII] lines at 6548 & 6583 Å. Slits are 3.23′ long, the spectral resolution is about 8 km/s. Beside the remote positions (40S, 46N) emission of the inner nebula was detected in all spectra and has the signatuture of an expanding bubble. Slit positions are shown in Fig. 4, an [NII] line echellogramm/position velocity diagram of slit 7S in Fig. 5. An expansion ellipse (in blue) has been fitted to the data.

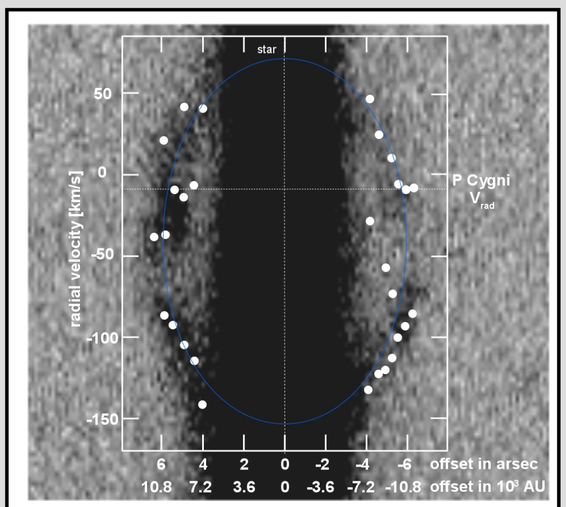


Fig 5.: Echellogamm, overplotted the pv plot for slit 7S. In blue the fit of an expansion ellipse with v_{exp} = 111 km/s

LBT LUCI AO images + KPNO Echelle Spectra =

Several other images in various wavelength regimes were made, but this LBT LUCI AO image is the one with the highest resolution so far, surpassing the LBT PISCES image (Arcidiancono et al. 2014) by a factor of ~ 2.
The new image allows us now a good morphological analysis of the inner nebula. Individual regions in the image can be matched to structures in the spectra (Fig. 6). Adding the kinematics leads us to get a true 3D picture of the inner nebula.

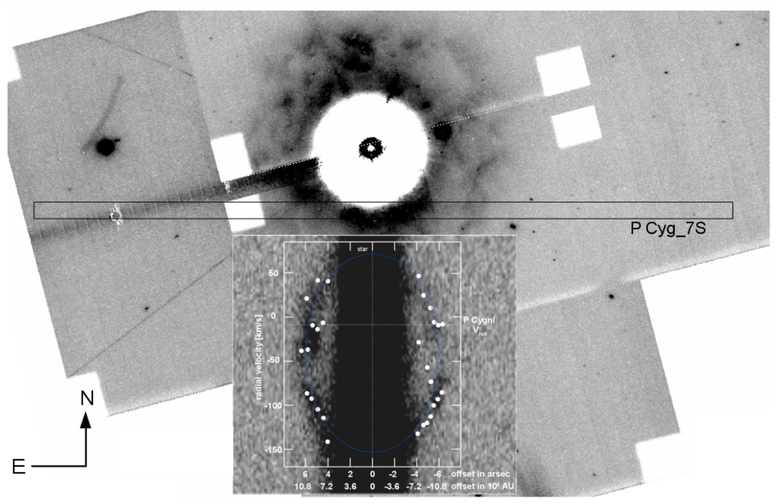


Fig 6.: Coparing the spatial axis in the Echellogamm with the LBT LUCI AO images – sorting clumps ...

RESULTS

- best image of P Cyg inner nebula
- allows for the first time a true kinematic study by identifying individual structures
- preliminary spectral analysis → bubble expands v ~ 100-150 km/s → matches inner shell was ejected in the 1600 giant eruption
- substructures hint for multiple phases during the eruption

LBT LUCI AO images
… simply the BEST ...