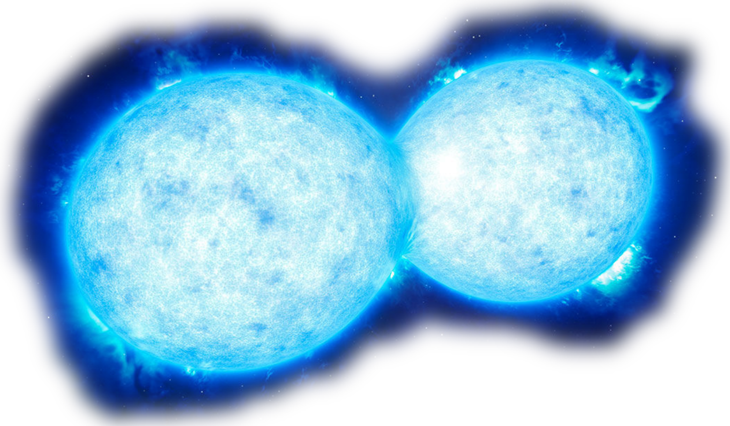
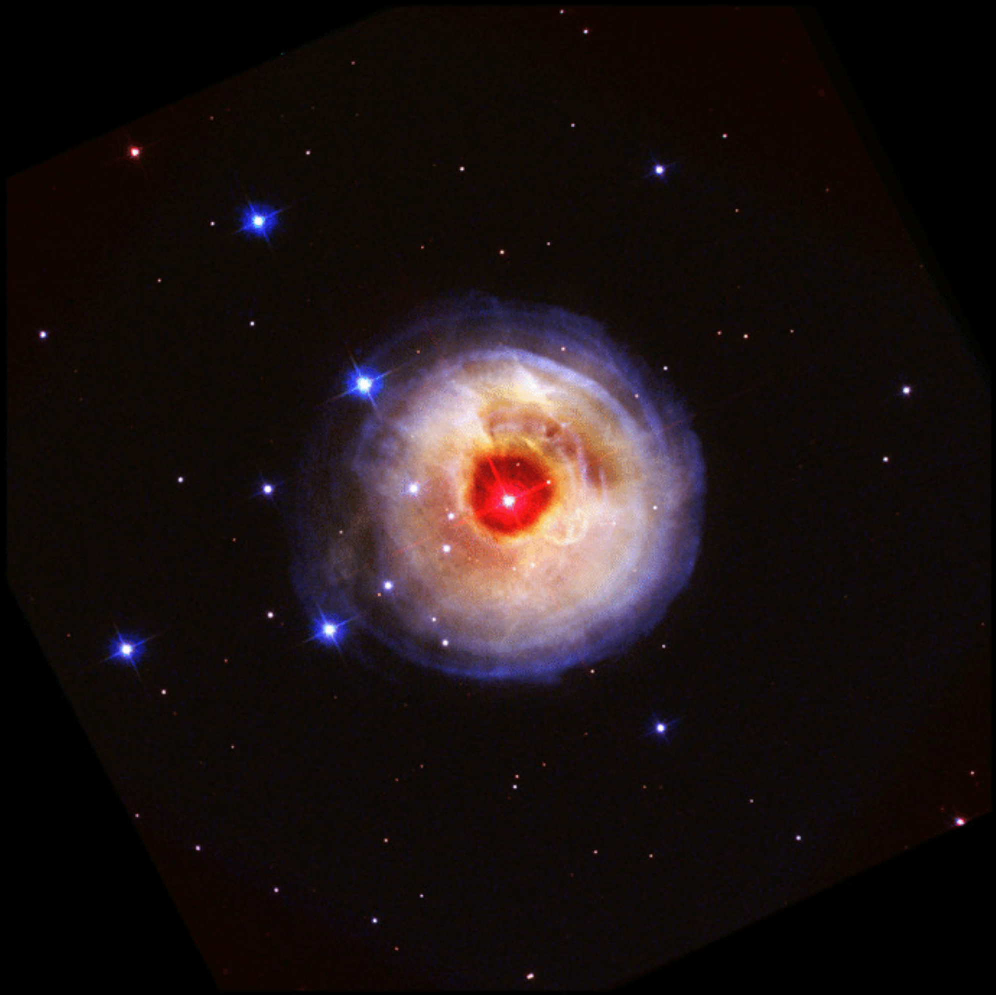
Observing remnants of red novae: what happens after the merger?



Tomek Kamiński
SMA fellow
Harvard-Smithsonian Center for Astrophysics

and
R. Tylenda, M. Schmidt, E. Mason, K. Menten et al.

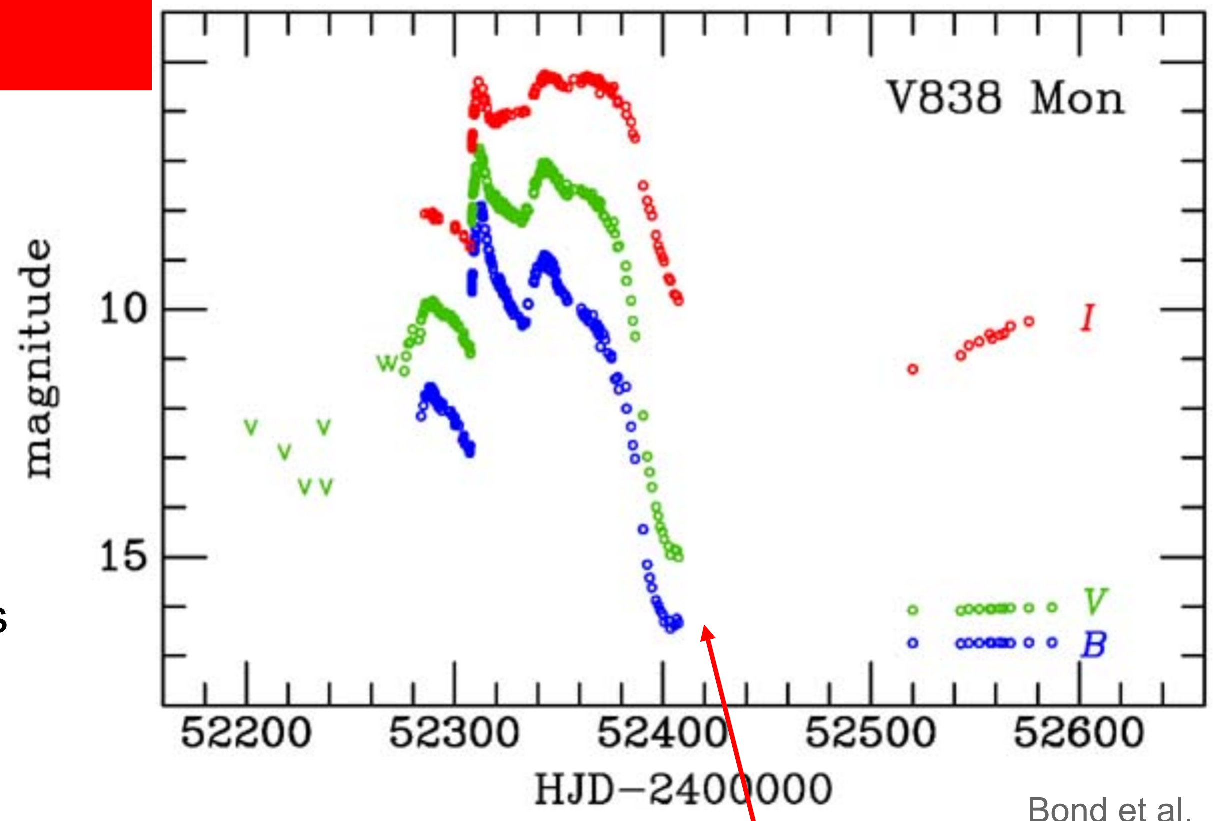
ESO, Garching, July 2017



V838 Mon
light echo
2002-2006
HST Bond et al.

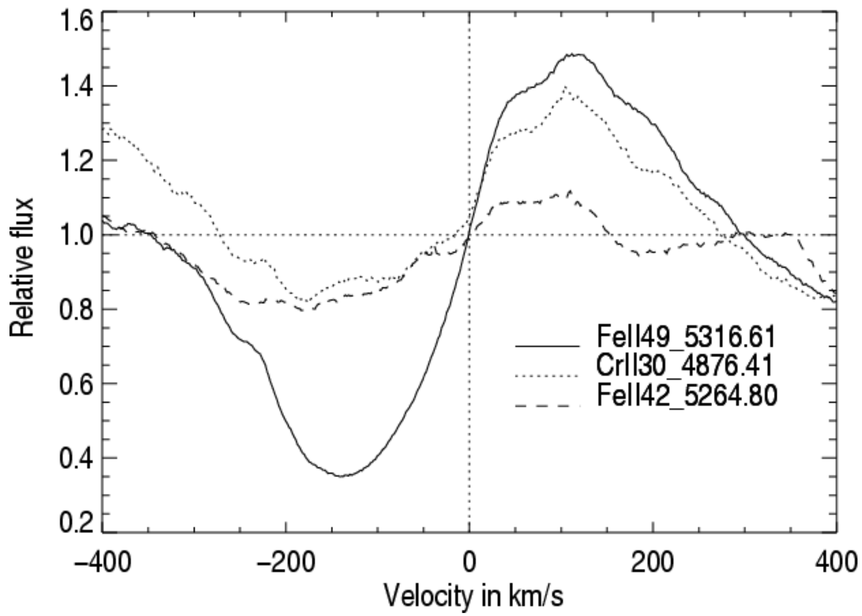
The outburst of V838 Mon

- caught in eruption in January 2002
- ~10^6 $L_\odot$ in maximum light
- multi-peak outburst
- no X ray flux detected
- matter ejected with velocities up to ~500 km/s, but mostly up to 350 km/s
- B-type MS progenitor!

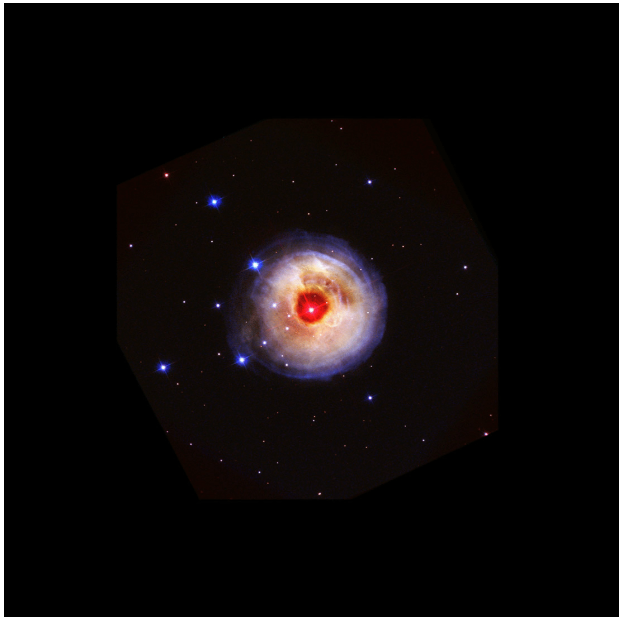


Bond et al.

