New insights into Eta Carinae with PIONIER

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Collaborators
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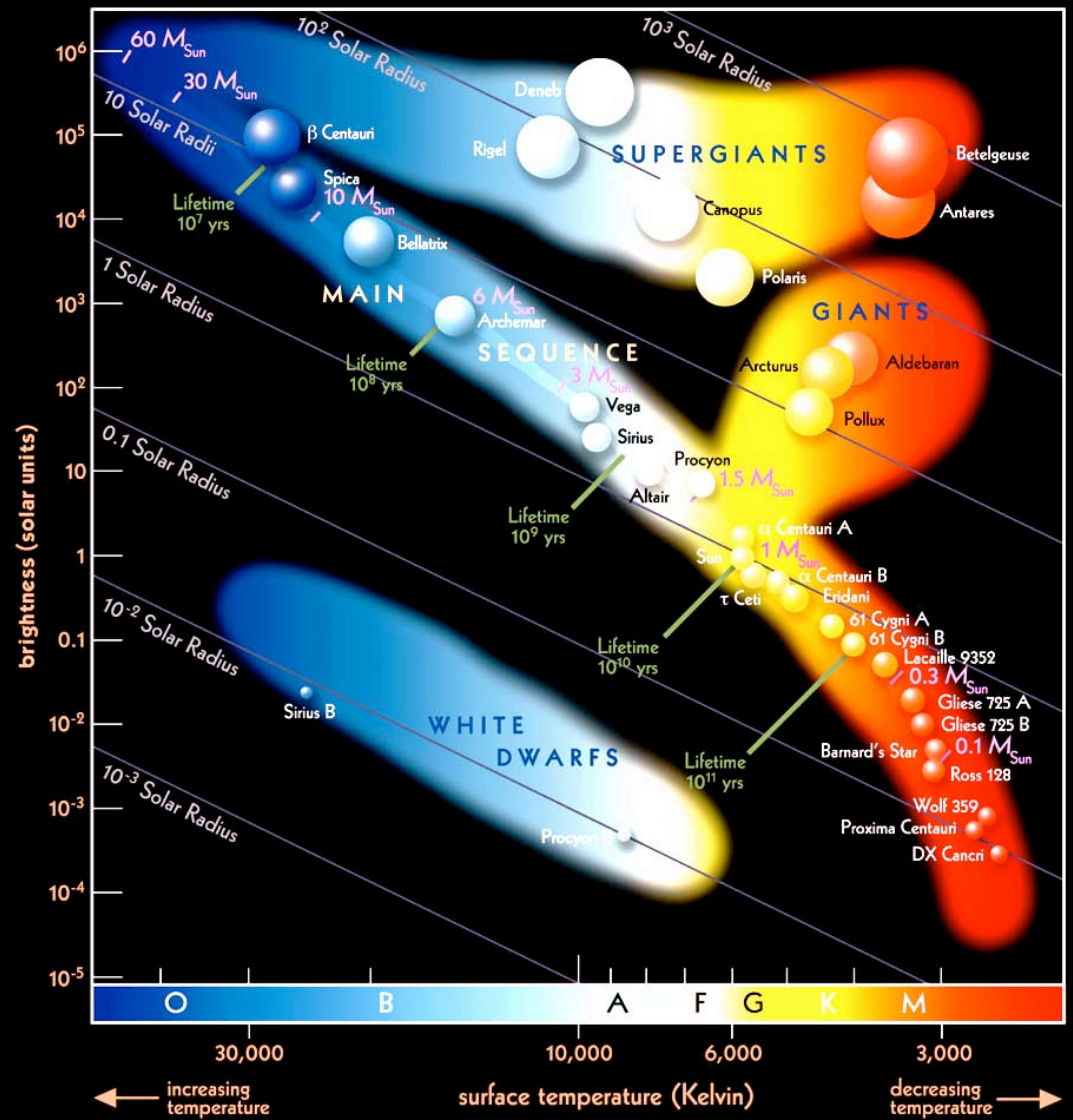
Observatoire de Genève, fondé en 1772
FNSNF
Fonds national suisse
Schweizerischer Nationalfonds
Fondo nazionale svizzero
Swiss National Science Foundation

Location of stars in the HR diagram



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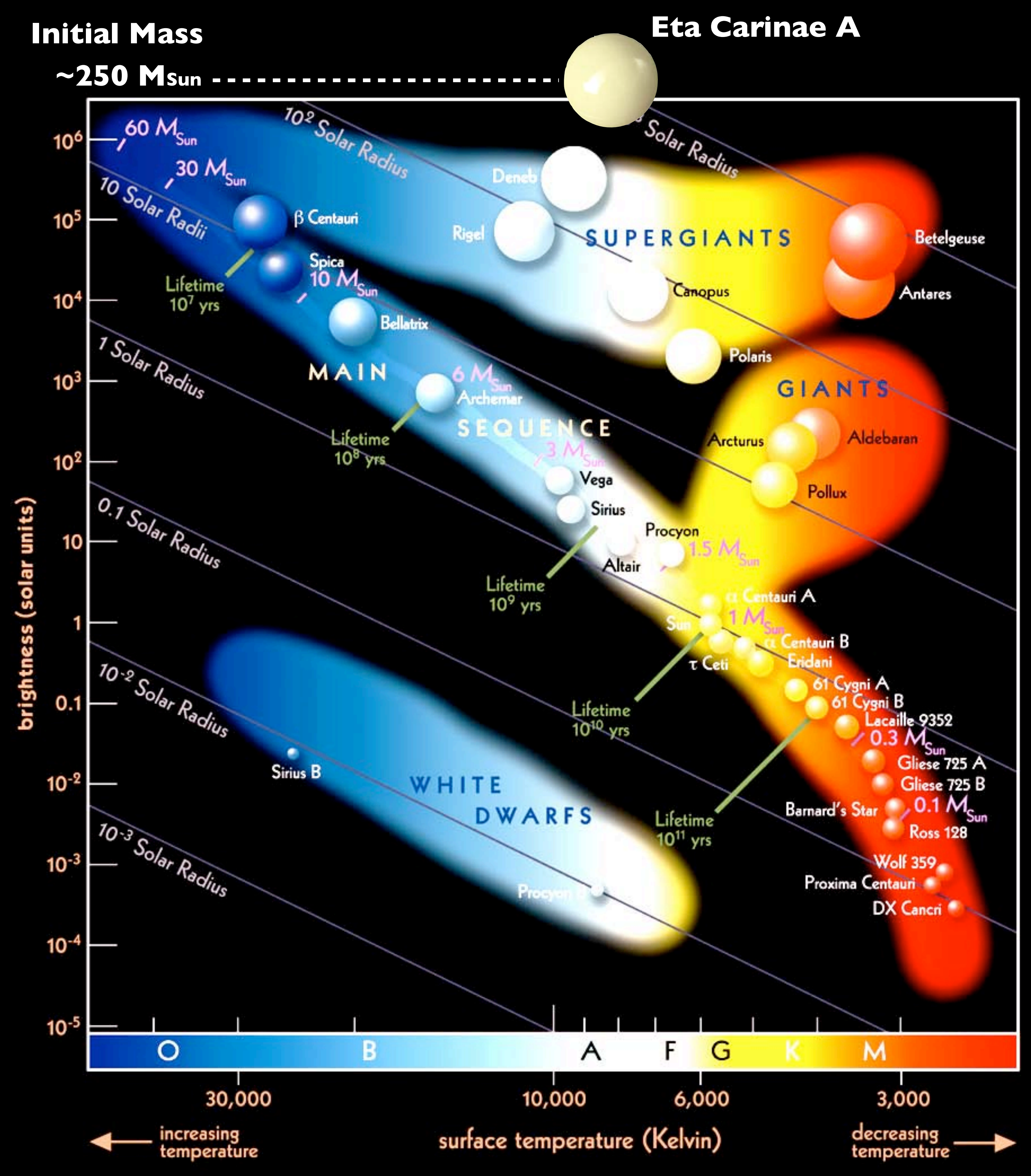
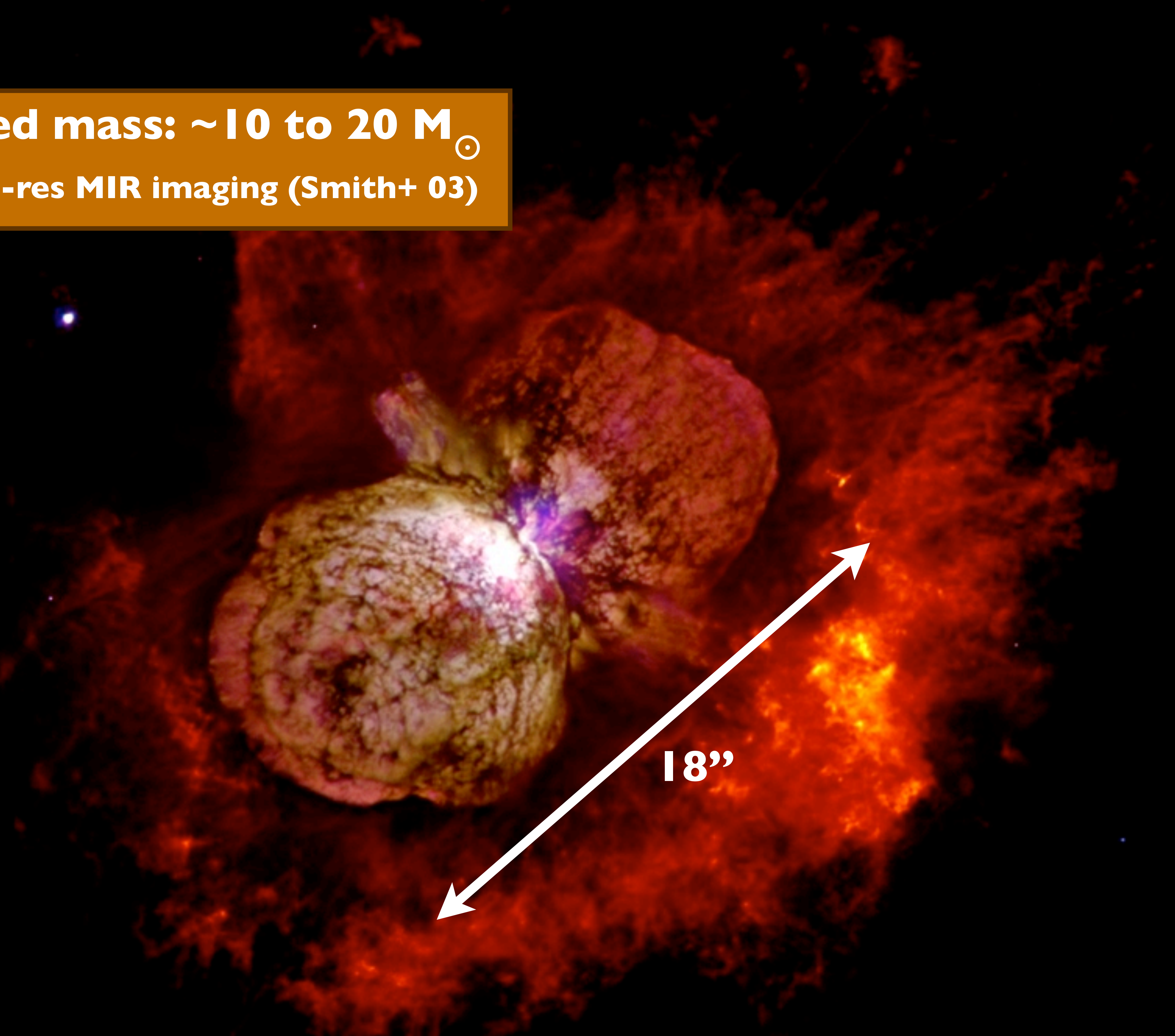
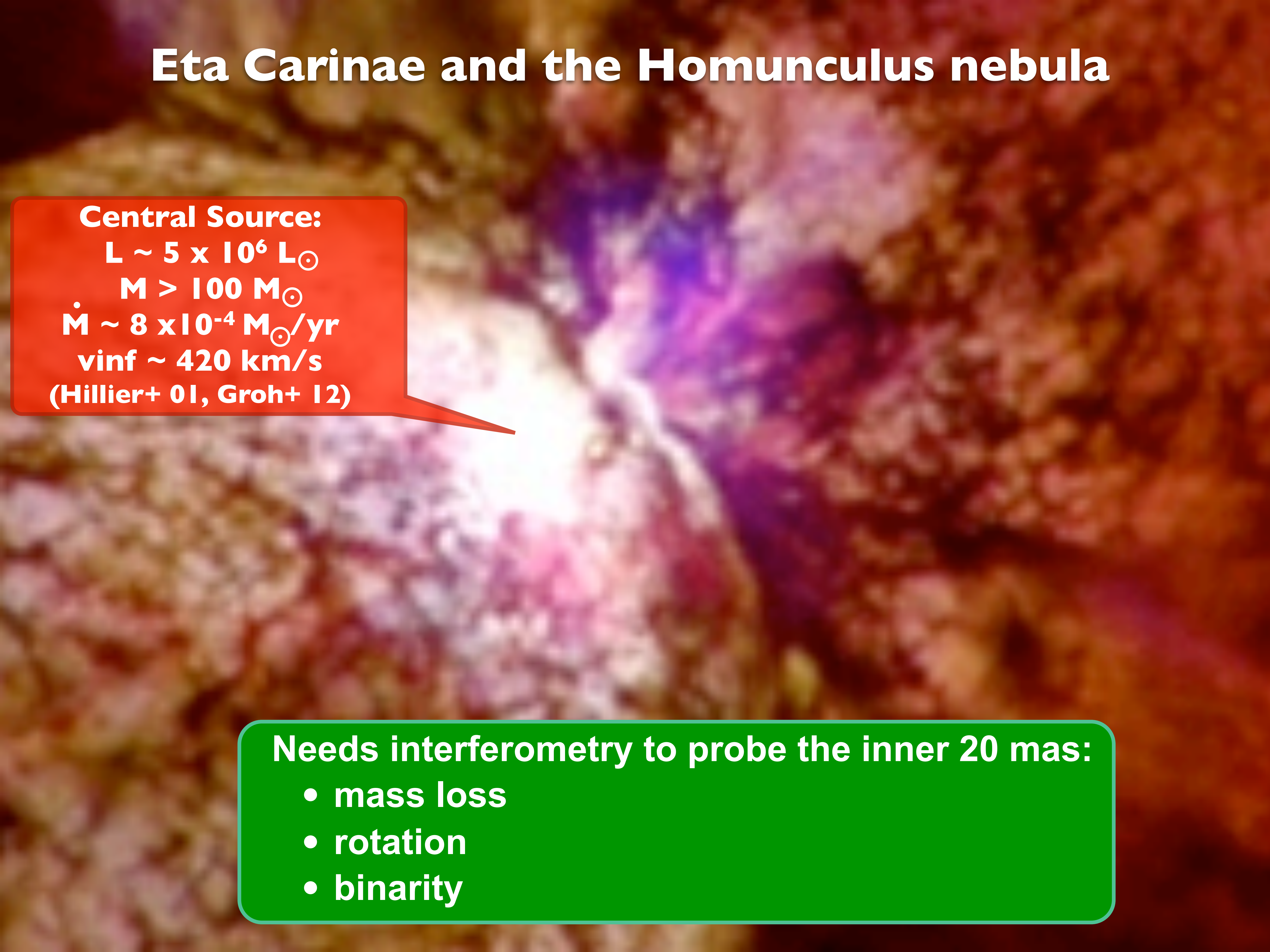


Eta Carinae and the Homunculus nebula

Ejected mass: ~10 to 20 $M_\odot$

from high-res MIR imaging (Smith+ 03)



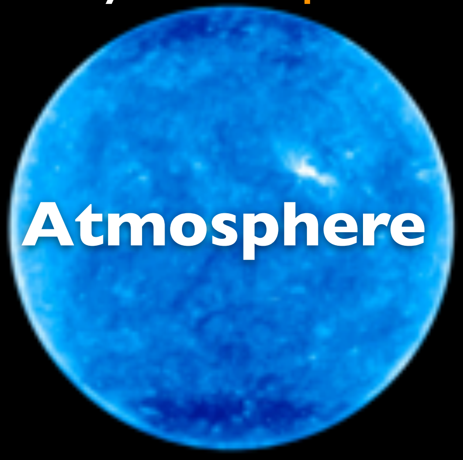

Eta Carinae and the Homunculus nebula
Central Source:
$L \sim 5 \times 10^6 L_\odot$
$M > 100 M_\odot$
$\dot{M} \sim 8 \times 10^{-4} M_\odot/yr$
vinf ~ 420 km/s
(Hillier+ 01, Groh+ 12)
Needs interferometry to probe the inner 20 mas:
• mass loss
• rotation
• binarity

Mass loss and extension of the photosphere

Strong stellar wind causes the photosphere to be formed in the wind

Sun

$r_{hydr} = r_{phot}$



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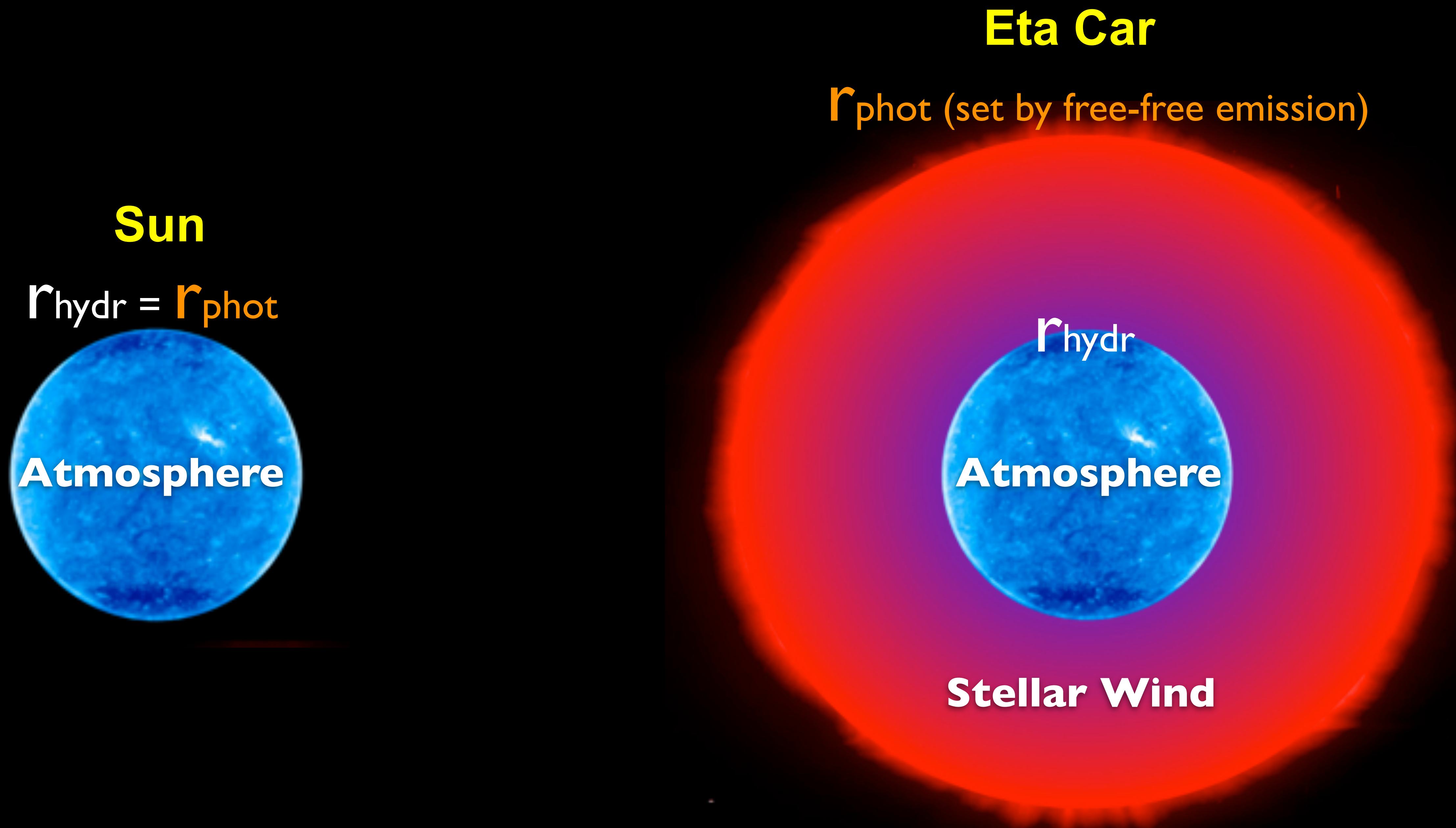

