High angular resolution observations of novae in the infrared

Olivier CHESNEAU

A special thank to D.P.K. Banerjee (Mt Abu, India)
Special BASI issue on Novae, with various contributors
BASI review on this topic: Chesneau&Banerjee

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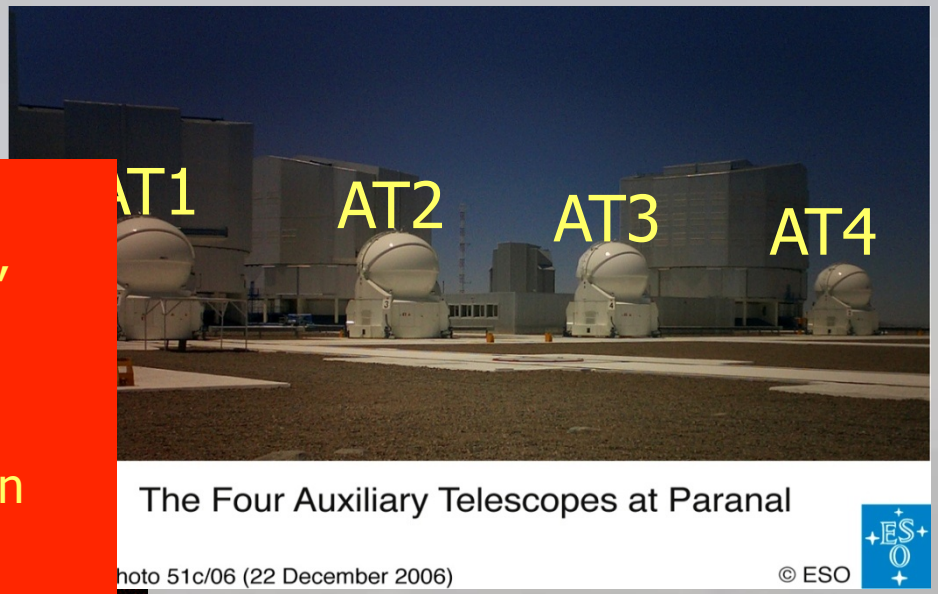
LAGRANGE

Observatoire de la CÔTE d'AZUR

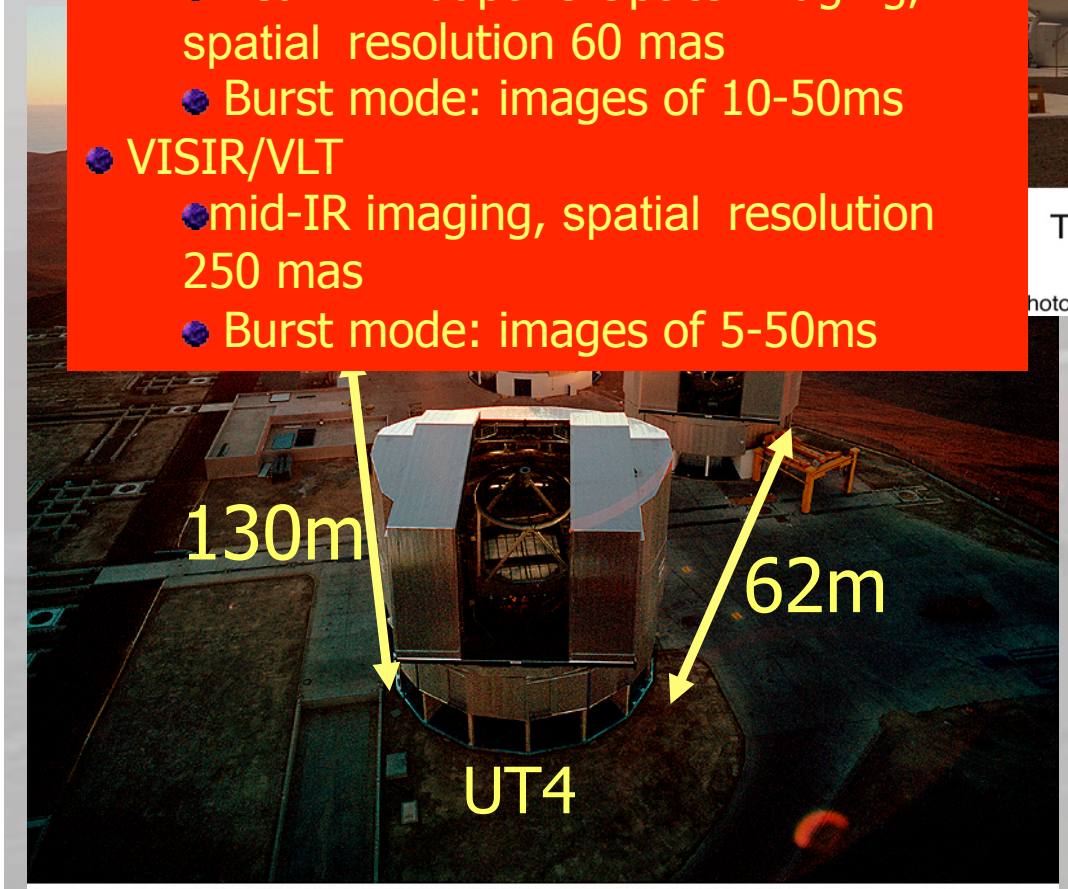
The VLTI

- NACO/VLT
  - near-IR Adaptive Optics imaging, spatial resolution 60 mas
  - Burst mode: images of 10-50ms
- VISIR/VLT
  - mid-IR imaging, spatial resolution 250 mas
  - Burst mode: images of 5-50ms



