The potential of the IR to constrain mass-loss rates in massive stars

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Beijing, 23-Aug-2012

Motivation

Address two fundamental problems related to mass-loss in massive stars:

- **Clumping**
- **Weak-winds**

Mass-loss diagnostics : Multiwavelength view

- **UV (PV, OIV-V, CIV)**
- **Optical (e.s.), Halpha**
- **IR + Radio continua**

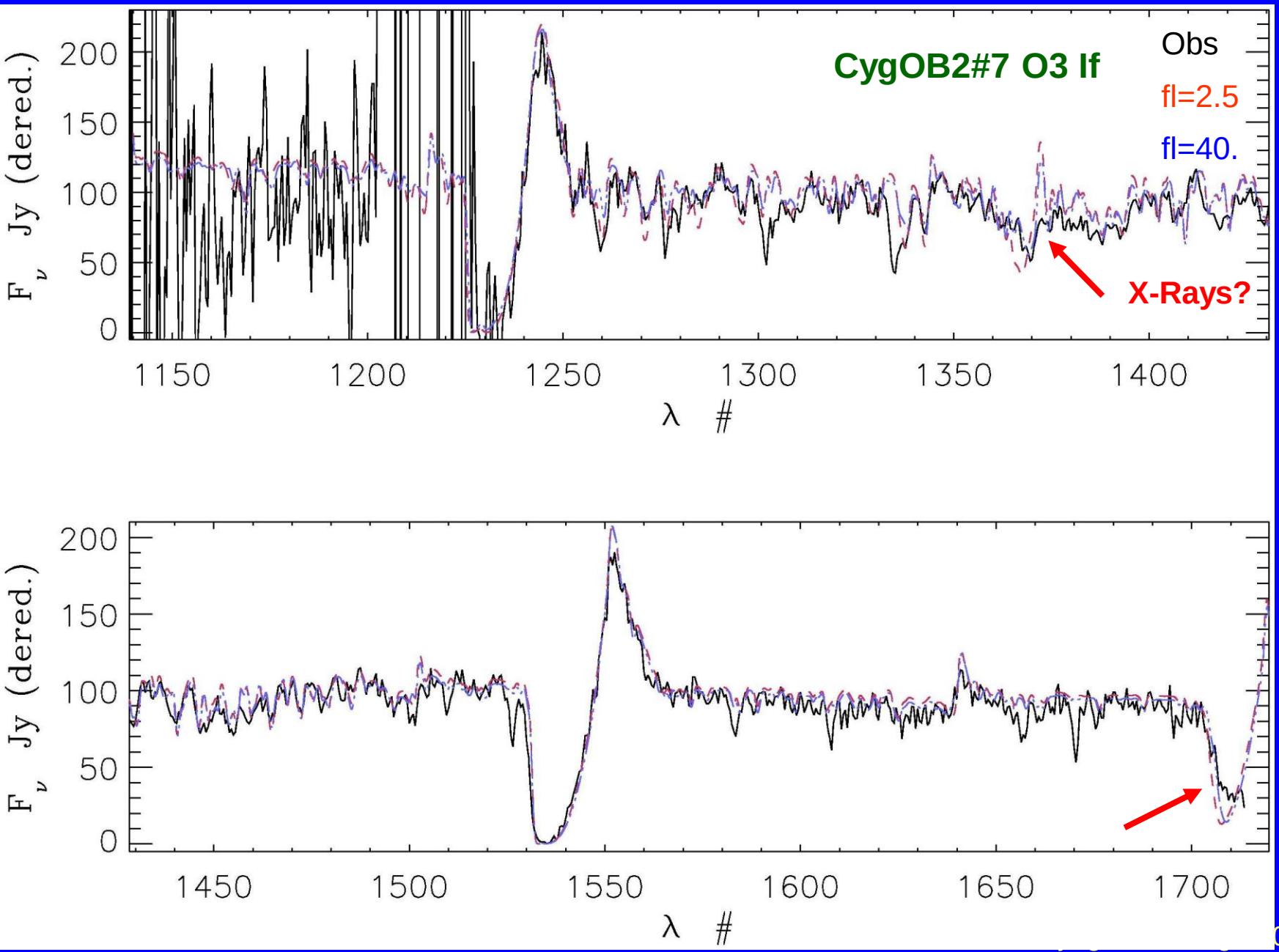
+

- **IR L+K Band spectroscopy**

Potential of IR spectroscopy for Mdot estimates:

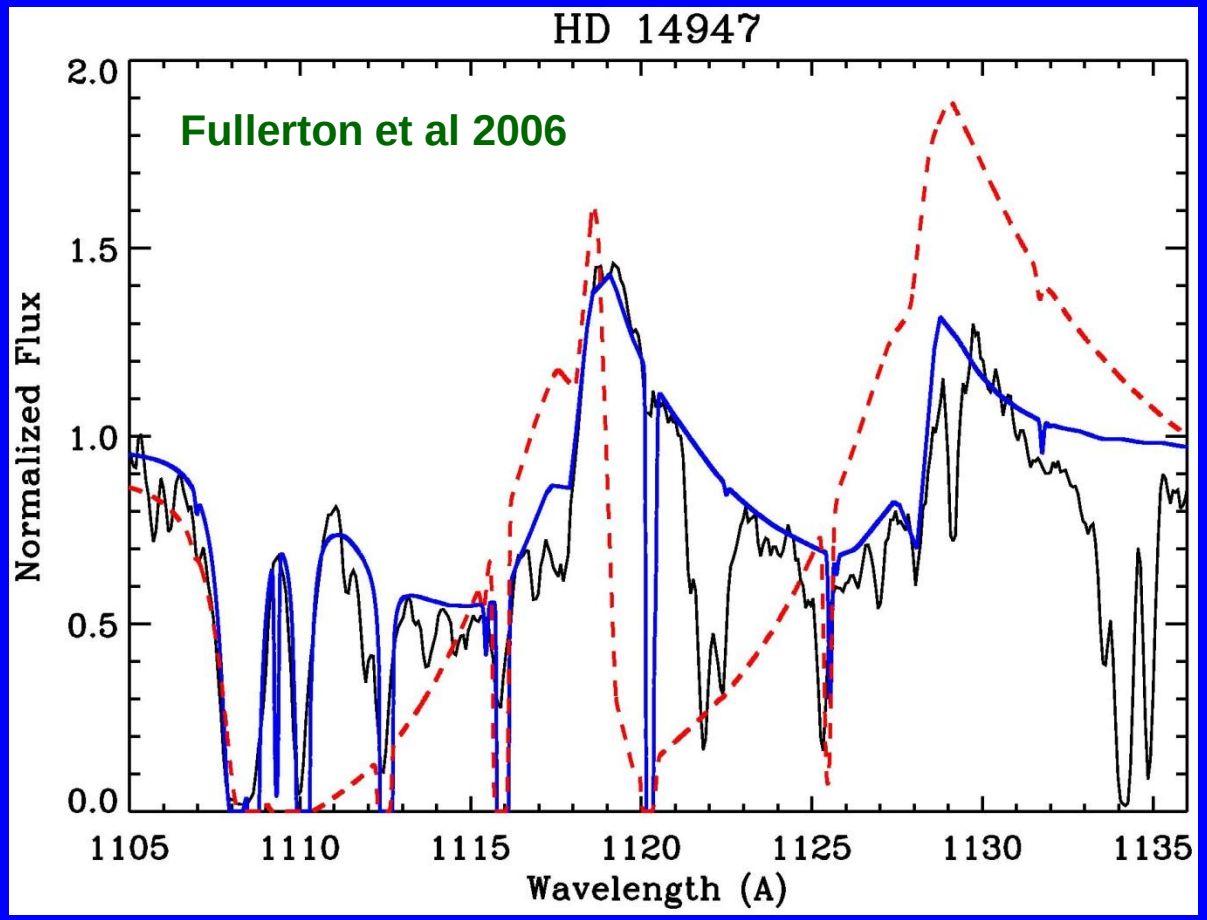
- **Dense winds ➔ Mdot + clumping**
- **Weak winds ➔ Mdot**

Mdot from UV: Clumping ?