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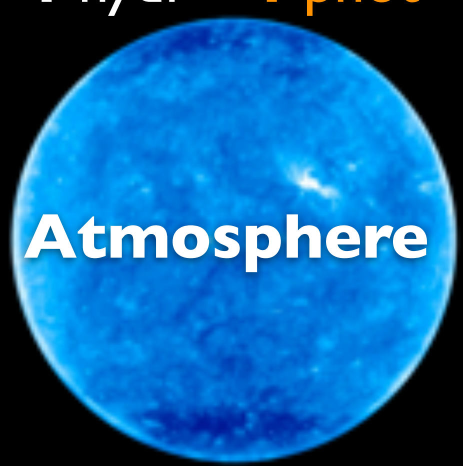
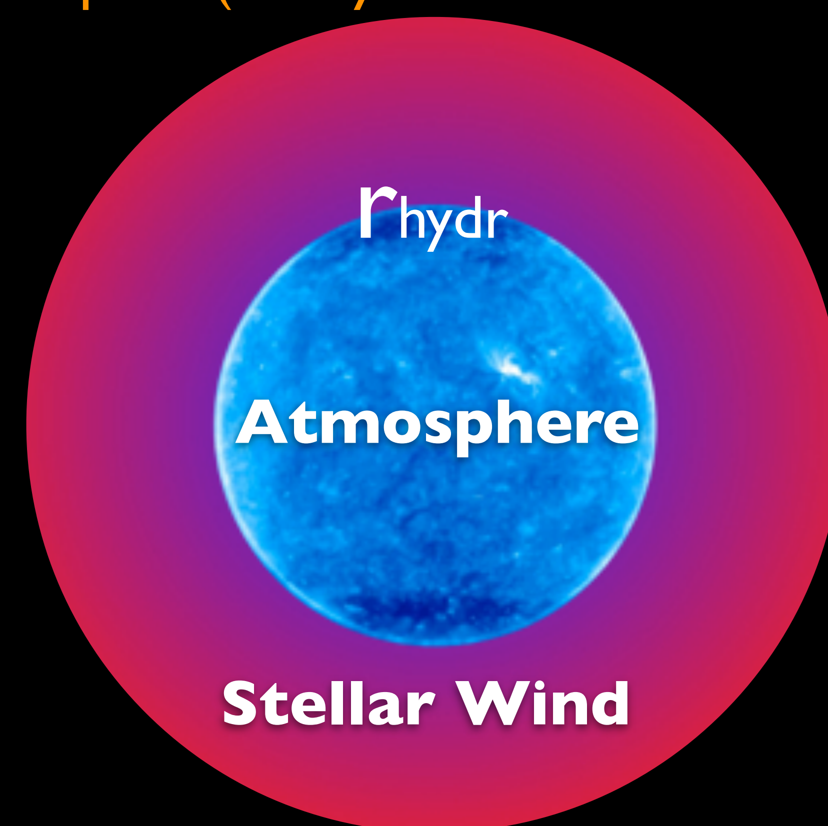


Eta Car ($\dot{M}$/2)

r_{phot} (set by free-free emission)



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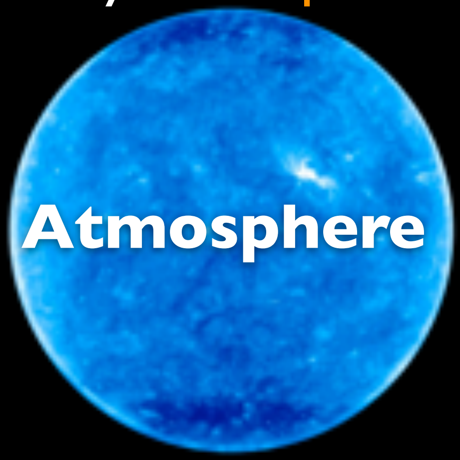

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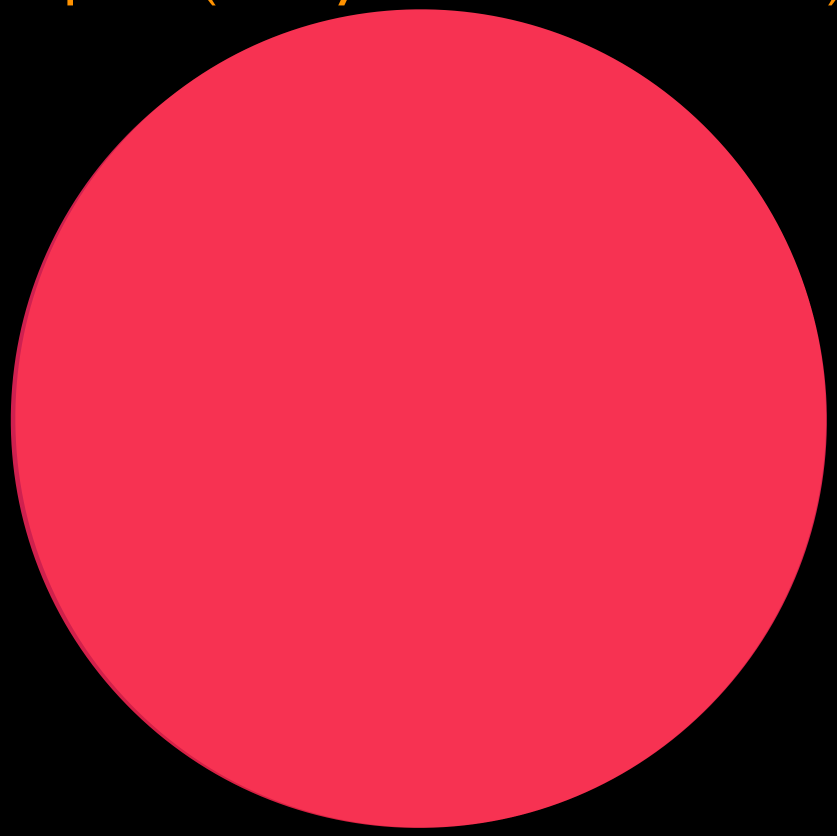
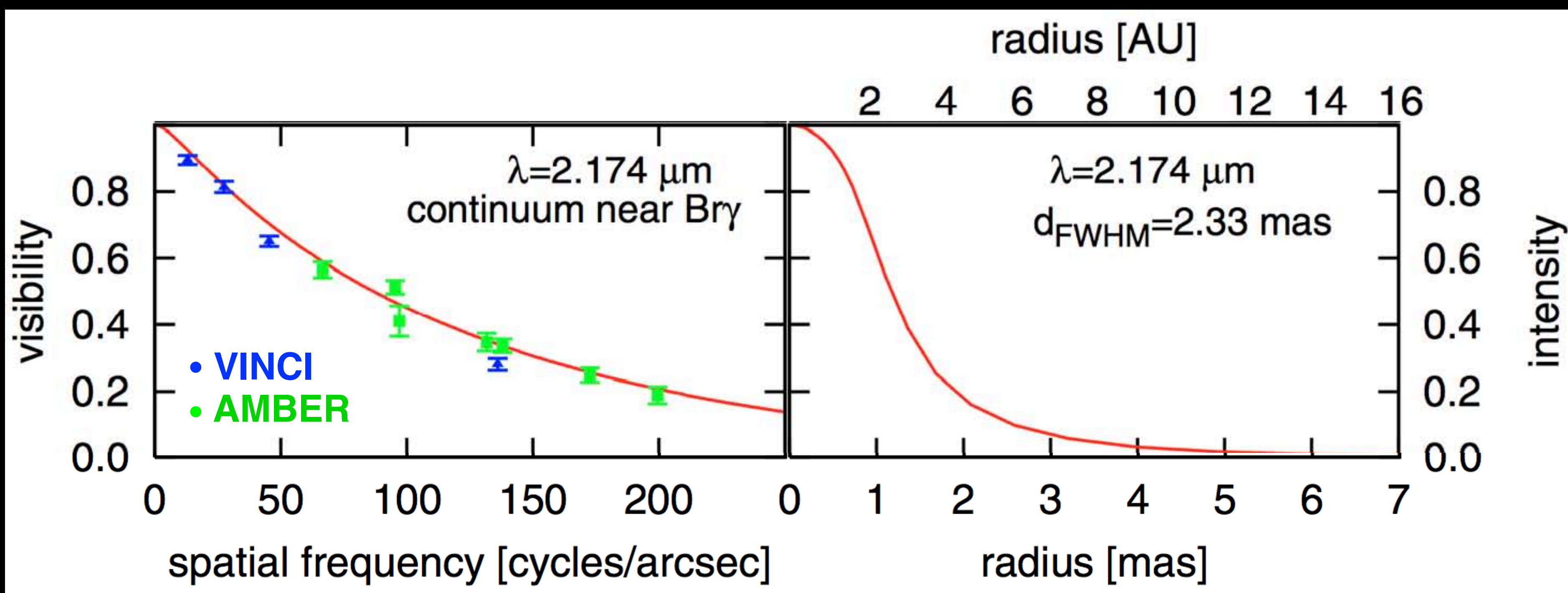


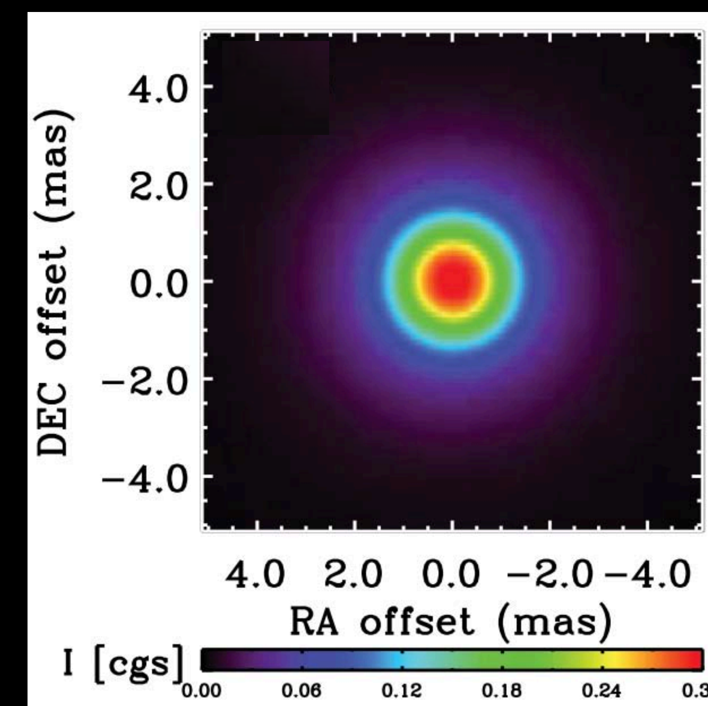
Eta Carinae mass loss

(van Boekel+03; Weigelt+07; Kervella 07; Groh+10, 12)

Observations **NLTE 1D model** **NLTE 1D model image**



Weigelt+07



Groh+12

Eta Carinae mass loss

(van Boekel+03; Weigelt+07; Kervella 07; Groh+10, 12)

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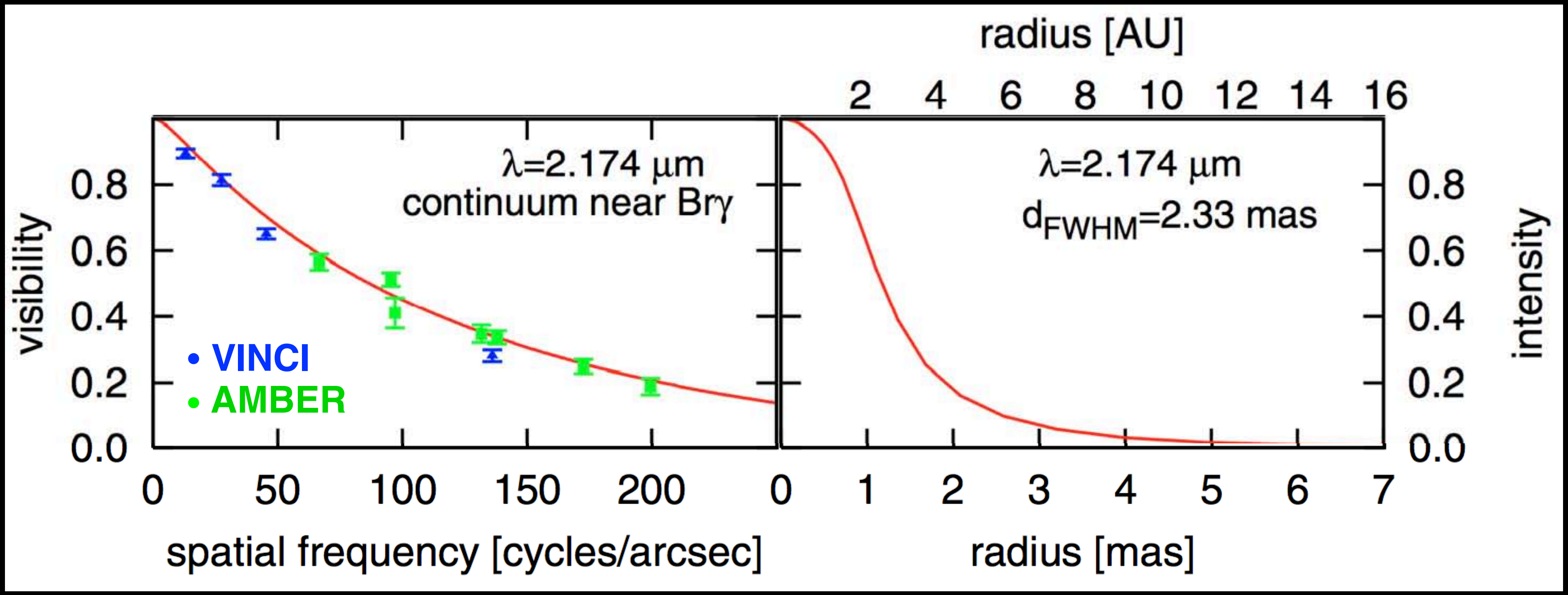

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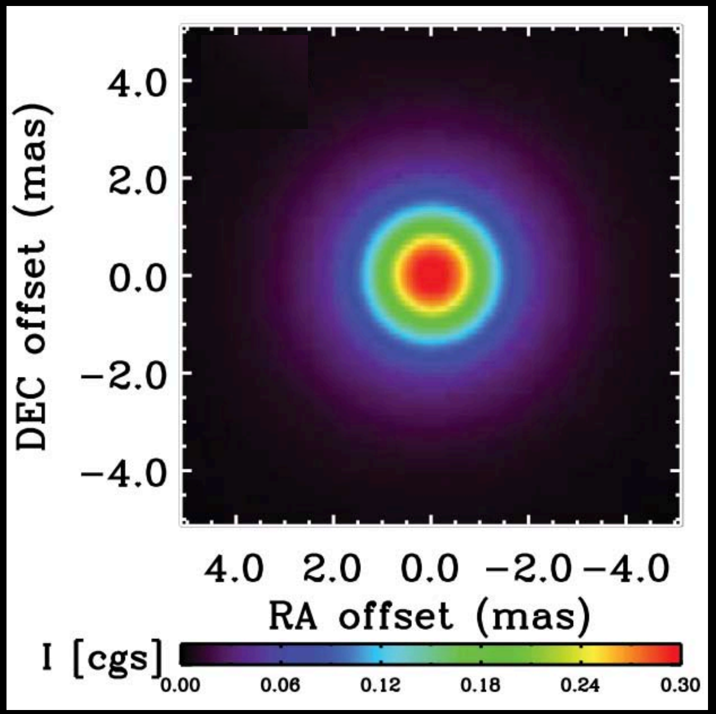


Groh+12

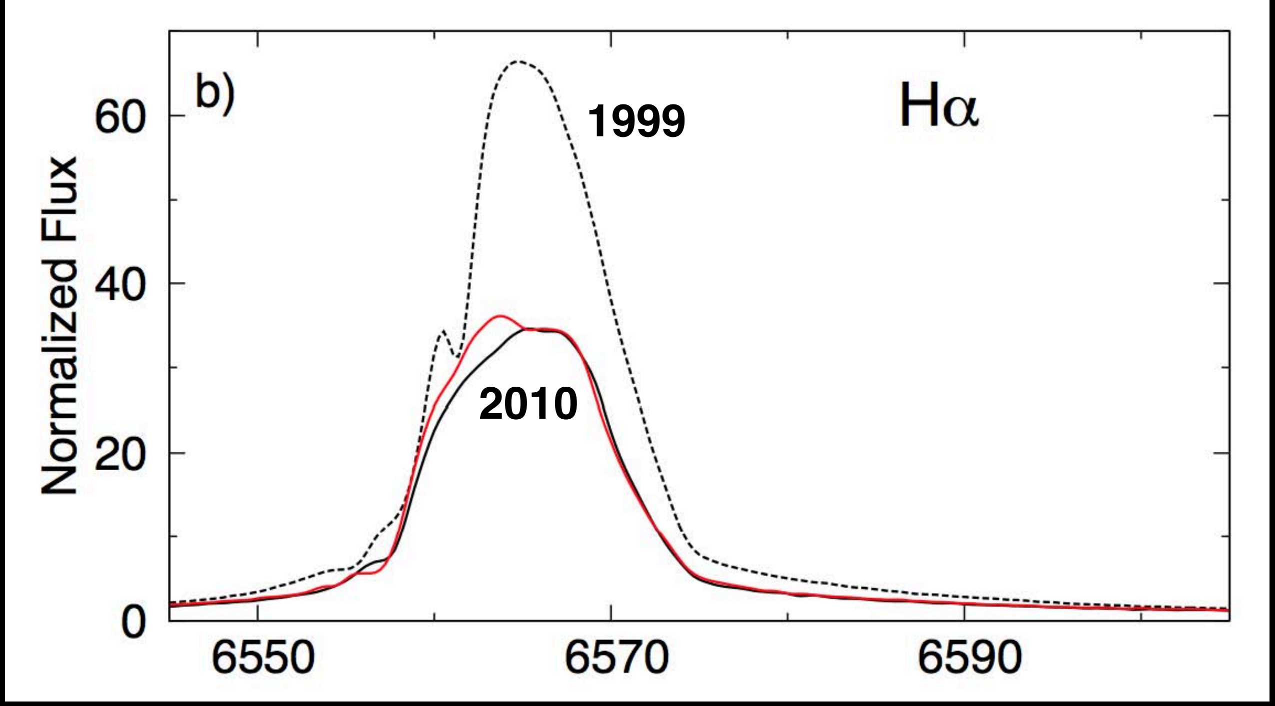
Mass-loss rate in 2002-2005: ~ 8.4 x 10^{-4} Msun/yr

Groh+12

Variability in Eta Carinae mass loss?