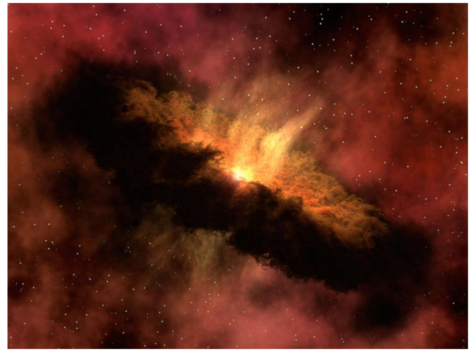
L-type supergiant producing dust



Kipper et al. 2004

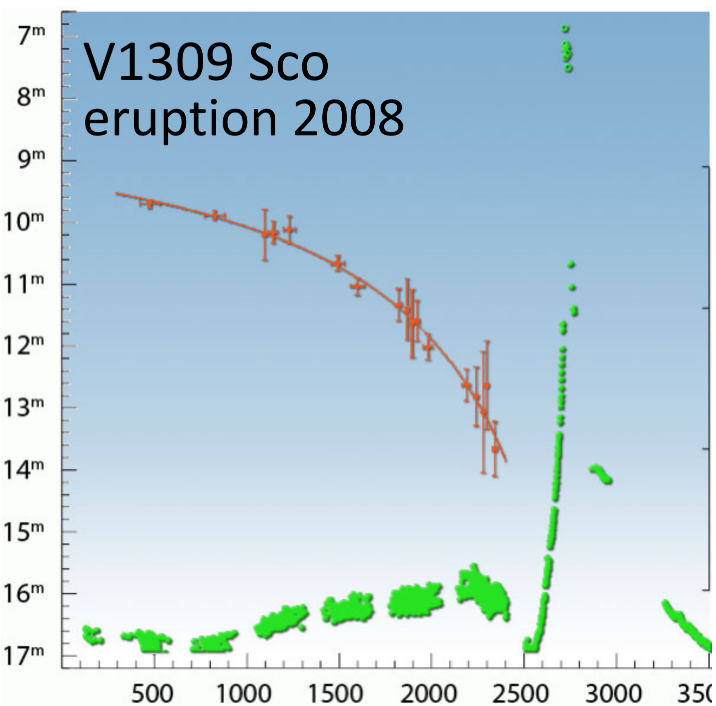


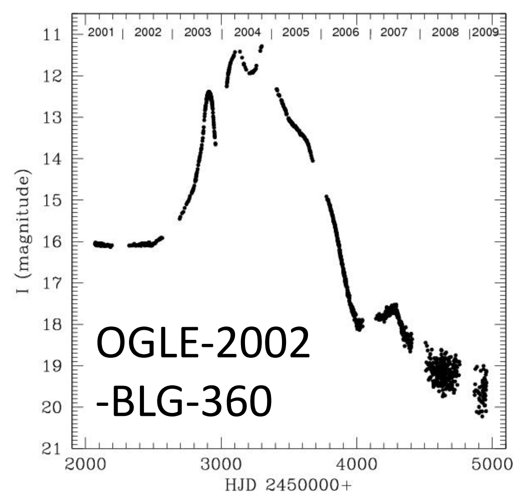
V838 Mon
eruption: 2002



V4332 Sgr
eruption 1994

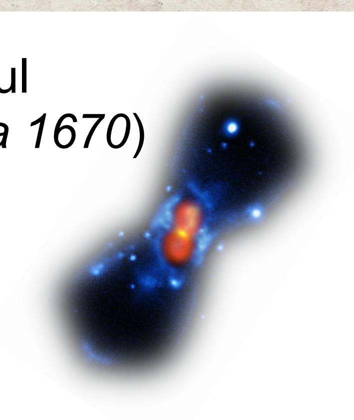
Galactic
red novae
a.k.a red transients



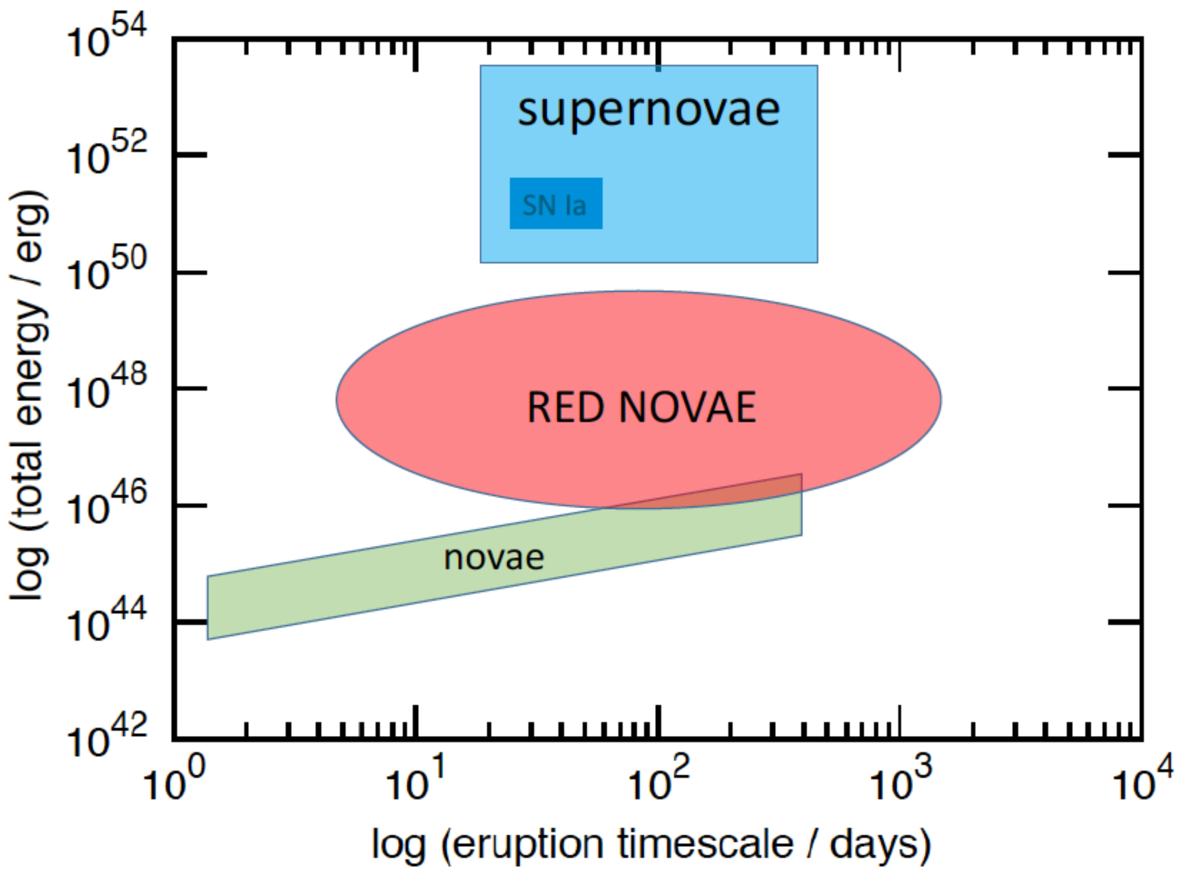


eruption 2003-2005

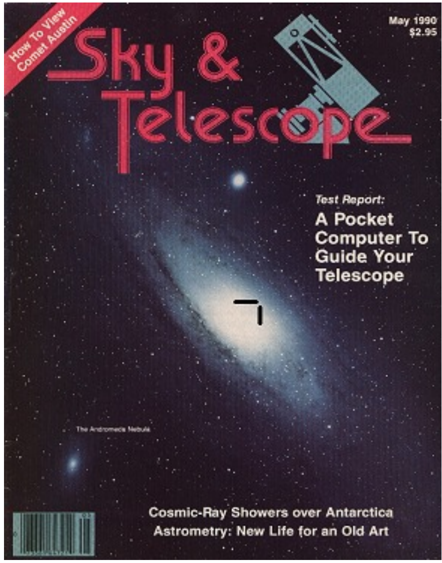
CK Vul
(*Nova 1670*)



Red novae
can be extragalactic



based on diagram of Kashi & Soker



M31-RV
(Red Variable)
eruption: 1989

extragalactic **red novae**:

M85 OT2006
NGC300 OT2008
PTF10acbp
NGC 4490-OT2011
M31 LRN 2015
M101 OT2015-1
and more !

too weak to be observed after their outbursts

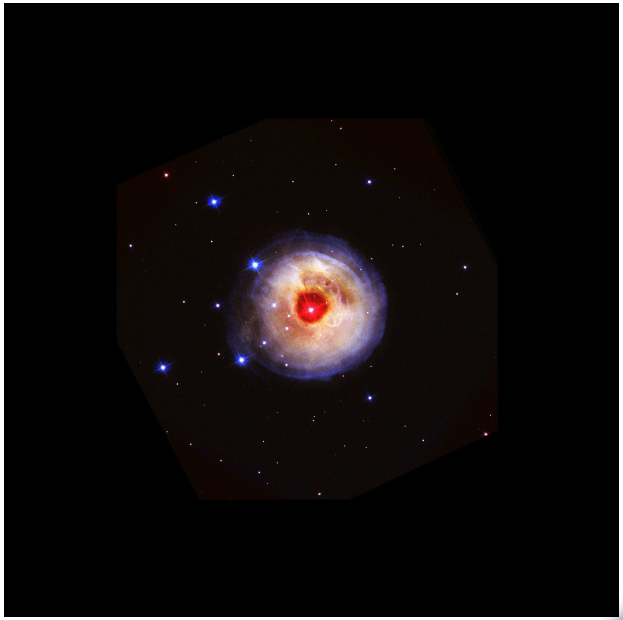
Red novae characteristics

- intermediate spectral types in outburst
- light curve with multiple peaks
- matter ejected at velocities of a few hundred km/s
- quick cooling after the outburst (no coronal phase)
- cool stellar remnant (M-type spectrum)
- produces lots of molecules and dust
- (oxygen-rich CSE)

☞ stellar mergers

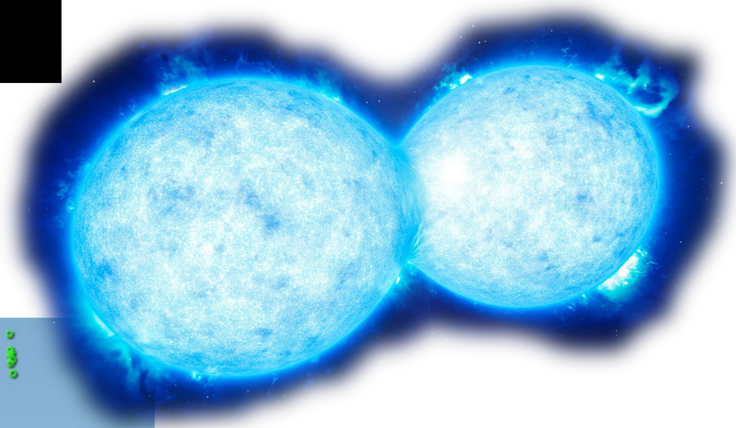
Soker & Tylenda 2003
Tylenda & Soker 2006
Tylenda+ 2011

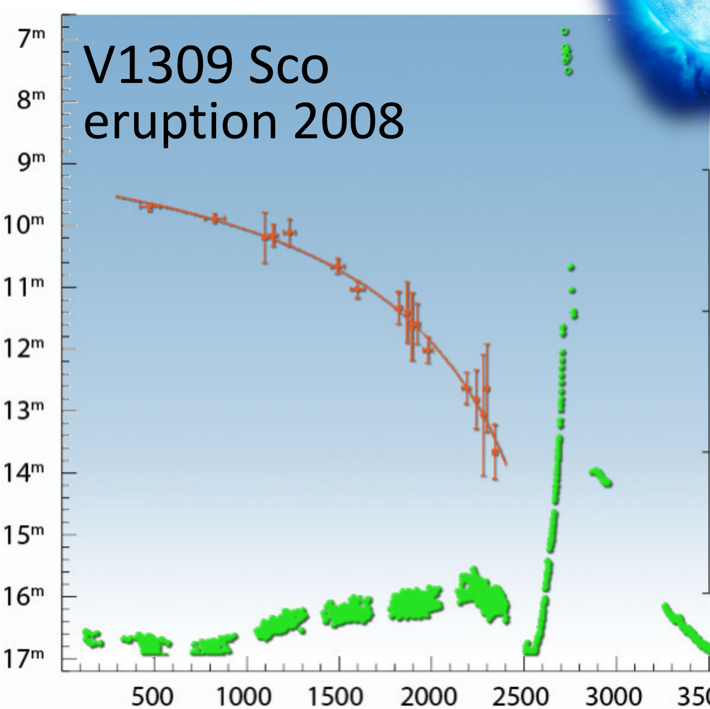
Red novae are stellar mergers

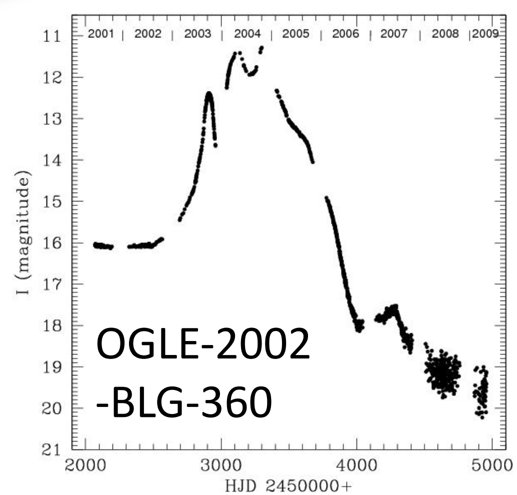


V838 Mon
eruption: 2002

V4332 Sgr
eruption 1994

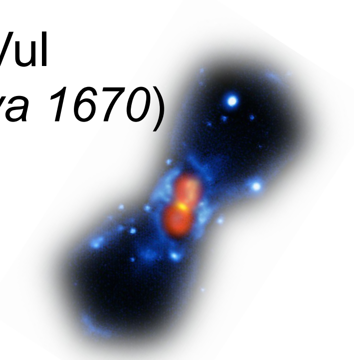




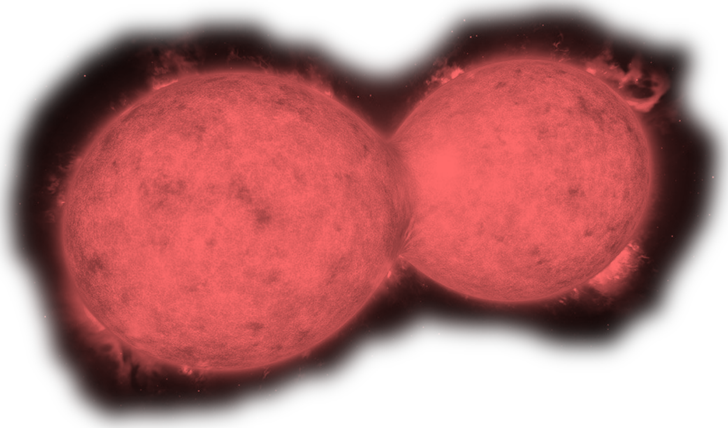


eruption 2003-2005

CK Vul
(*Nova 1670*)



Why bother to observe the remnants of red novae?