The Four Auxiliary Telescopes at Paranal

hoto 51c/06 (22 December 2006) © ESO

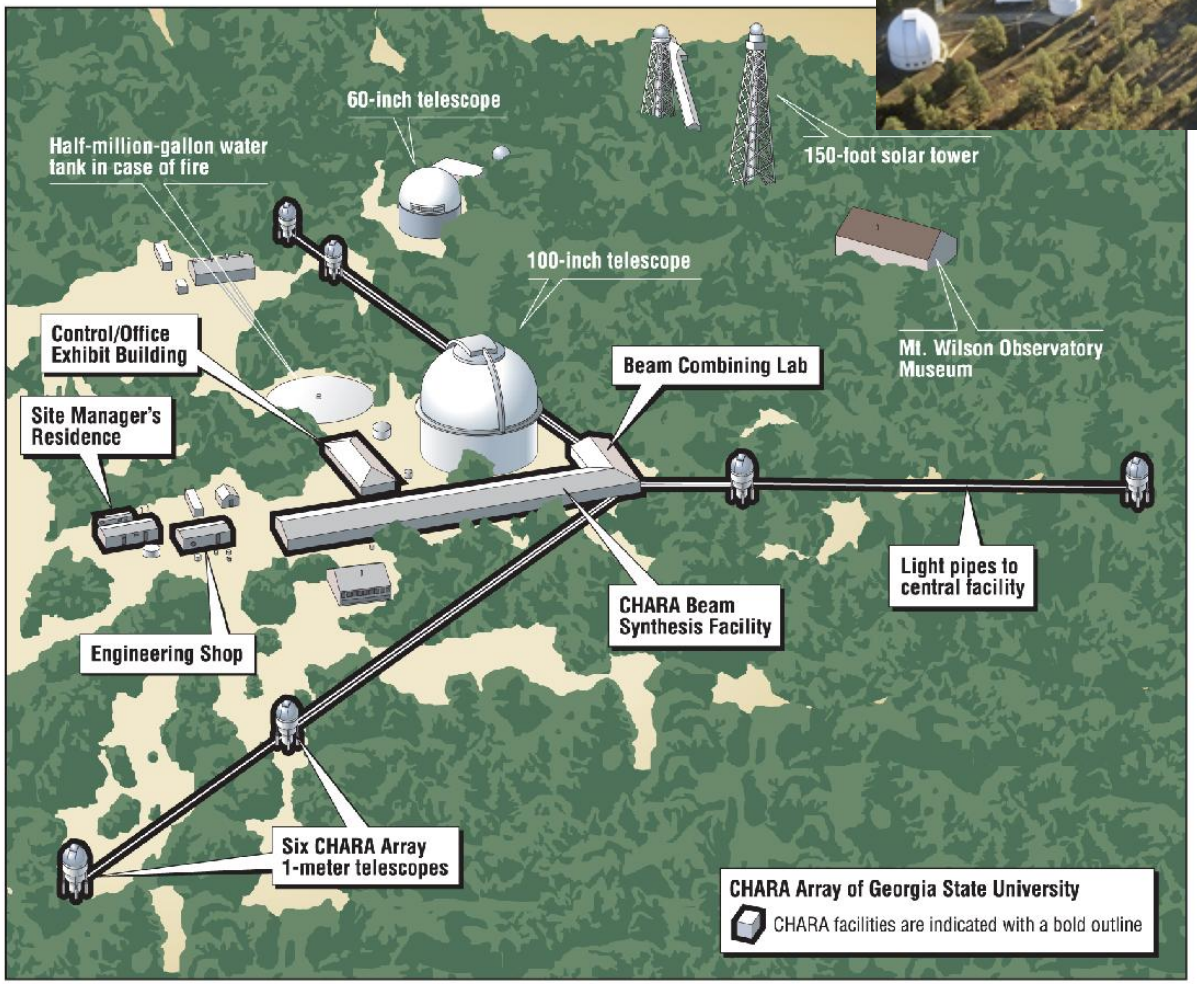


VLT at Paranal

ESO PR Photo 43a/99 (8 December 1999) © European Southern Observatory

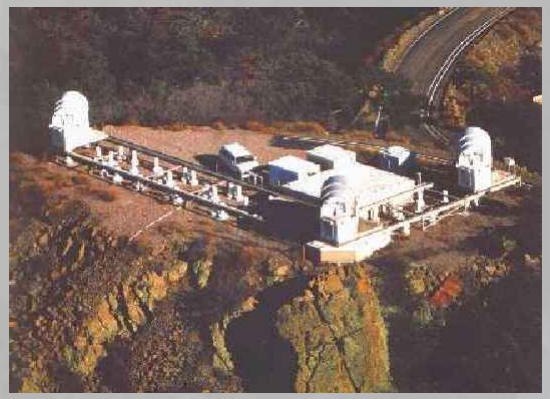
- MIDI/VLTI
  - Direct recombination N (8-13μm), R=30,230, spatial resolution 10 mas (10 AU/1kpc)
  - Sensitivity lim: N<4 (UTs)!
- AMBER/VLTI
  - near-IR recombiner (1-2.5μm), R=35, 1500, 12000, spatial resolution 2 mas (2 AU/1kpc)
  - Sensitivity lim: K<7 (UTs), R=35

N(*P*)OI array ⟶



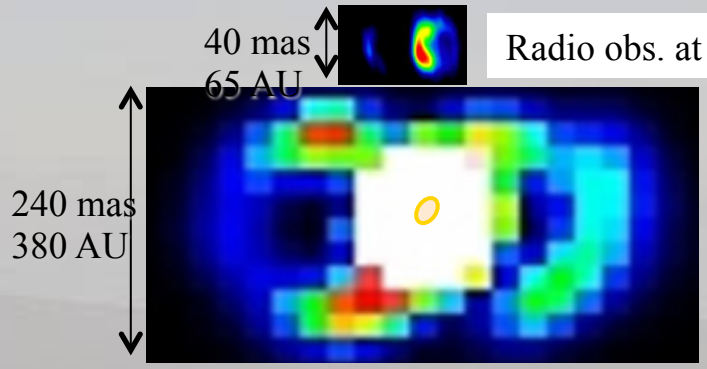
⟵ CHARA array

IOTA array ↓



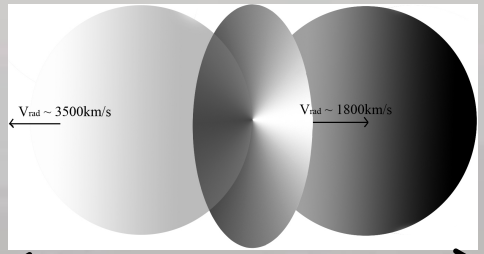
Novae: fast creation of highly bipolar nebulae

Recent examples of bipolar nebulae observed less than 1-2yrs after outburst



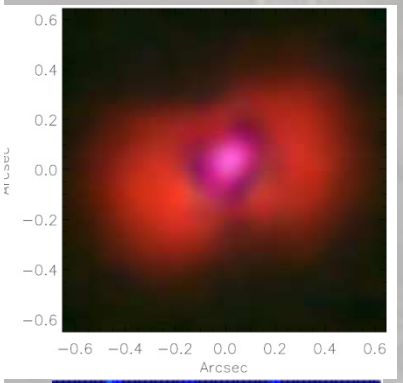
Radio obs. at t=22 days

HST visible image at t=150 days

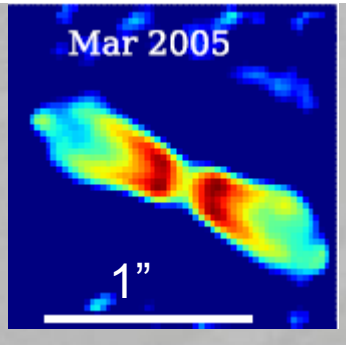


9 mas – 15 AU, t=5d

The recurrent RS Oph:
O'Brien et al. 2006,
Chesneau et al. 2007,
Bode et al. 2008…

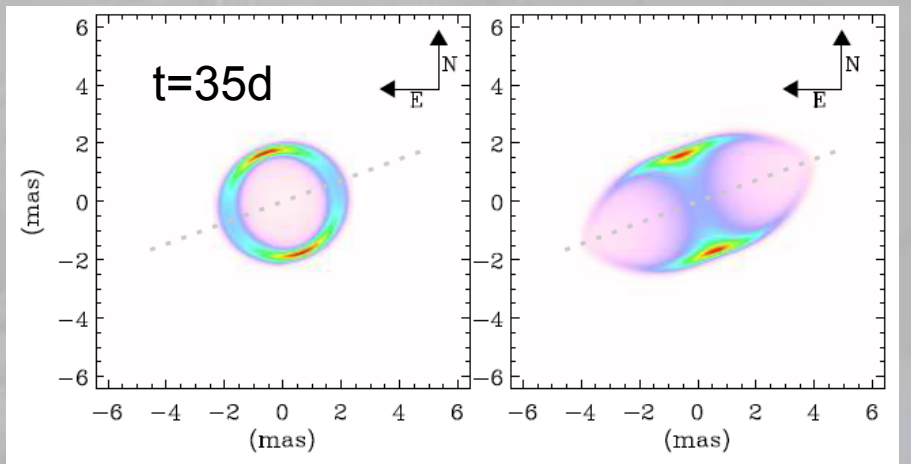


The classical V1280 Sco:
Chesneau et al. 2008,
Chesneau et al. 2012
A slow nova (Vej~500km/s): large mass ejection, dust created, no equatorial material



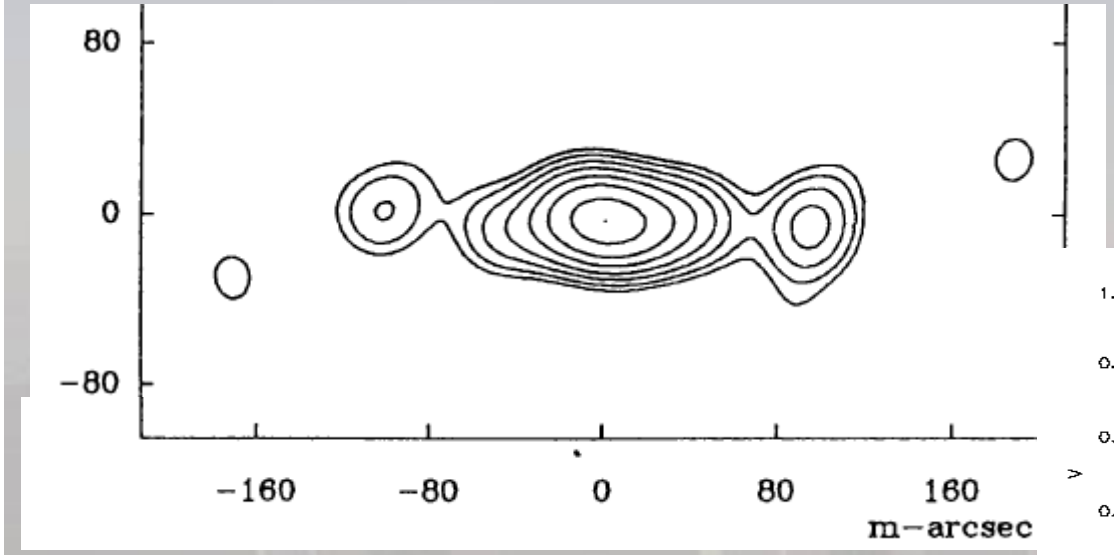
The classical V445 Pup:
Woudt et al. 2009,
Fast nova (Vej~4000km/s): An extremely asymetrical outburst?
Dense equatorial material