(Mehner+10, 12, Corcoran+10, Gull+11, Groh+12, Teodoro+12, Madura+13)

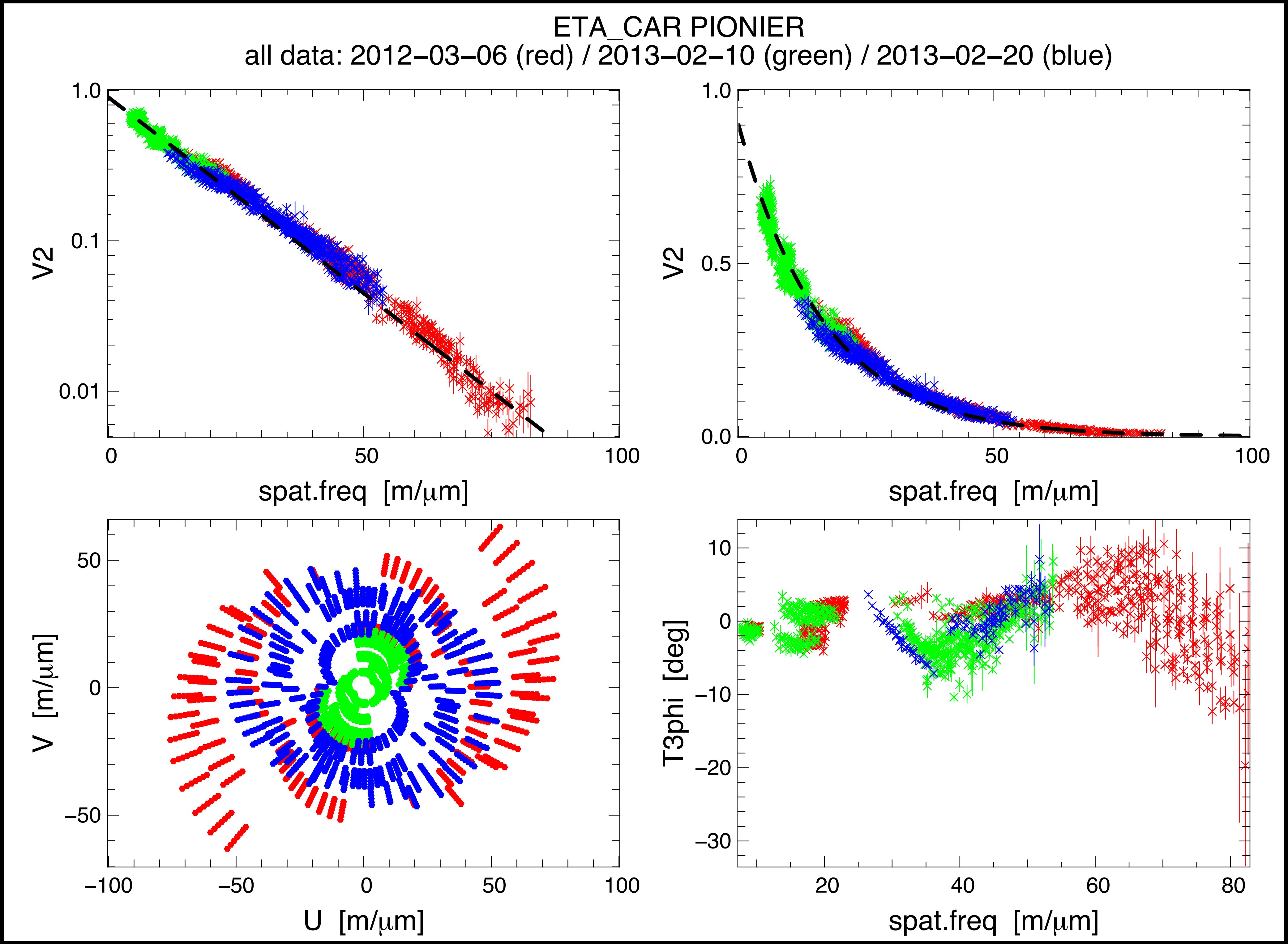
Mass-loss rate reduction by a factor of 2 in the last 10 yr?



Mehner+12

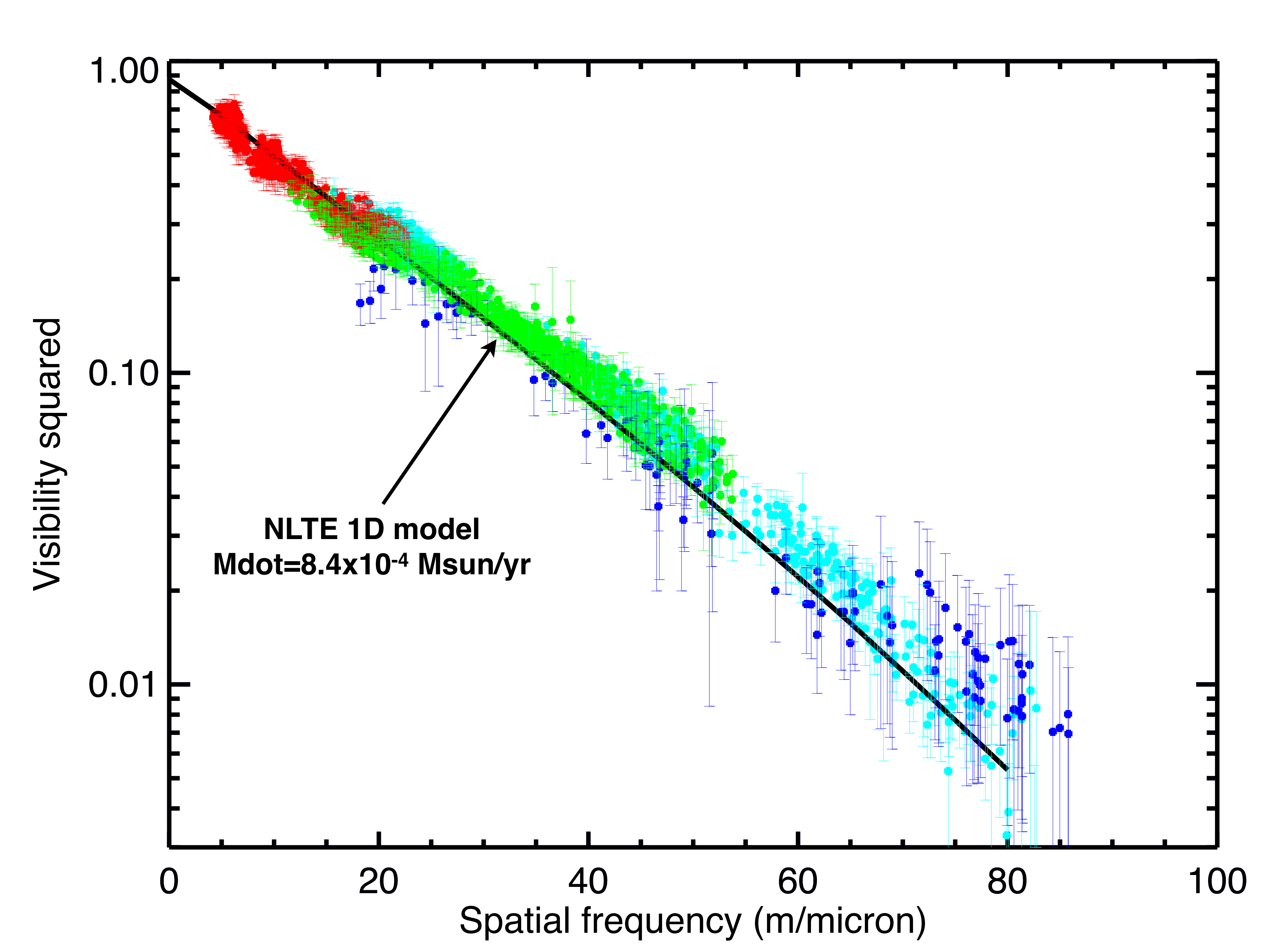
Eta Car PIONIER data

Data taken by O. Absil on 2012 Mar and 2013 Feb
7 spectral channels across the H band



Probing changes in mass loss with PIONIER

Data taken by O. Absil on 2012 Mar and 2013 Feb



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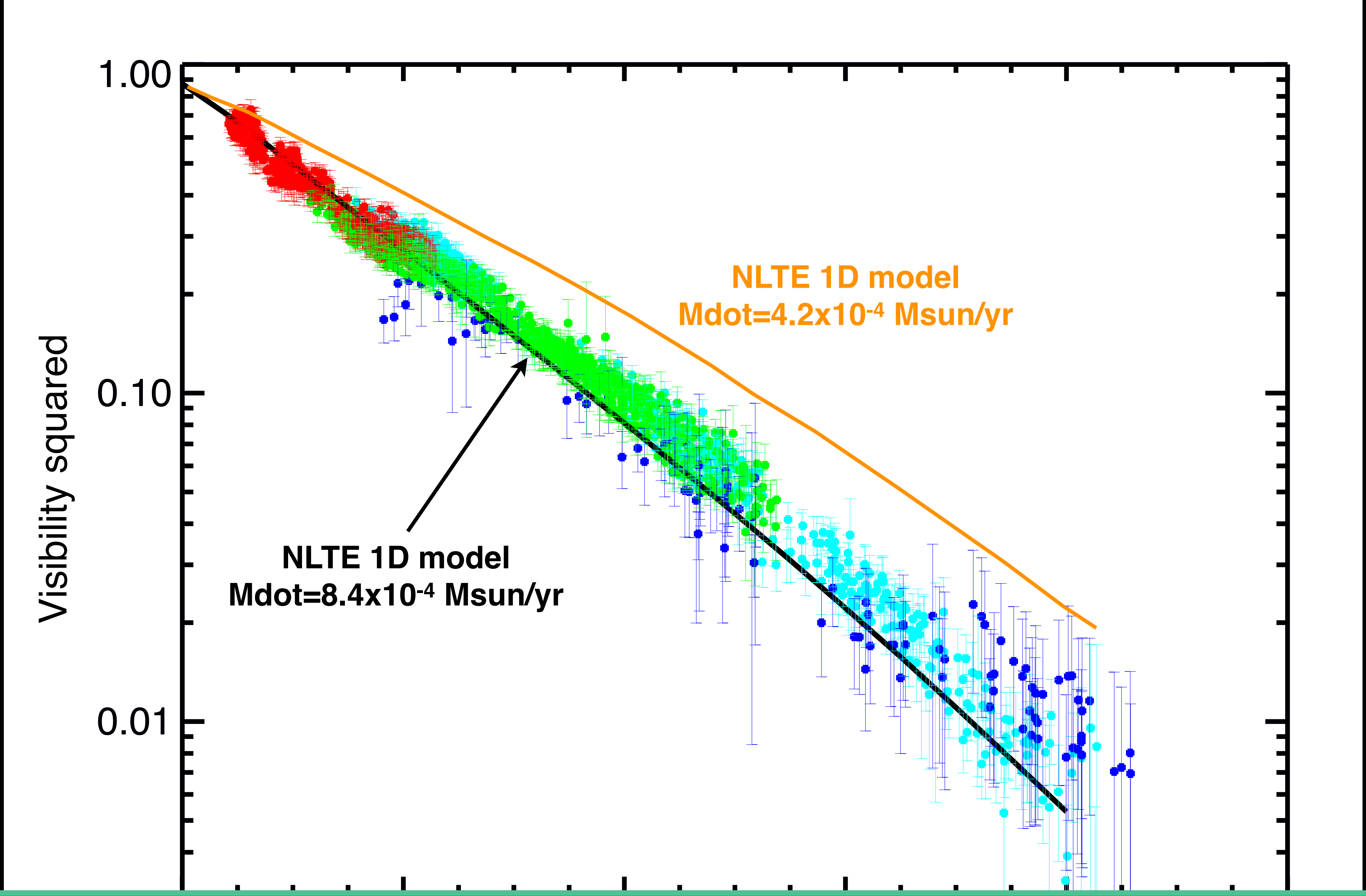
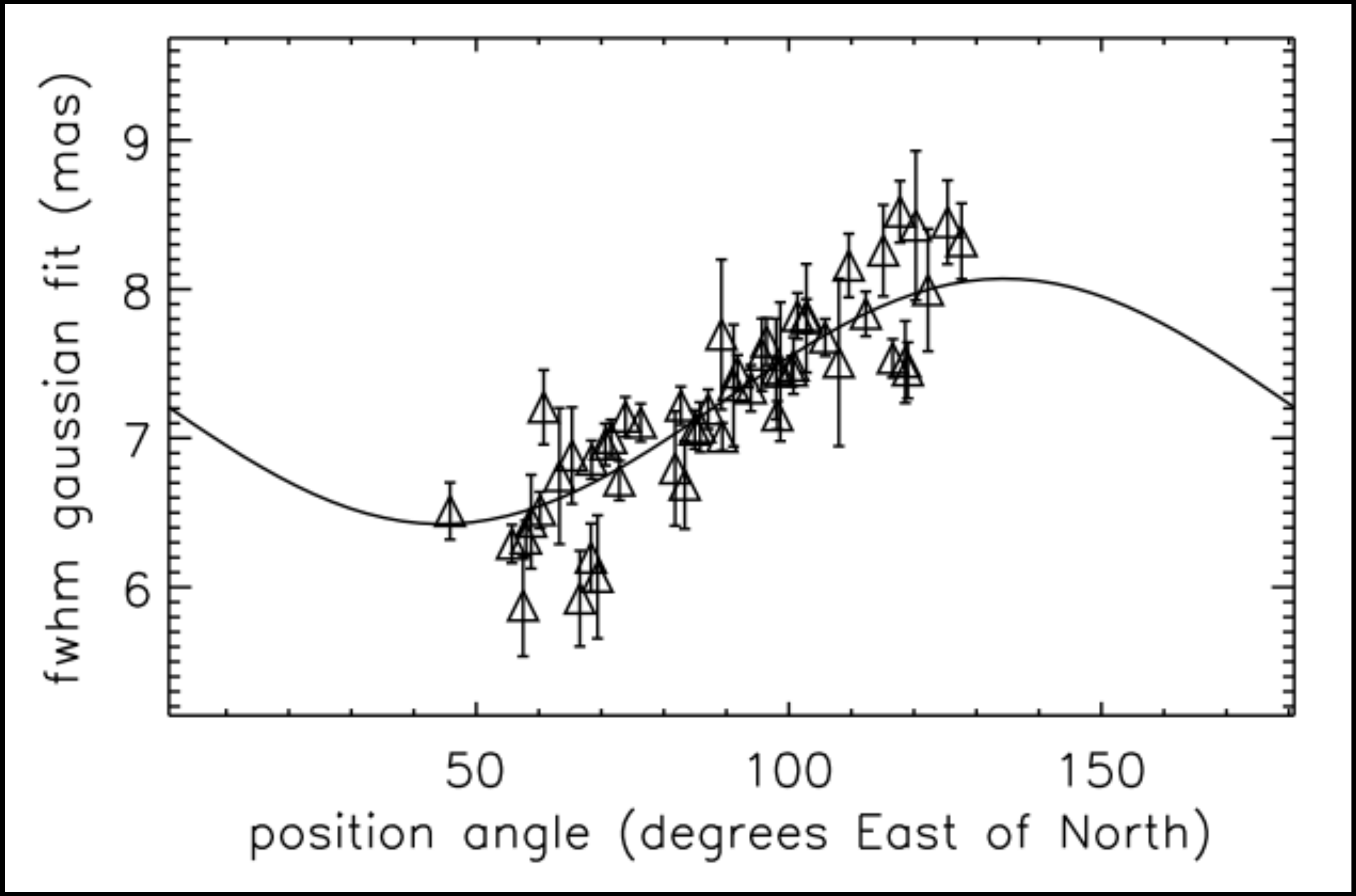


PIONIER 2012-2013 data do NOT support a noticeable change in Eta Car's mass-loss rate.

