The Light Curve of Eta Car's Great Eruption from its Light Echoes

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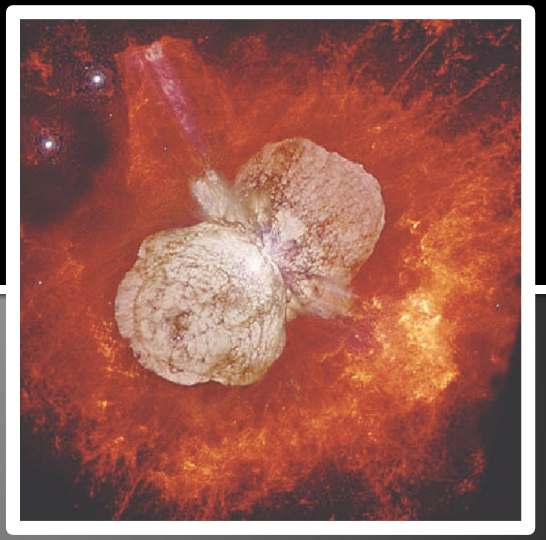
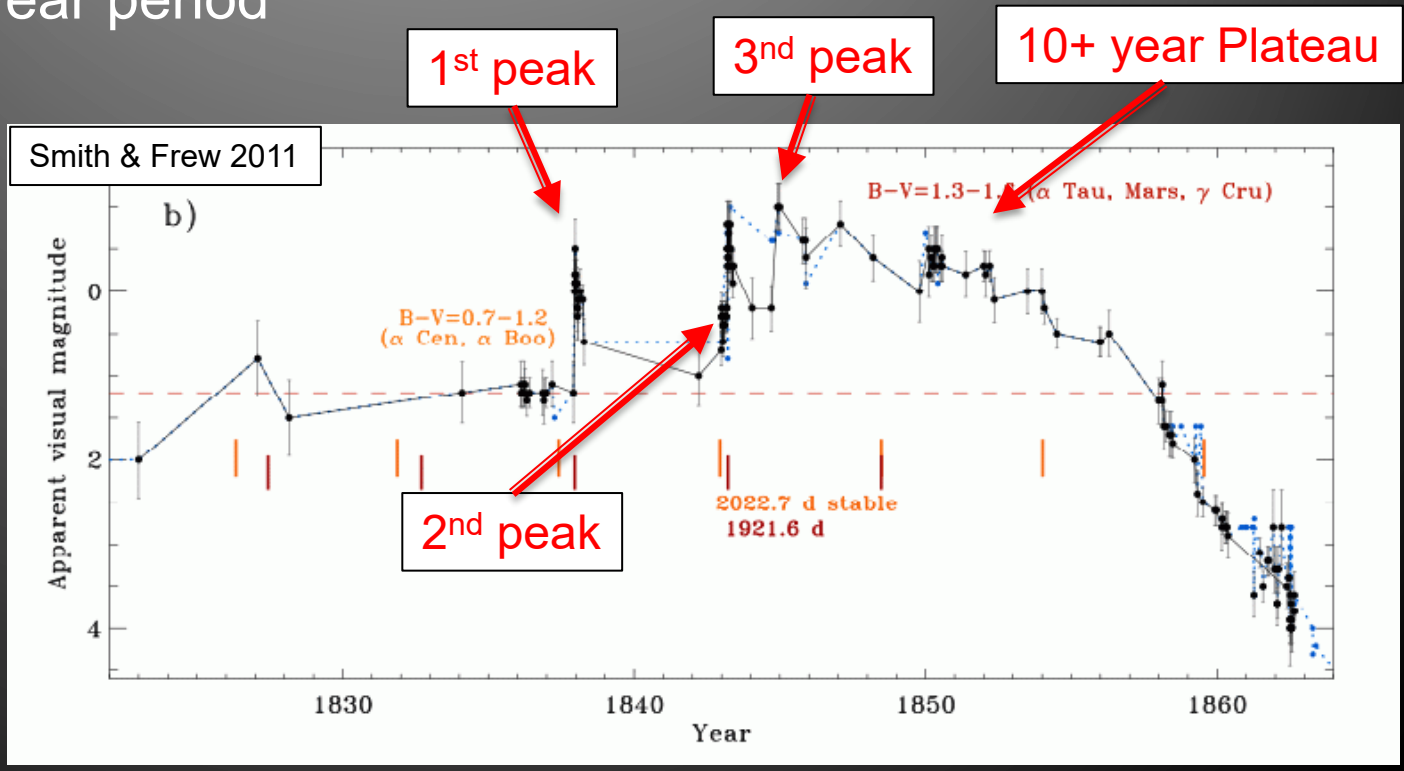
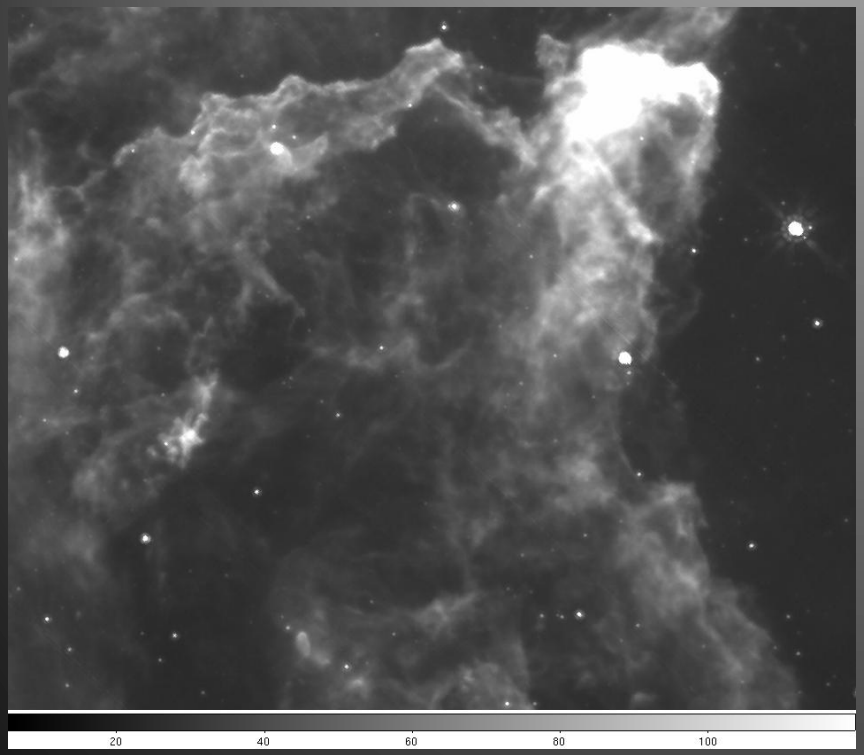
Background η Car



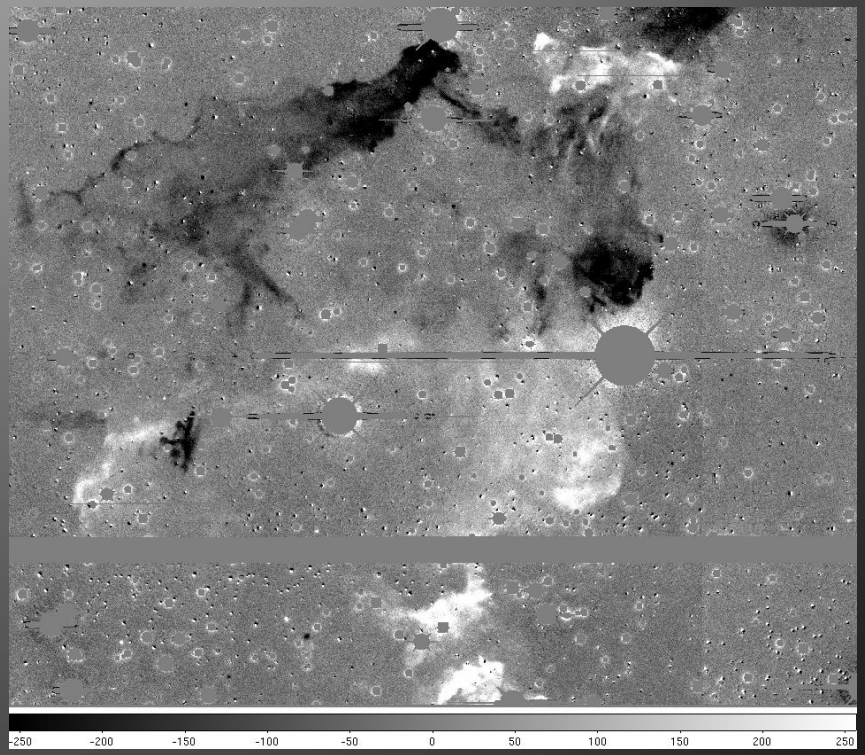
- MWG's most massive star system (140 M_{solar})
- Great Eruption from 1838-1858 (20 years!!)
  - Visual observations John Herschel
- Mass loss ~20 M_{solar}
- Binary with ~5 year period



Eta Car light echoes!



Spitzer Image (8 microns)



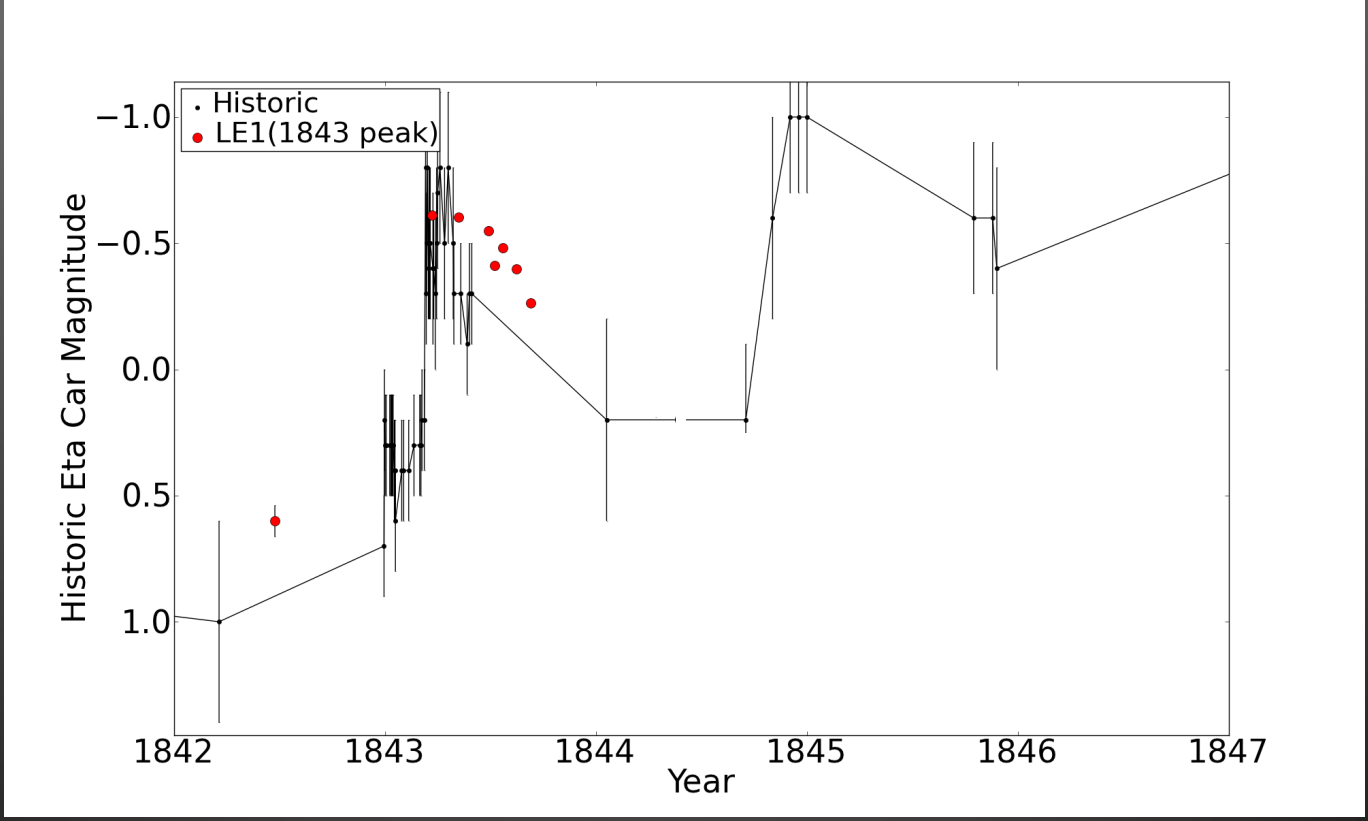
Difference Image (8x8 arcmin^2)
black: light echo in 2003
white: light echo in 2011

Connection between light echoes and light curves

- Light echoes are projected event light curves, smeared out due to dust filament thickness and FWHM (Partoush+, in prep.).
- Case 1: short event like SN: Light curve can be inferred from single image
- Case 2: long event like Eta Car Great Eruption: **light curve: measure flux at fixed position over many years!!**