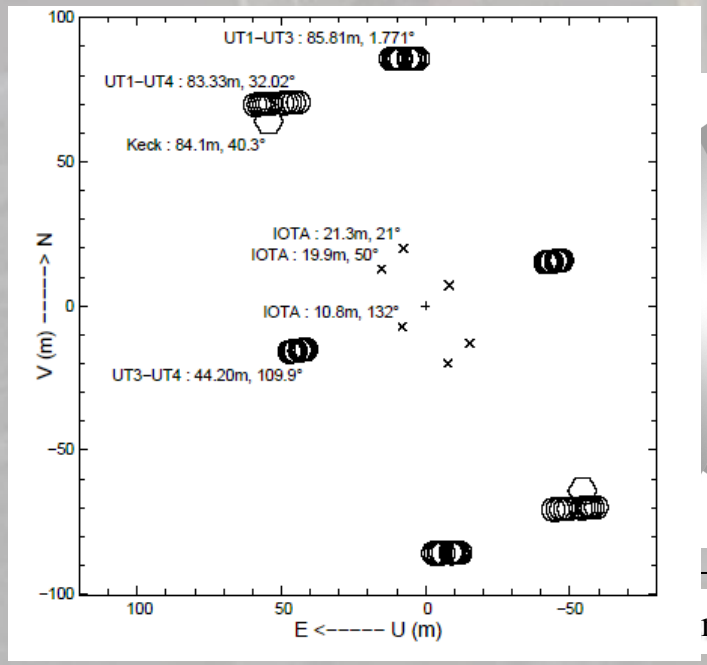
The recurrent T Pyx: a near-pole on bipolar nebula
Chesneau et al., 2011, wind acceleration observed

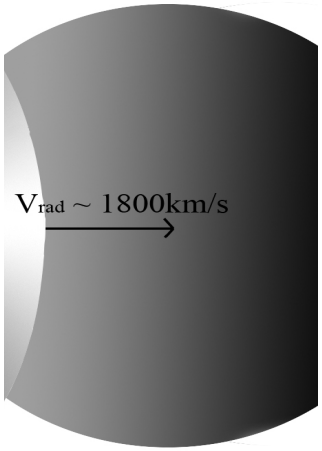


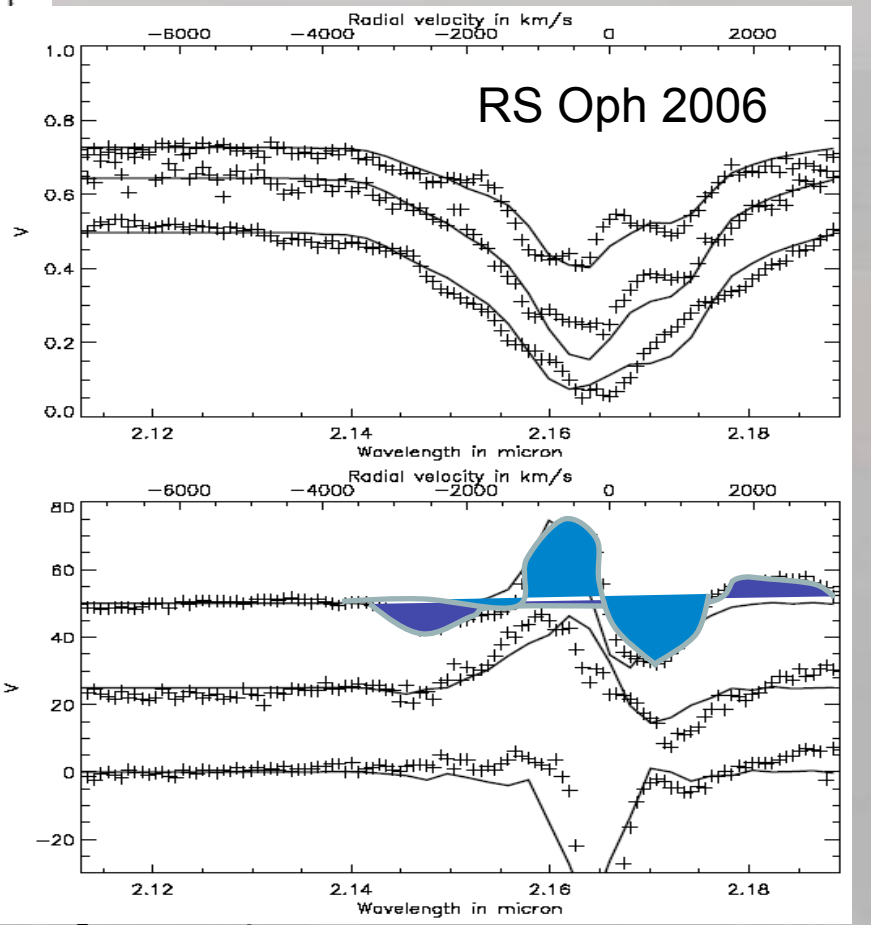
RS Oph outburst: April 1985

EVN radio sparse uv coverage reconstruction (Davis et al. 1988)