Rotation: elongation of the K-band photosphere

(van Boekel+ 03; Kervella 07; Weigelt+07; Groh+10)



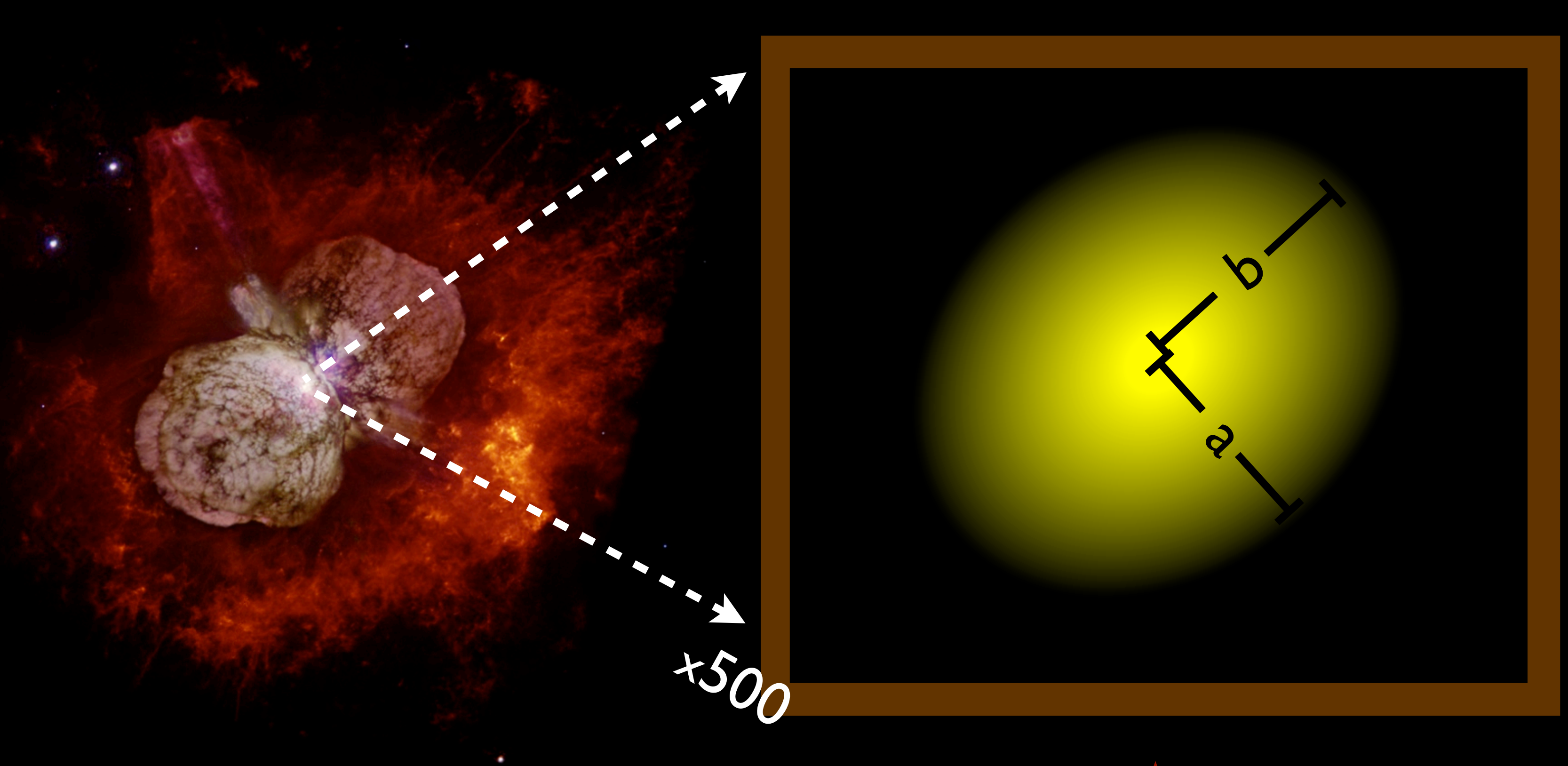
van Boekel+03

Rotation: elongation of the K-band photosphere

(van Boekel+ 03; Kervella 07; Weigelt+07; Groh+10)

Homunculus
i=41° ; PA=131°

Geometric model
PA~134° ; b/a=1.25

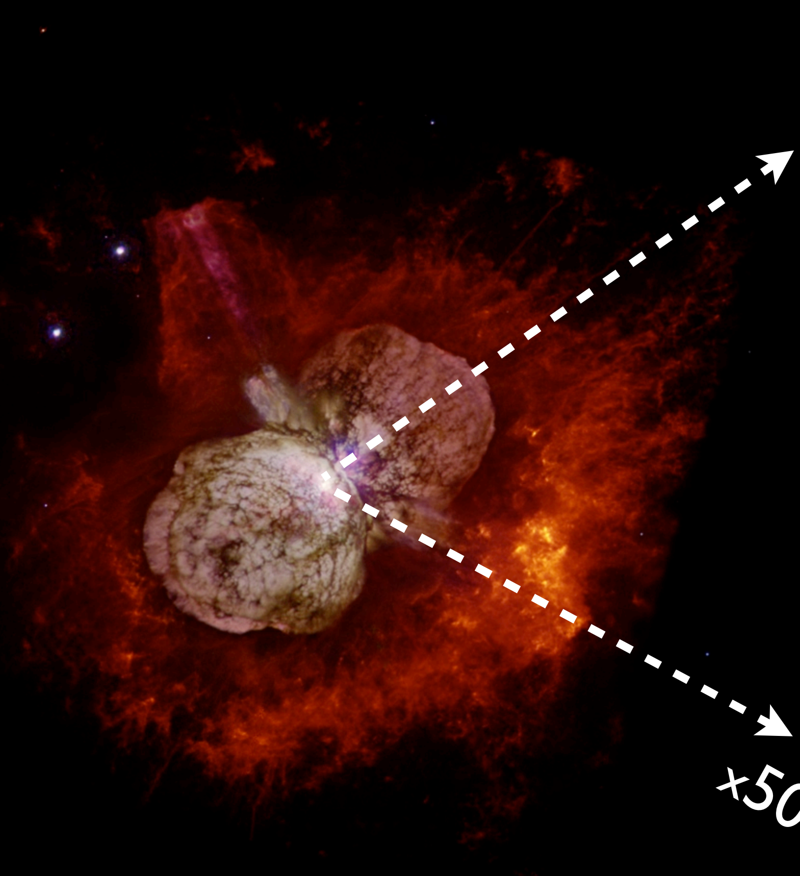


Eta Car A
rapid rotator: rot. axis aligned
with the Homunculus polar axis

Rotation: elongation of the K-band photosphere

(van Boekel+ 03; Kervella 07; Weigelt+07; Groh+10)

Homunculus
i=41° ; PA=131°



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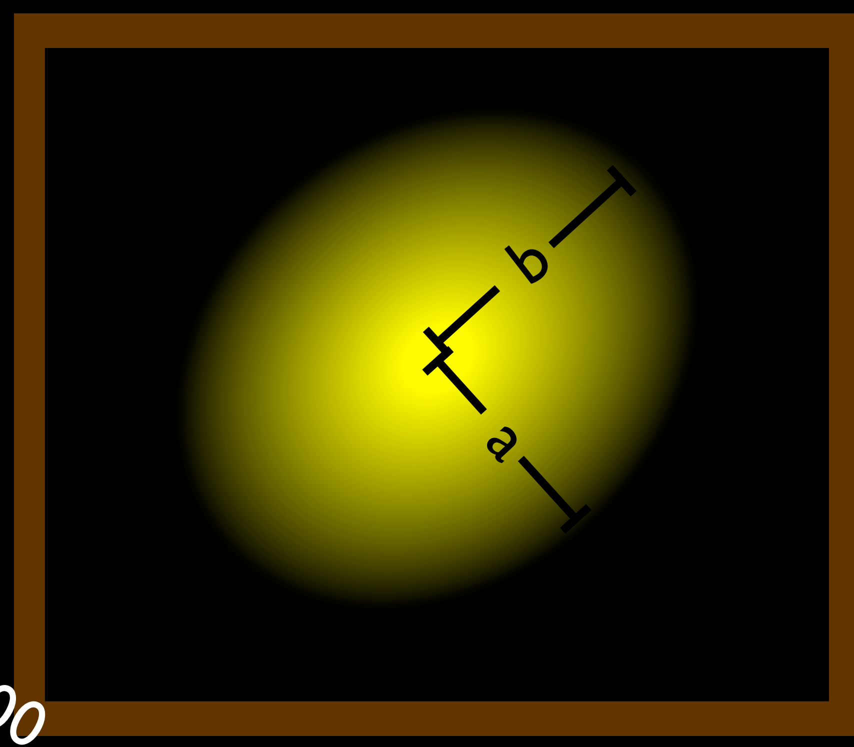
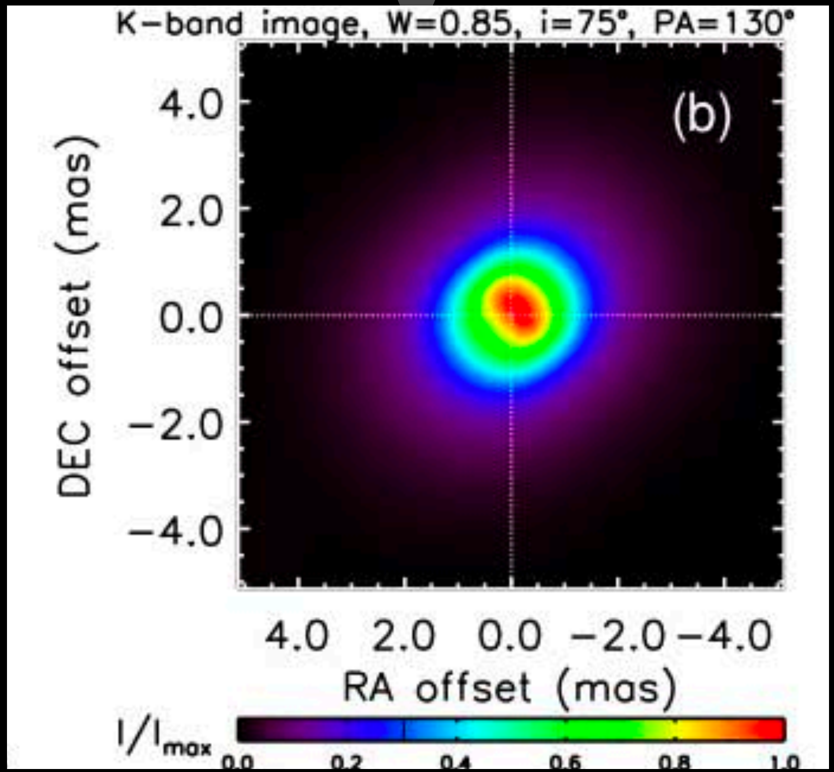


Rad. Transf. VINCI+AMBER
v_{rot}/v_{crit}=0.77 to 0.92
i=60° to 90°
PA=108° to 142°



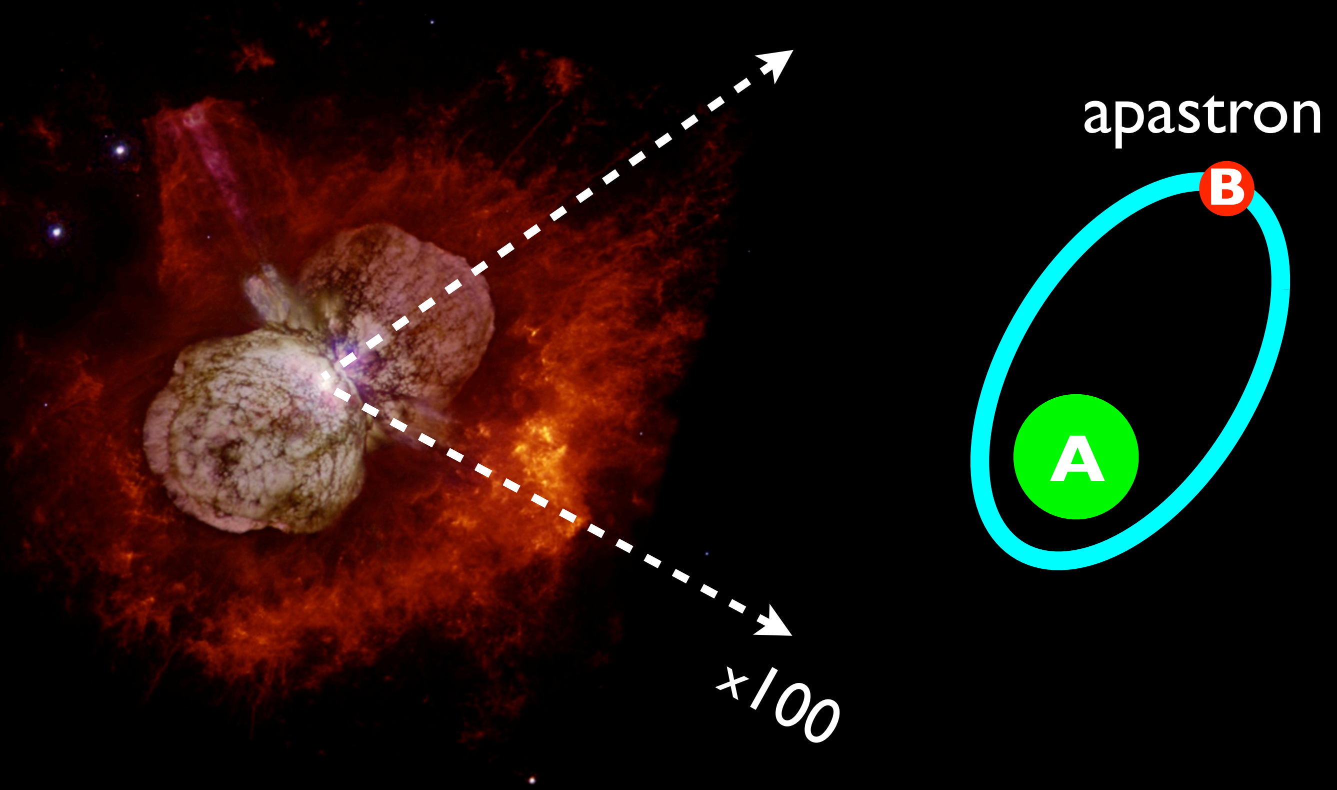
Eta Car A
rapid rotator: rot. axis aligned with the Homunculus polar axis

Eta Car A
rapid rotator: rotation axis **misaligned** with the Homunculus

Groh+10

Binarity of Eta Carinae: effects are time dependent

Orbit: i=139° , ω=243° , PA=312° , e=0.9, P=5.54 years
(Damineli 96; Madura 12)



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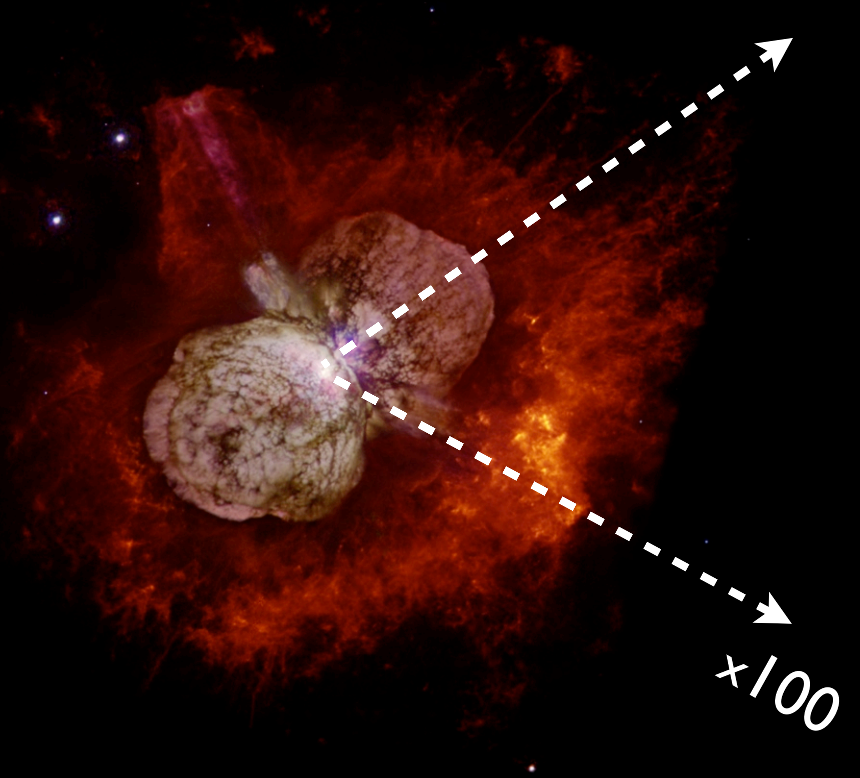

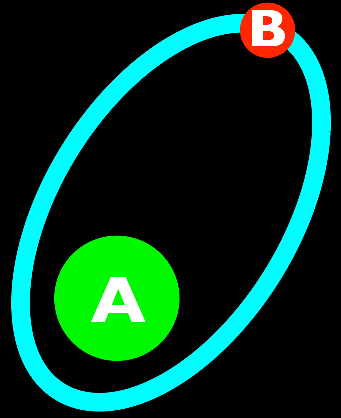

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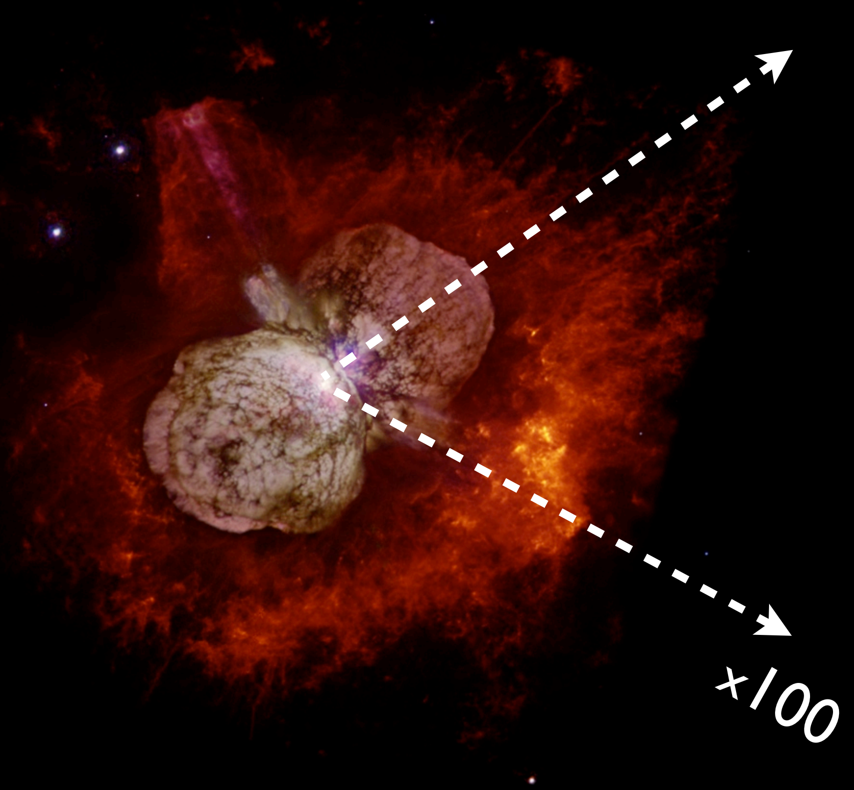

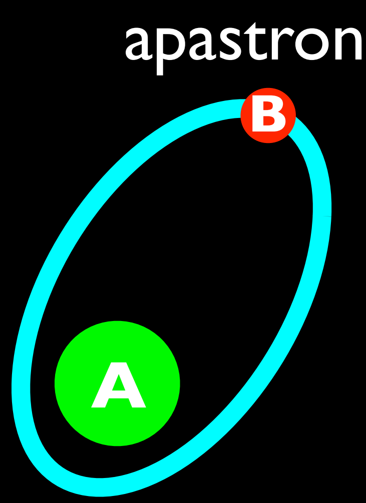

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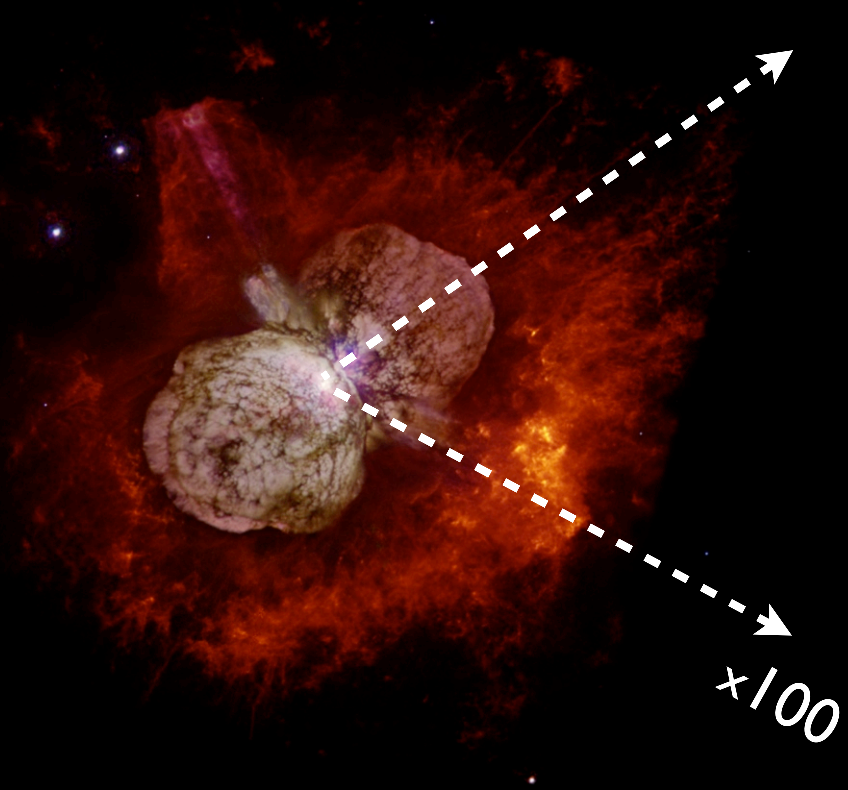