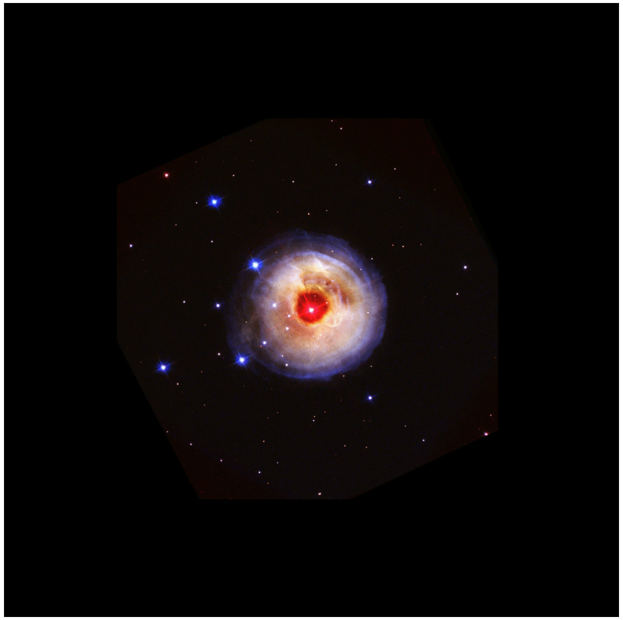


➢ investigate the product of the merger and verify predictions about the remnant

- fast rotators
- disk/torus formation
- mass loss (outflow, wind, ejecta)
- strong magnetic fields (magnetic braking?)
- elemental abundance patterns

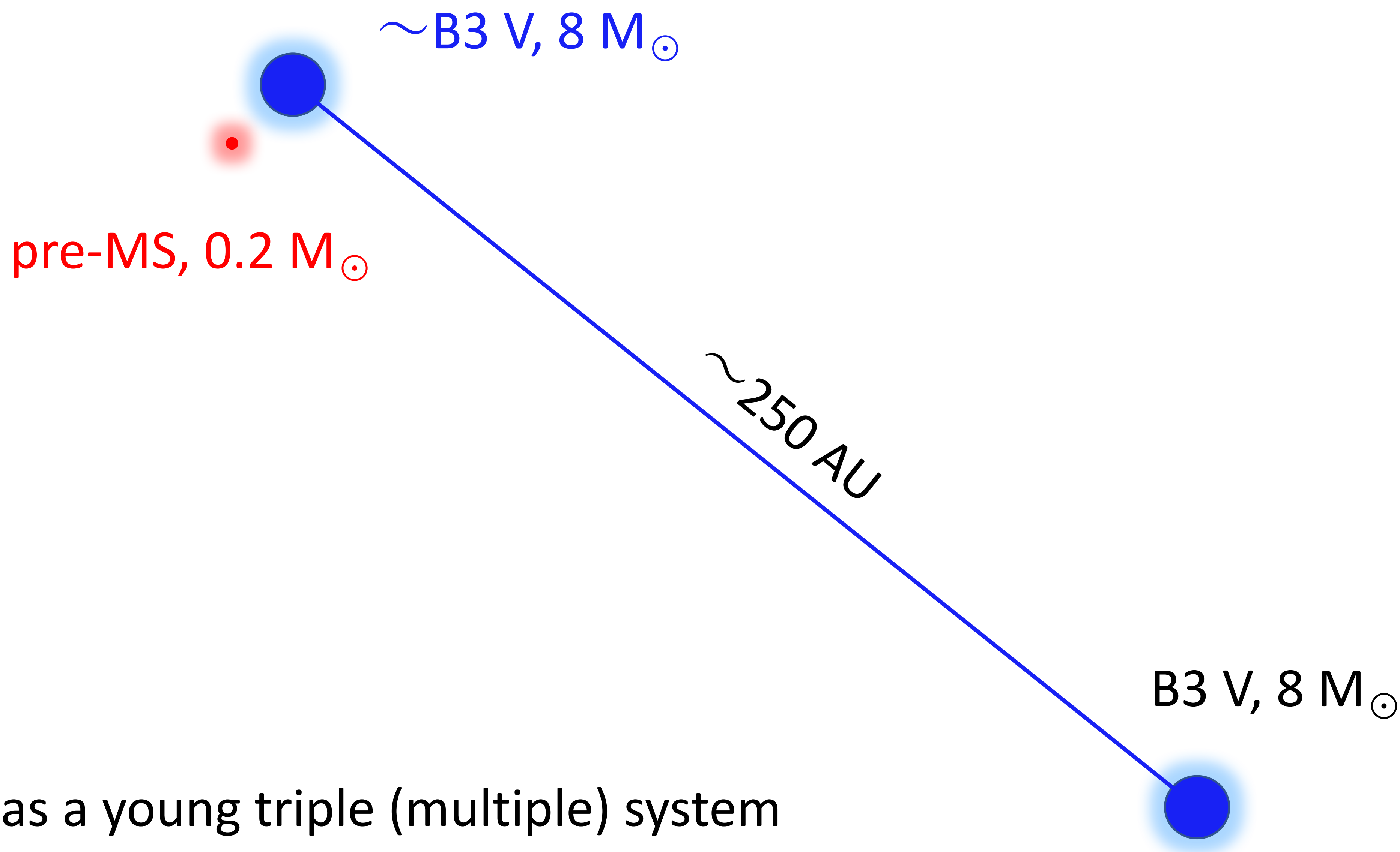
➢ constrain better the nature of the progenitors

- look for material of the common envelope?
- mass-loss history
- interstellar environment