Eta Car's light curve derived from light echoes

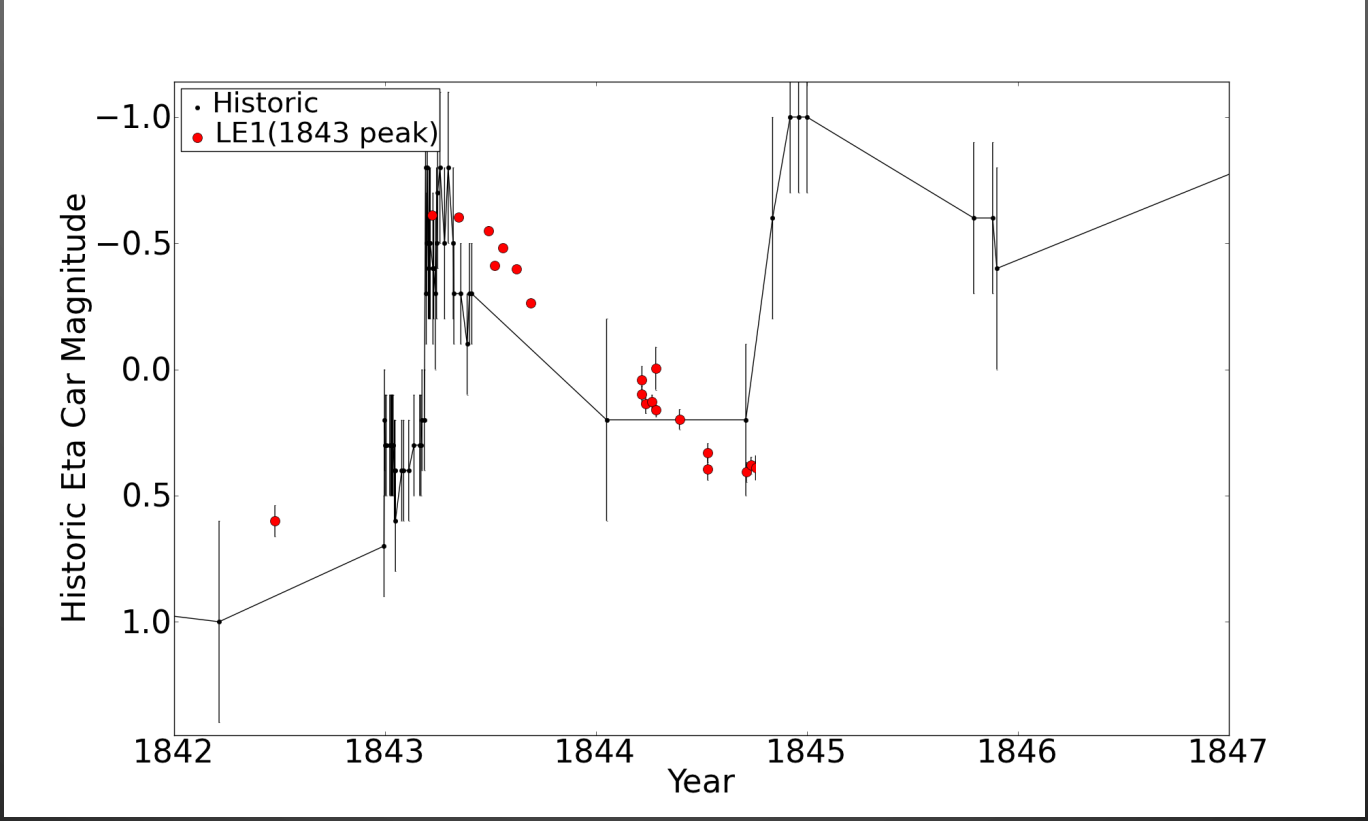
i band Light curve in Rest+ 2012



Assumption: peak is the 2nd peak (1843)!

Eta Car's light curve derived from light echoes

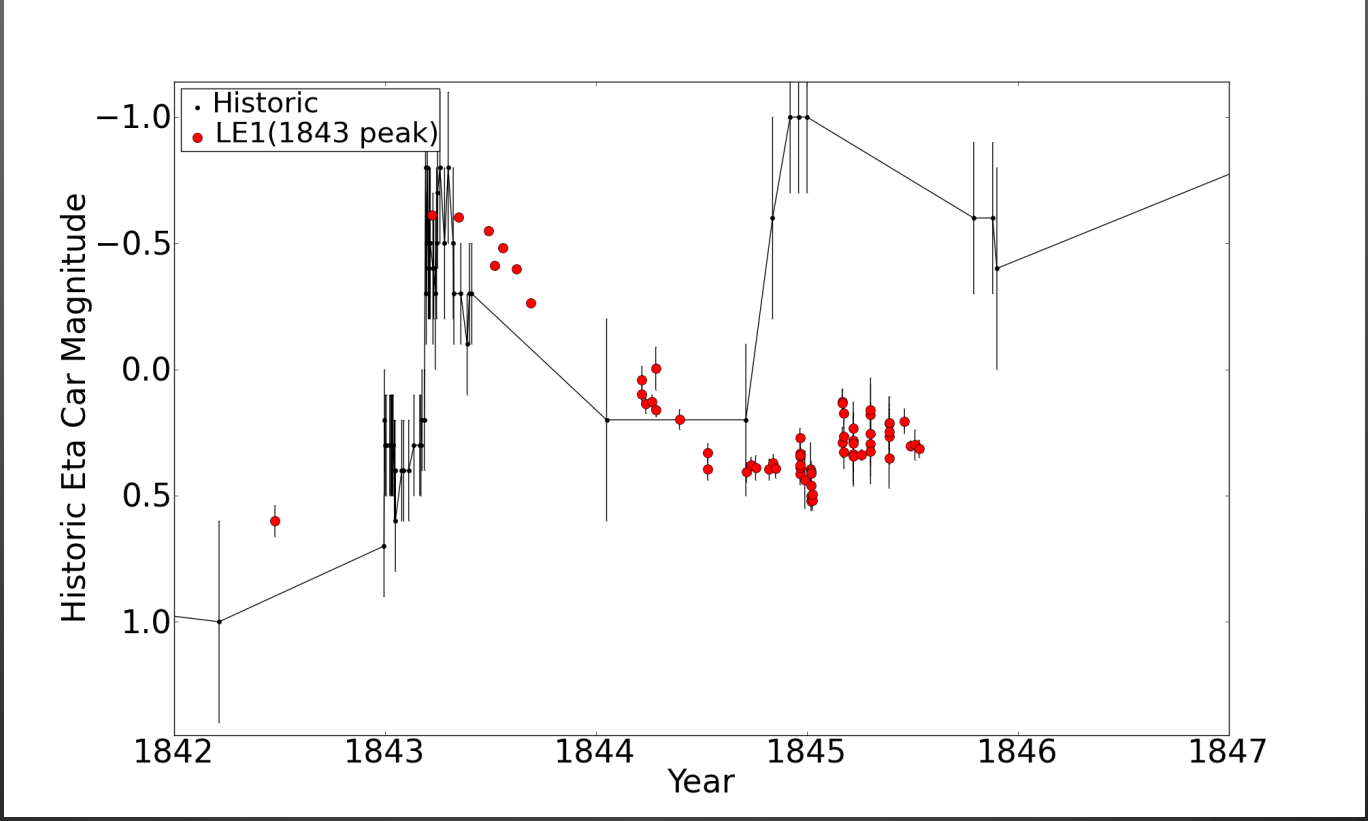
New data points… waiting for the 1845 rise!



Assumption: peak is the 2nd peak (1843)!

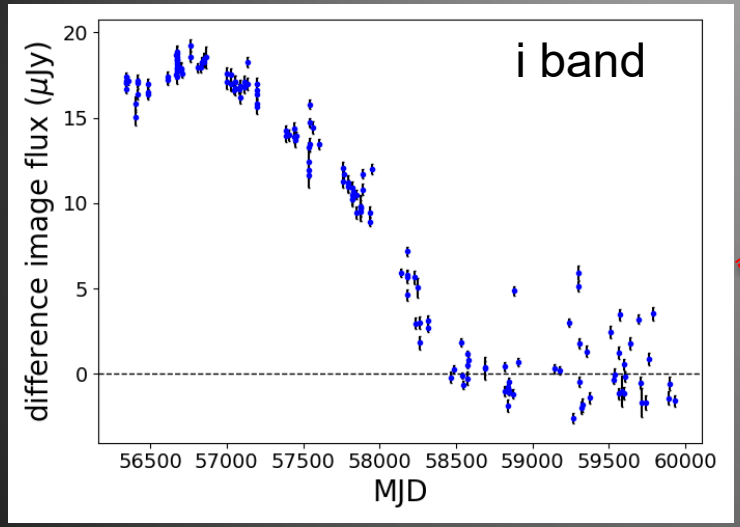
Eta Car's light curve derived from light echoes

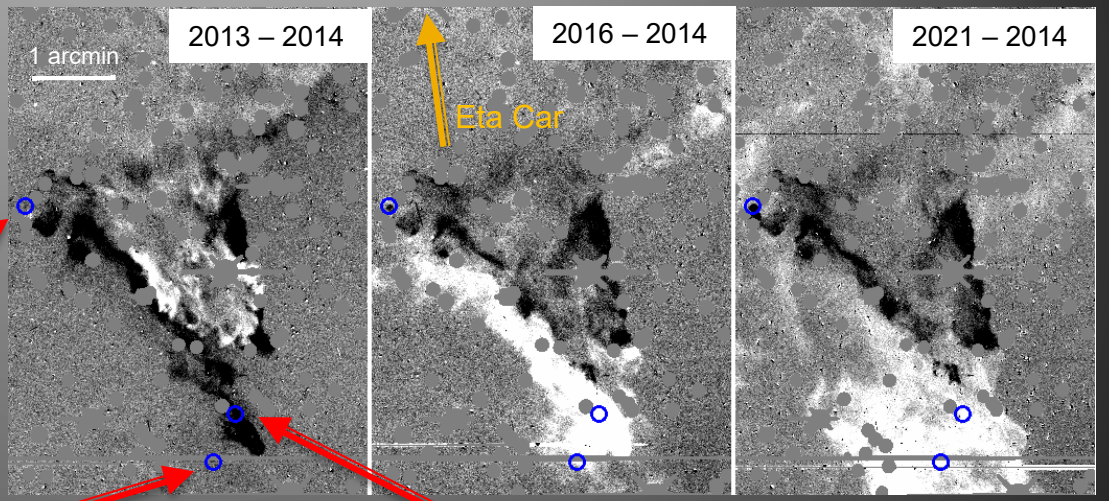
Still waiting….

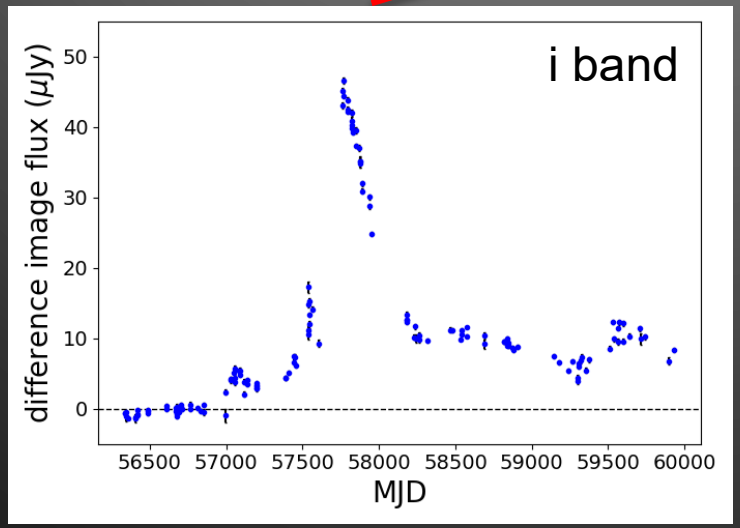


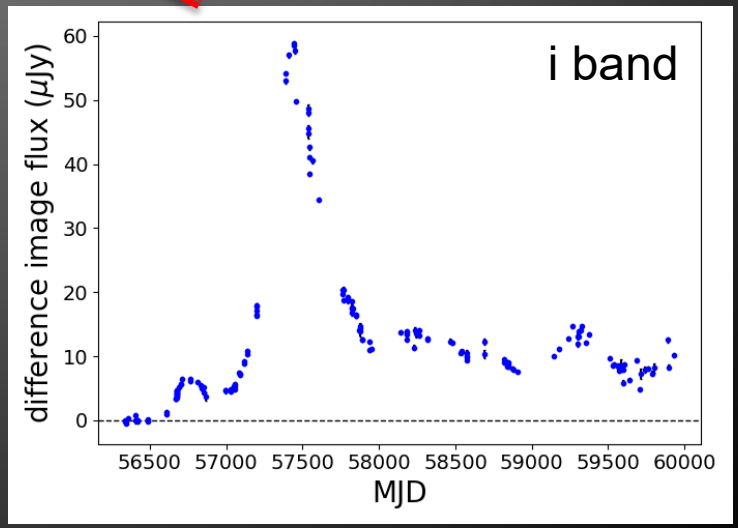
We were wrong!