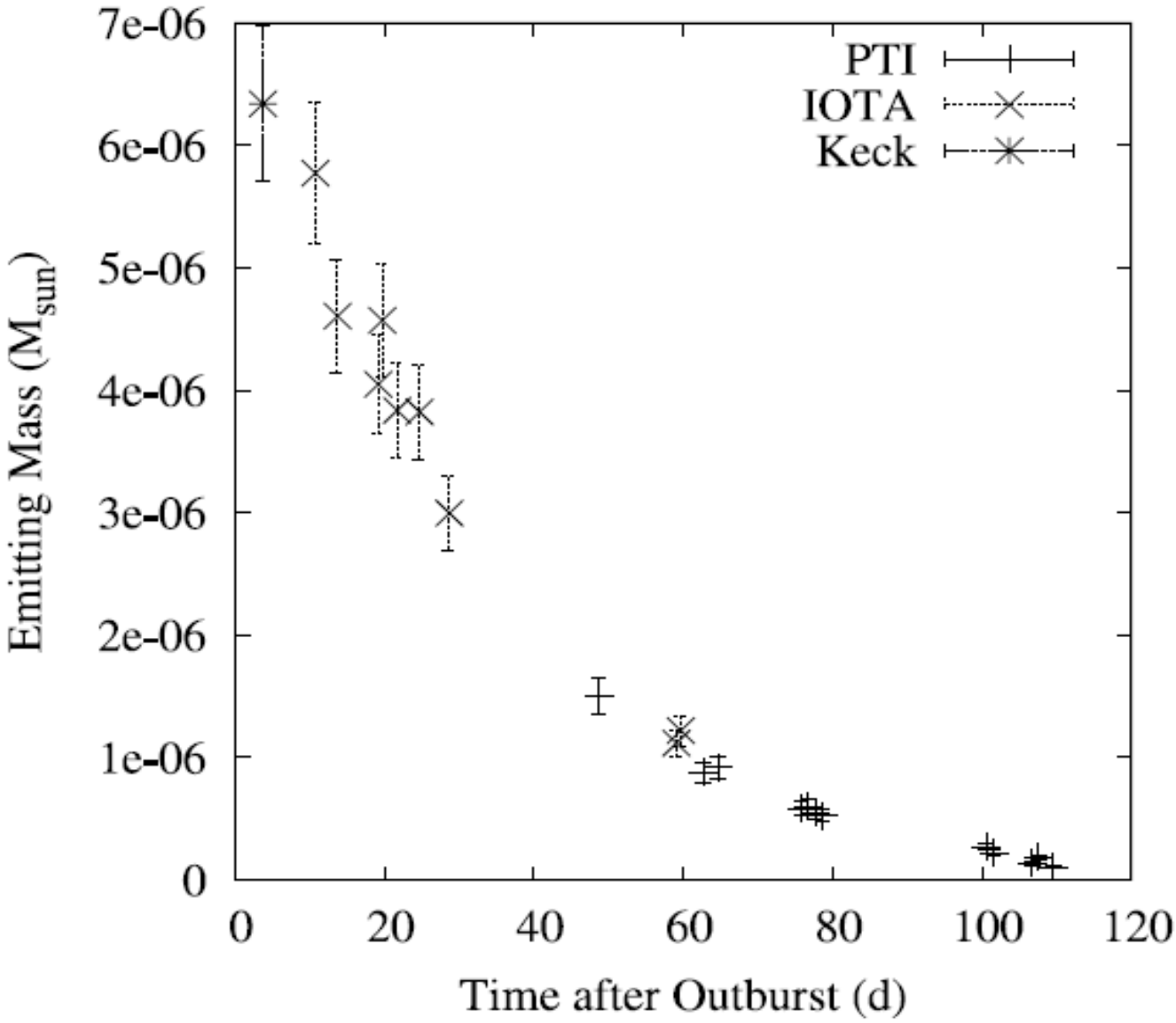




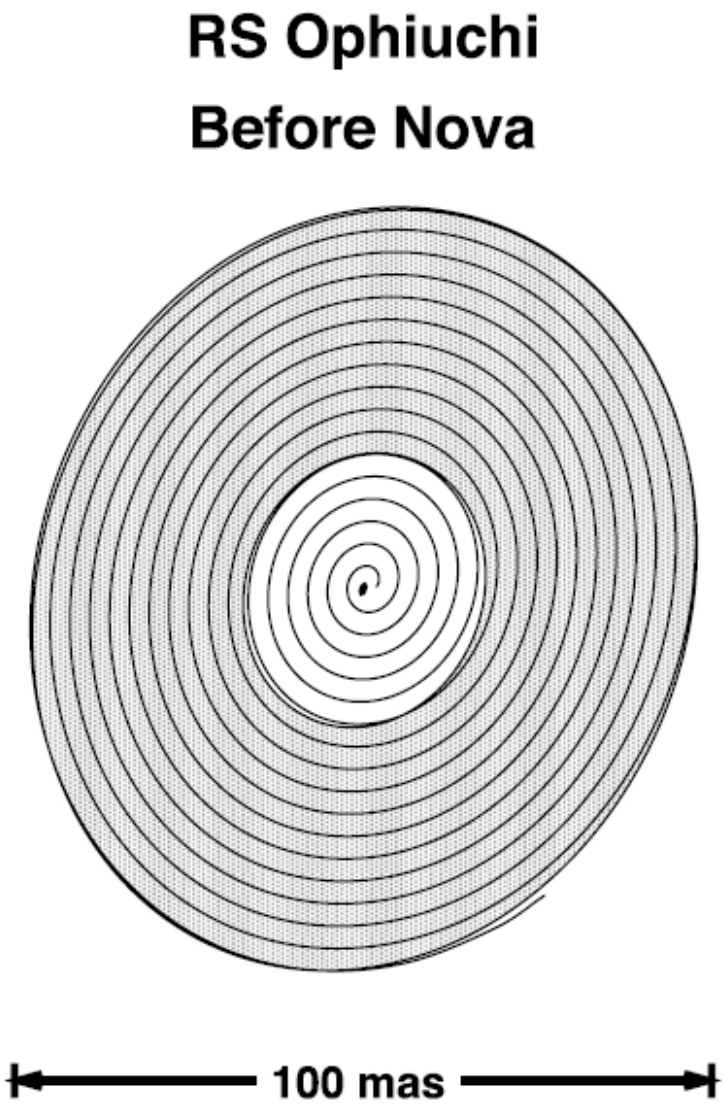


neau et al. 2006, 2007

outburst



Lane et al. 2007: the time variable emission measure (volume) of the free-free emission is determined. Strong constraint on the nova wind.



Barry et al. 2008:
With the Keck nuller

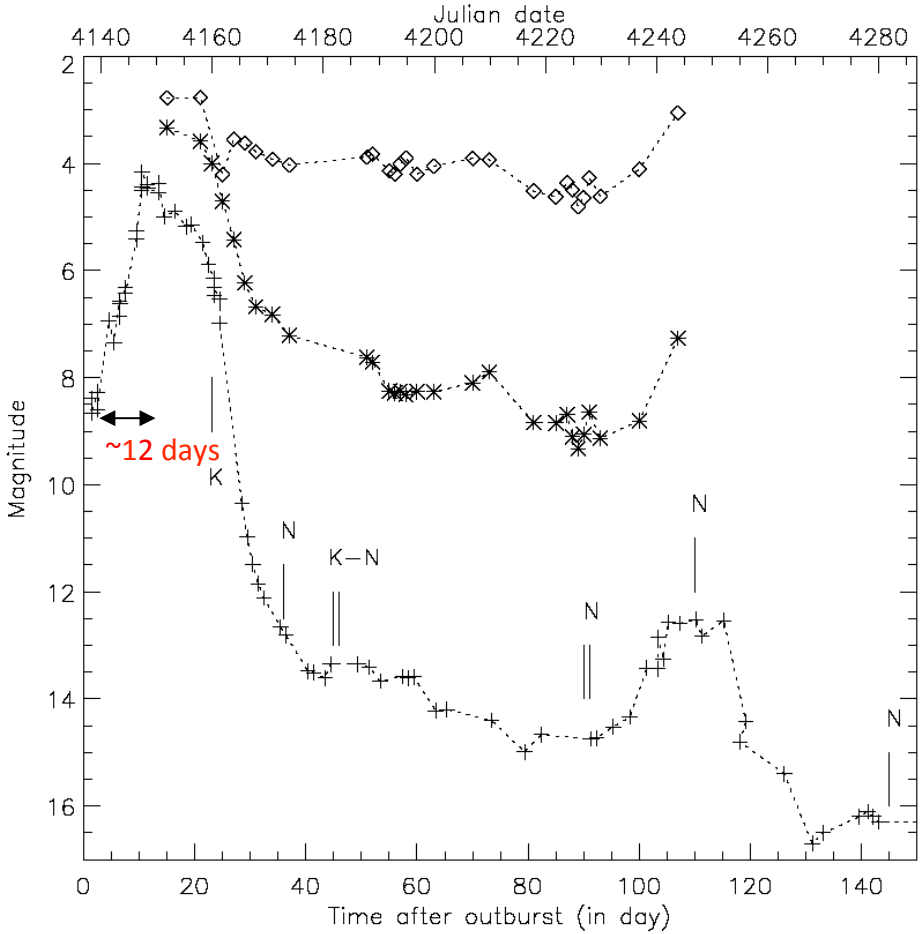
Questions:

Is the material detected massive enough to have played any role in the bipolar shape of the ejecta?

Why such dense material is so difficult to detect? Recurrence time scale short for the building up of a dense circumbinary disk-like environment: a pre-exisiting nova stage structure?

The equatorial plane density of this kind of objects has to be carefully measured.

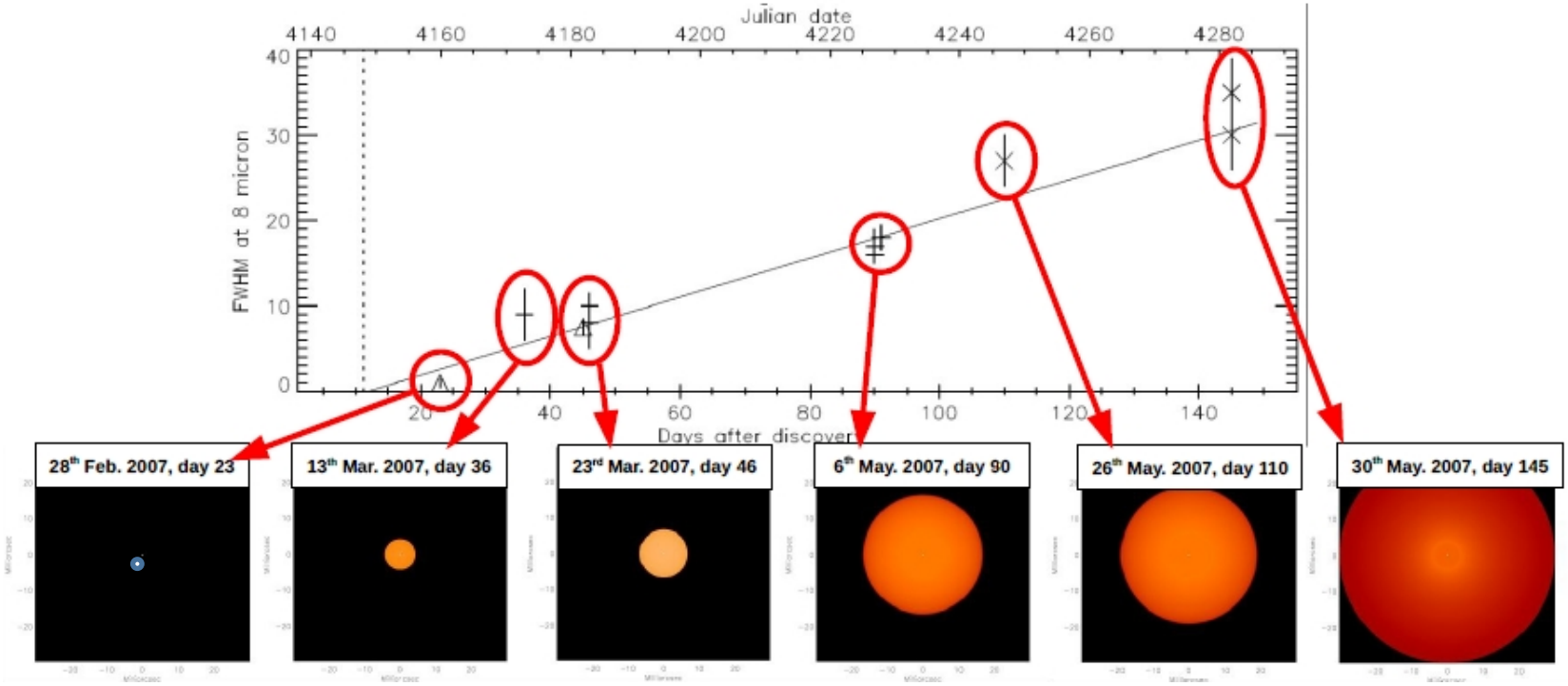
The dust formation event of V1280 Sco monitored by VLTI, VLT and Mt Abu