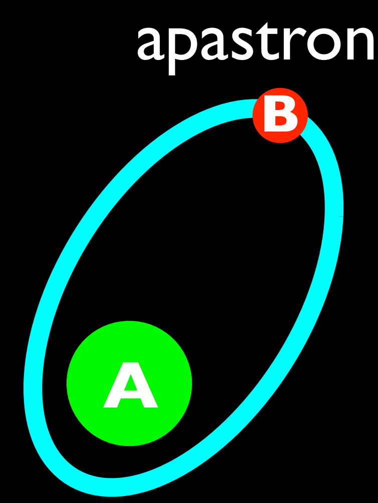

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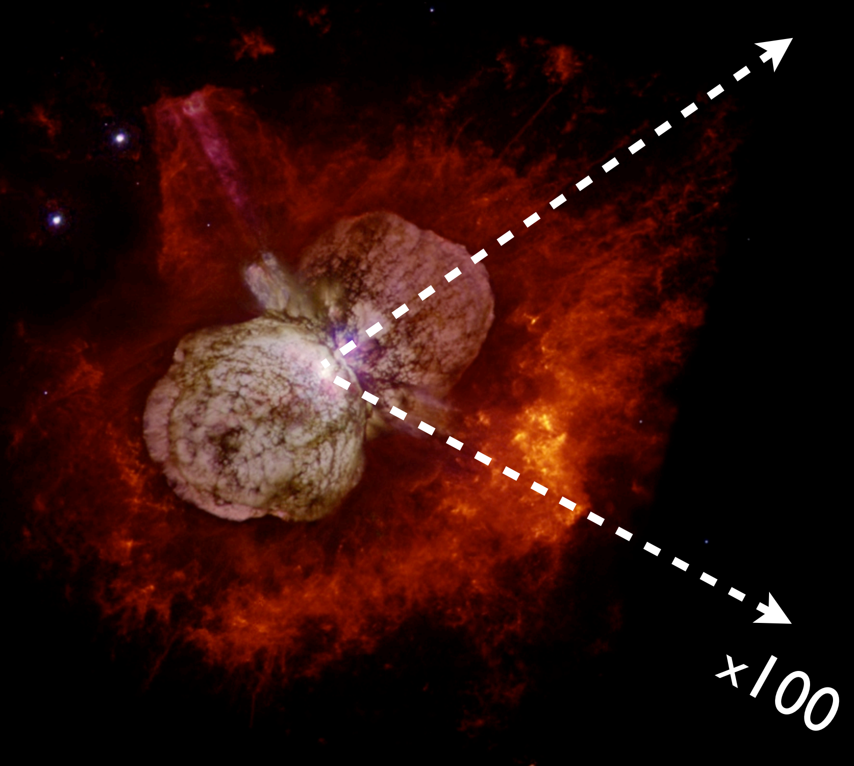
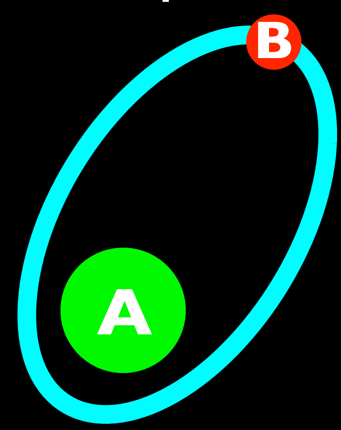
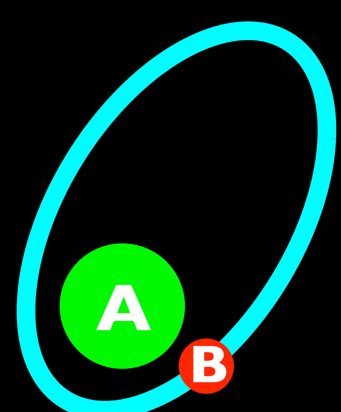


apastron



Around periastron



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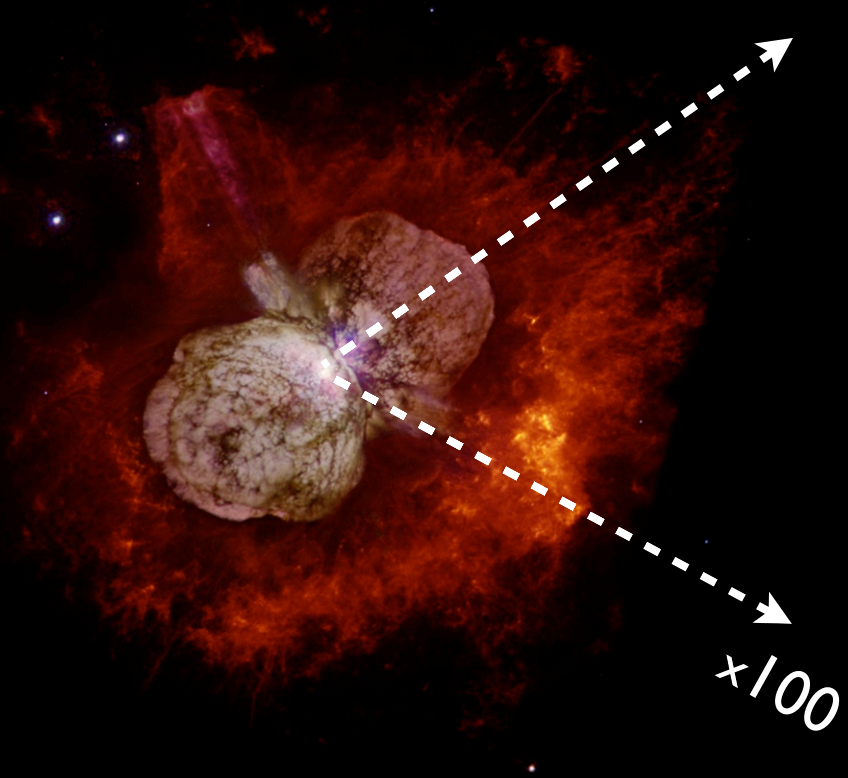
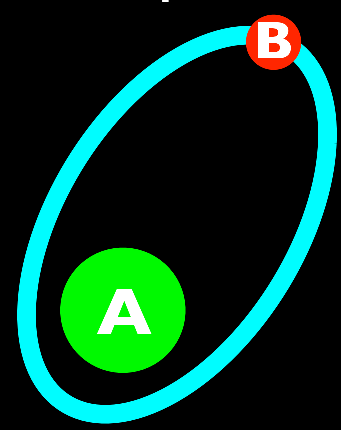


apastron



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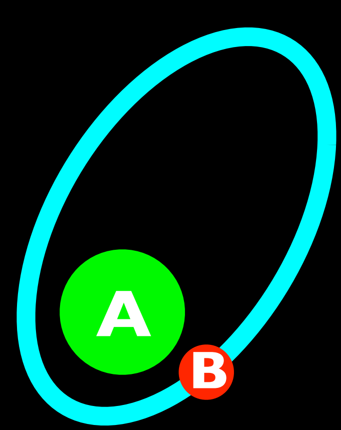
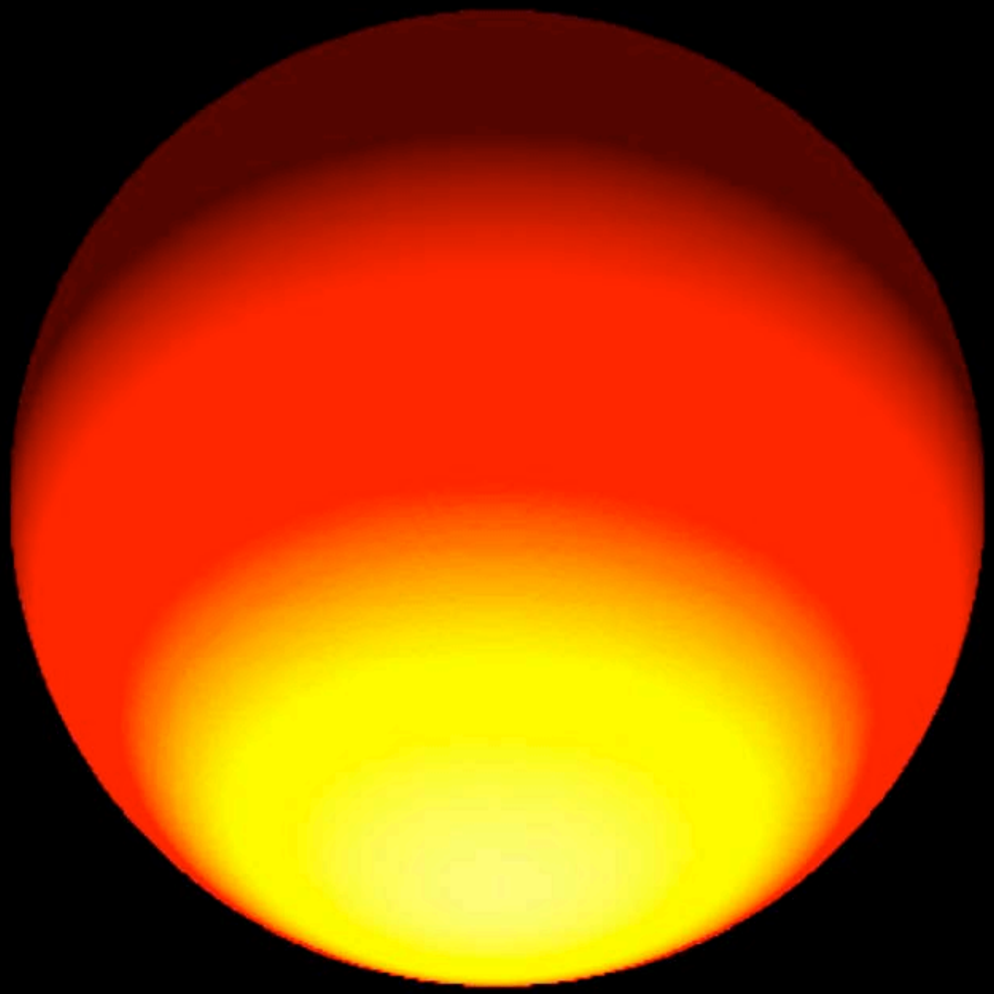


wind-wind collision zone

Effects due to the companion star around periastron

‘bore hole’ and free-free emission from the wind-wind collision

3-D isodensity surface



Groh+10,12

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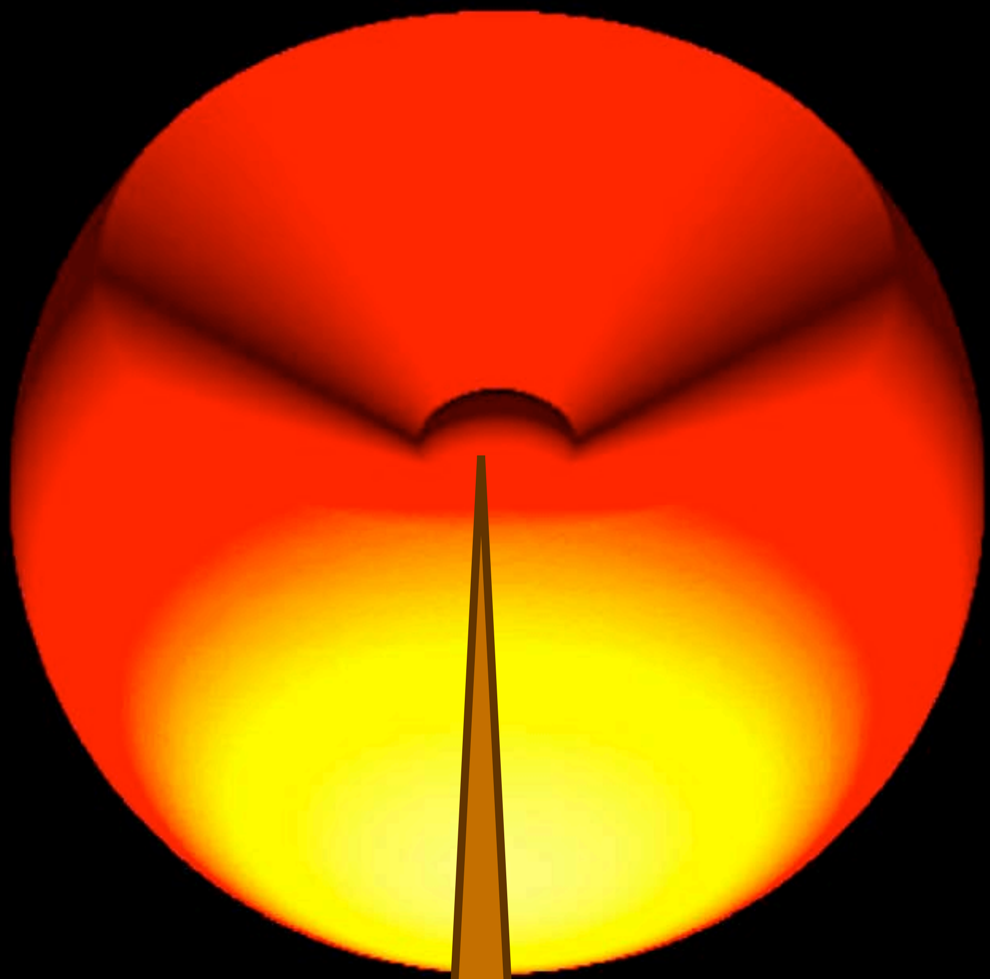

carving of the wind, exposing the hotter, inner parts (‘bore hole’ effect, Madura & Owocki 2010)

Groh+10,12

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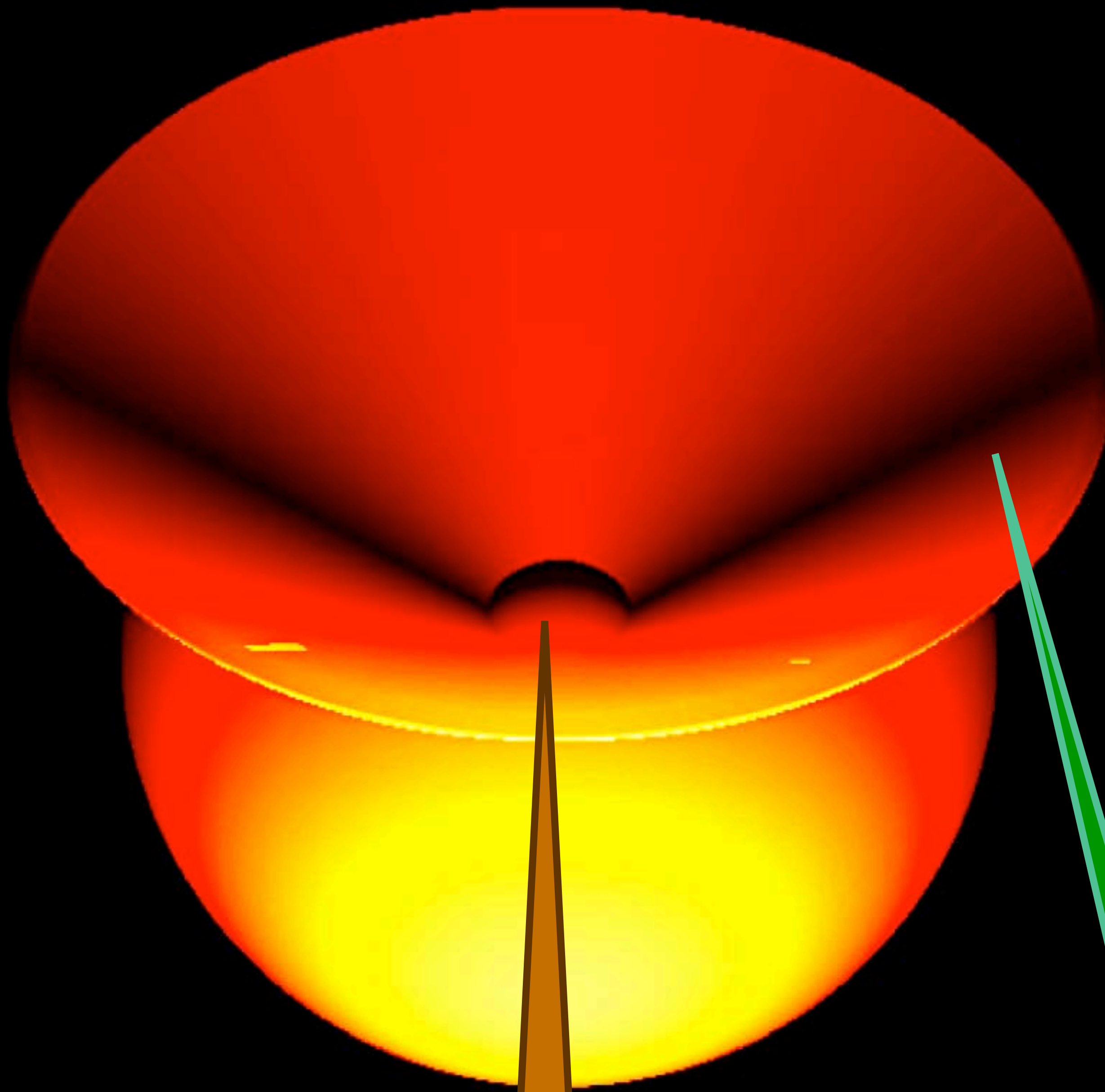


carving of the wind, exposing the hotter, inner parts (‘bore hole’ effect, Madura & Owocki 2010)