Mdot from UV: Clumping

DENSE WINDS



<q> Mdot

Unsaturated PV:

Mdot ⬇ factor 10!!

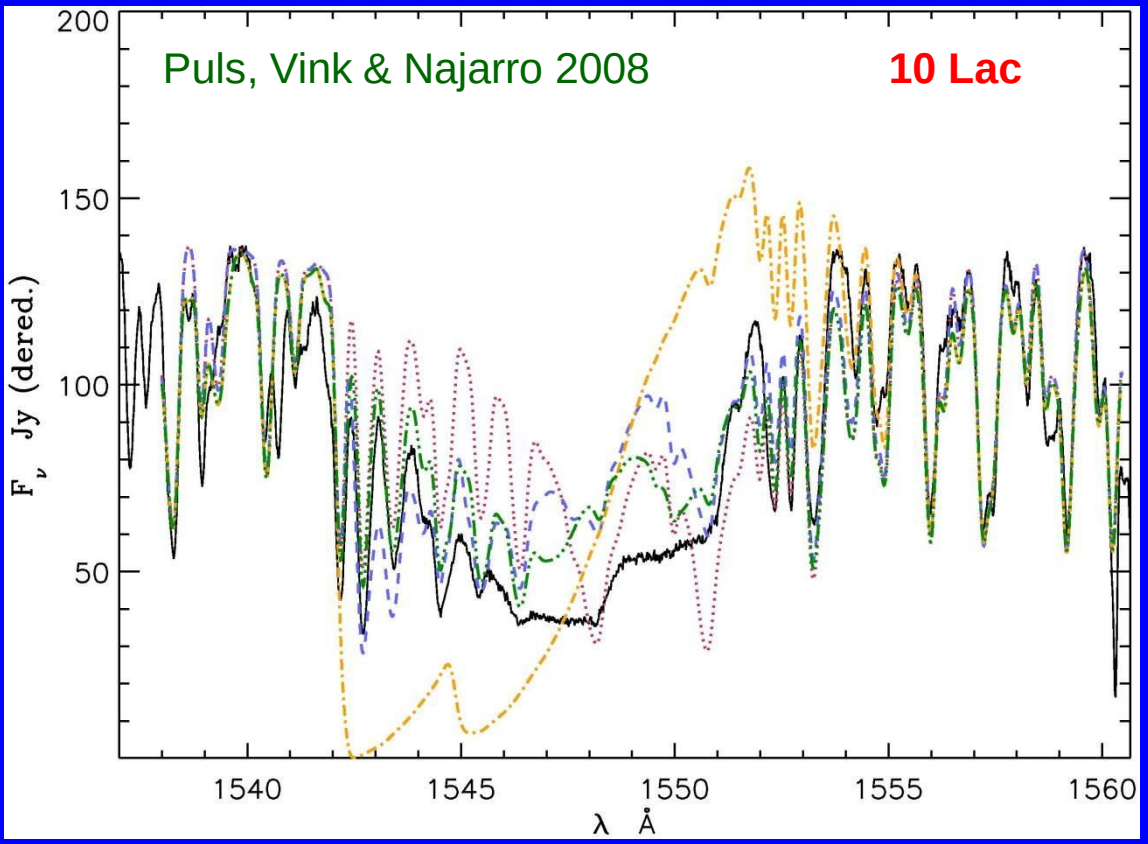
BUT

Macroclumping

(Oskinova et al 07, Sundqvist 2010,11)