V838 Mon
eruption: 2002

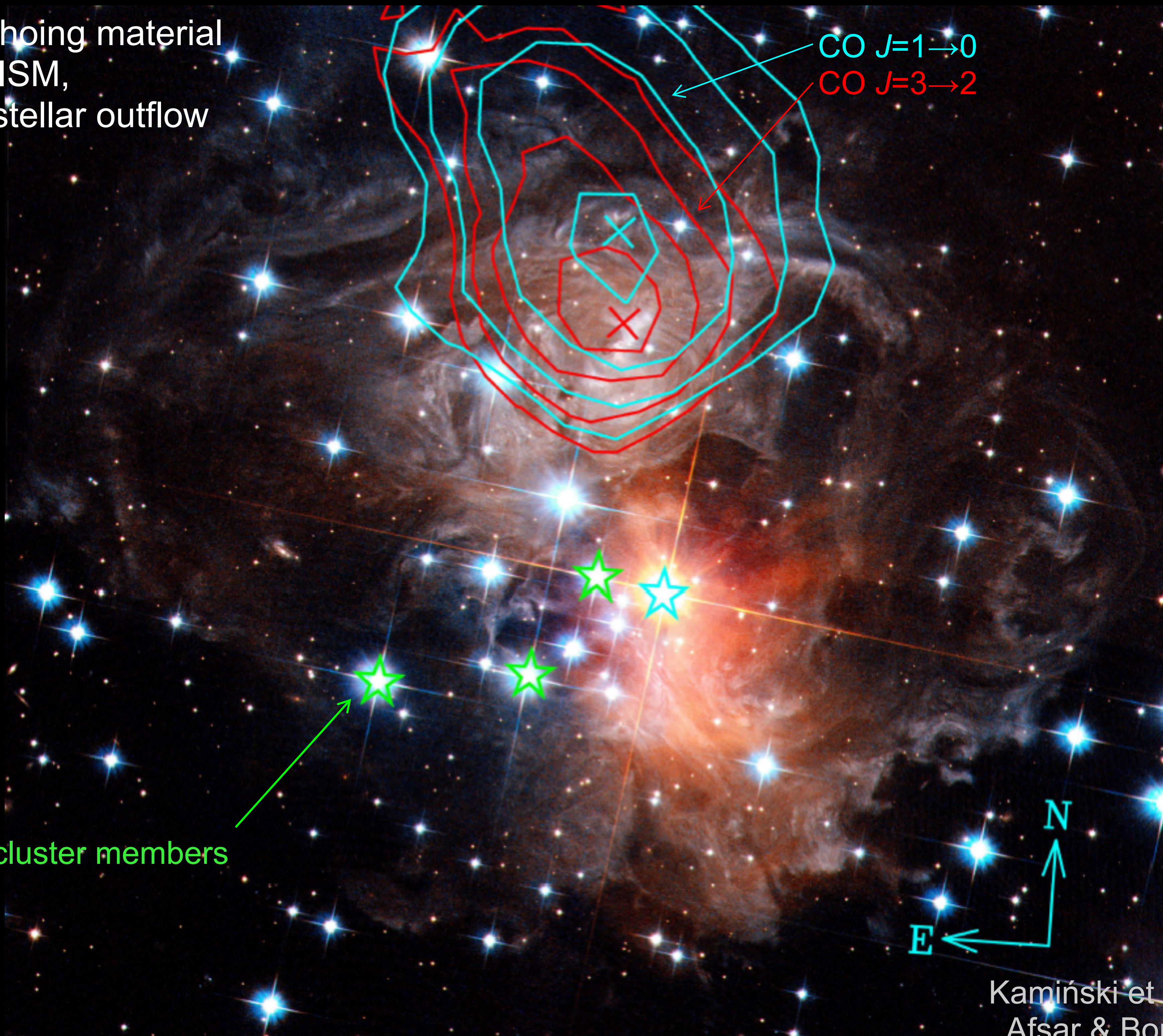
V838 Mon prior to the 2002 eruption



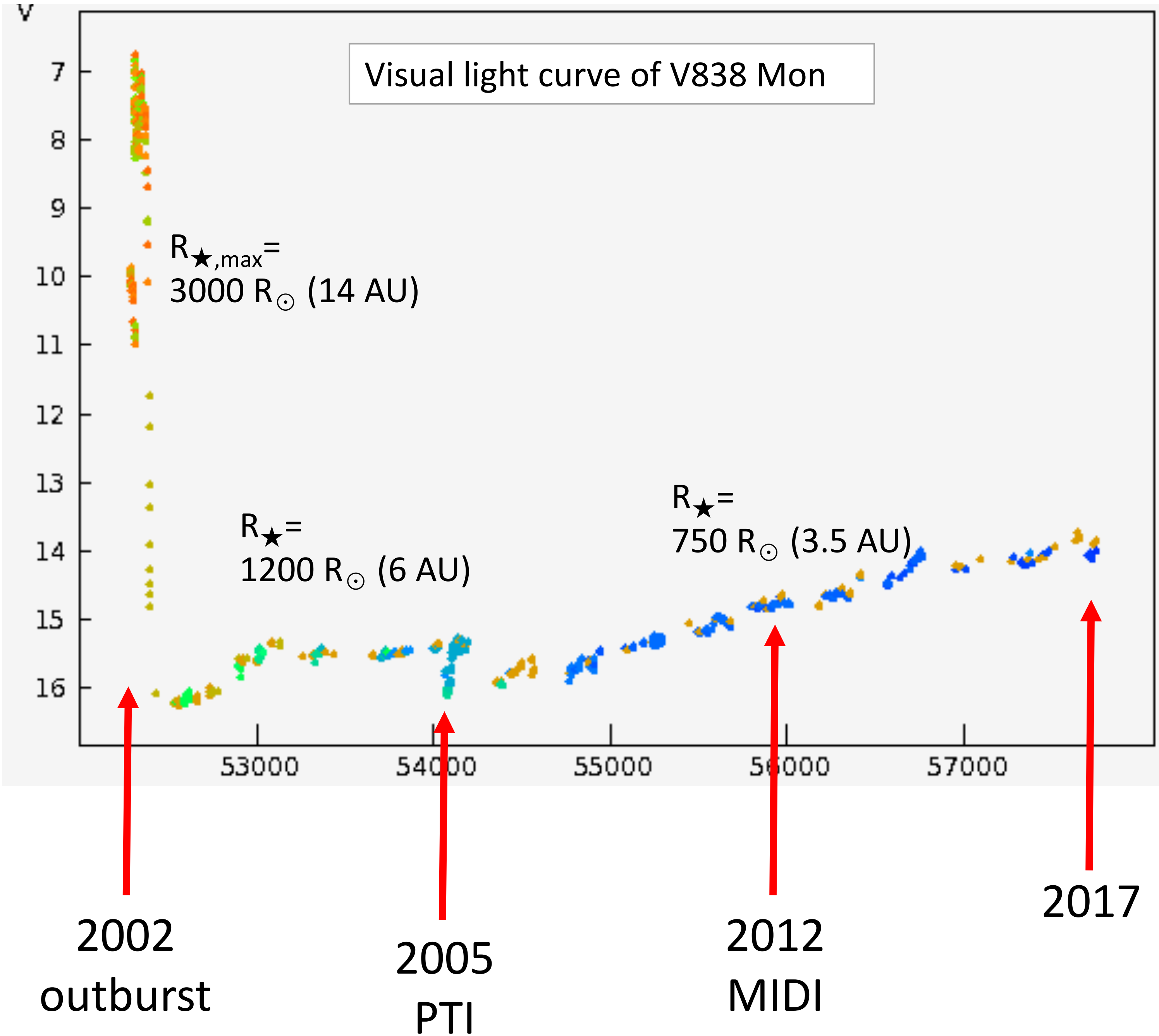
was a young triple (multiple) system

Tylenda et al. 2005
Tyelnda & Soker 2006
Tylenda, Kamiński, Schmidt 2009

the echoing material
is the ISM,
not a stellar outflow



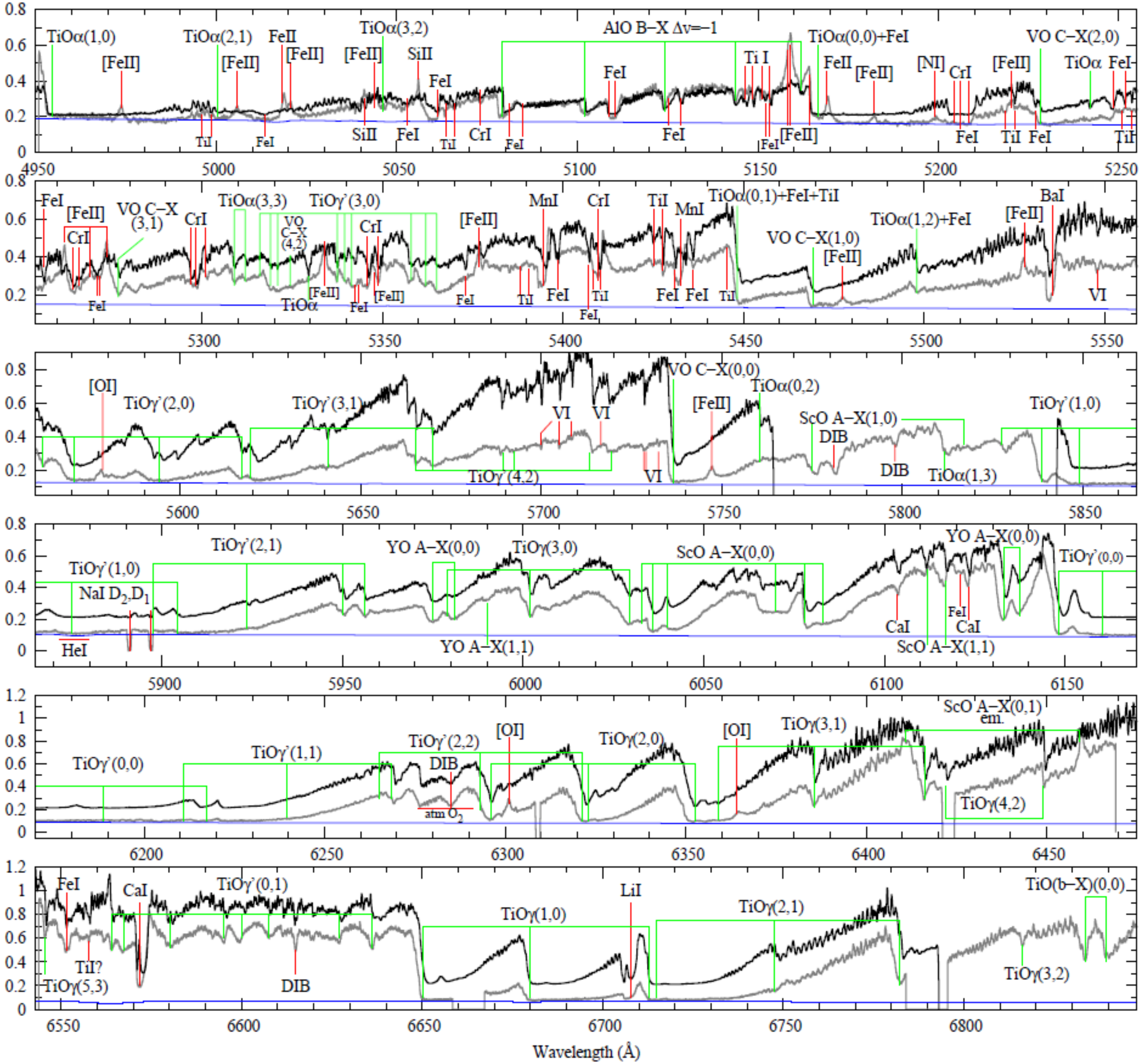
Kamiński et al. 2011
Afsar & Bond 2007



photometry of V. Goranskij

radius from Tylenda+ 2005, Chesneau+2014, Lane+2005 merger remnant in V838 Mon

2005 vs 2009



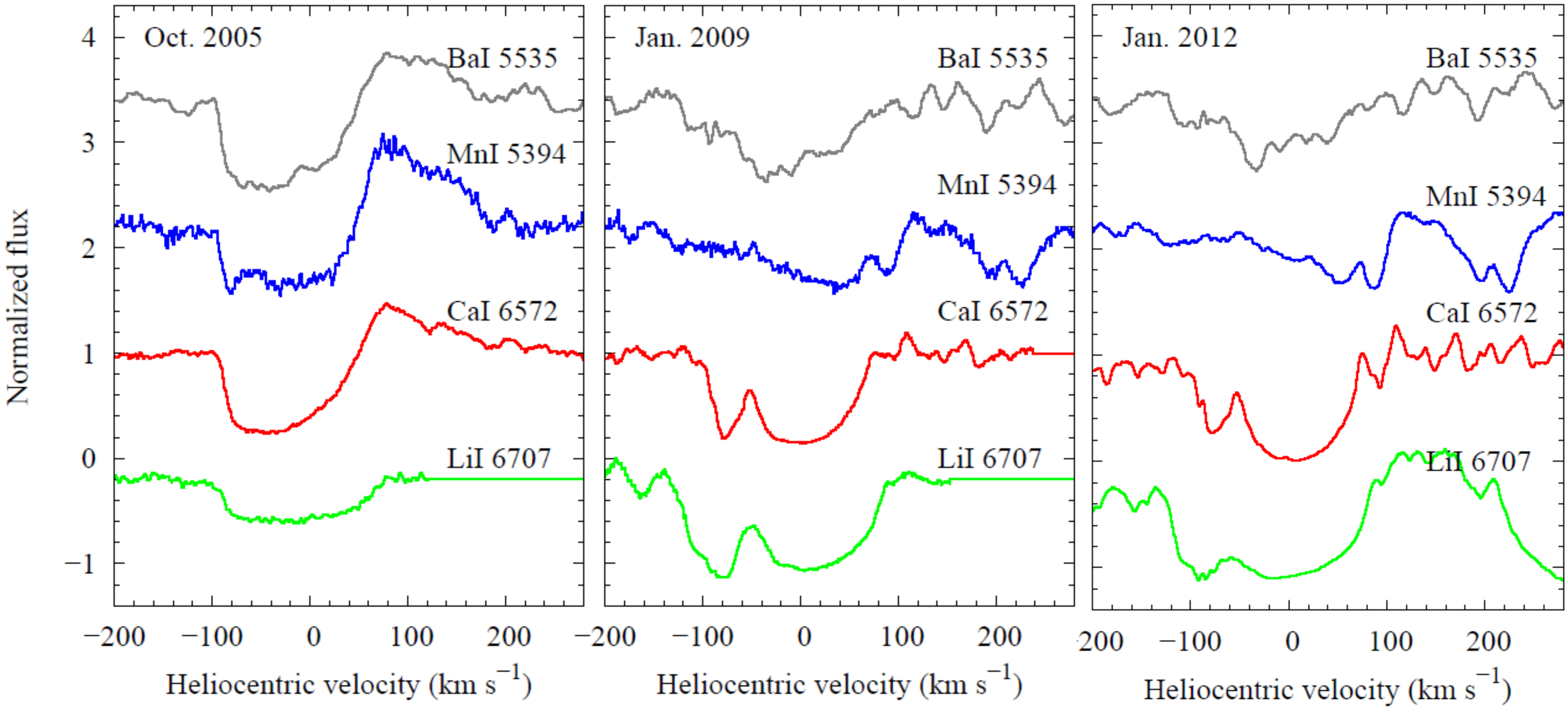
M-type giant + cool circumstellar gas

Kamiński+2009

Tylenda+2009

Tylenda+2011

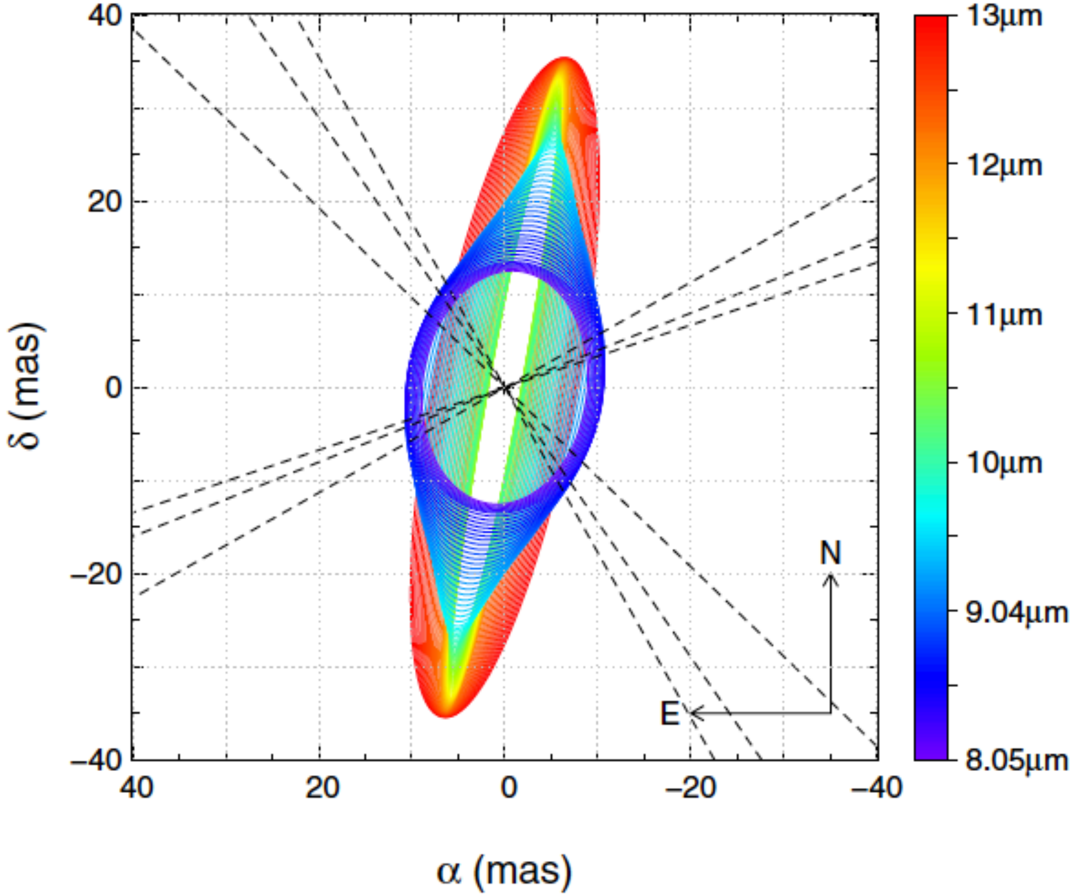
Profile changes in V838 Mon - variable wind?



Kamiński et al. 2009, 2010, +unpublished data

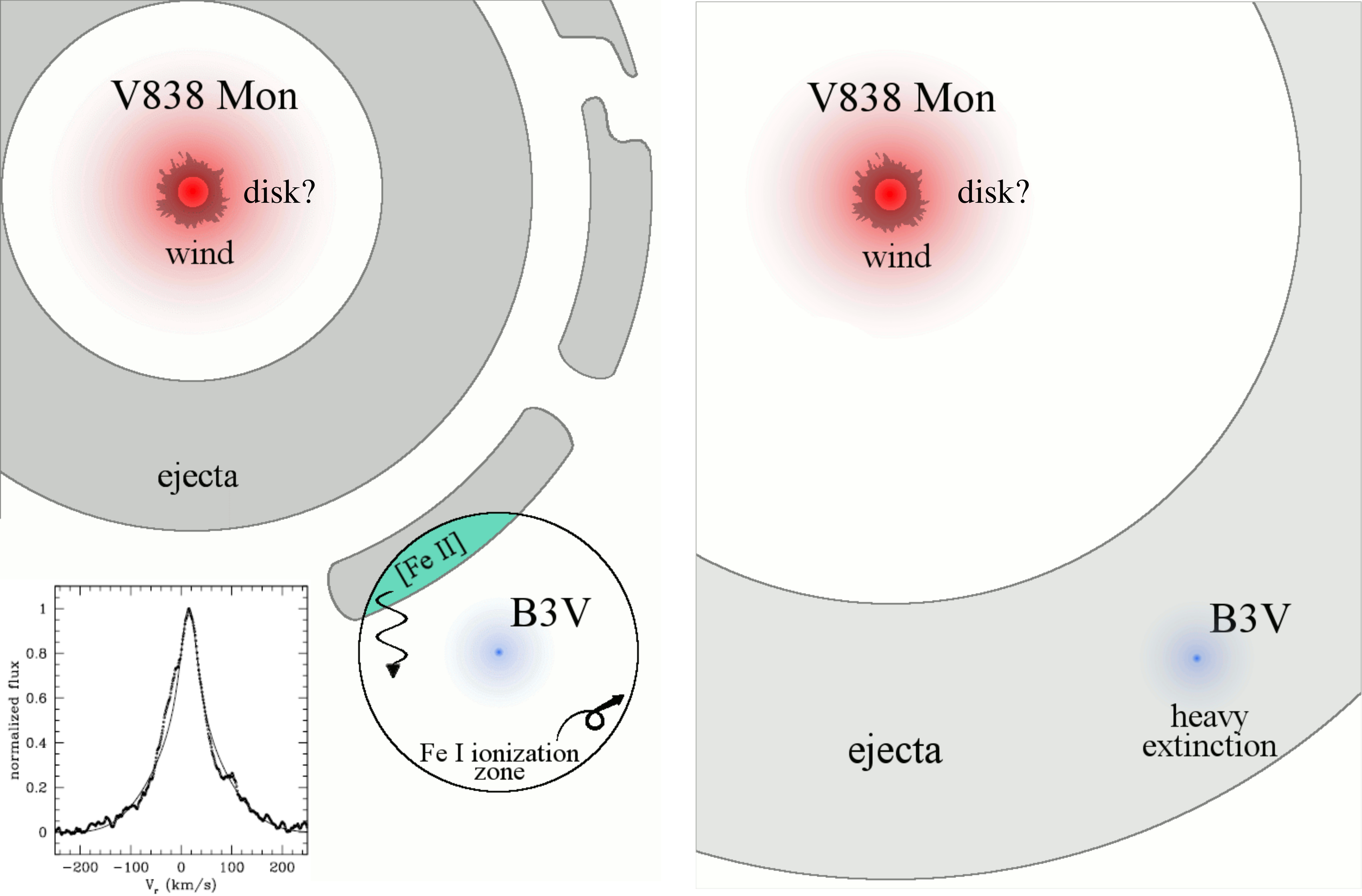
MIR interferometric observations 2011/2012

Flattened dusty structure (disk?)