Constructing the full light curve of Eta Car's Great Eruption



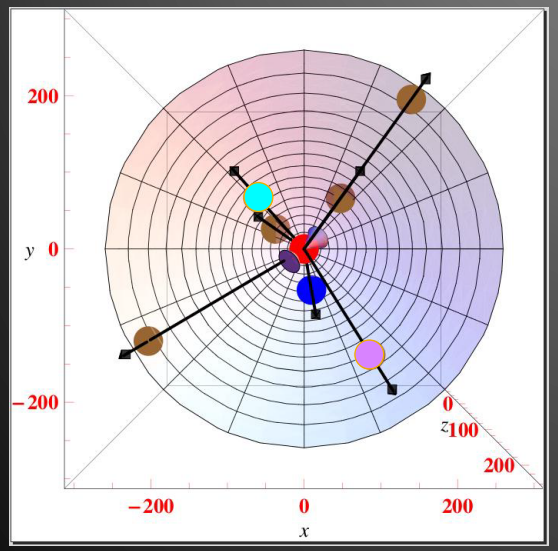


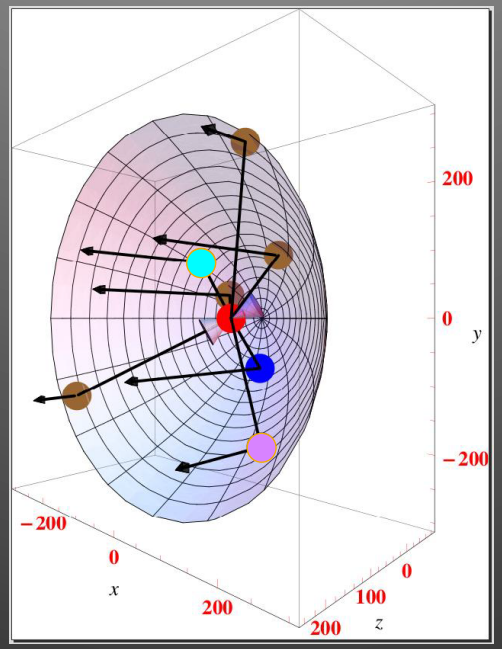


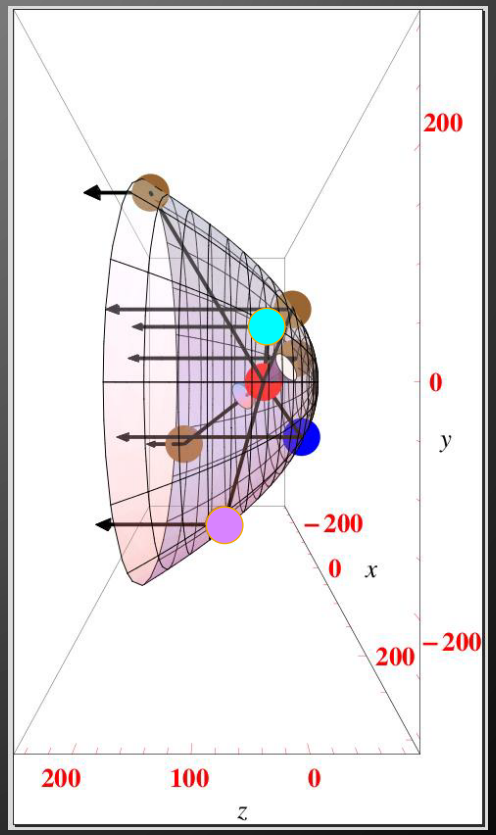


3D Photometry!

- **Light echoes are projected light curves, convolved by scattering dust width and PSF**
- Light curve: measure flux at fixed position over many years!!
- We have “Blue”, “Magenta” and “Cyan” direction!

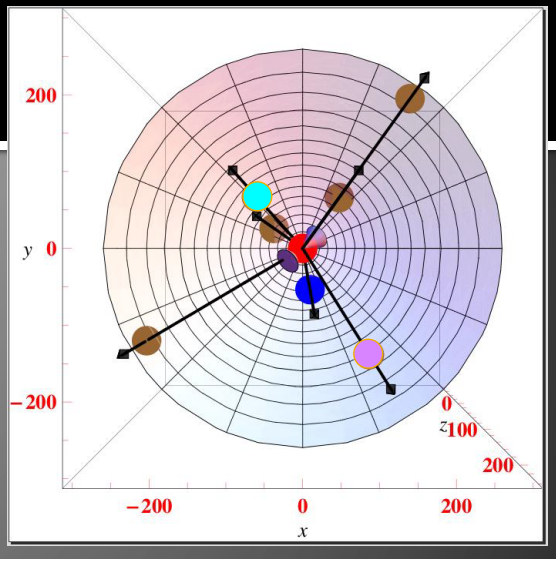


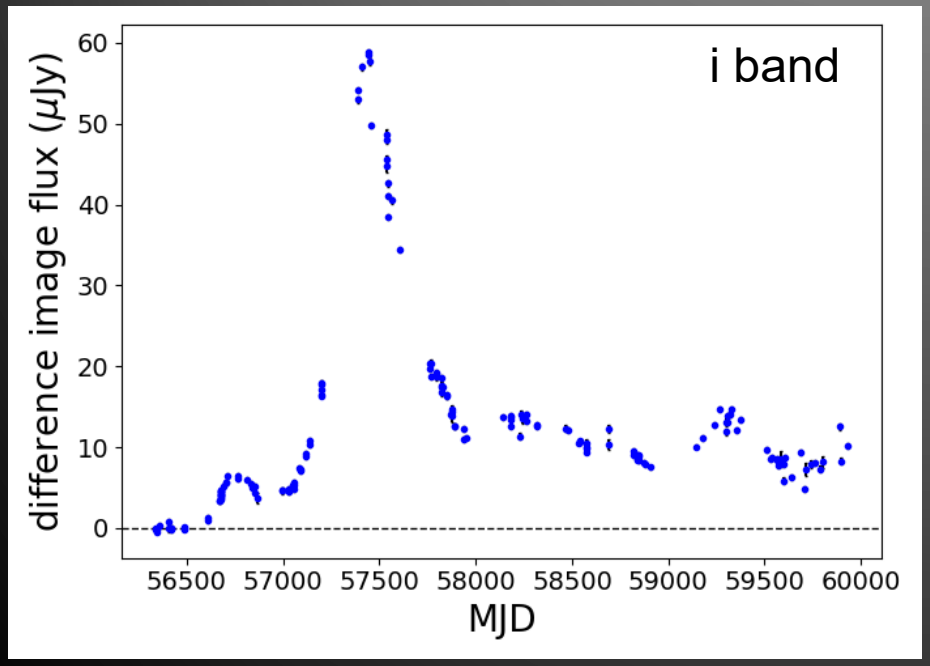


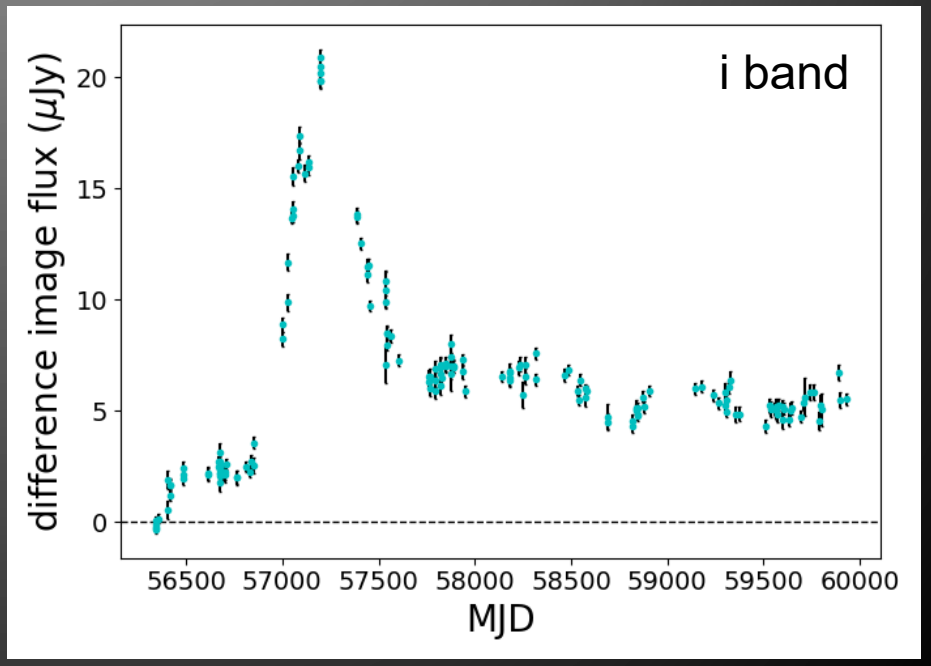


Light curve in “cyan” direction (i band)

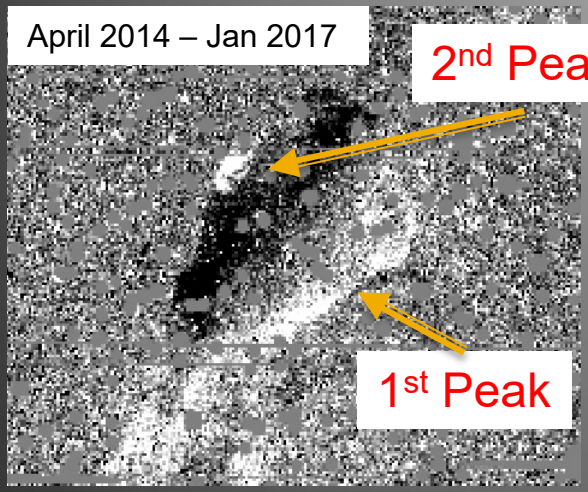
- Like “blue” direction!
  - Bump before main peak

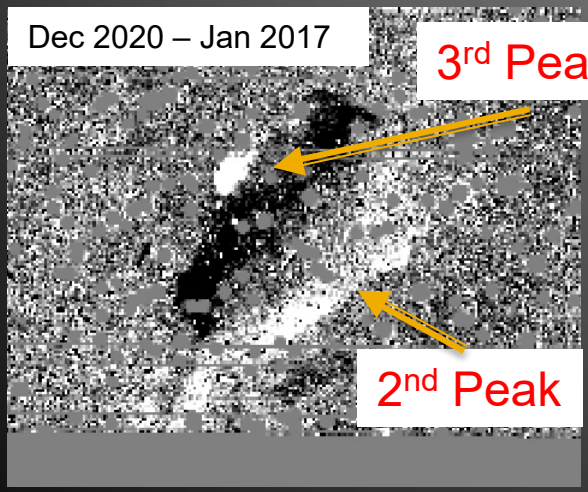


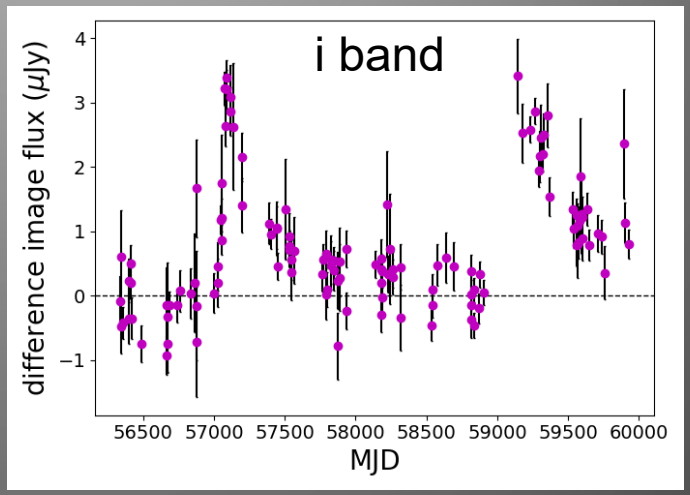


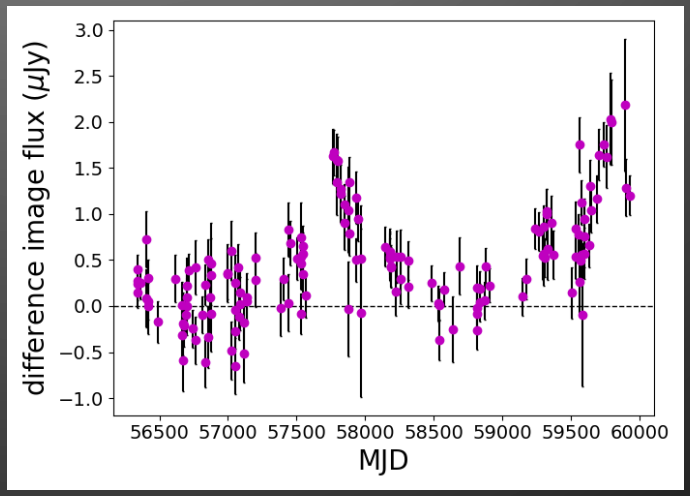


Light curve in “magenta” direction: Exactly the same peak 5.5 years apart!!