Mdot from UV

WEAK WINDS



Very low Mdot for Log L/Lsun < 5.3

BUT

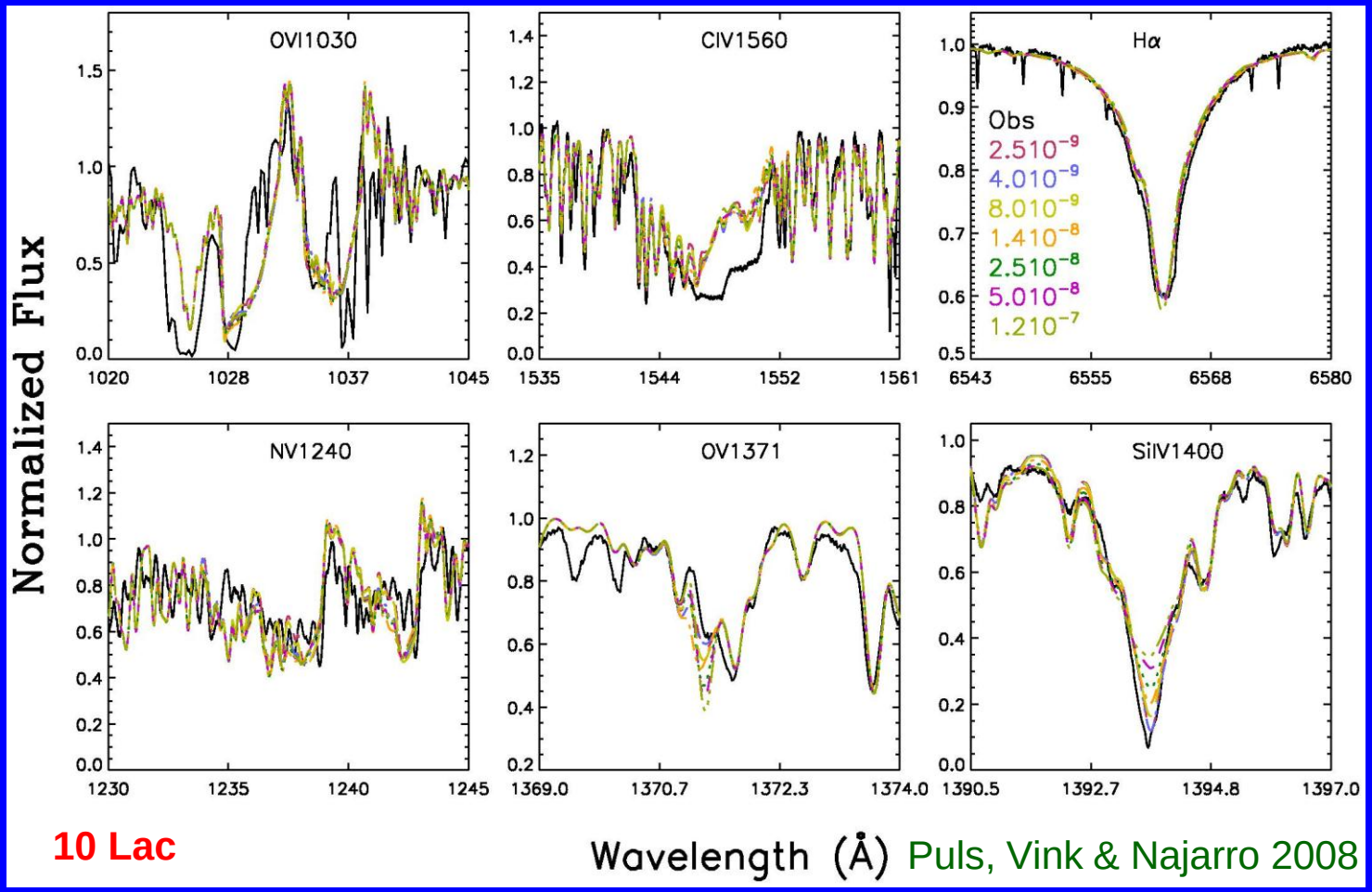
X-Rays

Mdot - Xray degeneracy

Mdot from UV

WEAK WINDS

X-Rays - Mdot degeneracy over 2 dex!!