70 mas = 427 AU
$R_\star$ = 3.5 AU

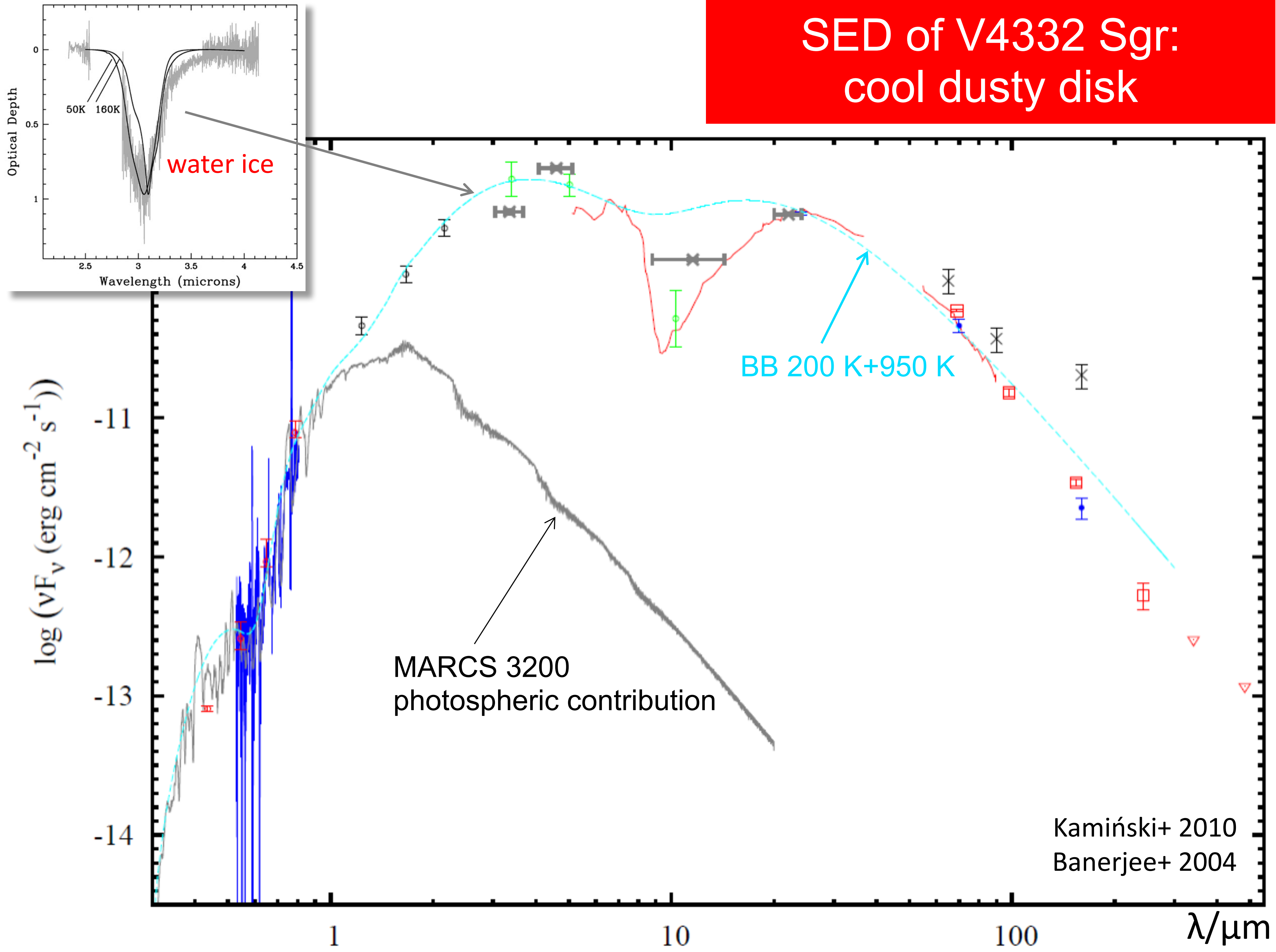
Chesneau et al. 2014



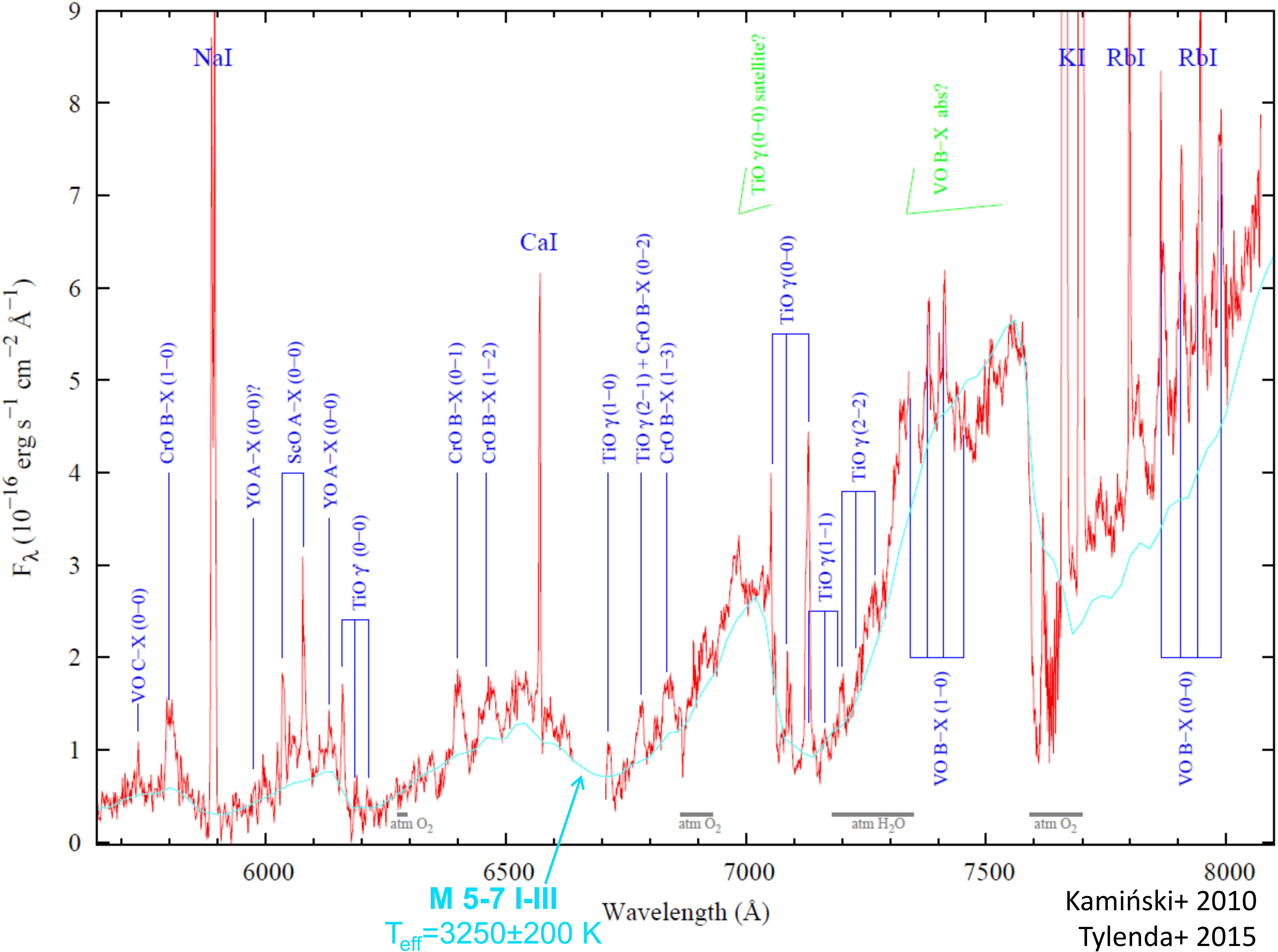
V838 Mon in ~2005 ⟶ and after ~2006


V4332 Sgr
eruption 1994

SED of V4332 Sgr: cool dusty disk

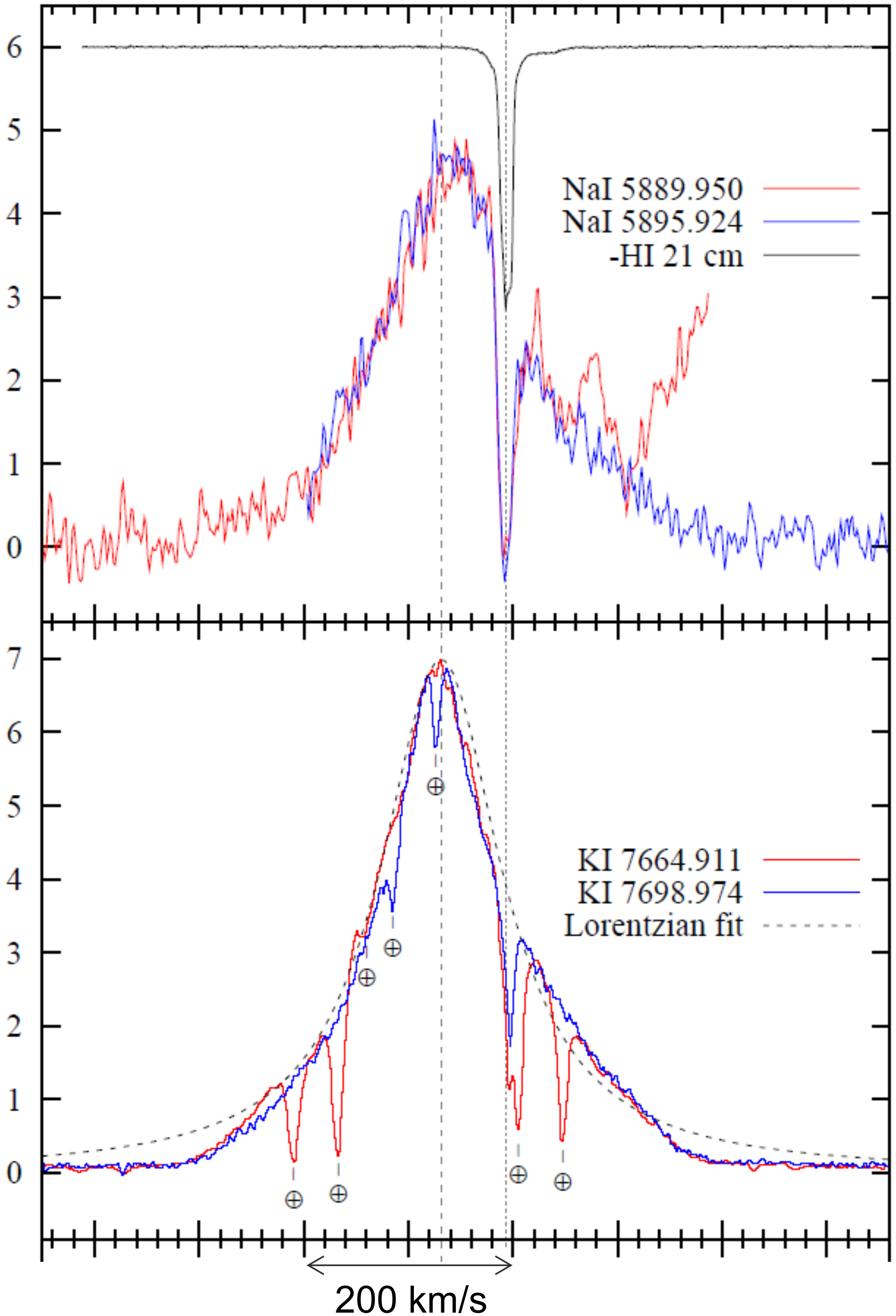


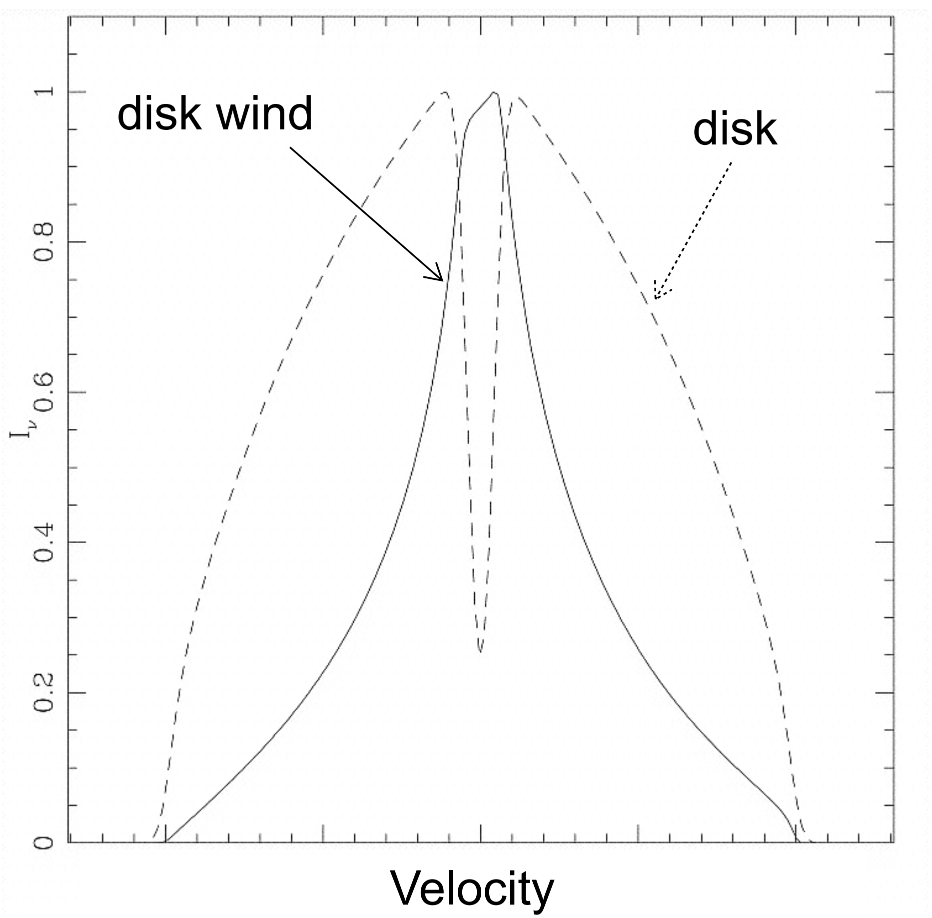
V4332 Sgr, 2009



Kamiński+ 2010
Tylenda+ 2015

Disk wind in V4332 Sgr

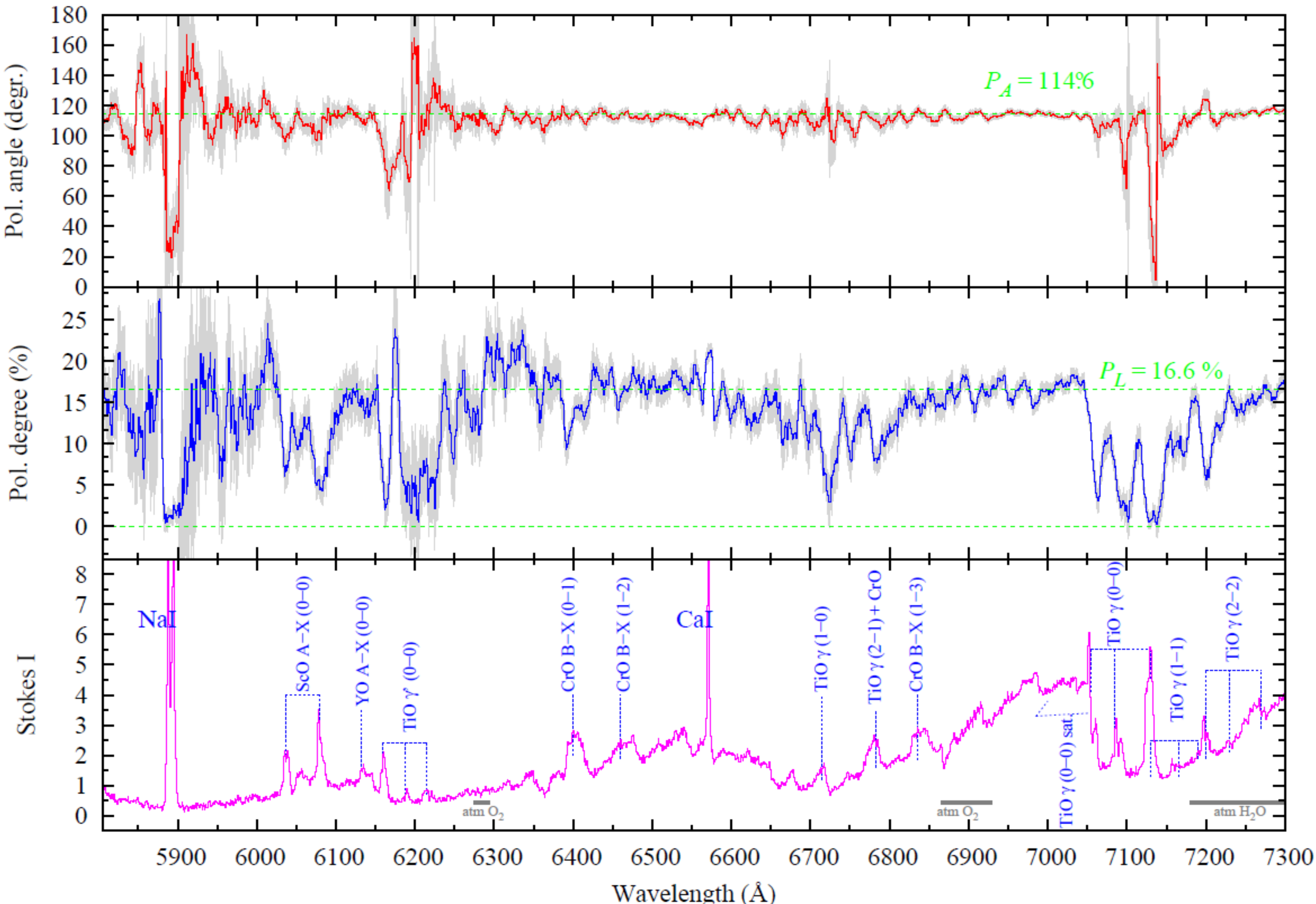