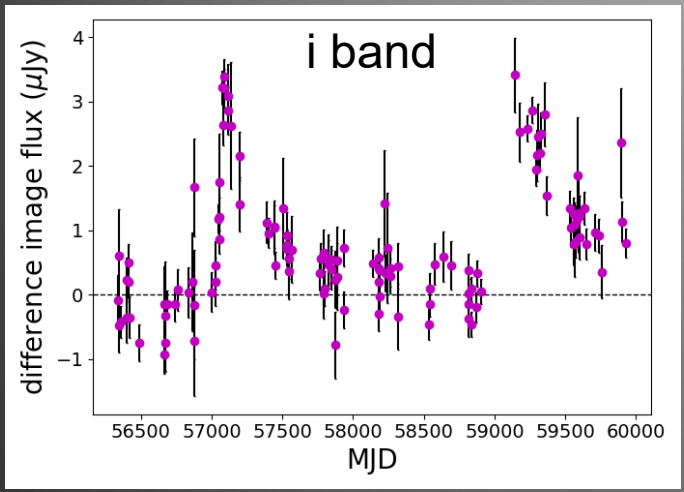


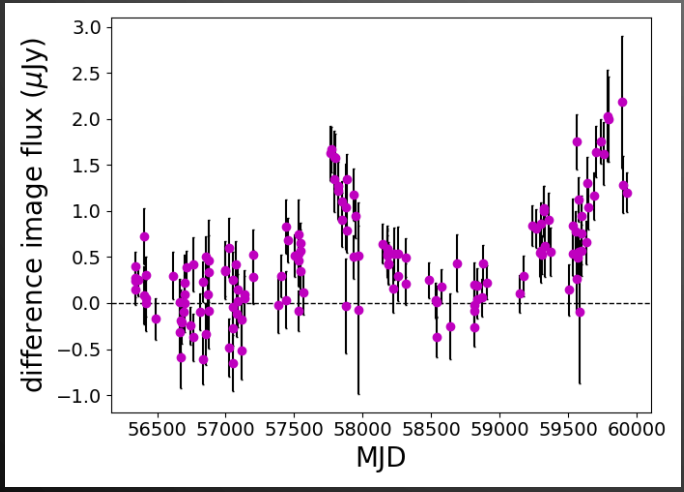






Light curve in “magenta” direction: Exactly the same peak 5.5 years apart!!

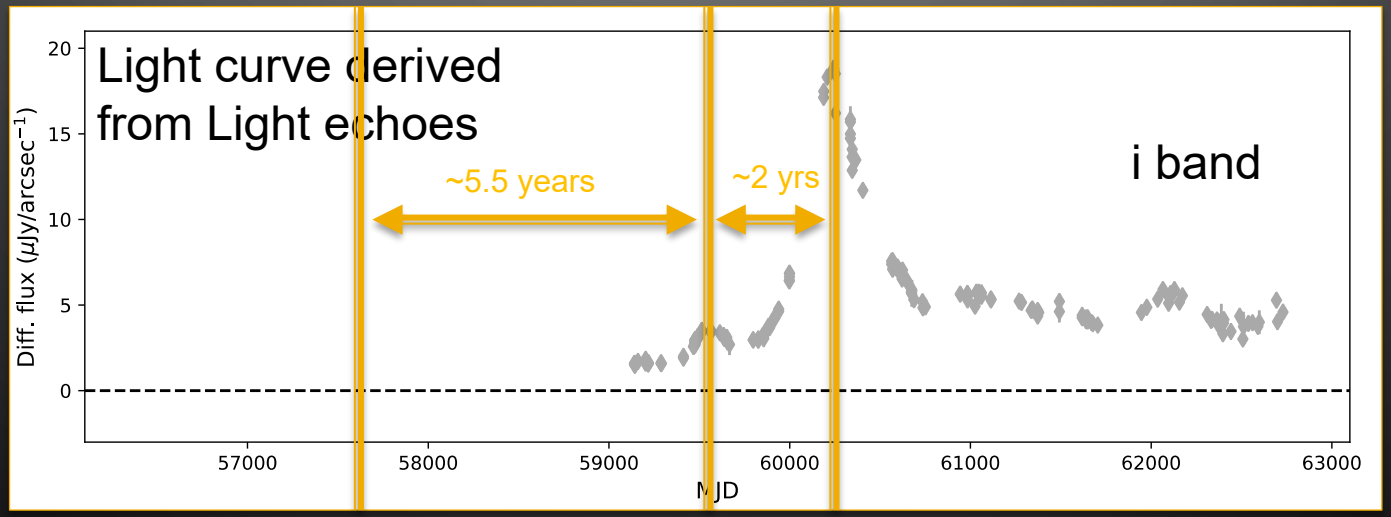




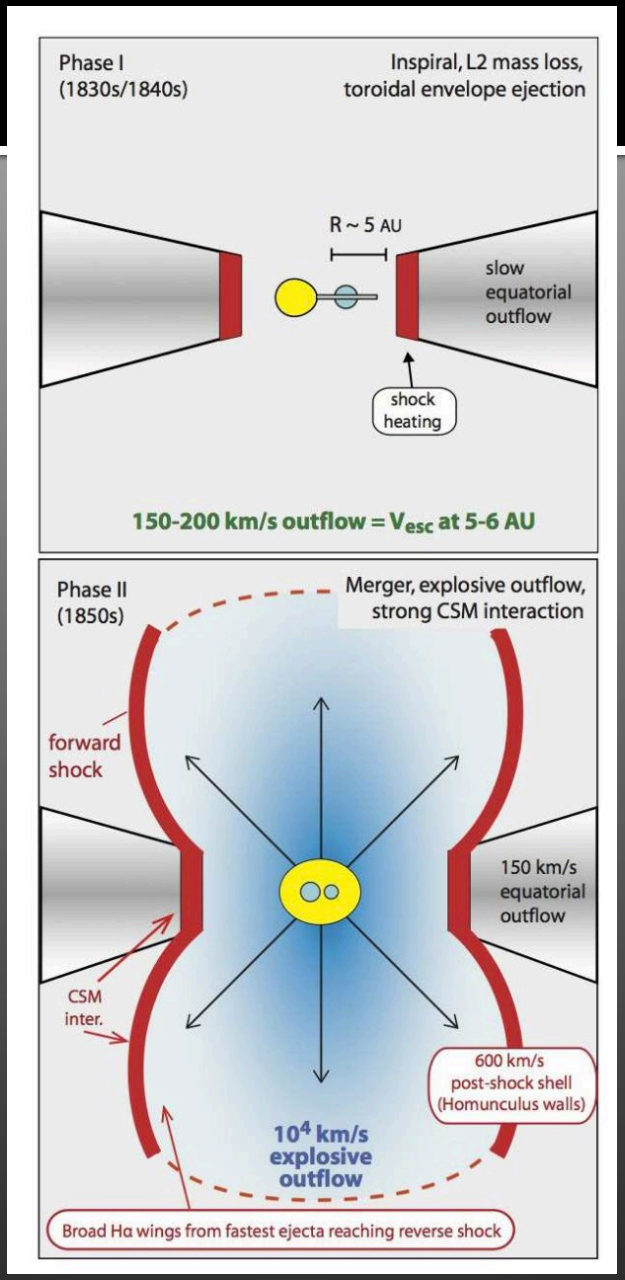
- 3 peaks!
- They are at a cadence of about 5.5 years
- Same brightness!
- NOT because of more than one dust filament!

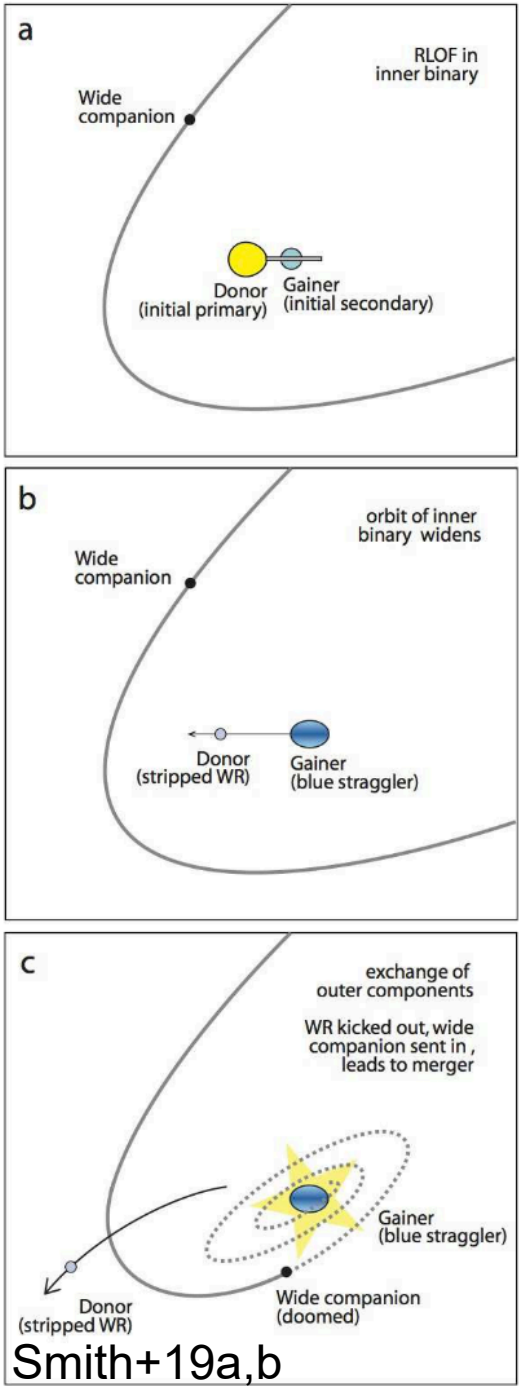
Summary

- Eta Car's Great Eruption g and i band light curve reconstructed!
- Timing of peaks in agreement with historic light curve.
- One direction: different light curve!
- First time we can directly observe different light curves from different directions for the same object!
- Spectroscopic observations in progress

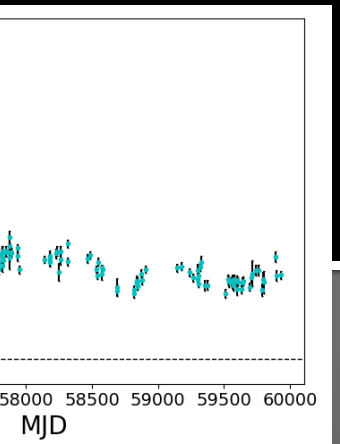


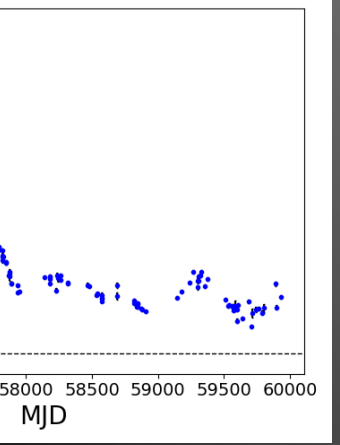
- Eta Car looses mass during RLOF
  - Torus
  - slow outflow (200 km/s)
  - Large mass
- Final merger
  - Explosive event
  - Fast ejecta (10,000 km/s)
  - Little mass
  - 600 km/s post shock