- One of the historically slowest nova observed
- Reached V~3.8,
- Monitored during 5 months by the VLTI and Mt Abu (1-2 and 8-13 micron observations)
- Sparse uv coverage (1-3 bases at a time): slow process, *assuming spherical symmetry*
- use of the DUSTY code for the interpretation.

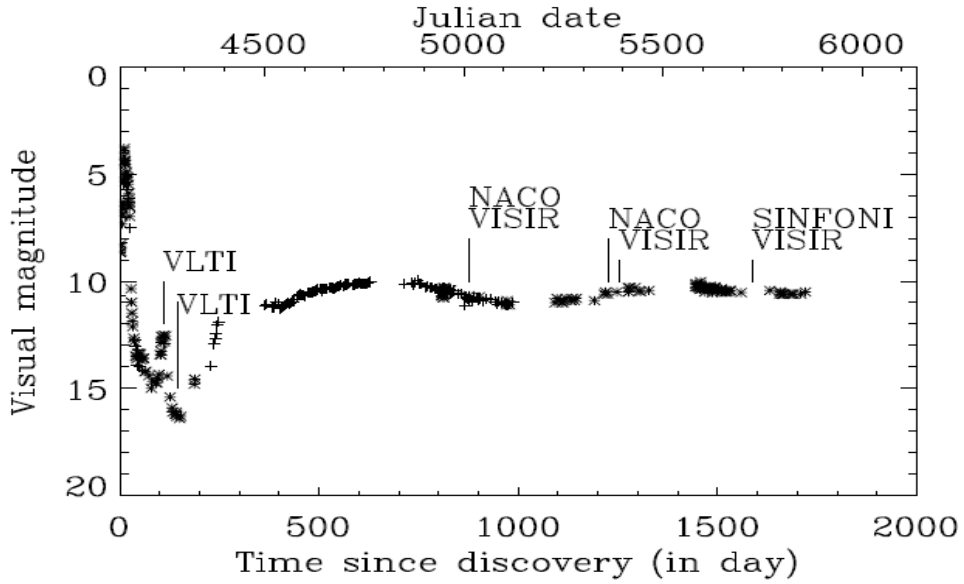
thanks to: D. Banerjee, Florention Millour, M. Wittkowski, E. Lagadec, Magdalena Otulakowska…

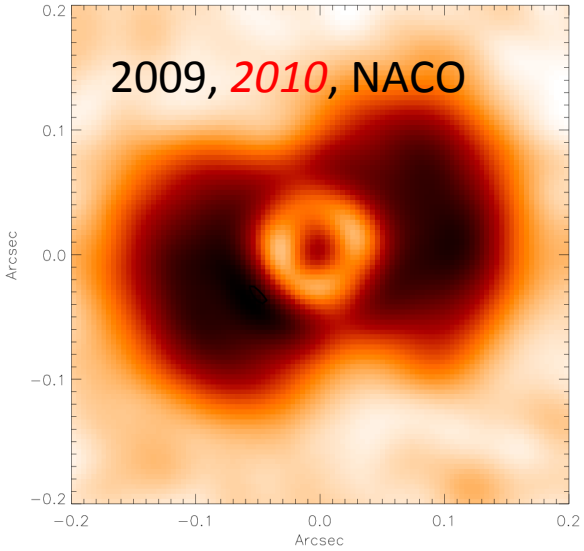
Chesneau, Banerjee, Millour et al. 2008,
Das, Banerjee, Ashok and Chesneau 2008
Chesneau, Lagadec, Otulakowska et al. 2012



From DUSTY modeling some investigations on the dust formation process could be carried out;
Suggesting in about 140 days an accumulation of about 10^{-6} $M_{\odot}$ of dust and an total mass of the shell ~ 10^{-4} $M_{\odot}$.

A precise expansion of 0.35mas per day measured. However, the scatter around the suggests complexity.

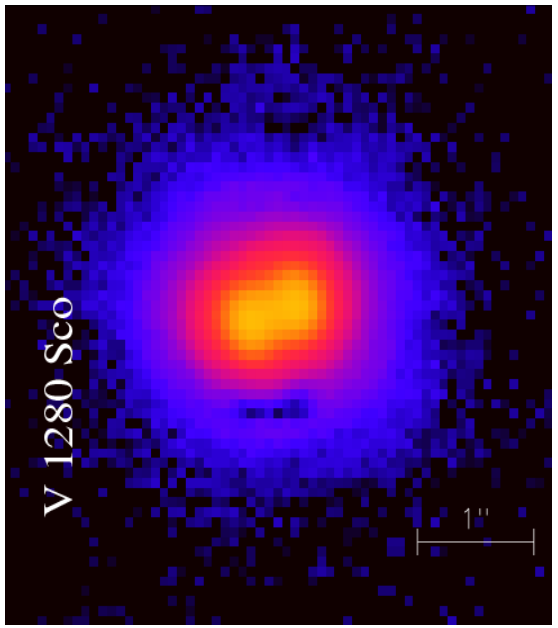


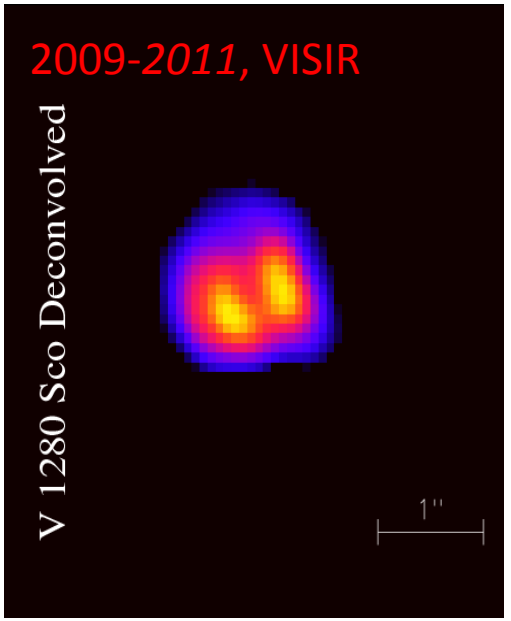


- High inclination bipolar nebula
- No equatorial structures in IR,
- VLTI expansion measurements in line with major axis expansion,
- D>1kpc (Sadakane et al. 2009, Naito et al. 2012)

A slow nova can ALSO create a striking bipolar nebula: common envelop effect?