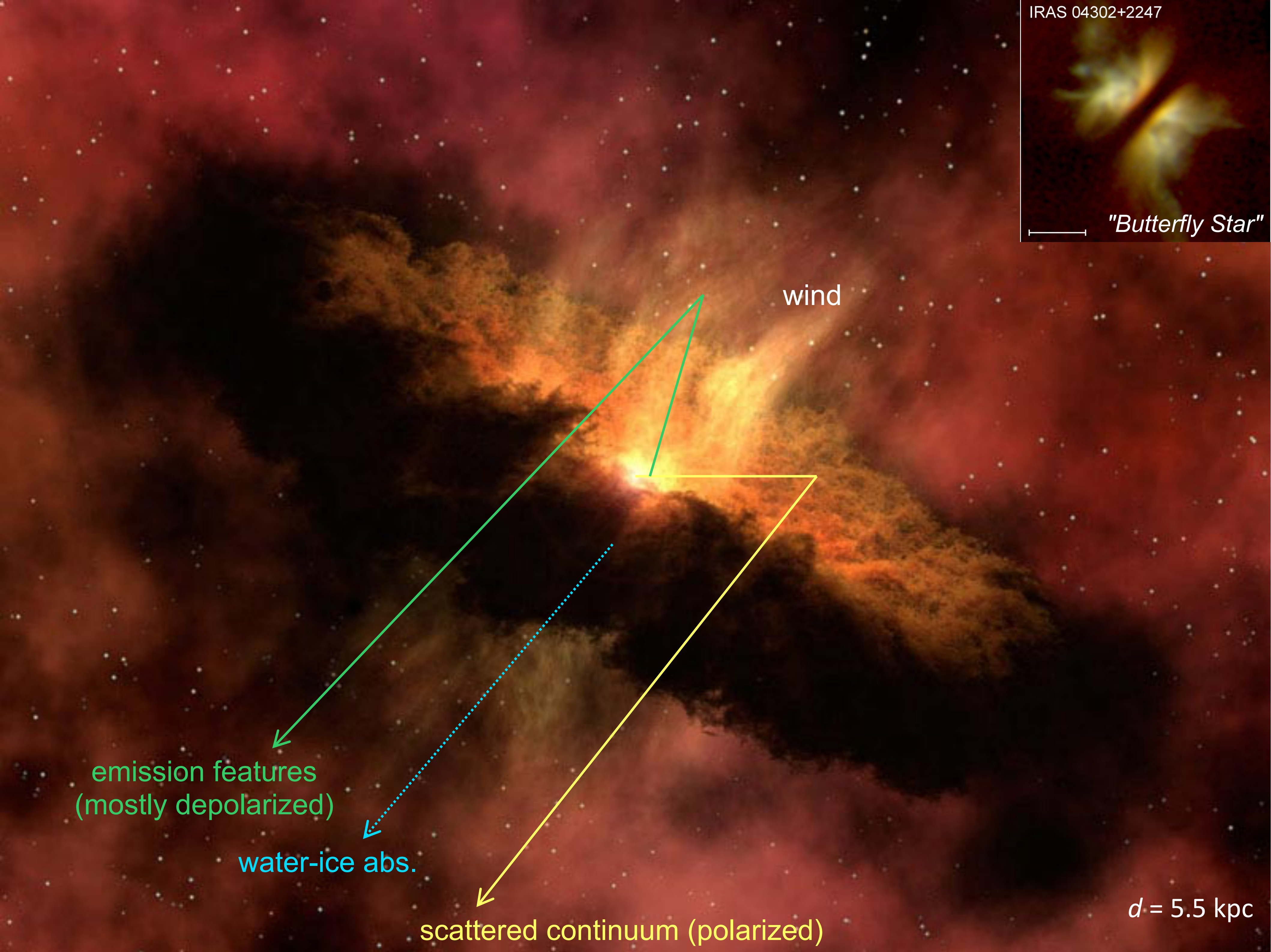
disk vs disk-wind line profiles
(Murray & Chiang 1996)

Kamiński+ 2010
Tylenda+ 2015

Spectropolarimetry of V4332 Sgr

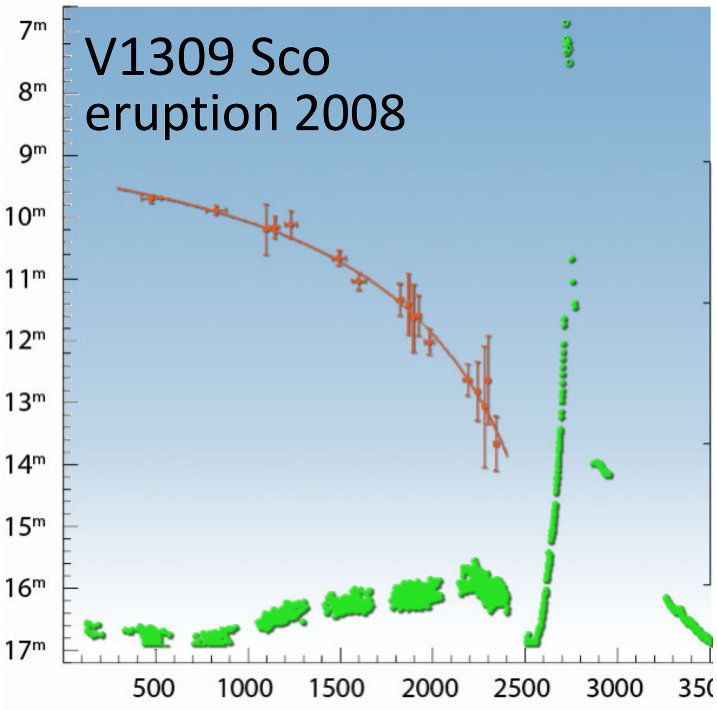


Kamiński & Tylenda+ 2011, 2013



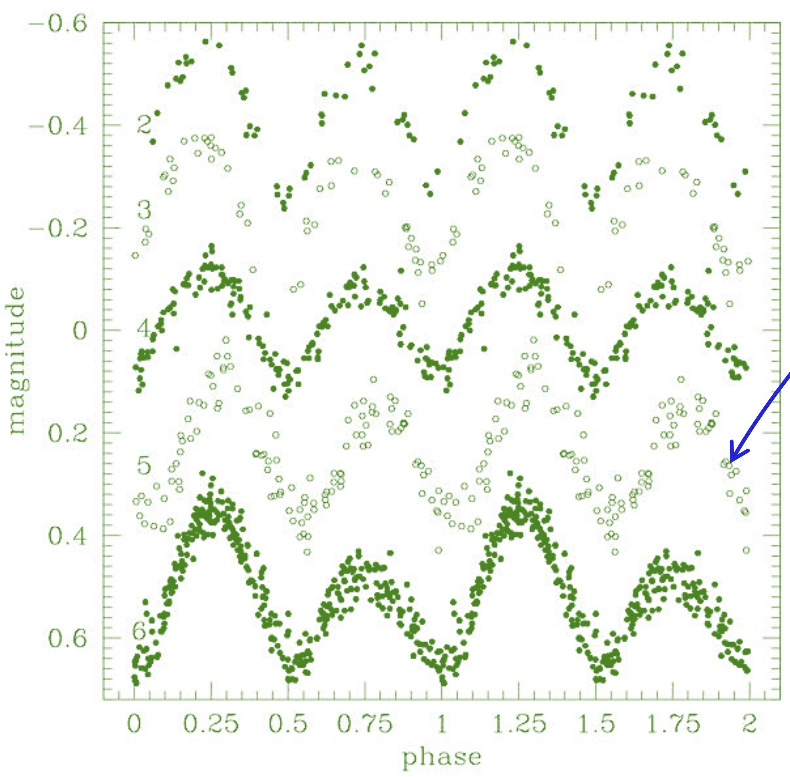
IRAS 04302+2247
"Butterfly Star"
wind
emission features
(mostly depolarized)
water-ice abs.
scattered continuum (polarized)
d = 5.5 kpc