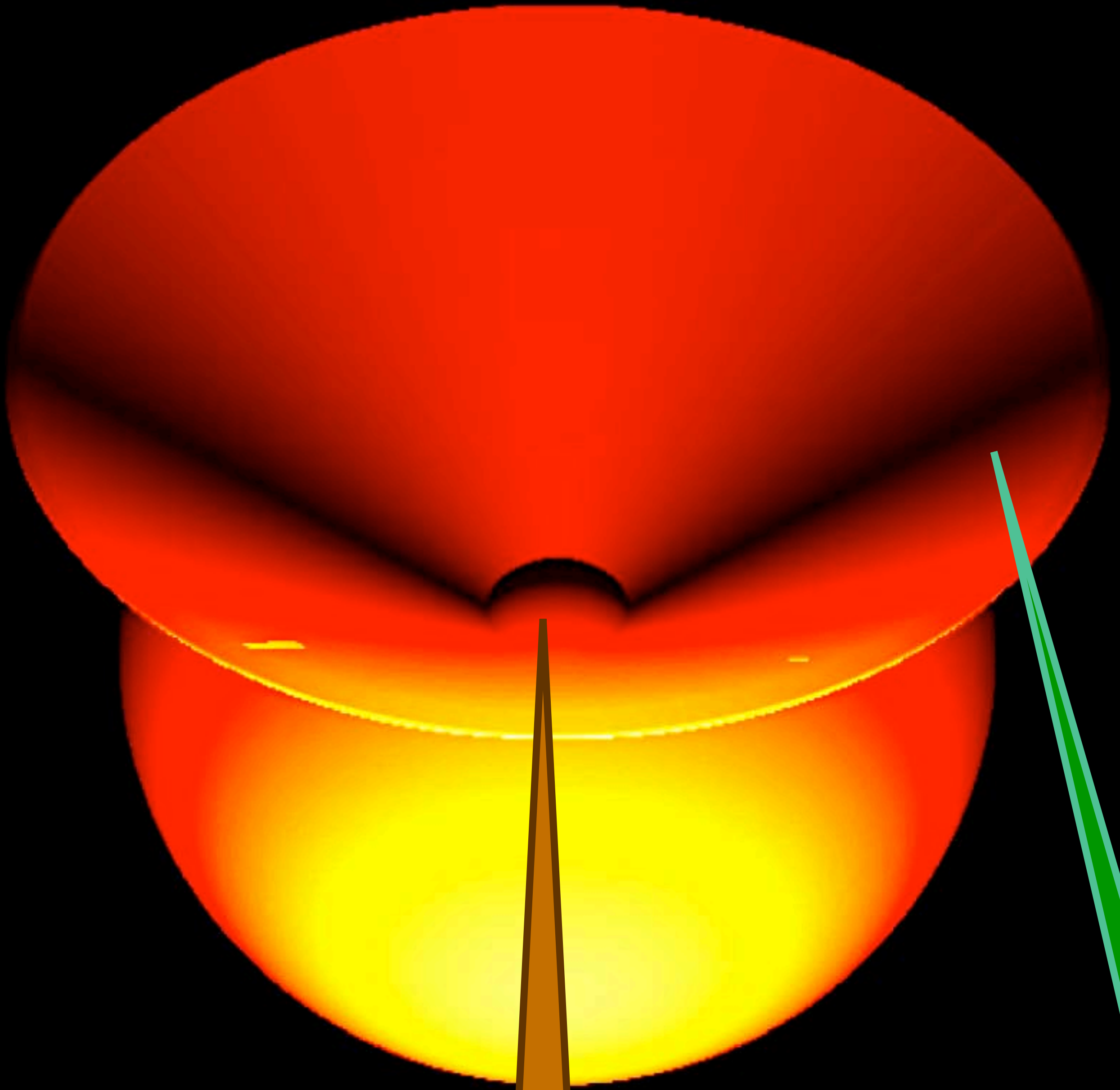
free-free emission from the dense post-shocked primary wind compressed along the shock cone walls

Groh+10,12

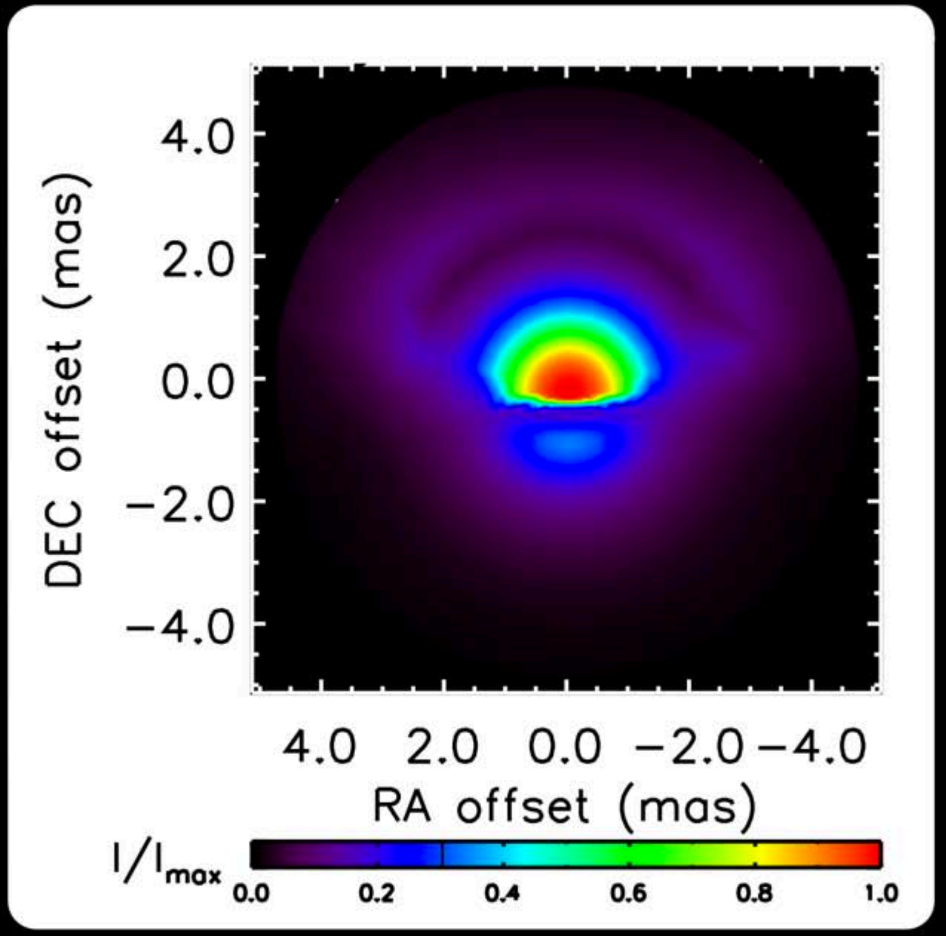
Effects due to the companion star around periastron

‘bore hole’ and free-free emission from the wind-wind collision

3-D isodensity surface



K-band continuum image



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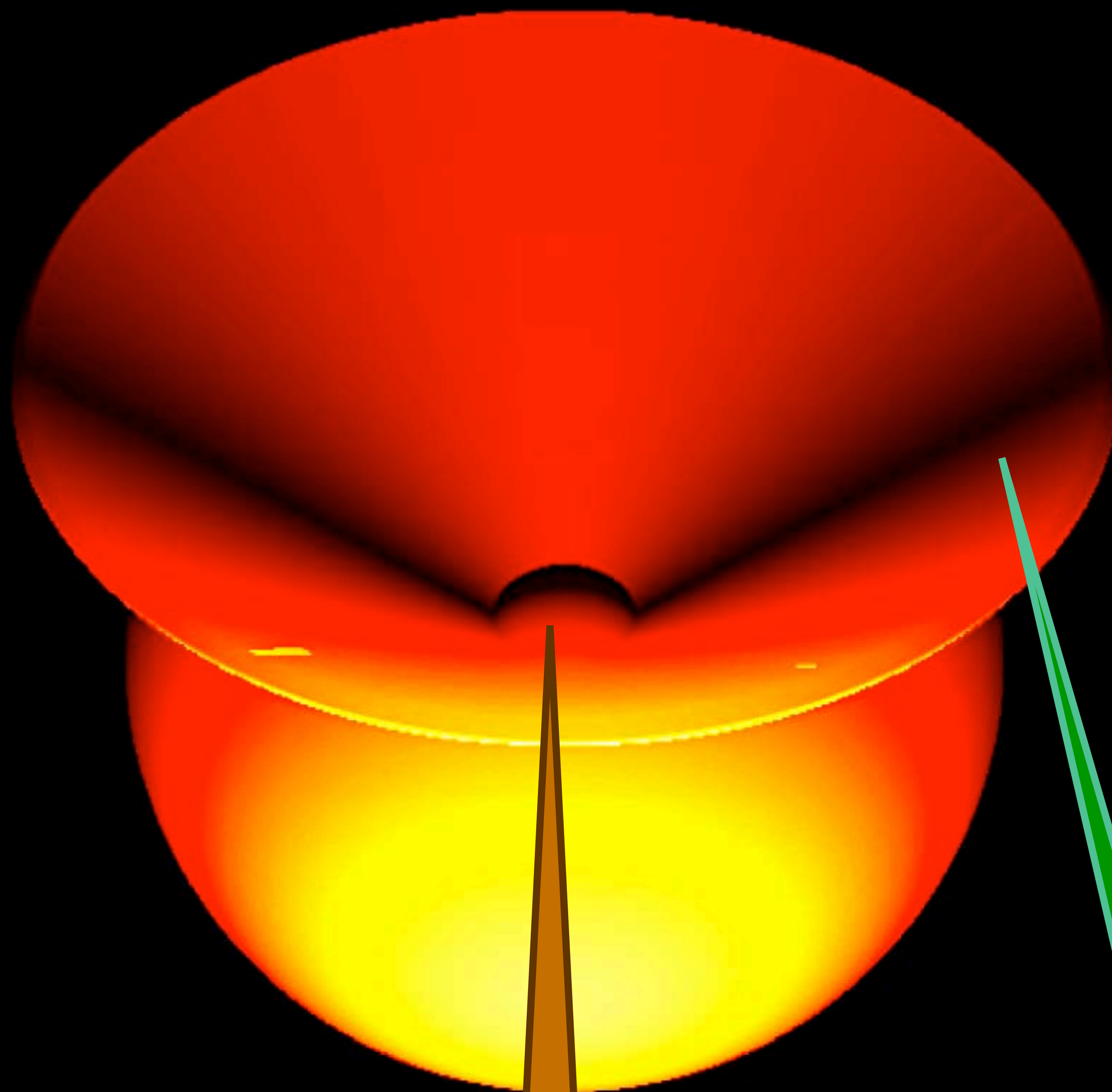
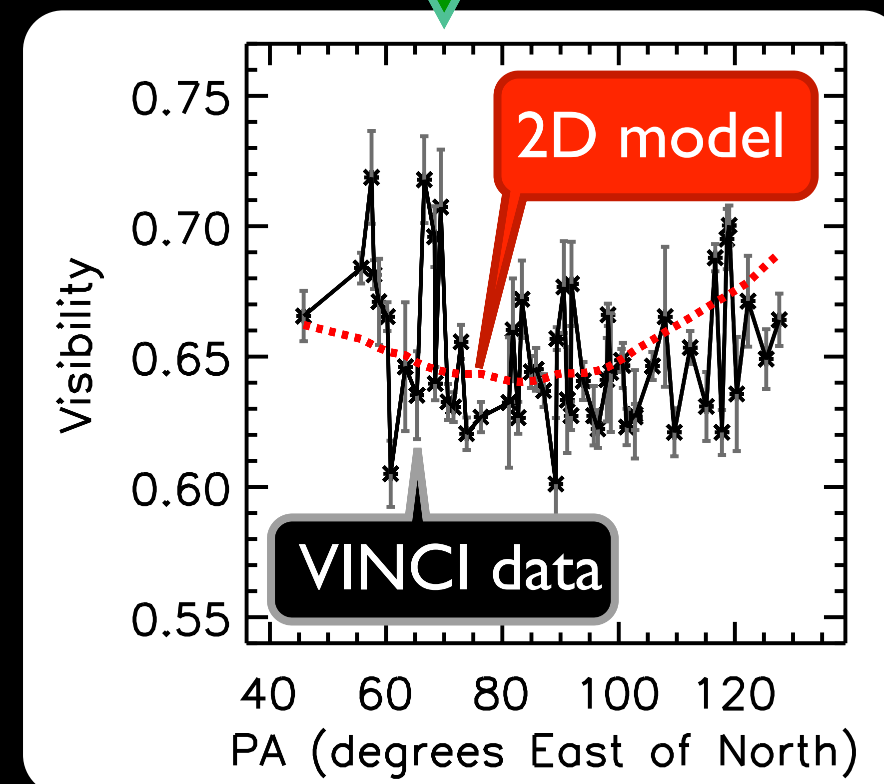


Fit to the visibilities



(Groh et al. 2010a)

carving of the wind, exposing the hotter, inner parts (‘bore hole’ effect, Madura & Owocki 2010)

free-free emission from the dense post-shocked primary wind compressed along the shock cone walls

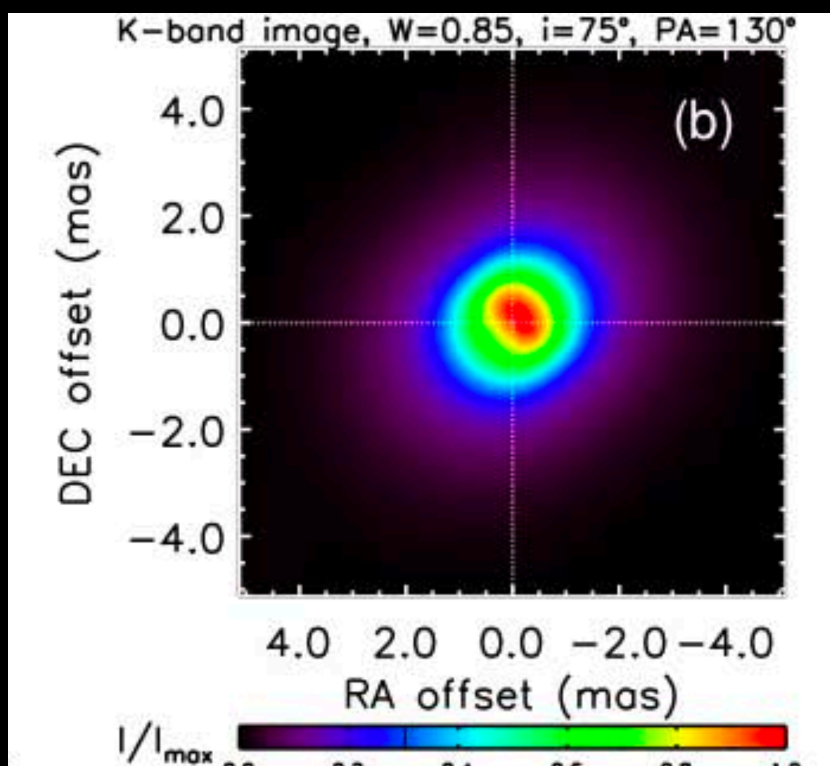
Groh+10,12

Both rotation and binary effects explain the previous data

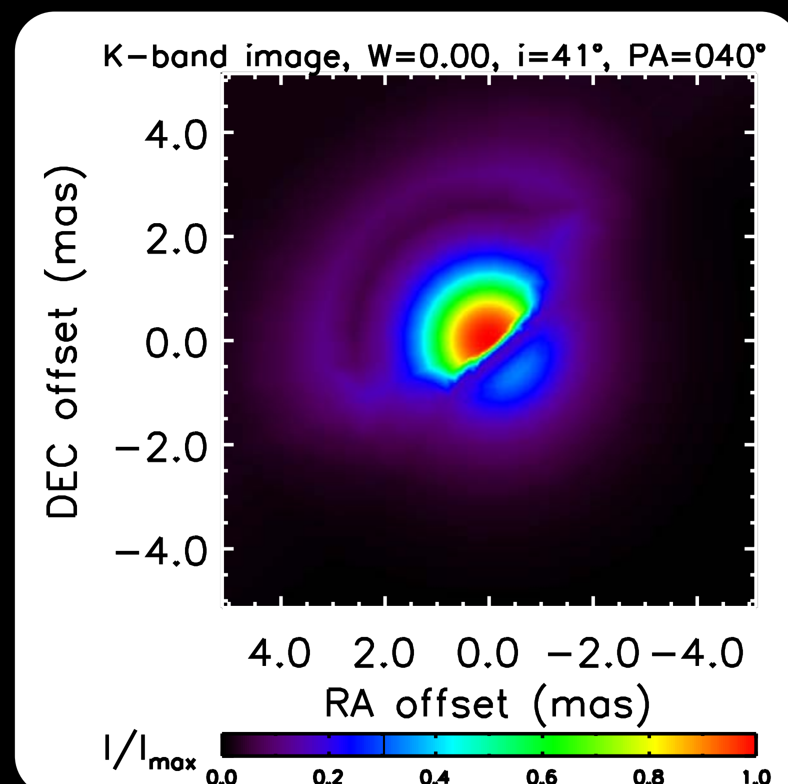
Near-infrared: geometry of the K-band continuum emitting region

Binary model fits data as well as single, rapid-rotating star

Rapid rotator



Wind-wind collision model



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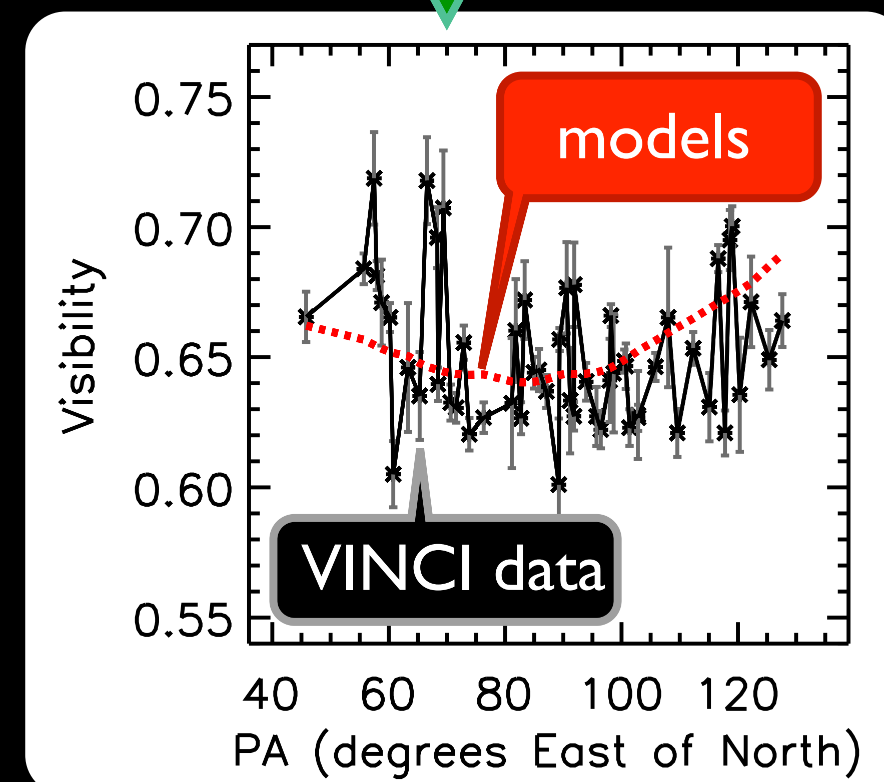
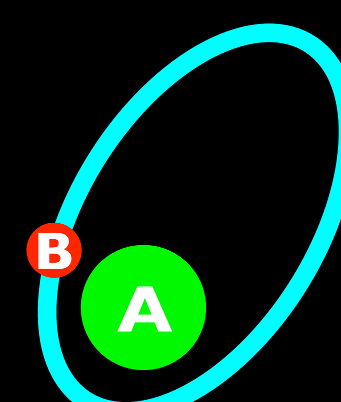