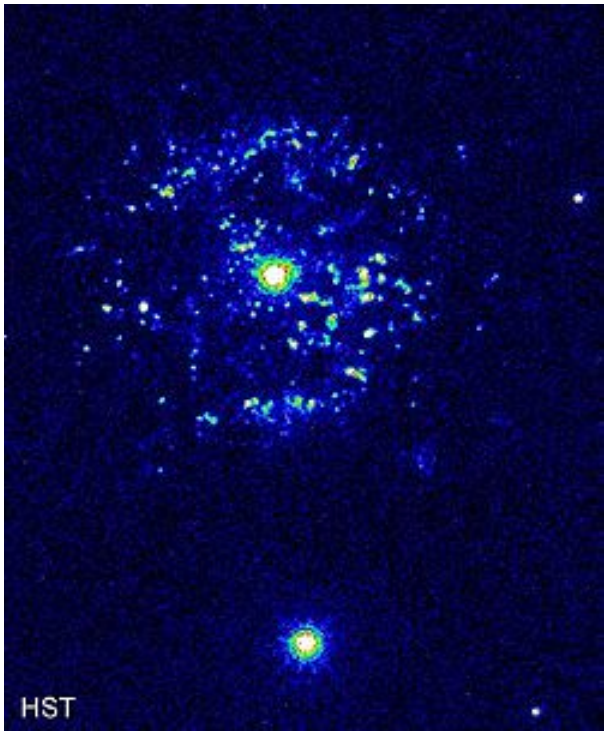
PERFECT (bright) ALMA TARGET!
Should now be a 1”x0.6” nebula
But need constant monitoring!





The recurrent T Pyx

Chesneau, Meillant, Banerjee et al. 2011



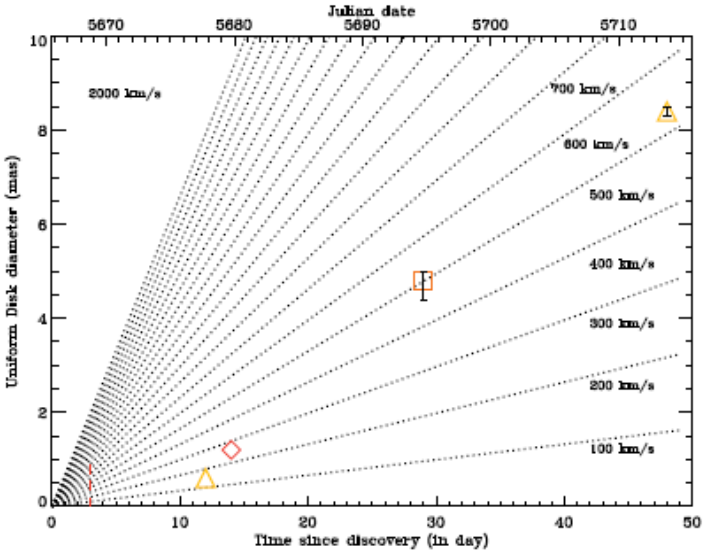
CV of T Pyx

- Discovered by H. Leavitt in 1913,
- First 'recurrent' nova, oubursts in 1890 and 1902,
- Then 1920, 1944, 1966… …. 2011

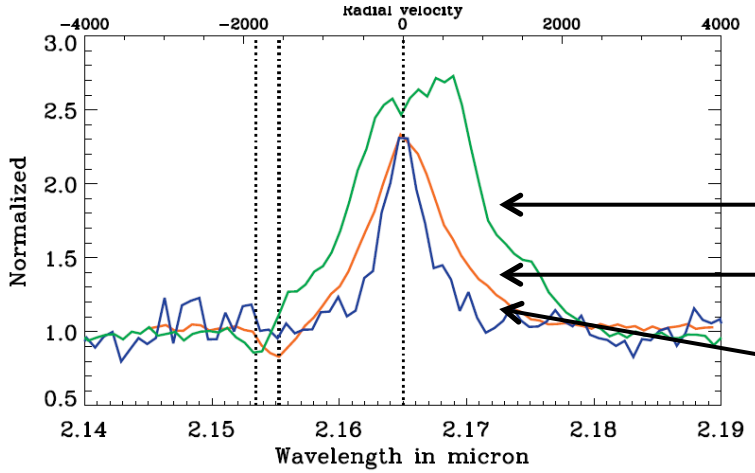
- Nebula deeply studied by the HST (Shara et al. 1997),
- 'Slow motions' measured (v~600km/s, Schaefer et al. 2010)
- Binary spectrocopic signal resolved, q=0.2, i~10 (Utas et al. 2010)

2011 T Pyx outburst: as seen by optical interferometry

- 2 *CHARA/CLASSIC* at Mt Wilson (1st: t=2.7d, to=14th April)
- 3 *VLTI/AMBER* and 2 *VLTI/PIONIER* obs. (until t=48d)
- Results
  - A slow expansion (v<700 km/s) measured assuming D=3.5kpc (but **Shore et al. 2011→ D>3.5 kpc**)
  - The source appears circular (r=1+/-0.07),
  - Extended complex phase signal in the Brγ line,



thanks to: A. Meilland, G. Schaefer, S. Ridgway, T. ten Brummelaar, J.B. Le Bouquin, F. Millour, M. Wittkowski…)

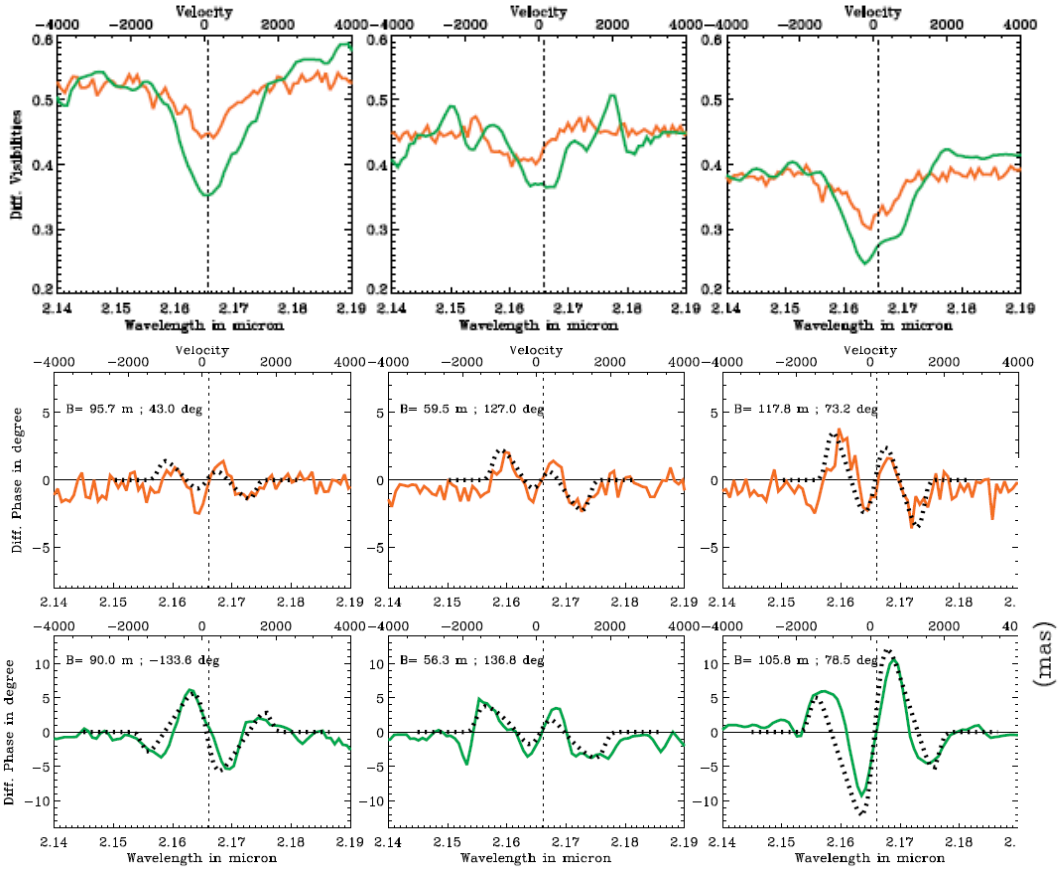


AMBER / VLTI obs.