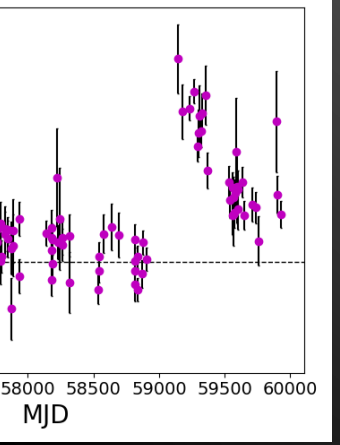




Smith+19a,b

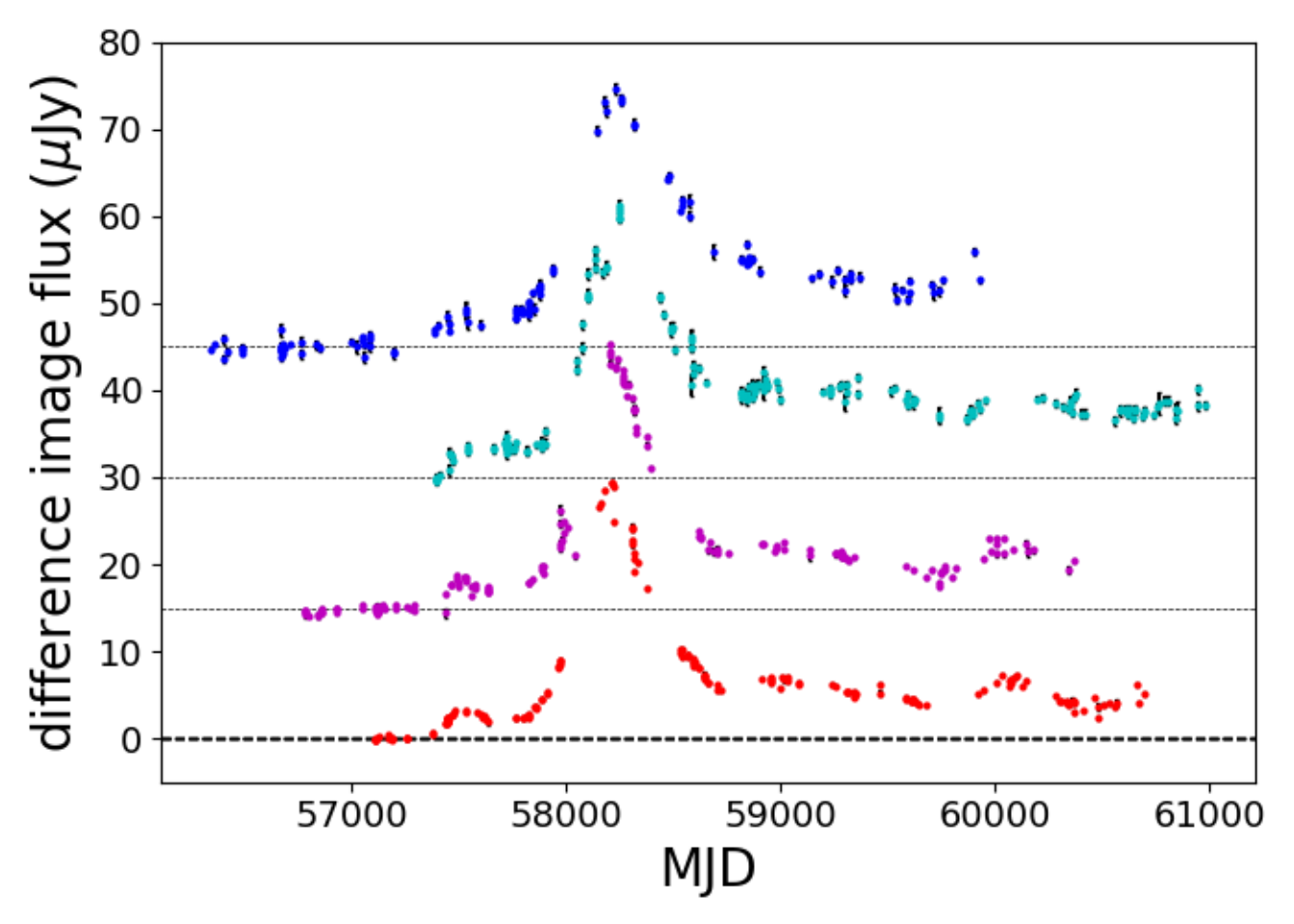




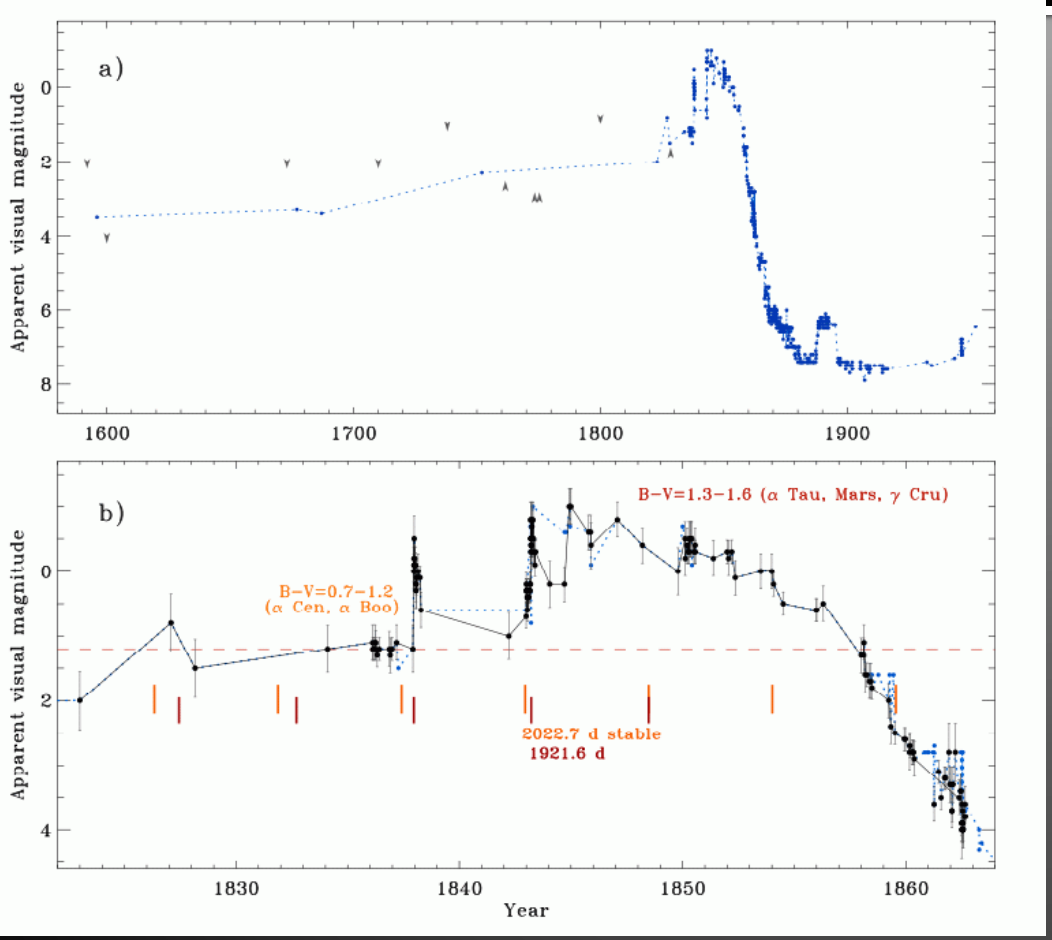


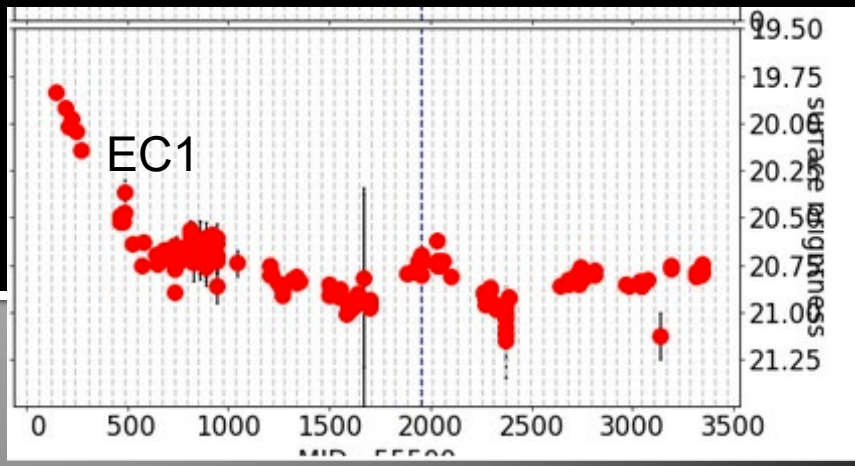
Summary

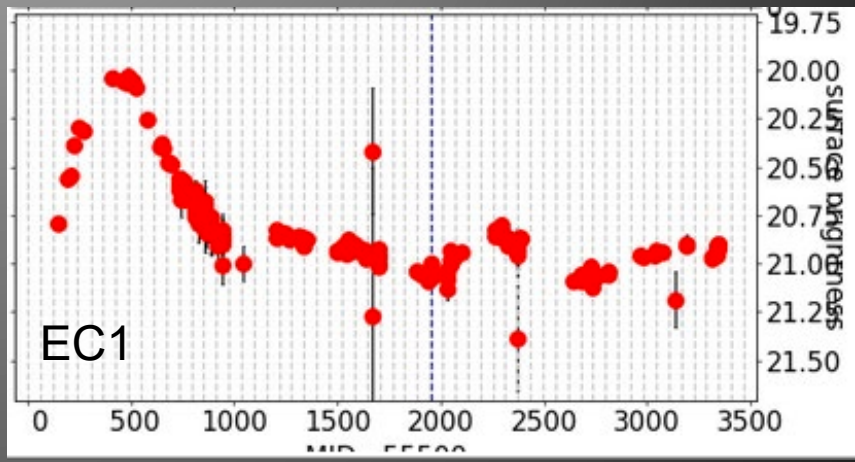
- The historic light curve of the Great Eruption
  - 3 peaks, spaced 5 and 2.5 years
  - 10+ year plateau
  - Very red color
- Light curves derived from light echoes
  - **One peak**, 10+ year plateau phase
  - Blue before peak, red during peak and plateau
  - In one direction: 3 peaks, same brightness, spaced evenly
    - Will there be the “big peak” at a later time?
- First time we can directly observe different light curves different directions for the same object!
  - Binary period of Eta Car before the Great Eruption!
  - Why different peaks in different directions?
    - Dust production/destructions?
    - How does it connect with properties of binary?
    - How does it connect with spectroscopy?
    - What caused the Big Eruption?

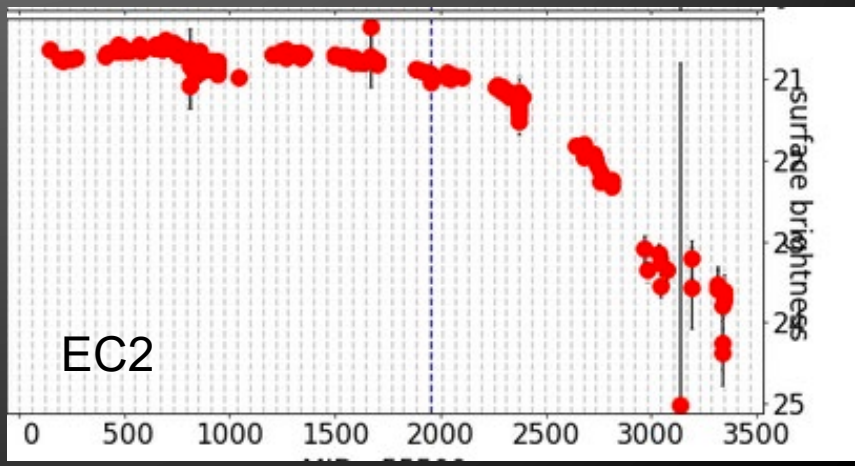

difference image flux (μJy)
80
70
60
50
40
30
20
10
0
57000
58000
59000
60000
61000
MJD