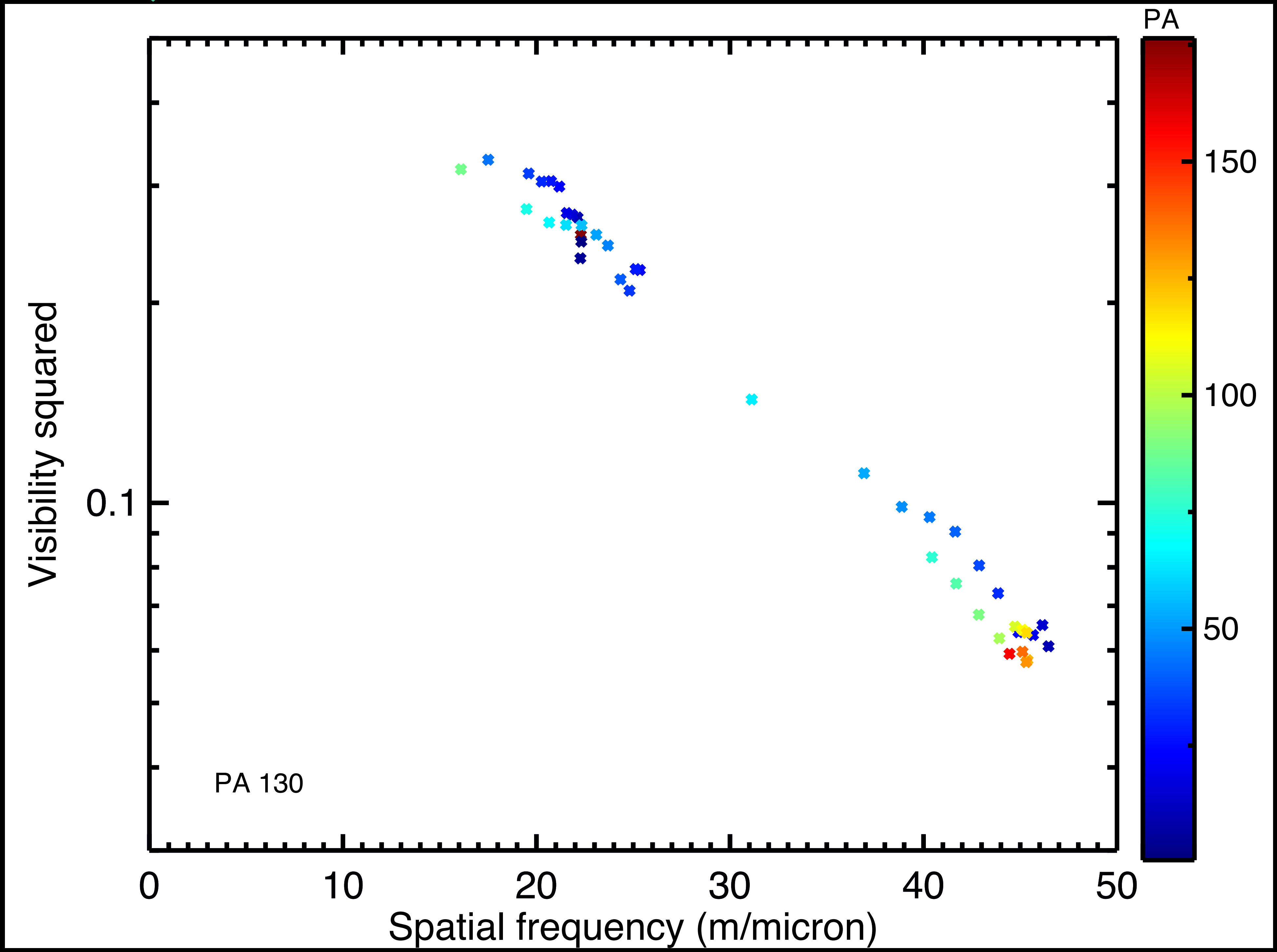
(Groh et al. 2010a)



Rotation as seen by PIONIER

Data taken by O. Absil on 2012 Mar (close to apastron) at 1.875 micron

Variation of visibility as a function of PA



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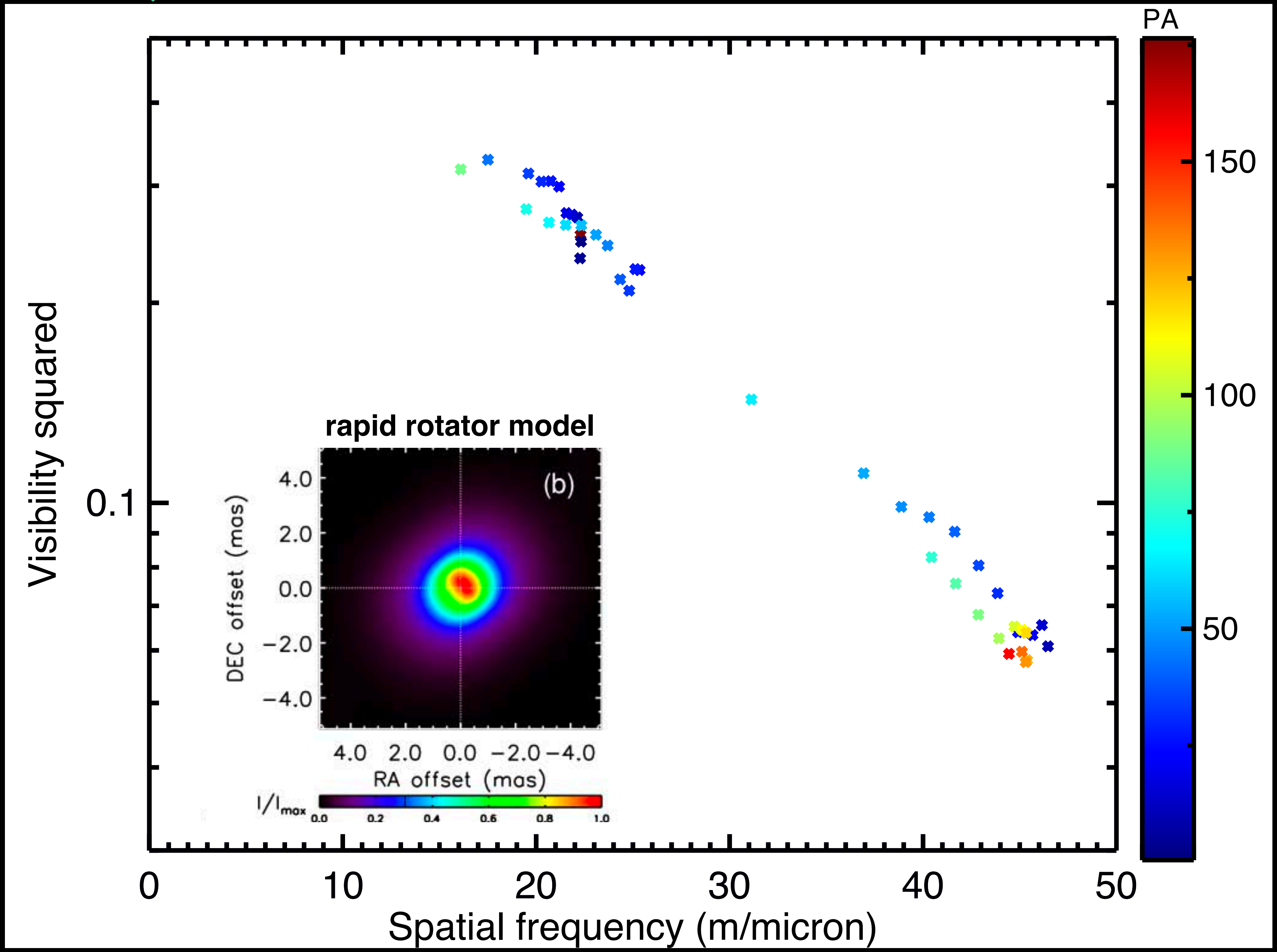
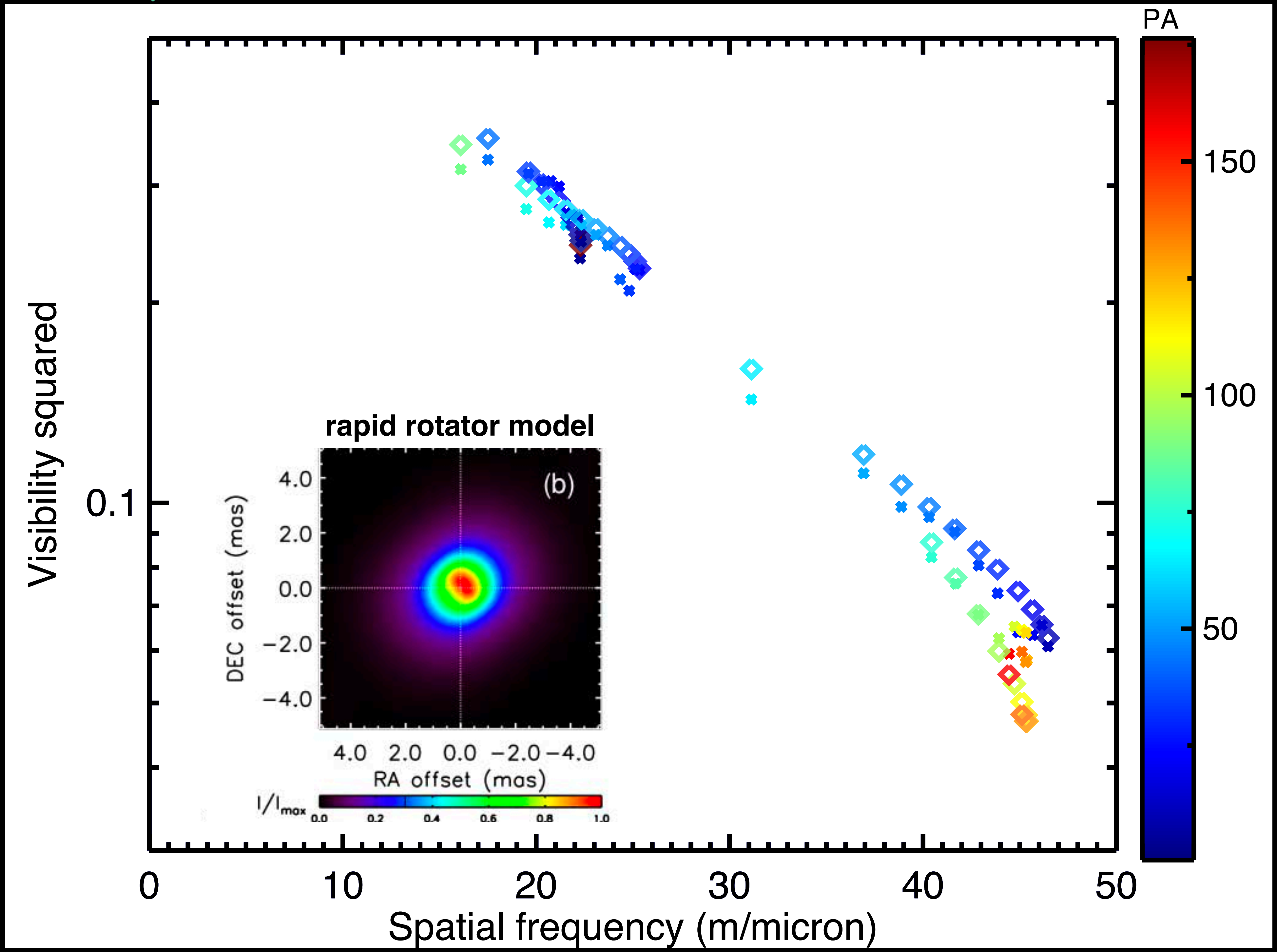


PIONIER data reveals a rapid rotator

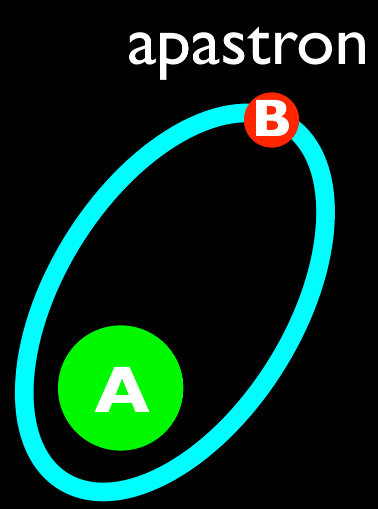
Data taken by O. Absil on 2012 Mar -- only spectral channel 6 (1.875 micron)

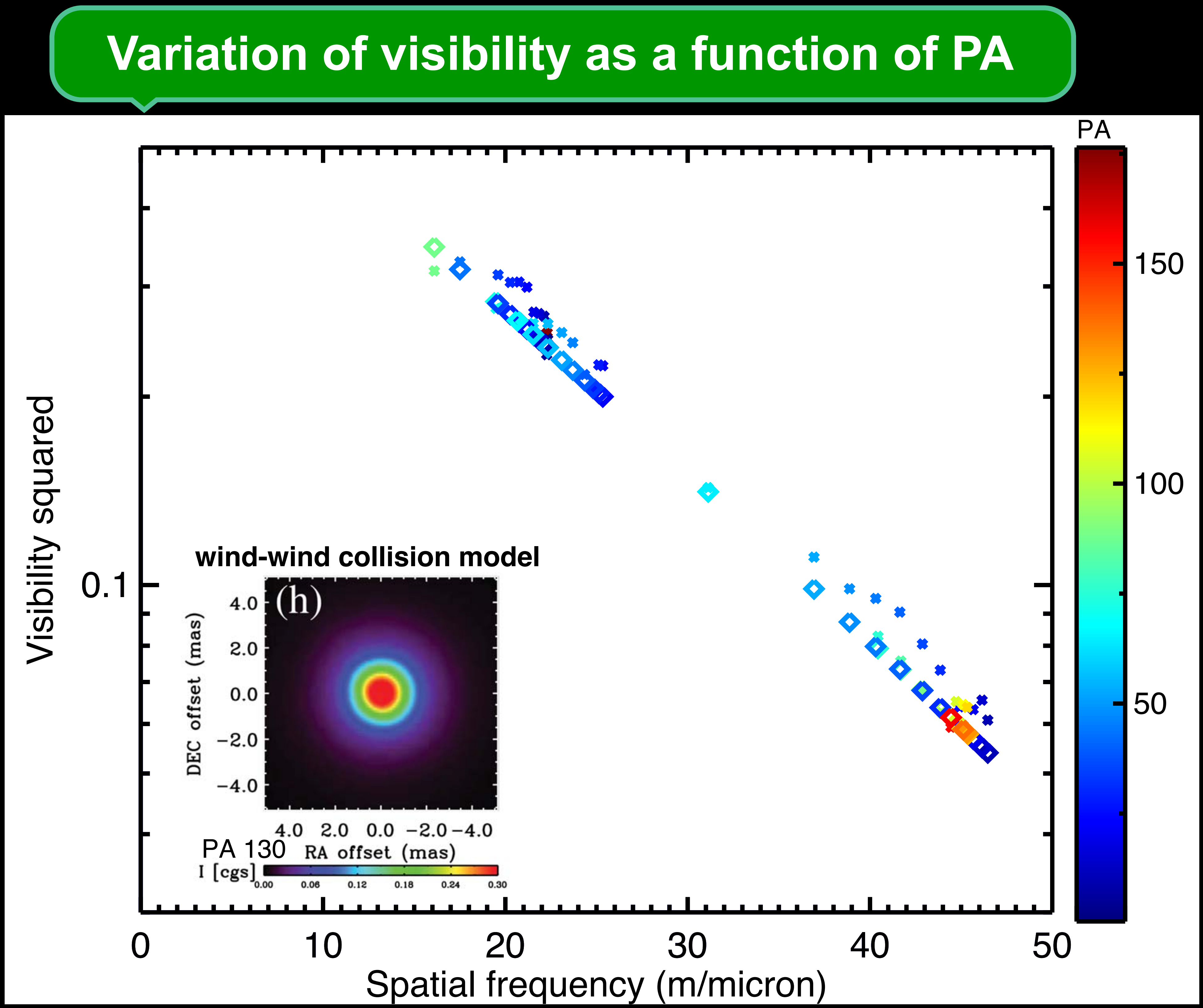
Variation of visibility as a function of PA



Binary effects not enough to fit PIONIER data

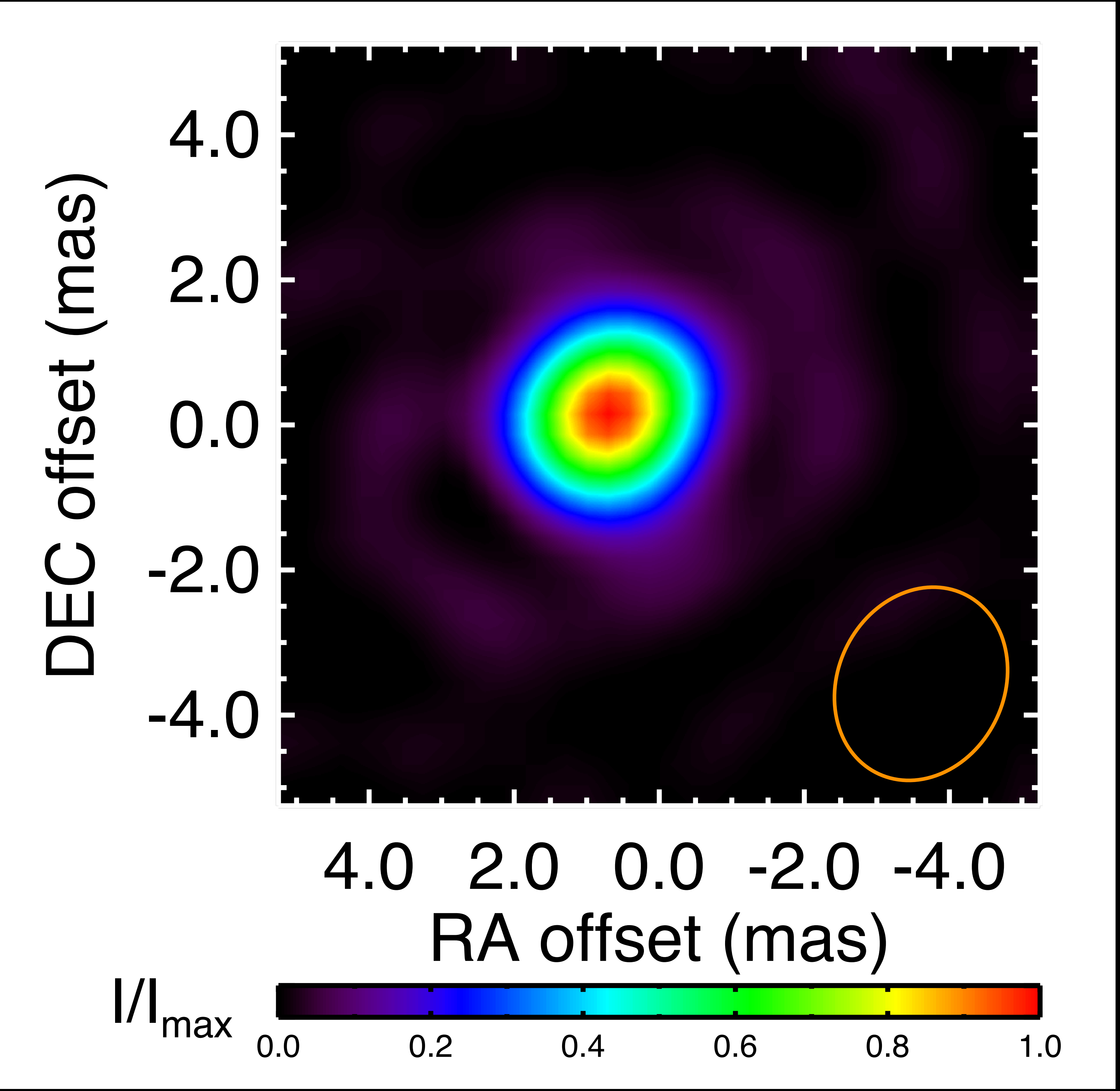
Data taken by O. Absil on 2012 Mar (close to apastron) at 1.875 micron