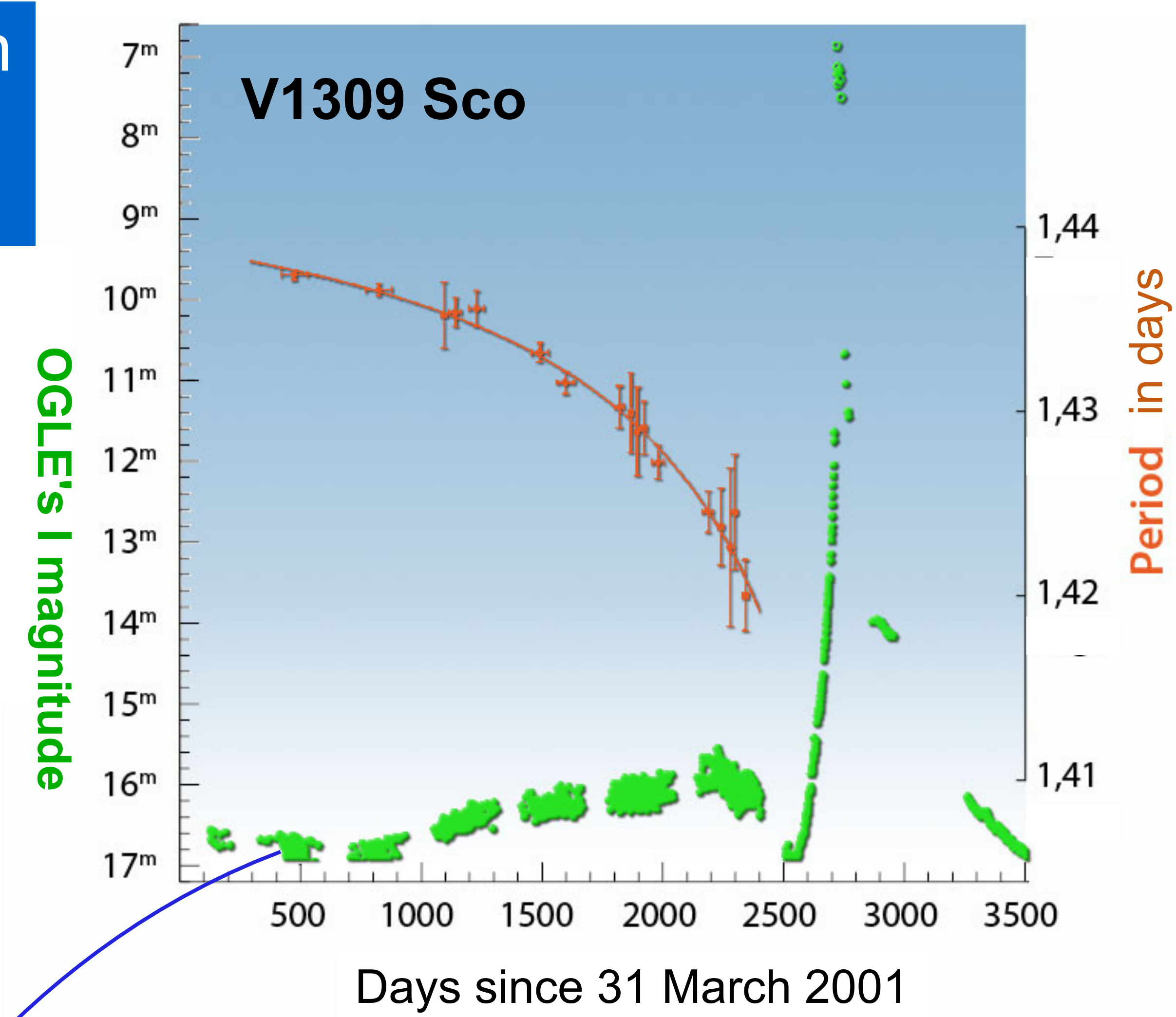
V1309 Sco
the Rosetta Stone



Most convincing observation of a merger in a binary to date

eclipsing contact binary before the eruption:





M_1 = 1.52 M$_\odot$ red giant

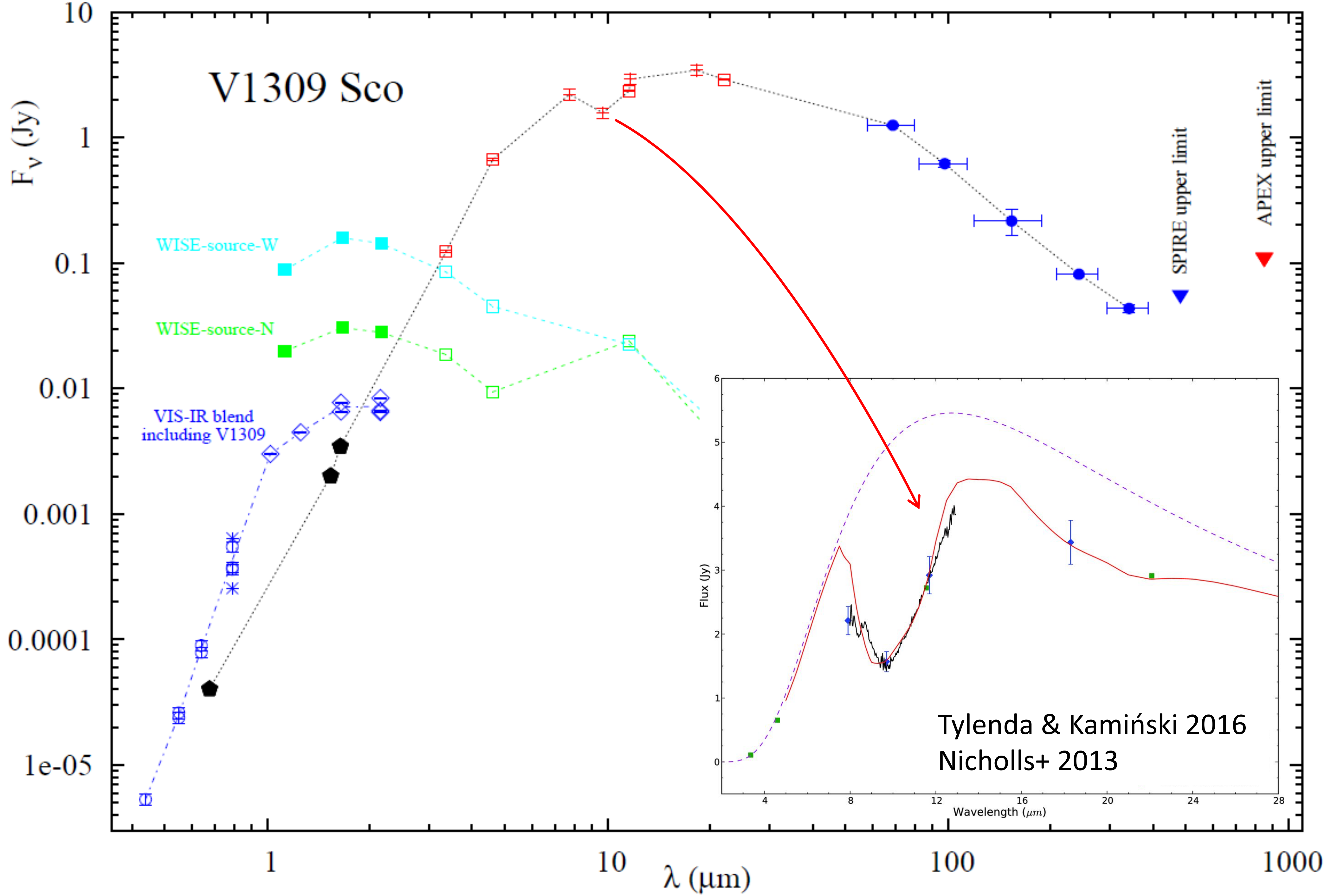
M_2 = 0.16 M$_\odot$ MS

P_0=1.4^d

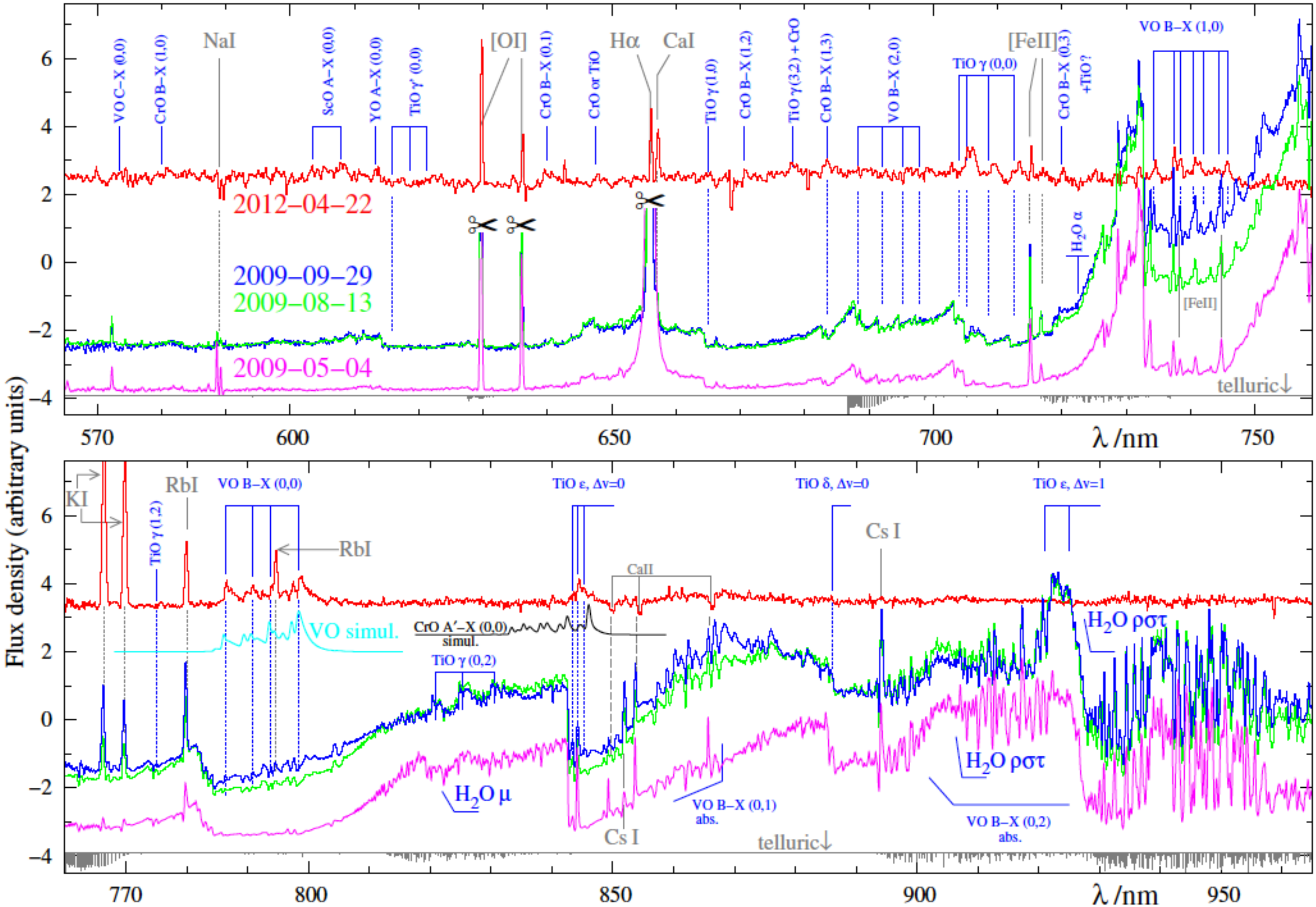
d = 3.5 kpc

Tylenda et al. 2011
Stępień 2011

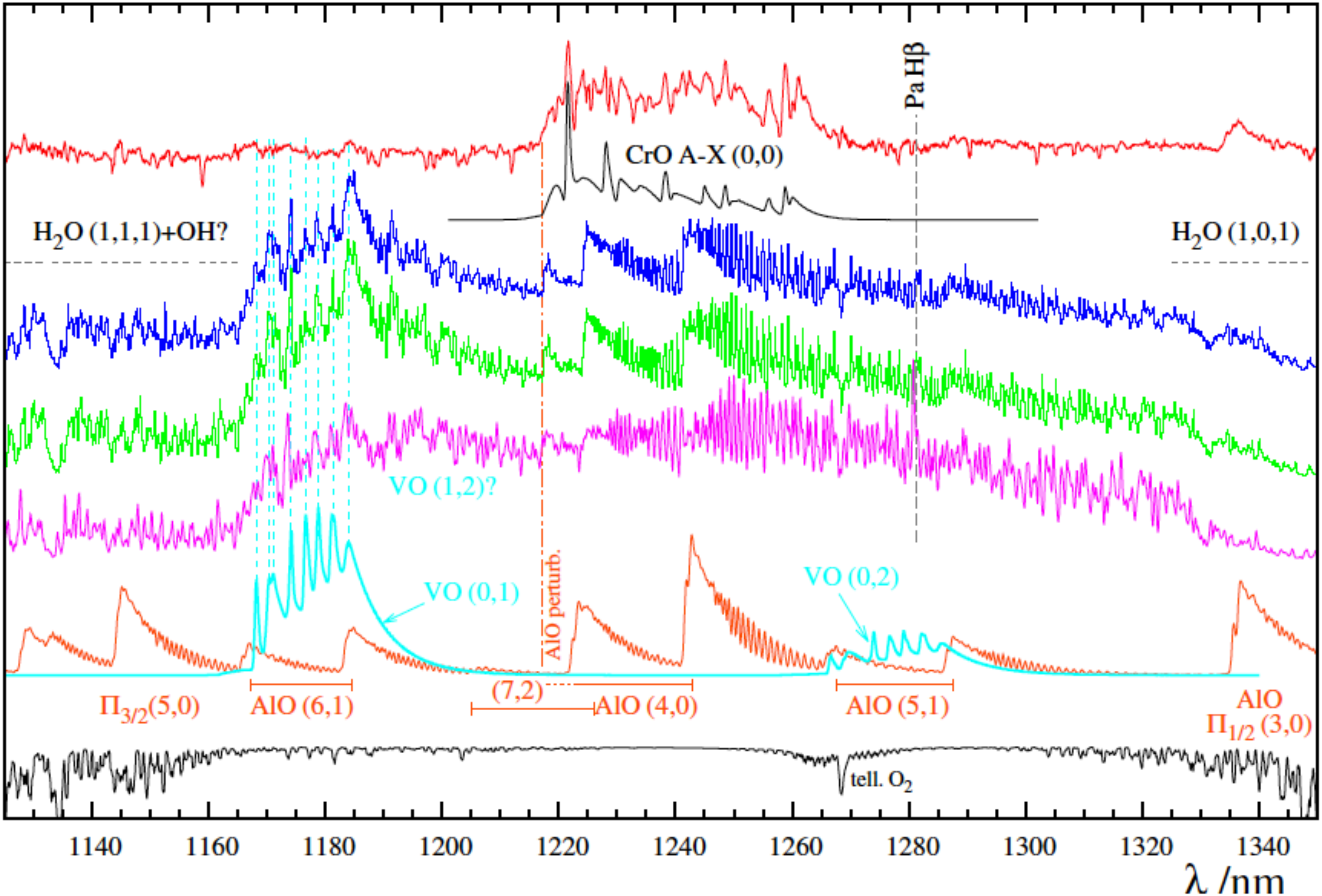
Dusty disk in V1309 Sco (just like in V4332)



V1309 Sco as a spectroscopic twin of V4332 Sgr



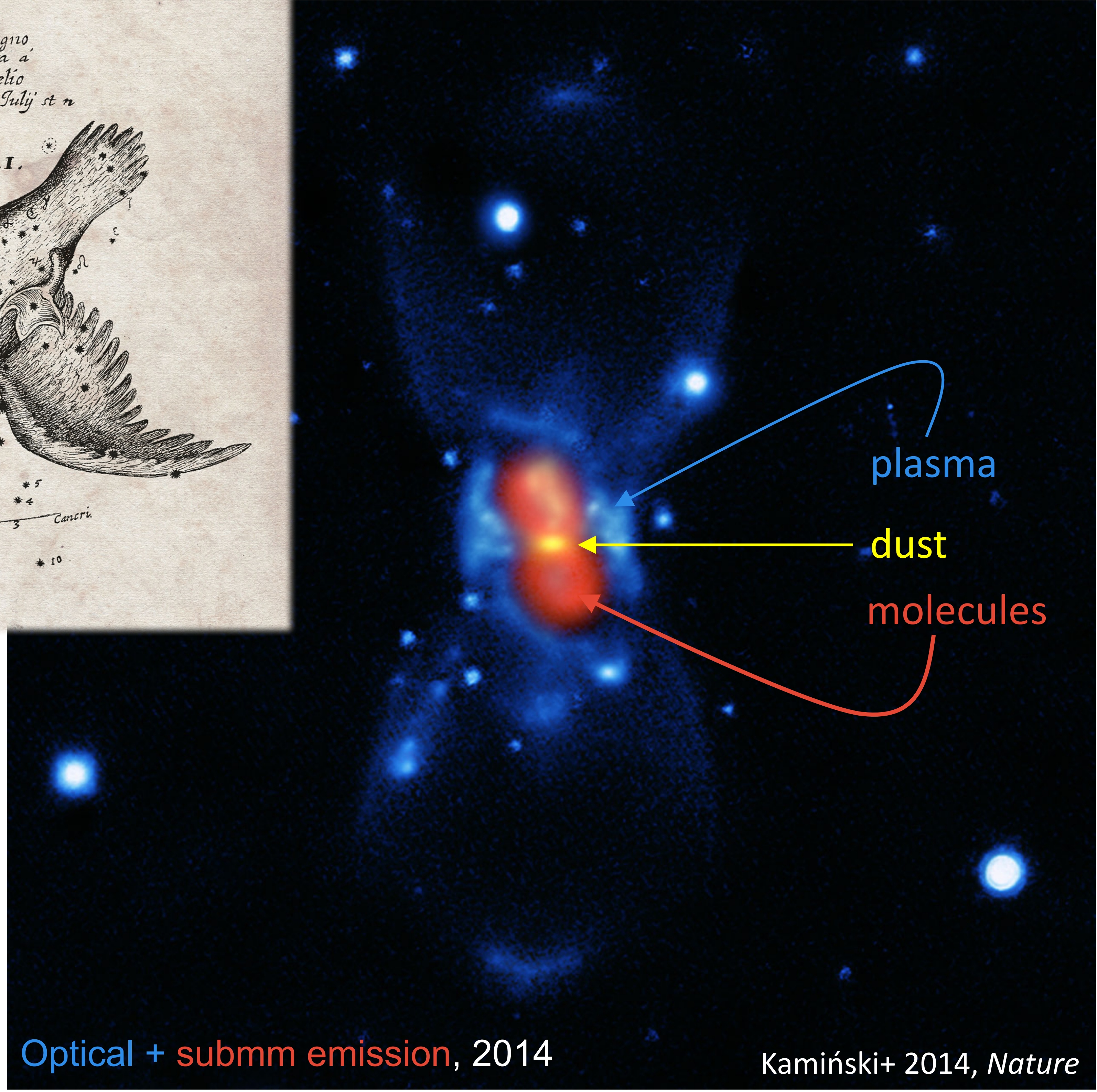
AlO & CrO in V1309 Sco



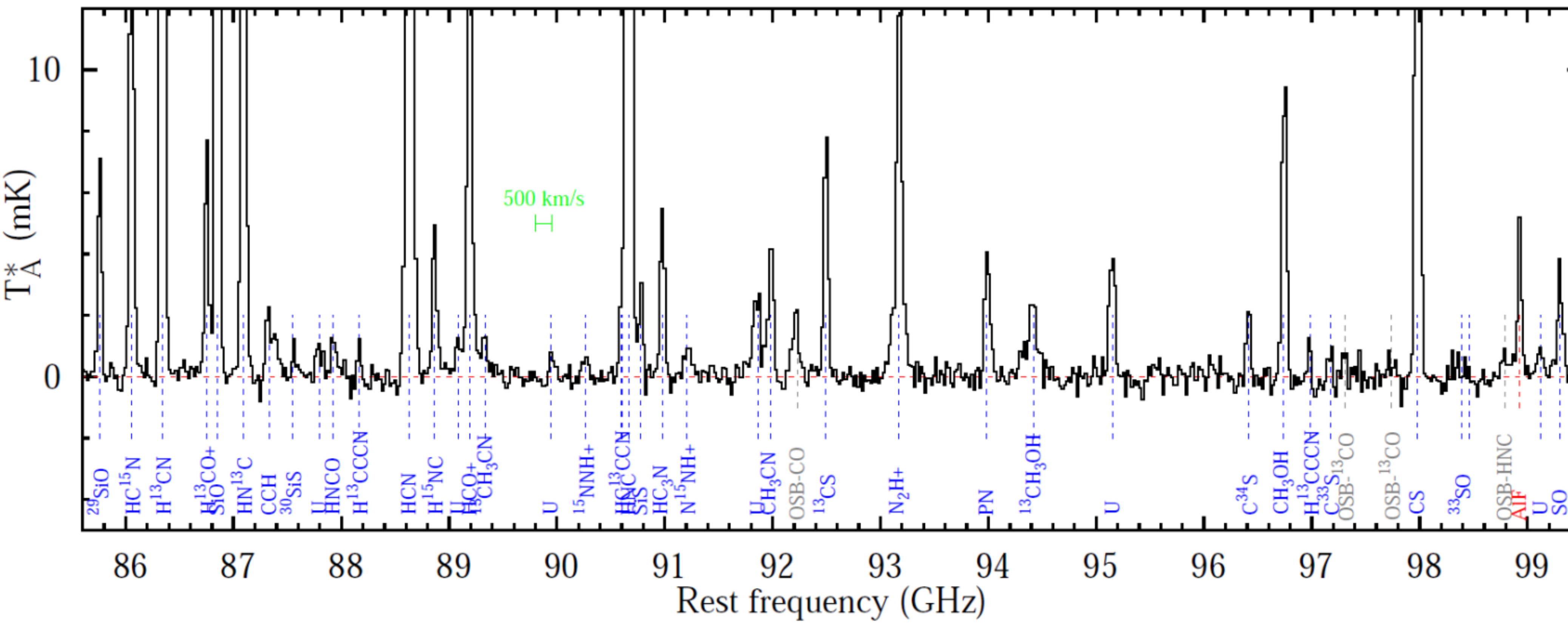
Kamiński+ 2016


V4332 Sgr
=V1309 Sco?

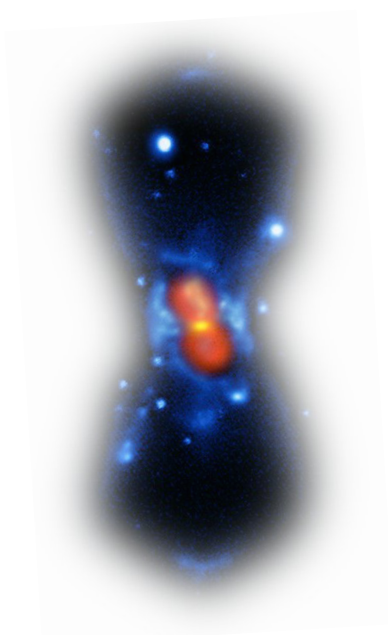
CK Vul (*Nova 1670*)
documented
by Hevelius & Cassini



Submm spectrum of CK Vul is full of rare isotopologues



Most peculiar isotopic composition



CK Vul	Solar
$^{12}C/^{13}C = 3.4 \pm 0.3$	89.3
$^{13}C/^{14}C > 142$	
$^{14}N/^{15}N = 17^{-2}_{+7}$	441
$^{16}O/^{18}O = 30 \pm 10$	498.8
$^{18}O/^{17}O \gtrsim 5$	5.4
$^{16}O/^{17}O \gtrsim 100$	2681
$^{27}Al/^{26}Al = 6 \pm 1$	
$^{28}Si/^{29}Si = 7.5 \pm 0.5$	19.7
$^{29}Si/^{30}Si = 1 \pm 0.1$	0.66
$^{32}S/^{34}S = 14 \pm 3$	22.5
$^{32}S/^{34}S > 29$	126.6

Kamiński+ 2014, *Nature*
Kamiński+ 2017, submitted
Kamiński+ 2017, in prep.

Summary:

- red novae can be produced in a broad range of binary configurations
- their circumstellar remnants are cool, rich in molecules and dust
- the stellar remnant is a cool supergiant, even decades after the merger
- they develop disks/tori and winds -- to get rid of angular momentum?


Urbi et Orbi