Light Echo Light Curves

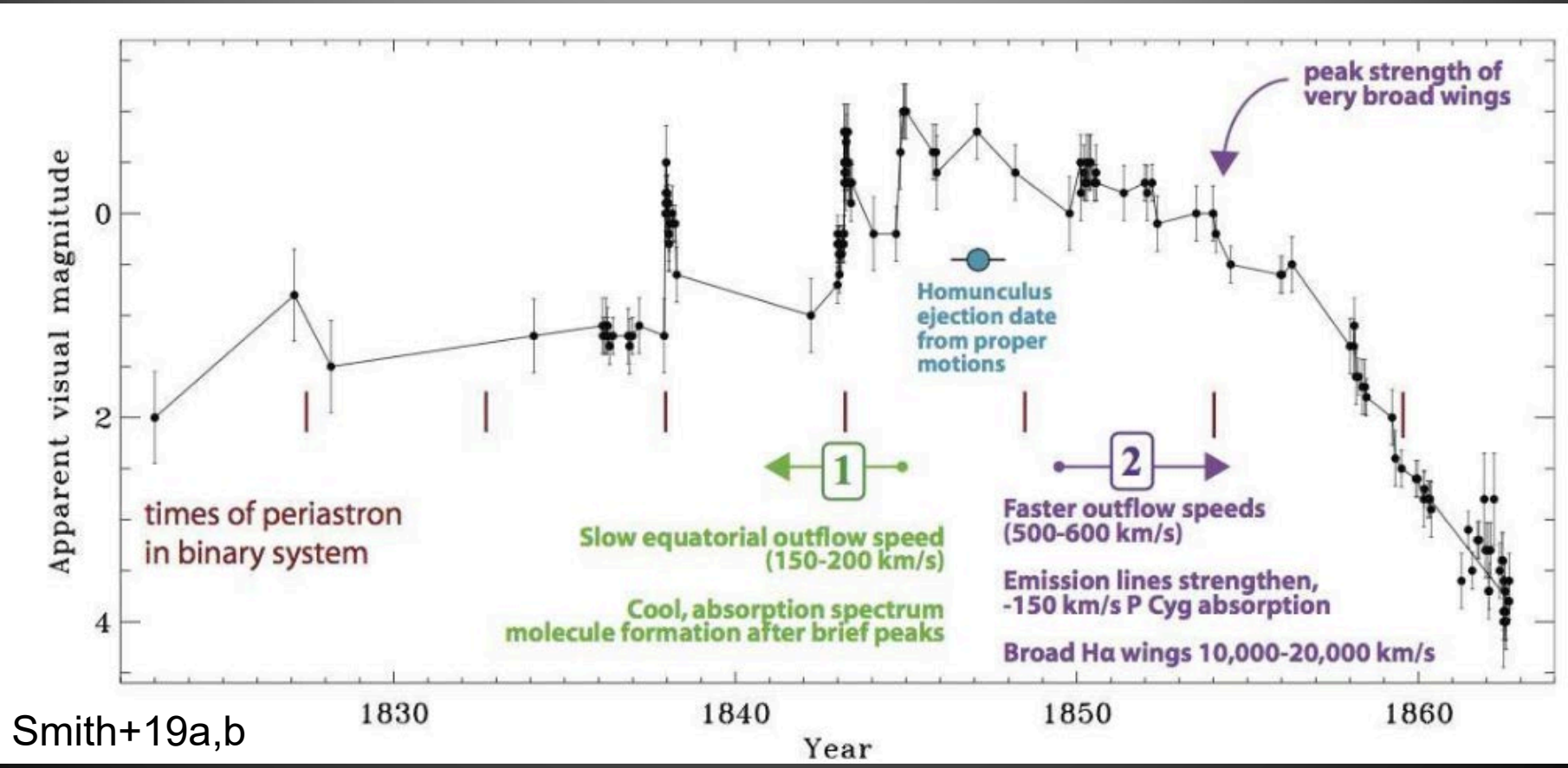








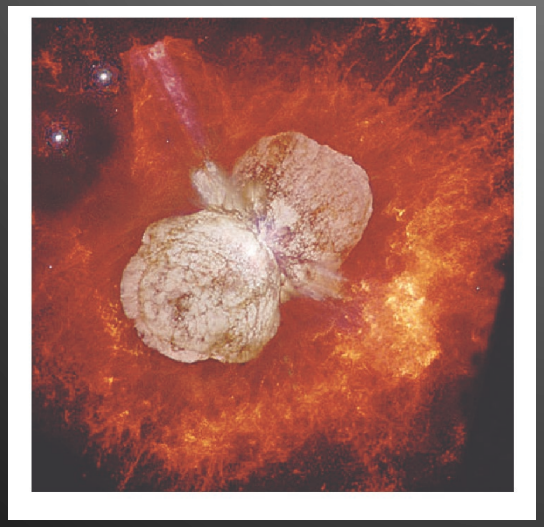
Eta Car observations at different epochs (Smith+19)

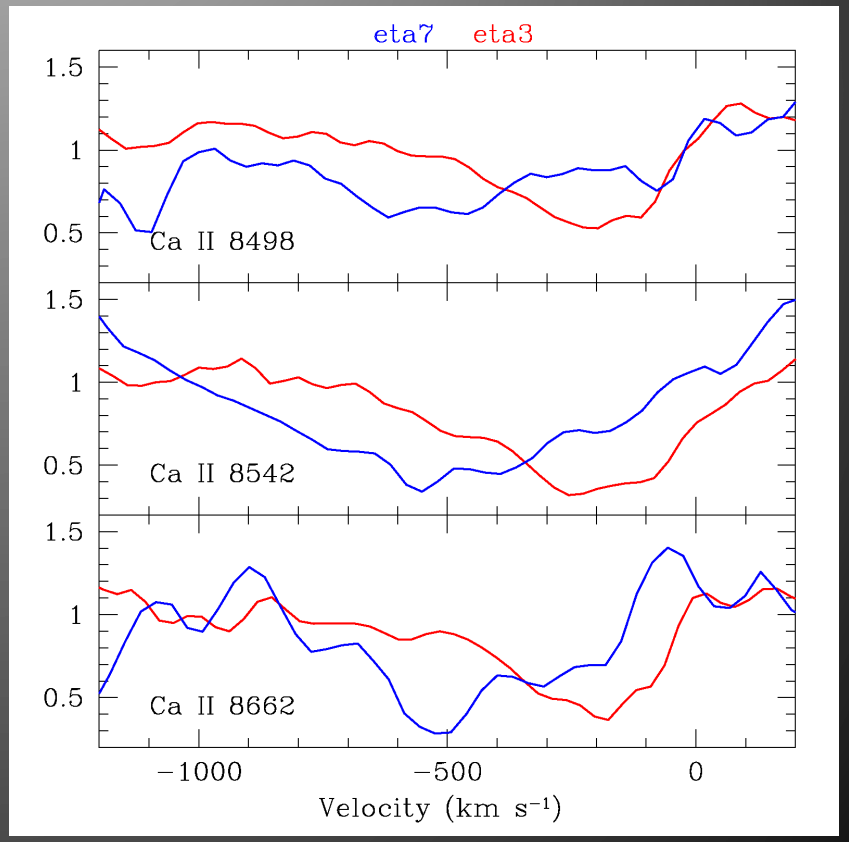


Smith+19a,b

3D-Spectroscopy

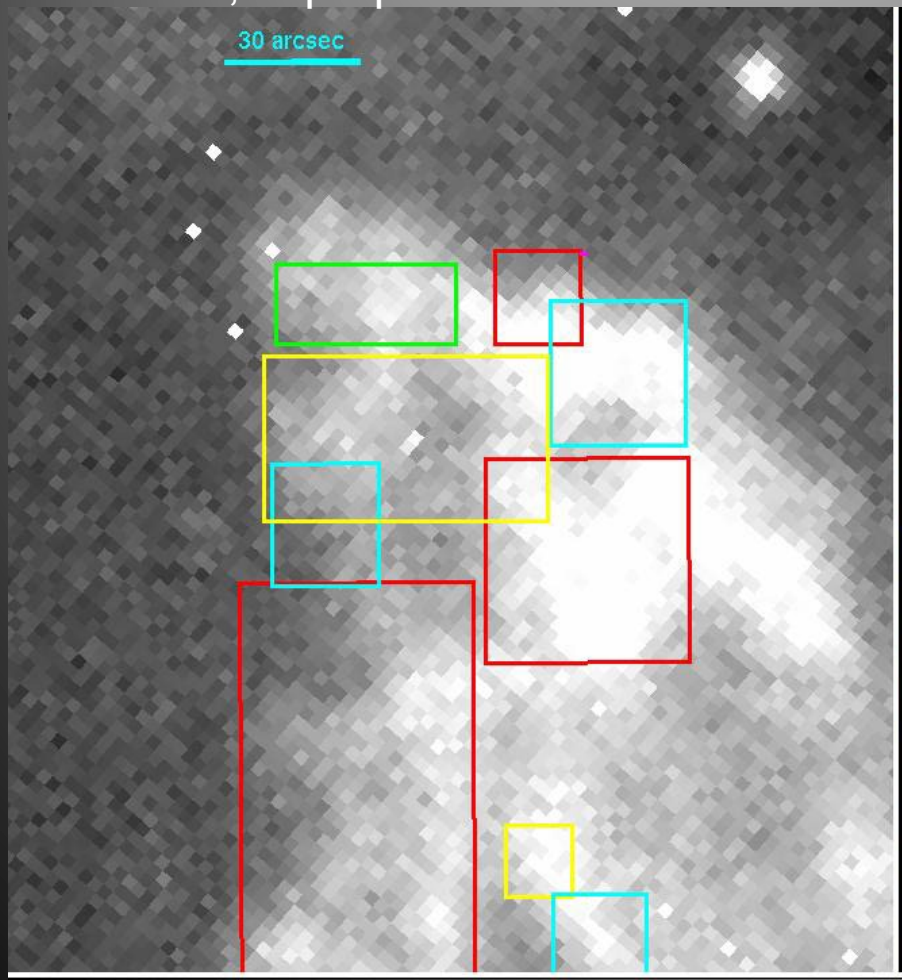
- Red: looking at equator. Blueshift ~200 km/s
- Blue: looking into lobe. Blueshift ~500-600 km/s (not the highest S/N…)



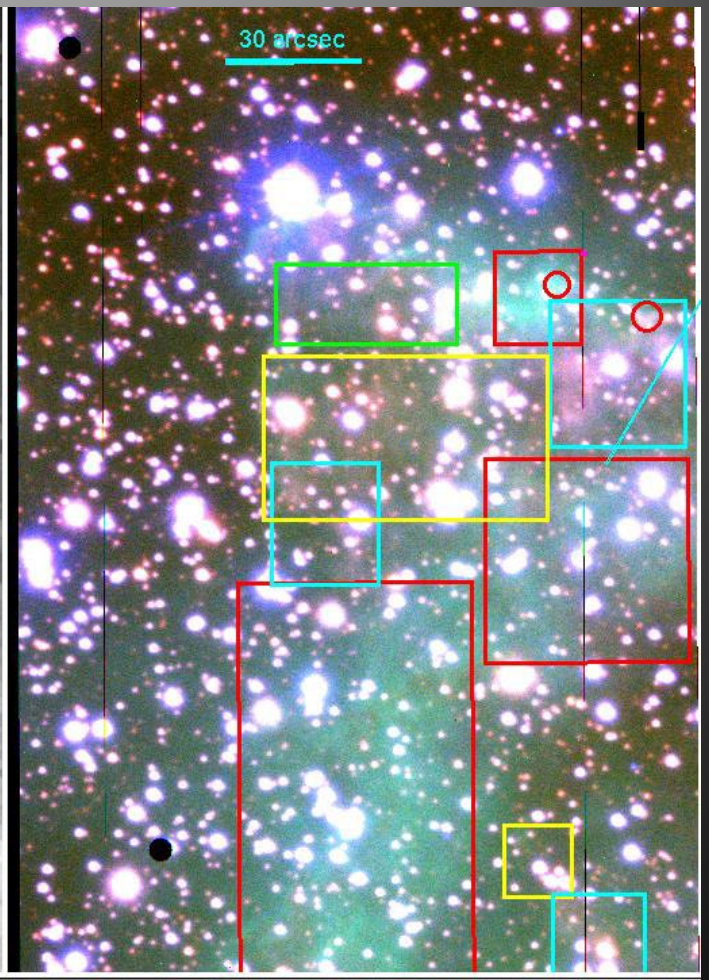


Pre-eruption spectrum

Rest et al., in prep.