Preliminary image reconstruction: all data

by JB Le Bouquin



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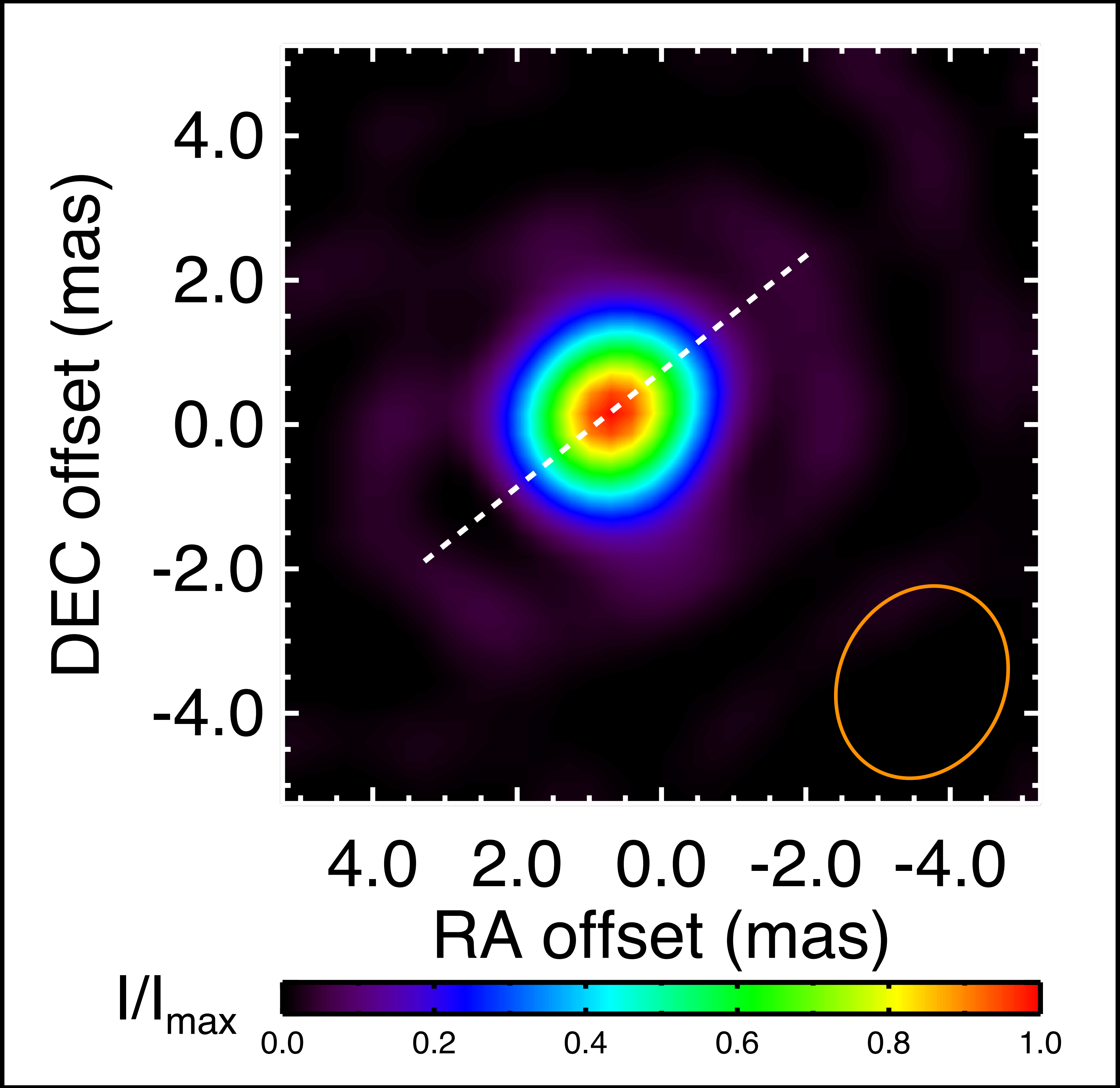
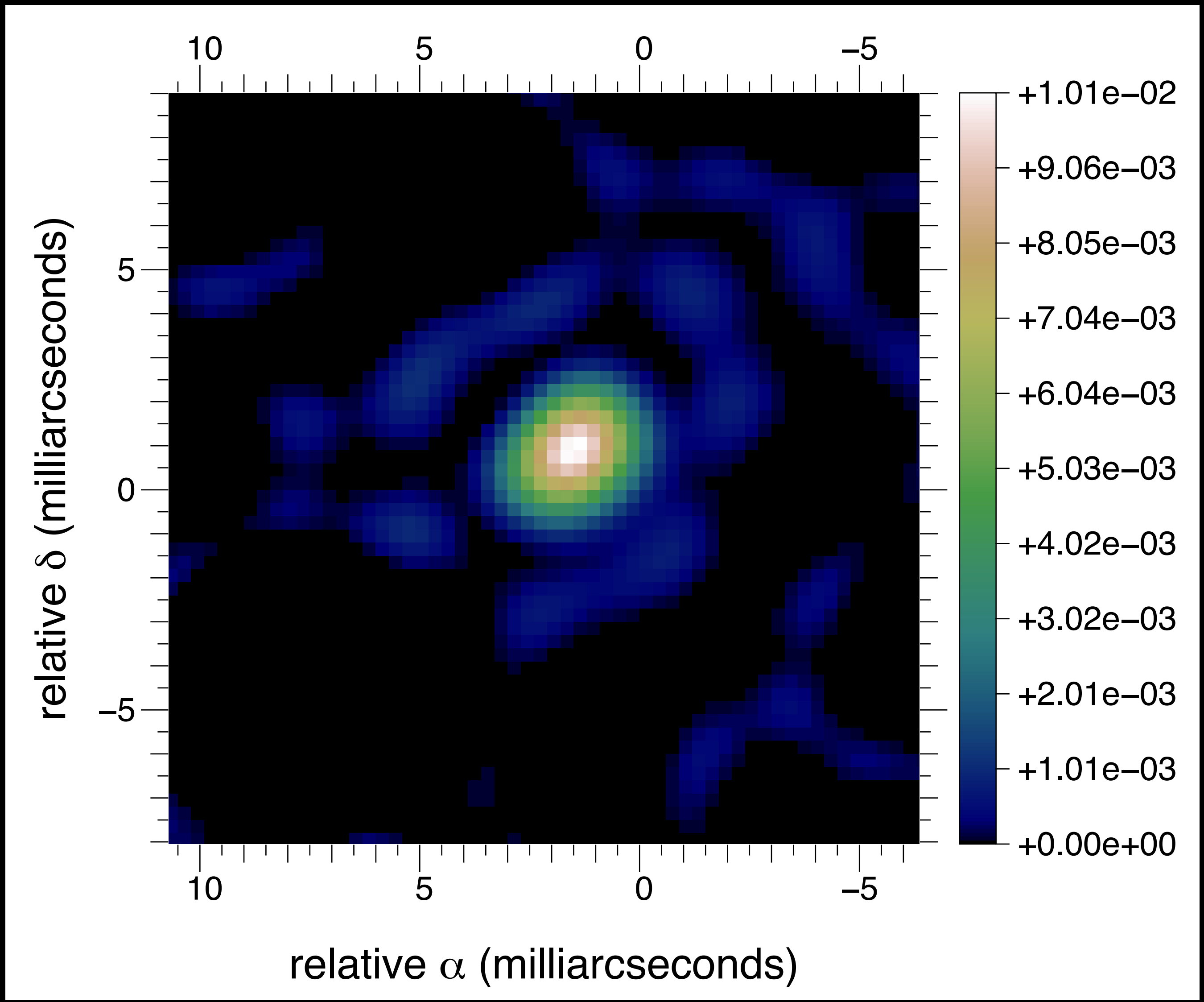


Preliminary image reconstruction: short+inter

by JB Le Bouquin

beam nearly circular



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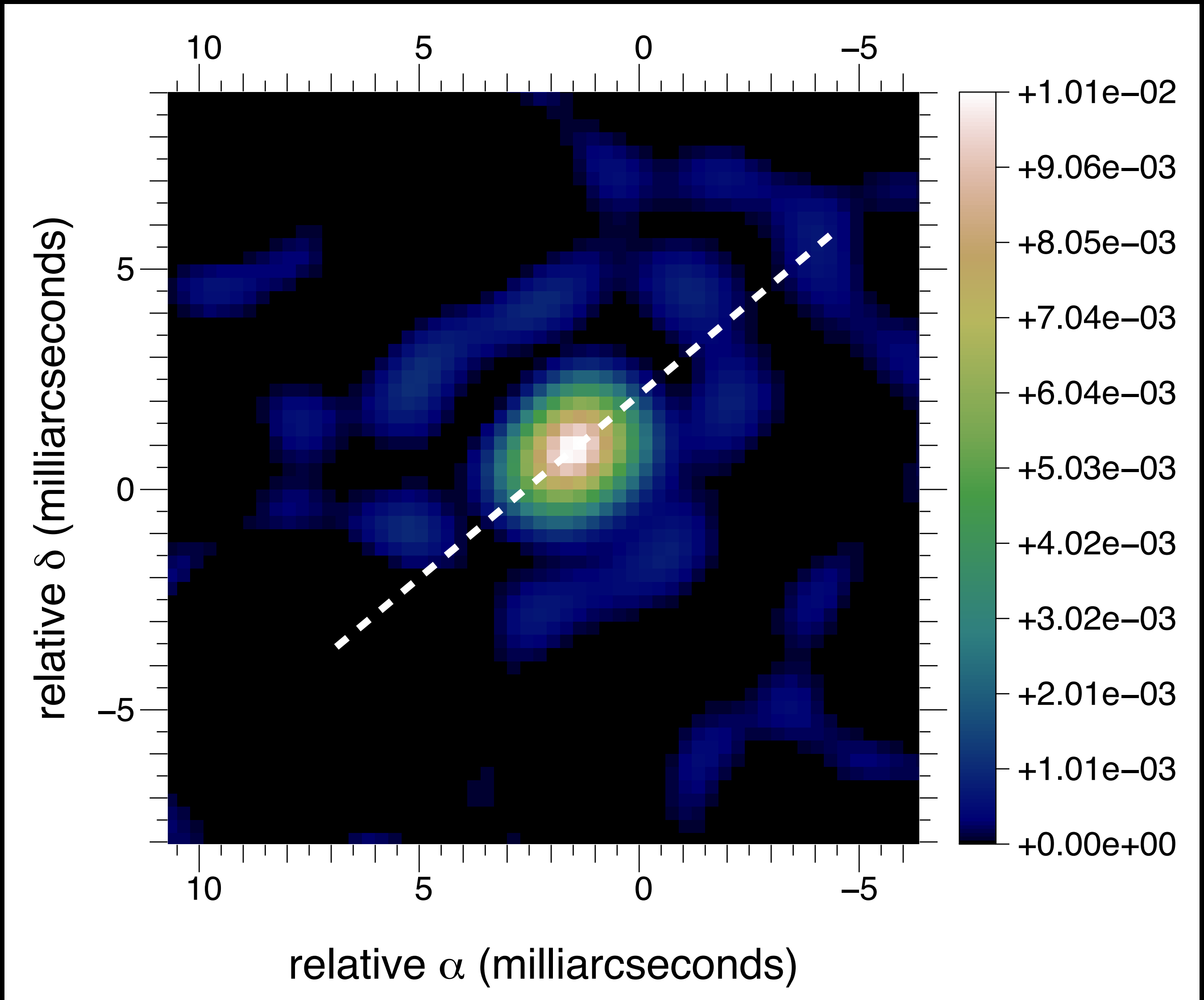
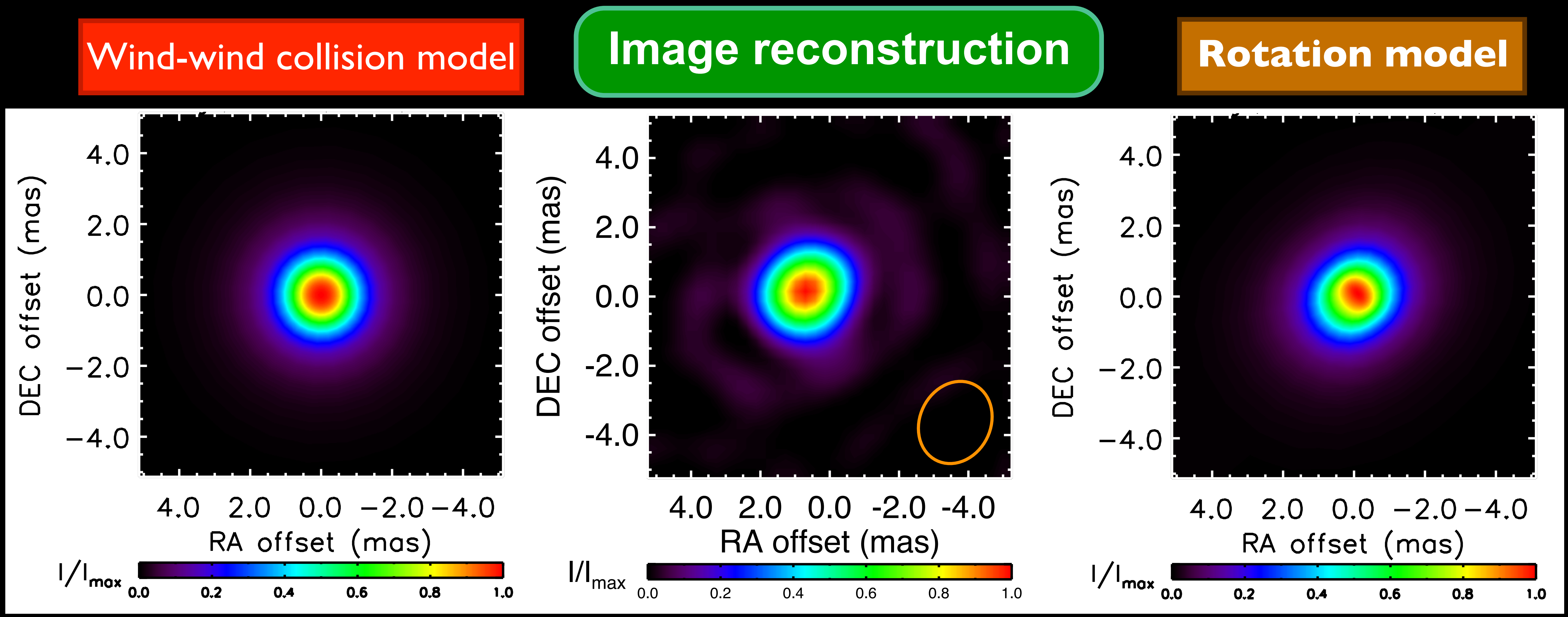
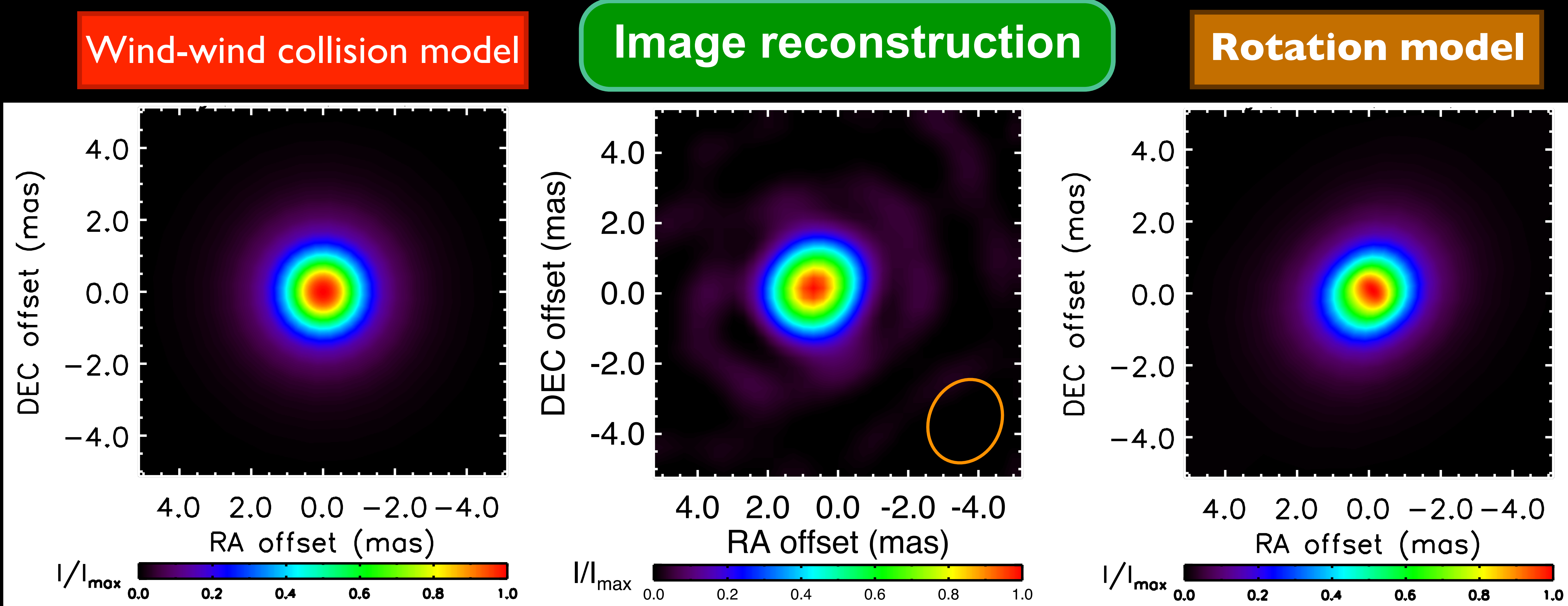


Preliminary image reconstruction



Preliminary image reconstruction



- no changes in Mdot over last 15 years;
- rapidly-rotating primary star (~80% critical speed) seem at i~70-90deg (misaligned with Homunculus);
- no strong binary effects (WWC) around apastron.


IAU SYMPOSIUM 307
NEW WINDOWS ON MASSIVE STARS
ASTEROSEISMOLOGY, INTERFEROMETRY
AND SPECTROPOLARIMETRY
GENEVA • SWITZERLAND
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