Green: **t=36 d, FWHM=1600, P Cyg=-1800 km/s**

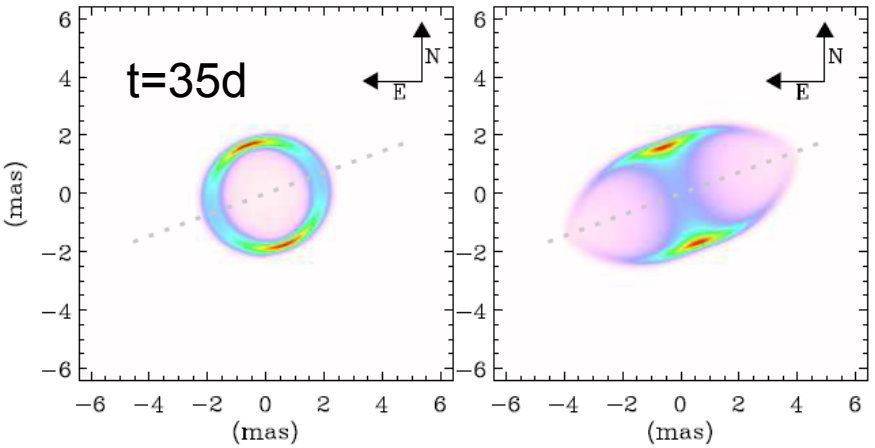
Red: **t=28 d, FWHM=1050, P Cyg=-1450 km/s**

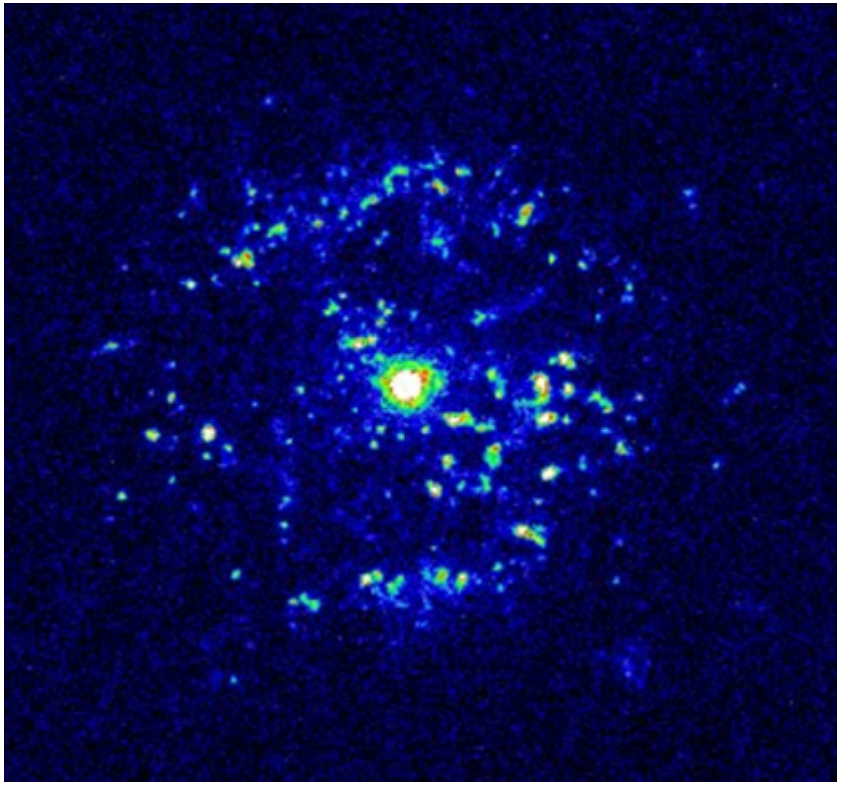
Blue: **t=13 d, FWHM=590 km/s,**



Observations best interpreted in the frame of a nearly pole-on, accelerating bipolar model, i~15°, P.A.~110°

- t=28d: Vpol=1200 km/s, Veq=600 km/s
- t=36d: Vpol=1600 km/s, Veq=700 km/s





Are these ejecta spherically distributed?

No, probably concentrated near the equatorial plane facing us.

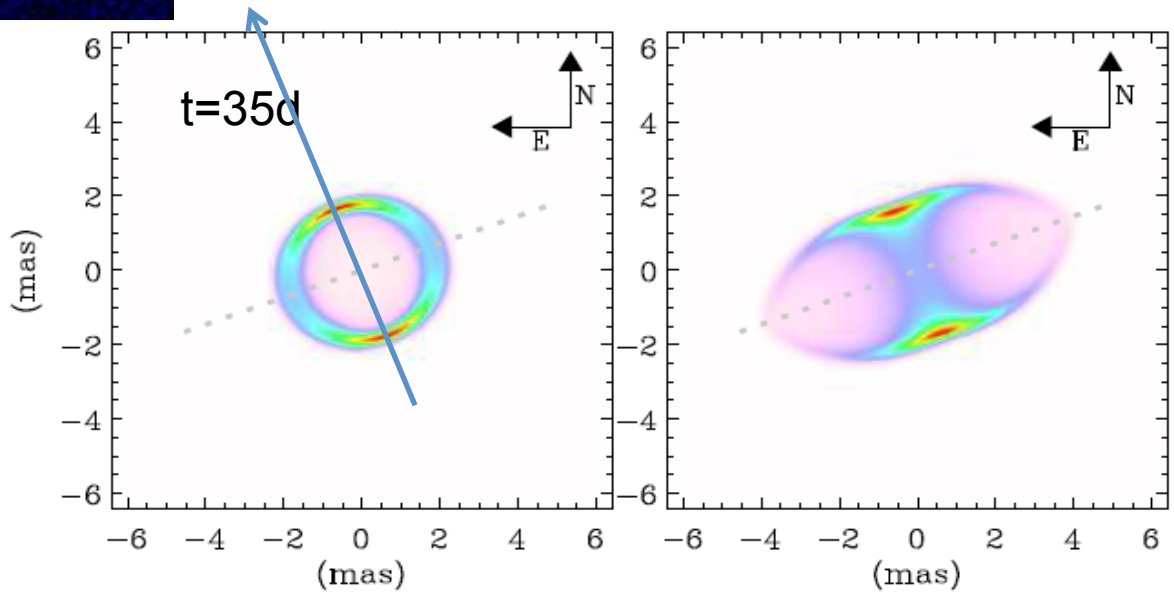
This should be checked with a careful polarization study of the clumps

(see the recent controversy on RS Pup, Kervella et al.; Bond et al.)

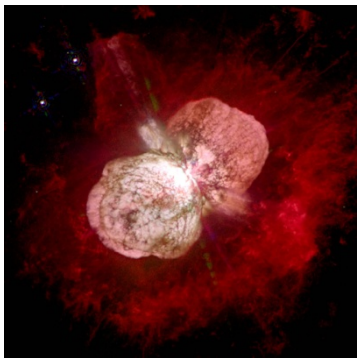
Bipolarity is necessary to explain the VLTI differential phase signal.

The PA angle (110°) is well constrained

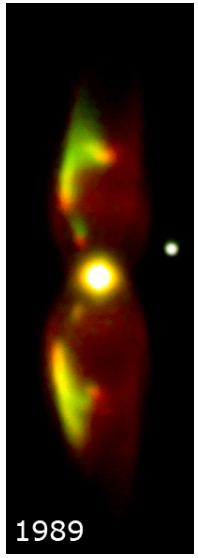
The inclination more difficult (degenerated models)



Why bipolarity?



Binary systems!



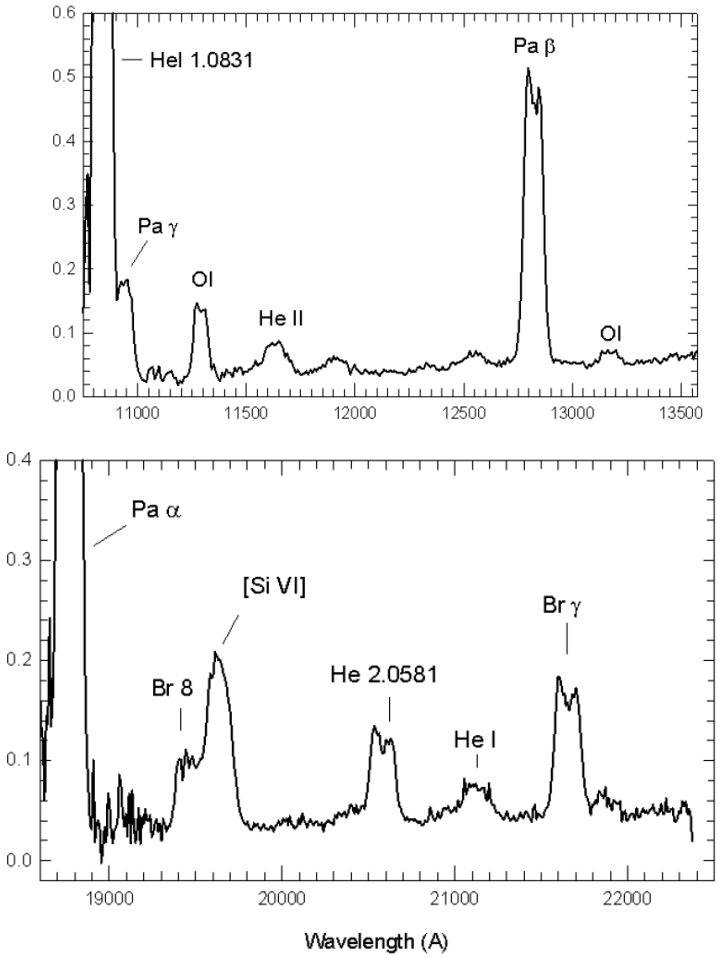
And then???