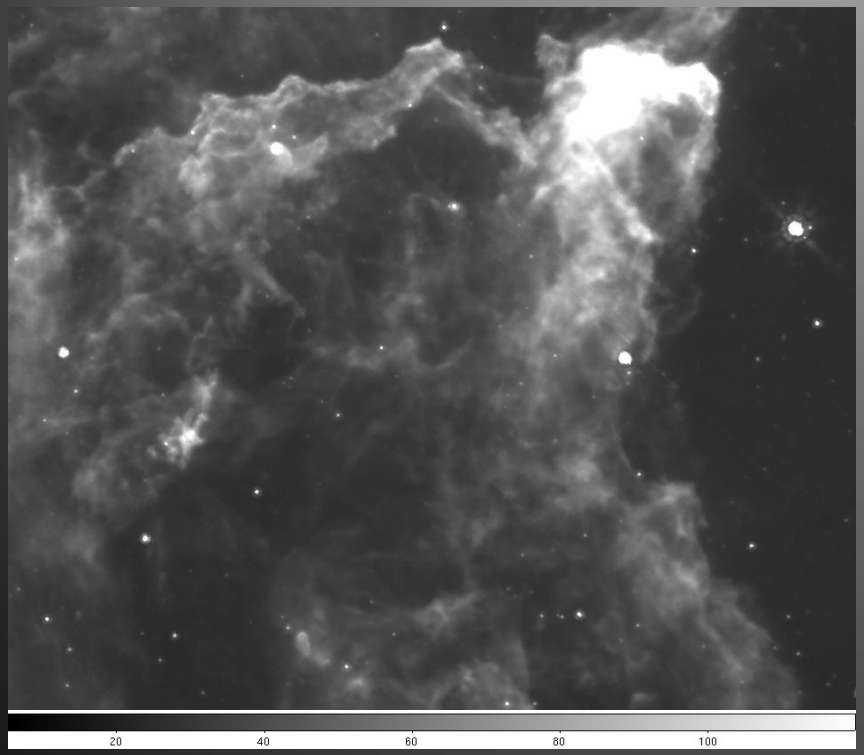


Wise 8 micron

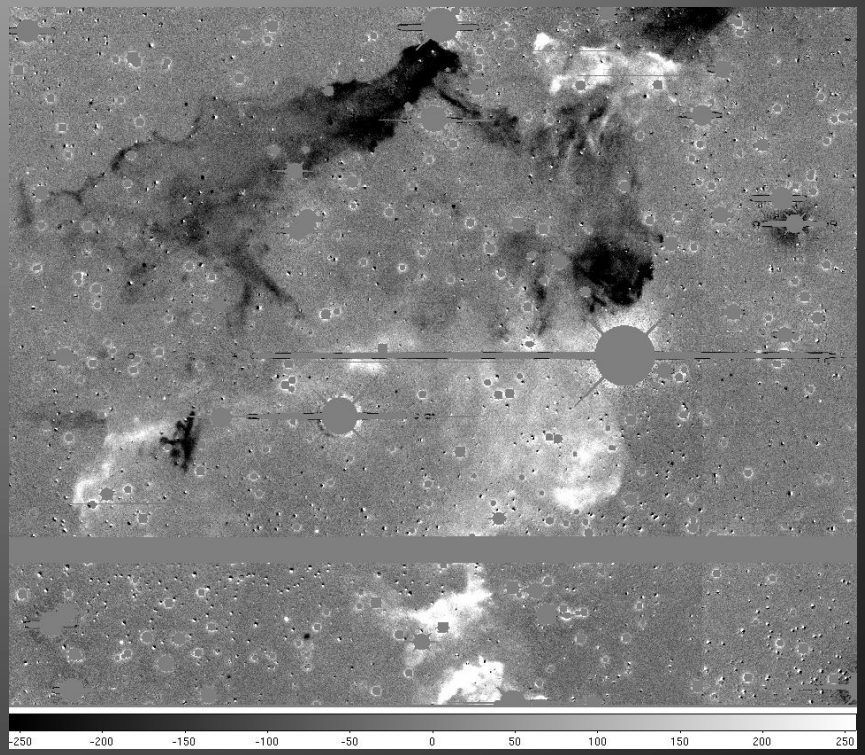


gri SOAR image

Eta Car light echoes: Scattering Dust



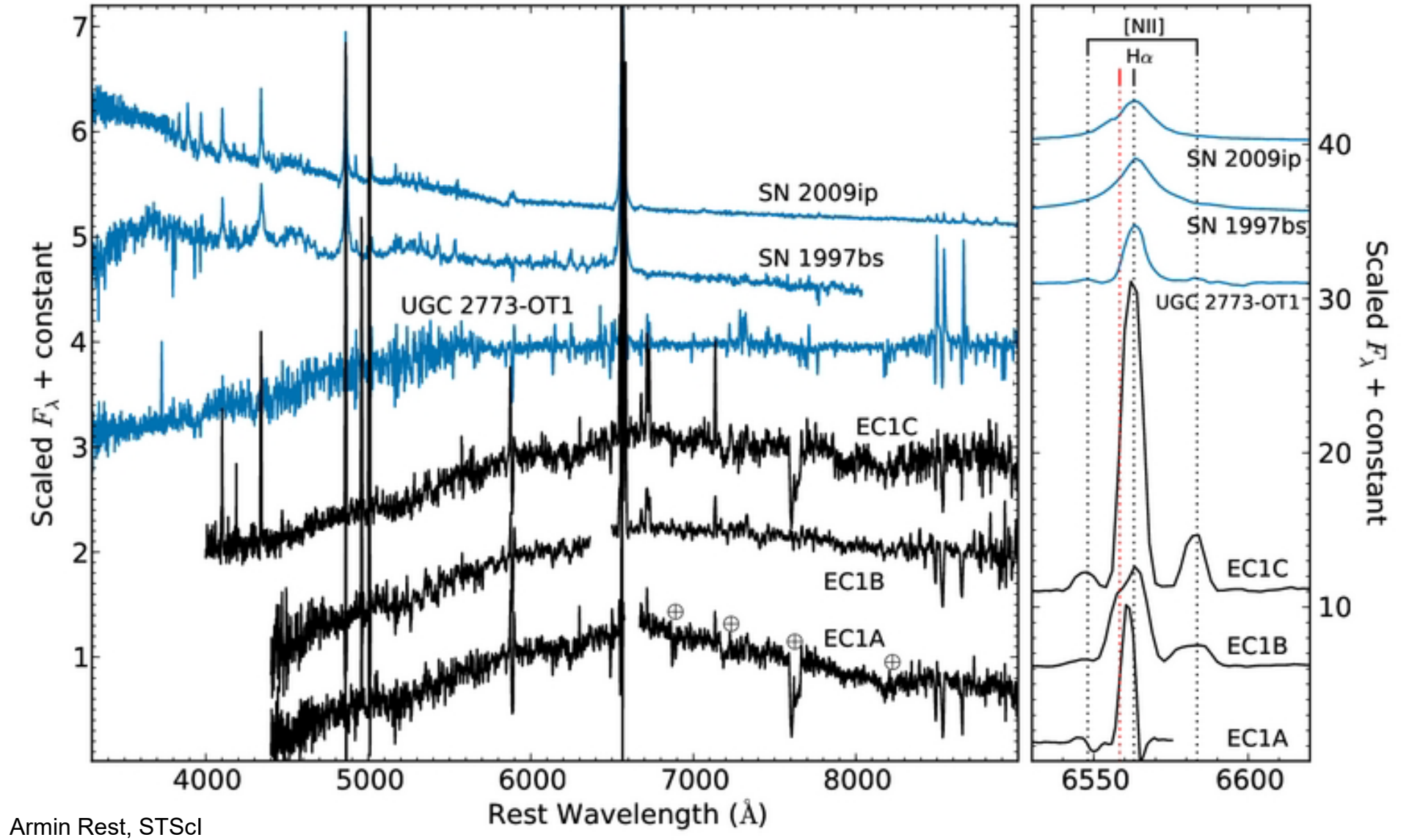
Spitzer Image (8 microns)



Difference Image (8x8 arcmin^2)
black: light echo in 2003
white: light echo in 2011

Armin Rest, STScI

η Car's Light Echo Spectra

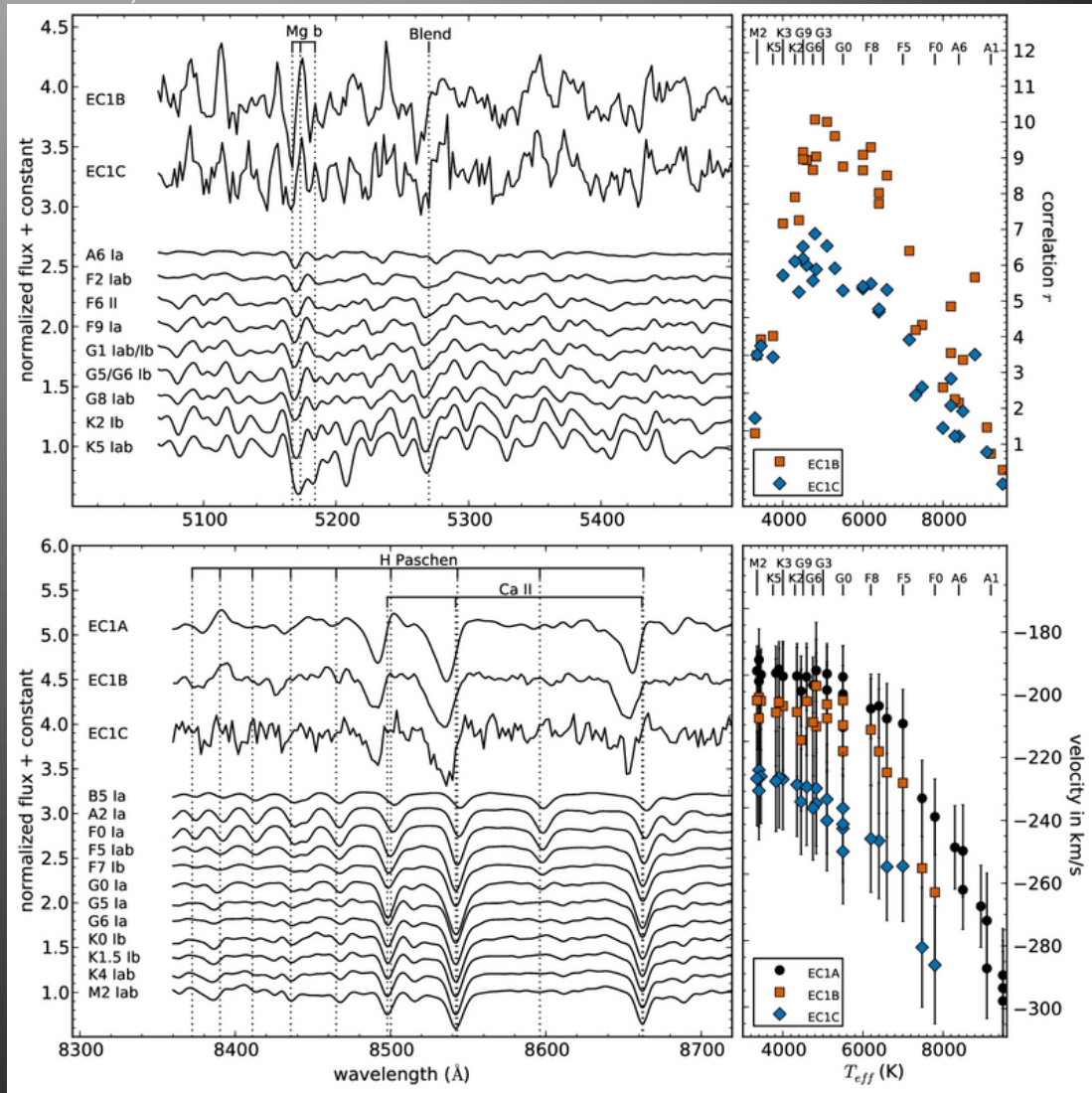


Armin Rest, STScI

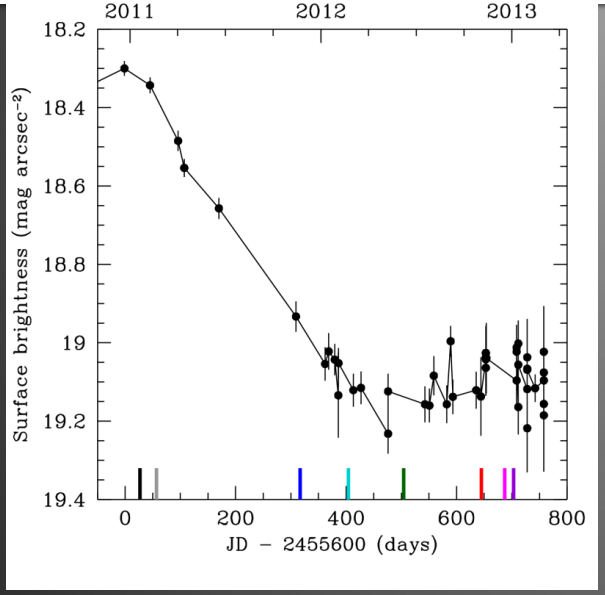
η Car's Light Echo Spectra

- Best correlation to supergiant spectra: G2-G5 (~5000 K)
- Ca NIR triplet: blueshift ~200 km/s, asymmetric shape
- Supergiant templates: UVES (Bagnulo+) and Ca IR triplet (Cennaro+)

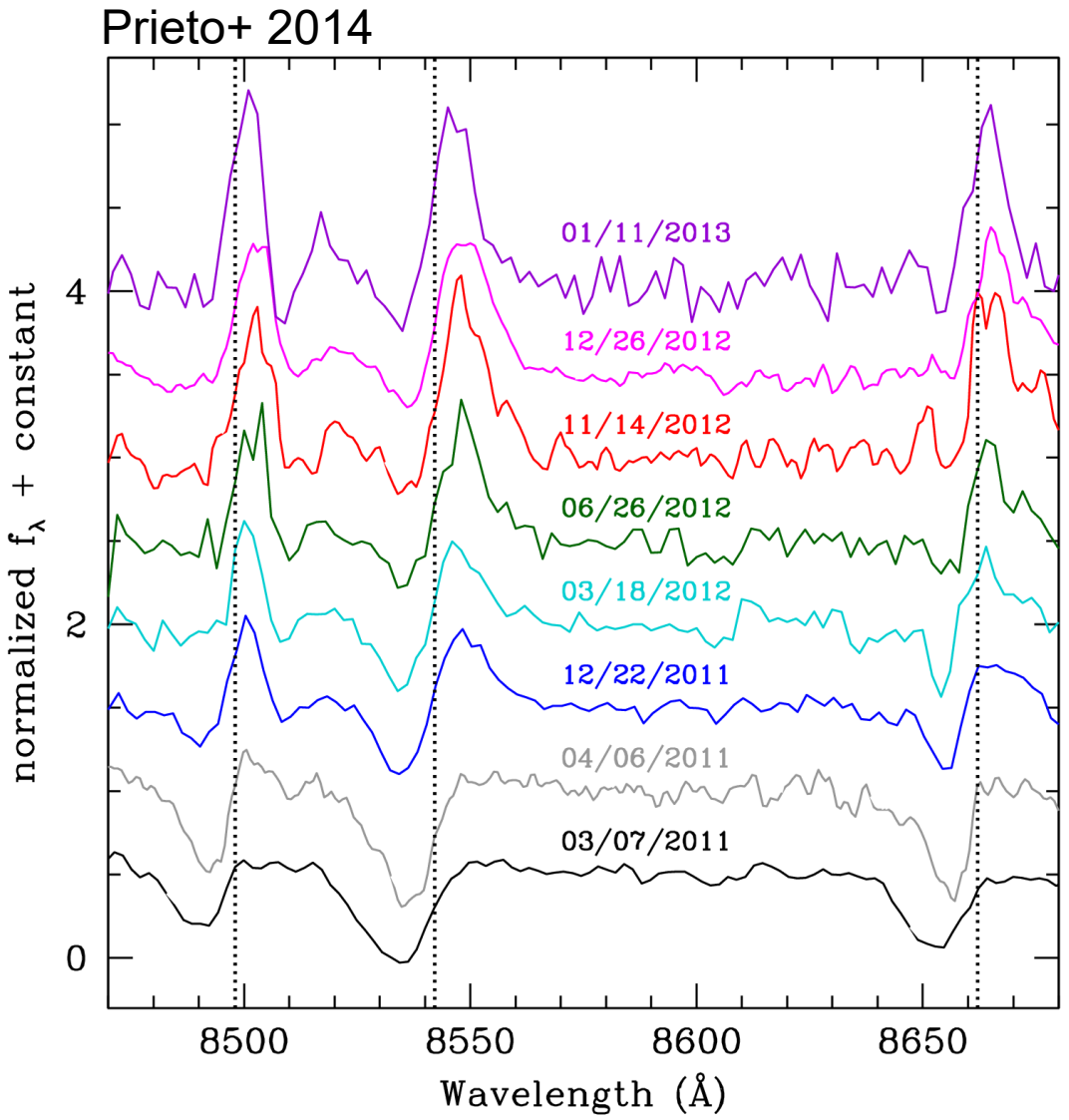
Rest+13, Nature



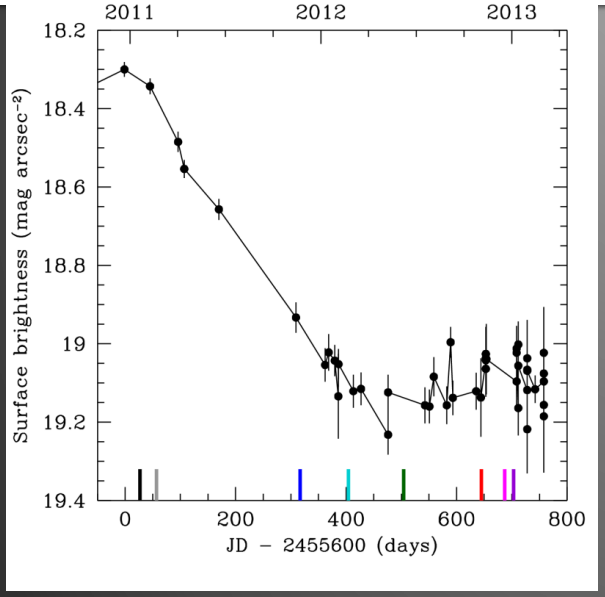
Spectroscopic Evolution of η Car's Great Eruption



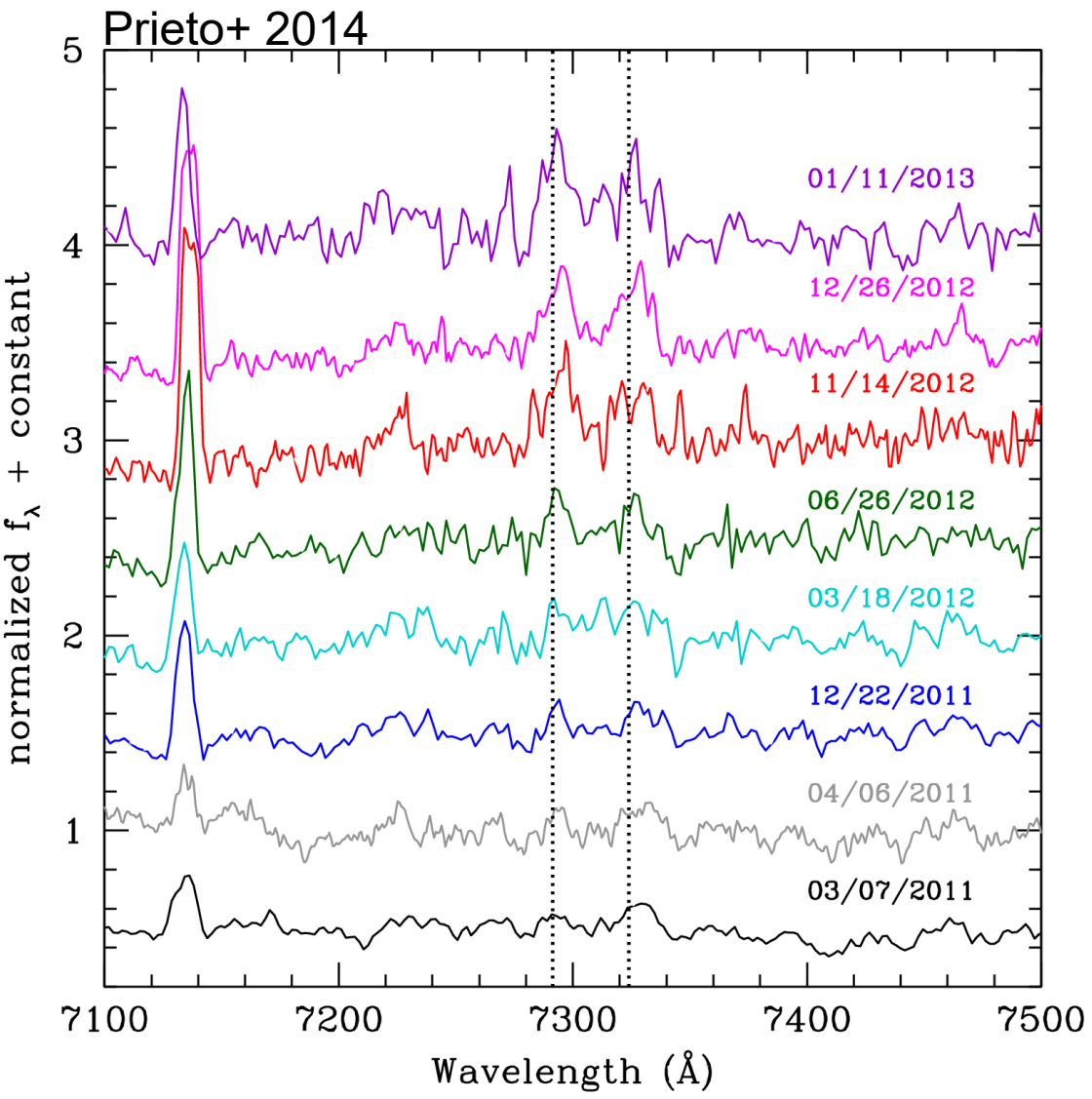
- Ca IR triplet: Absorption-only Spectrum at peak
- Transition to P-Cygni
- Emission-dominated at minimum



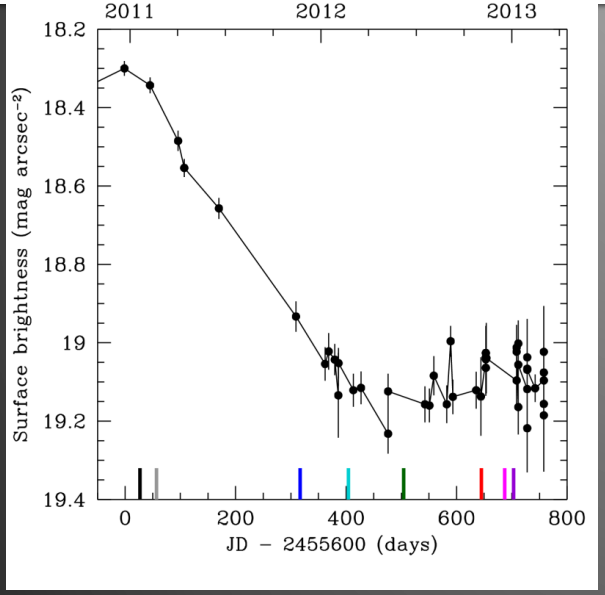
Spectroscopic Evolution of η Car's Great Eruption



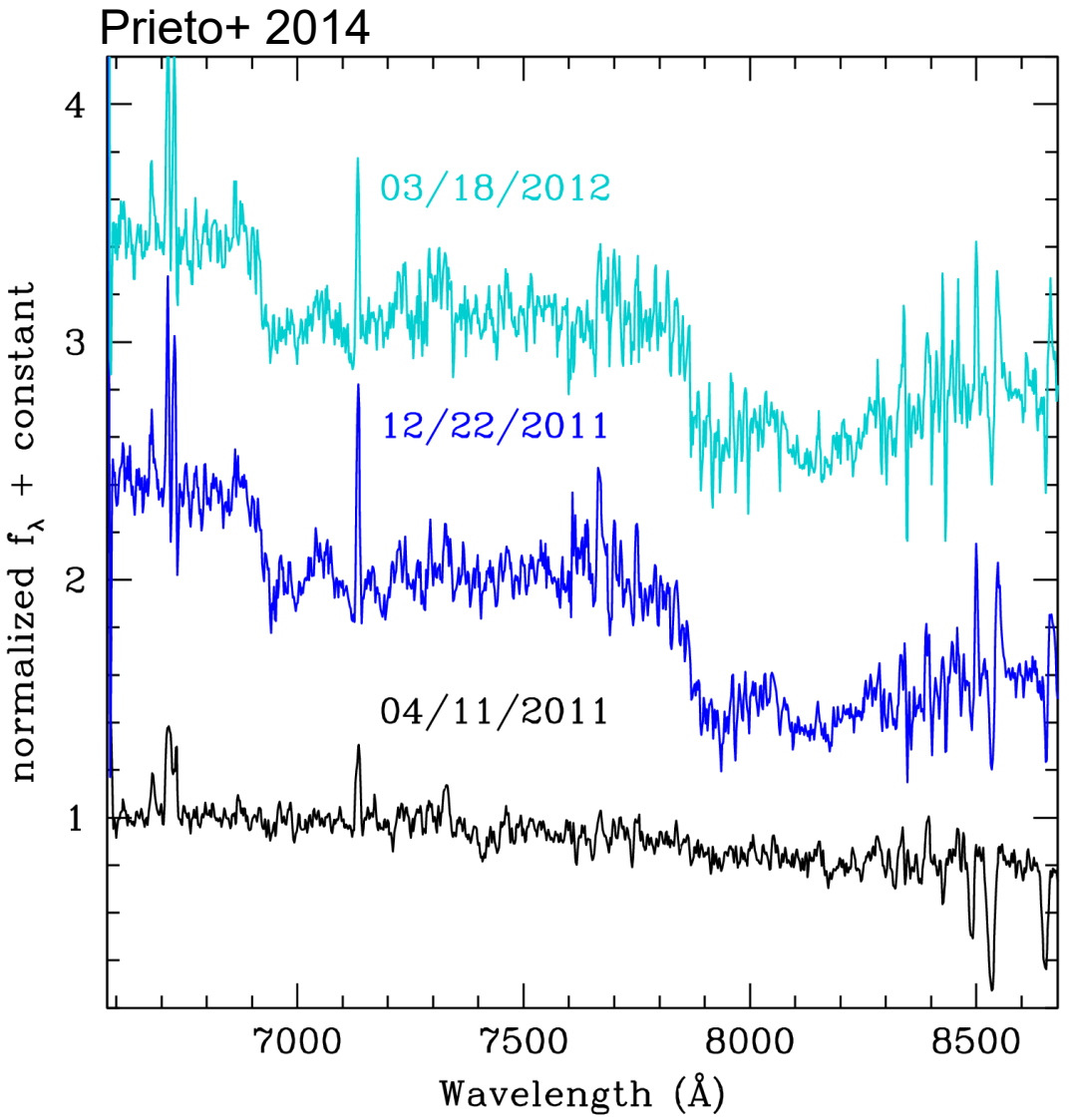
- [Ca II] doublet
- Also seen in cool SN imposters
- High density + dust formation



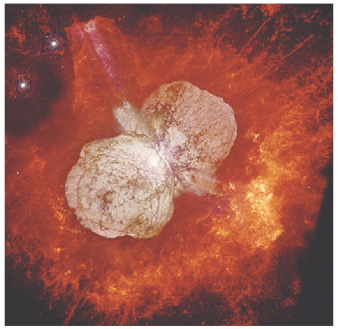
Spectroscopic Evolution of η Car's Great Eruption



- CN bands
- Develop during decline
- CN bands typically at T<~5000K
- N absorption found in UV (Gull+ 2006)



η Car



- Great Eruption from 1838-1858 (Mass loss ~20 M_{solar})
- Lesser Eruption in 1890

Smith & Frew 2011