1. Channeling of the outburst by dense circumbinary material?
   - Perhaps for V445 Pup,
   - Circumbinary density enough in the case of RS Oph?
   - Probably not applicable for V1280 Sco, and not for T Pyx,
   - We need to evaluate carefully the mass around many recurrent/classical novae
2. Common envelop interaction?
   - Favors slow nova, since time scale is short, and effects might be limited
   - Difficult to observed the effect of the companion during this phase
3. Transient jets?
   - Would explain velocities observed and collimation,
4. Intrinsically massive ejection?
   - Spun-up WD, rotating a P<1min → what effect on detonation/explosion?
   - Channeling through strong magnetic field, that *should* be detectable

Last but not least: with ejecta from some sources (e.g. GK Per) are roughly spherical???

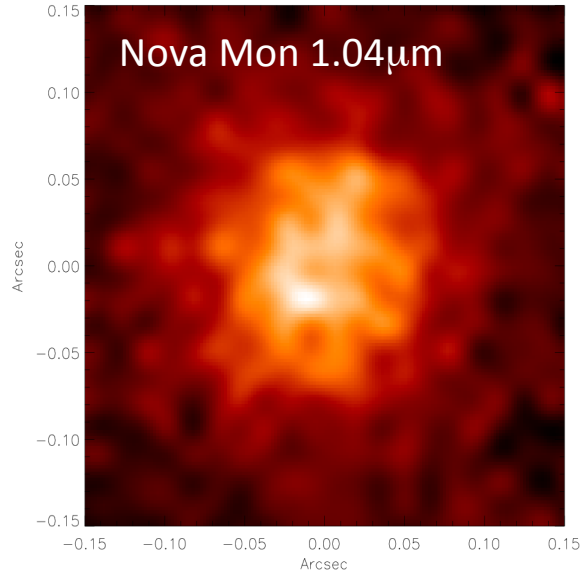
Nova Mon 2012

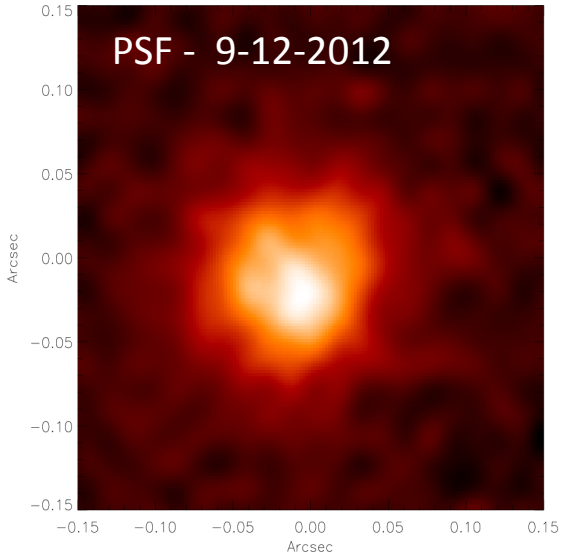
- Gamma Ray burst detected on June 29 2012 by FERMI/LAT,
- Source detected on June 30th by VLA
- Source (re)discovered by amateurs from 9th of August (after sun eclipse…)

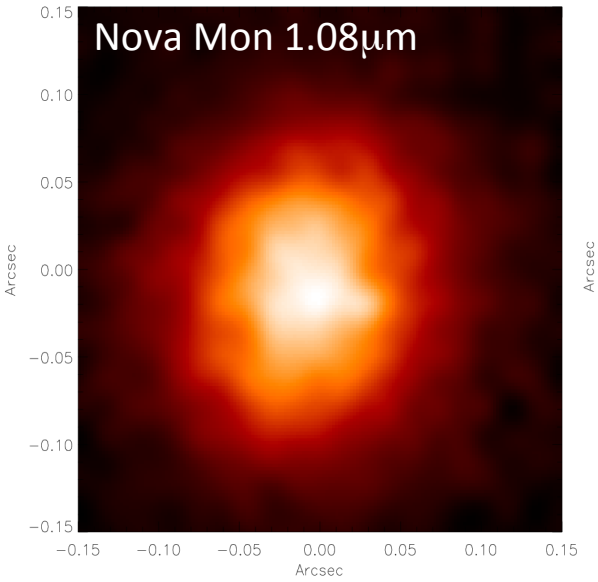


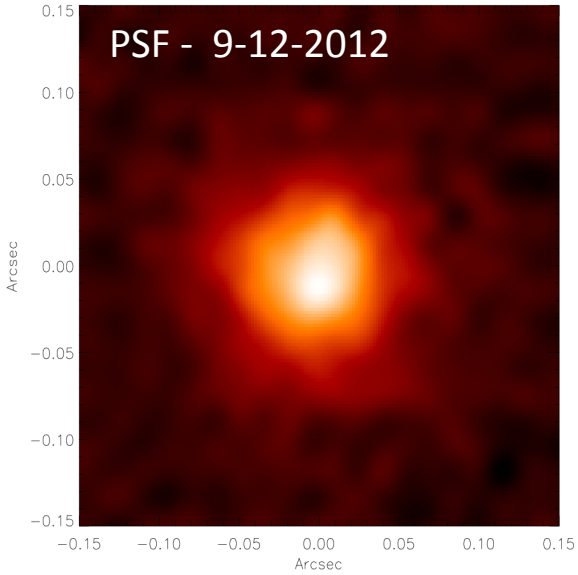
- Source entered coronal phase
- Mt Abut J and K spectra of the 2nd of November
- First NACO/VLT observation the 9th of December

Nova Mon 2012









- First NACO/VLT observation the 9th of December 2012.
- Second set obtained the 17th of January 2013, then 21th.
- Third set expected between now and end of March,
- Fourth and fifth datasets expected between April and August.

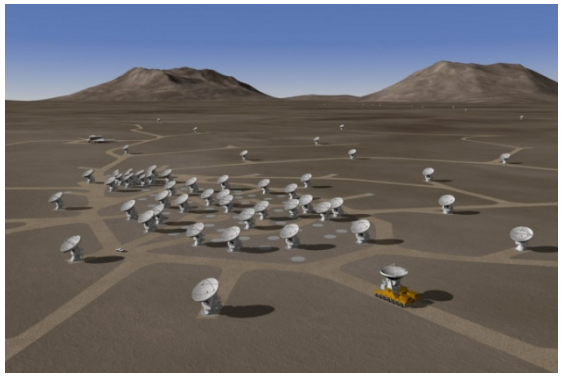
Source extension in December

- About 30+/-3mas
- Round in the continuum (J, H, K)
- Elliptical in 1.08μm line,
- 25/30% flattening,
- North-South elongation

Source extension in January

- About 32+/-3mas
- Continuum signal disappears
- Elliptical in 1.08μm line,
- 25/30% flattening,
- North-South elongation

Prospects



We NEED ALMA!!!

- Dust mass evaluation,
- Circumbinary material (V445 Pup, RS Oph, V1280 Sco…)
- Gas phase chemistry
- Clumping
- Kinetic energy budget:
  - Bipolar lobes/jets launching mechanism,

Second generation of the VLTI to come 2015-2016

- GRAVITY instrument (4 beams, H-K, R=4000)
- MATISSE instrument (4 beams LMN bands, R~300/3000)

SPHERE/VLT instrument will replace NACO: an exoplanets hunter

Limited to R<9, but extreme AO, coronography, polarisation

MATISSE
Multi AperTure Mid-Infrared SpectroScopic Experiment

- Imaging capabilities in the N (8-13.5 μm) band (4T)

- Opening the spectra window L (3.5 μm) &M (4.5 μm)
  - Spectral resolutions: from 30 to 5000

- FDR passed in late 2012, first light foreseen in late 2015.

- Planet formation,
- Star formation (low and massive stars,
- Circumstellar disk evolution, ,
- Active Galactic Nuclei,
- Extrasolar planets,
- Solar System Minor Bodies,
- Dust and winds from evolved stars,

Maximum Spatial Resolution

Band	Usage of ATs	Usage of UTs
L	3 – 4 mas	6 mas
M	5 mas	8 mas
N	10 mas	16 mas

dispersed MIDI fringes of V Oph