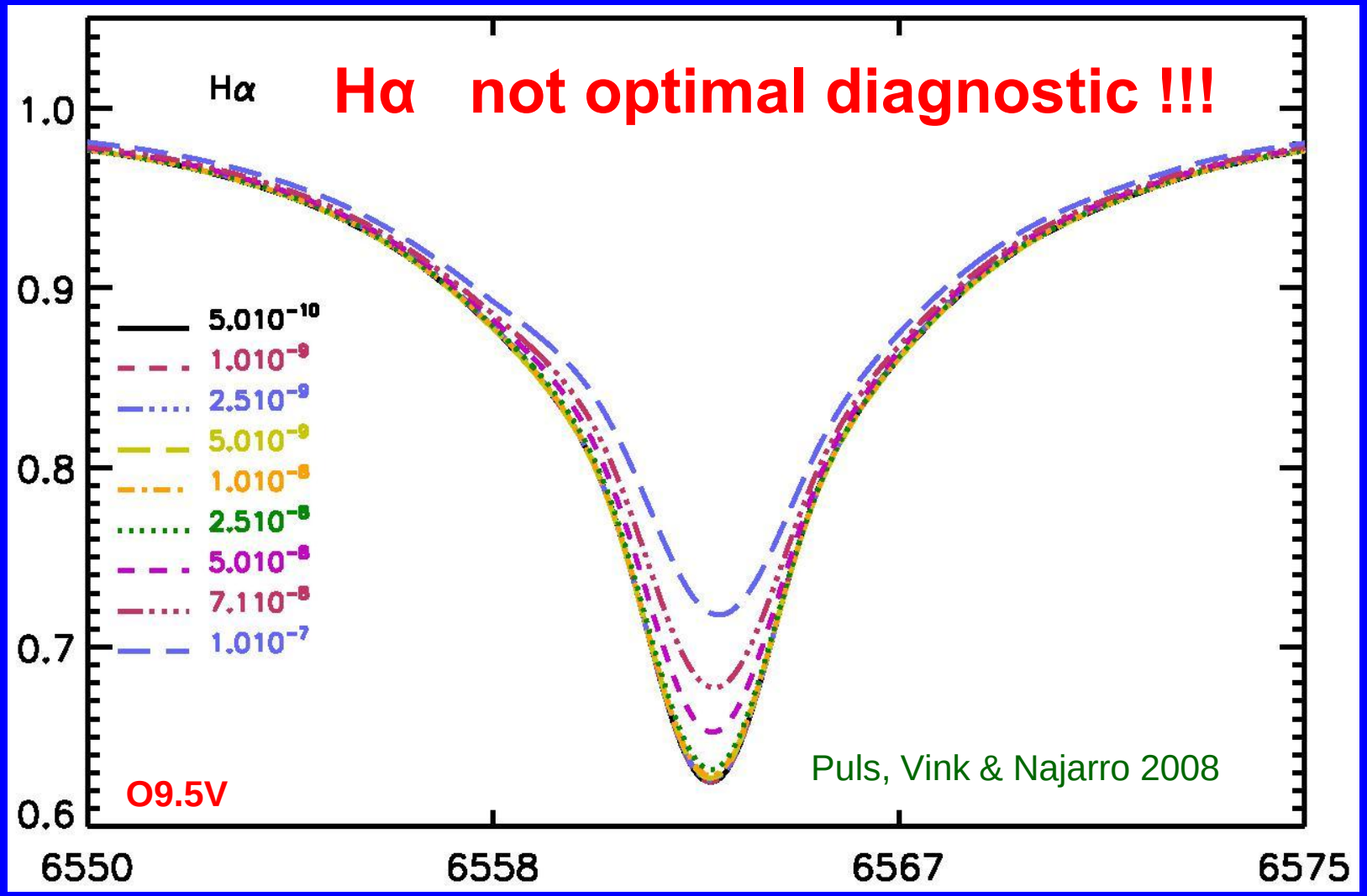


10 Lac

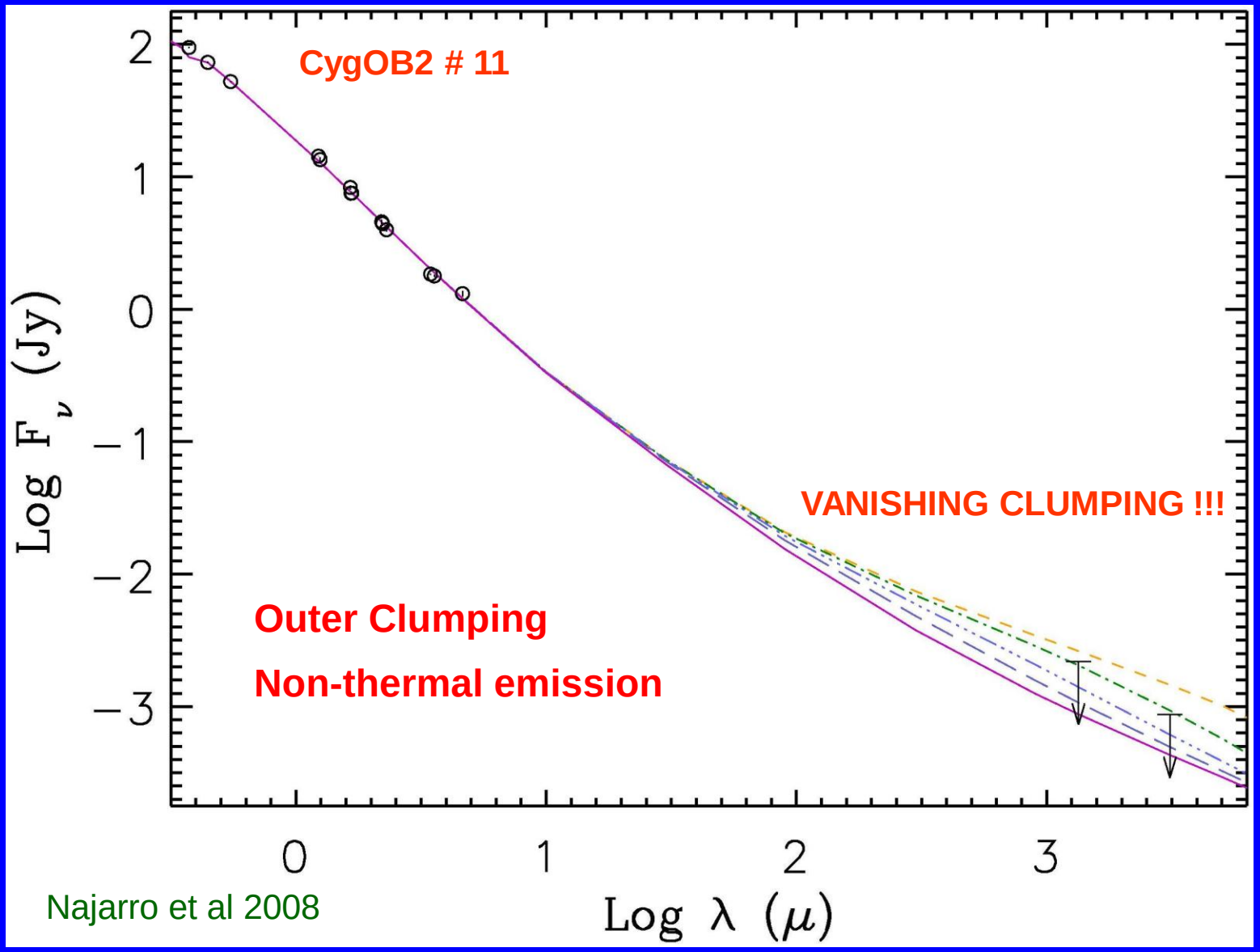
Puls, Vink & Najarro 2008

Mdot from OPTICAL

WEAK WINDS



Mdot from IR – RADIO : CLUMPING



Najarro et al 2008

Potential of IR Lines to constrain Mdot

Auer & Mihalas (1969), Mihalas (1978):

NLTE- effects amplified in the IR in hot stars (hν/kT < 1)

$$S_L / B_\nu \approx (1 + \delta/(h\nu/kT))^{-1}, \qquad \delta = b_l/b_u - 1$$

E.g. T=30000 K hν/kT =0.24 at Bγ and 0.11 at Bα

Bα bl/bu=0.95 SL/Bν =1.83

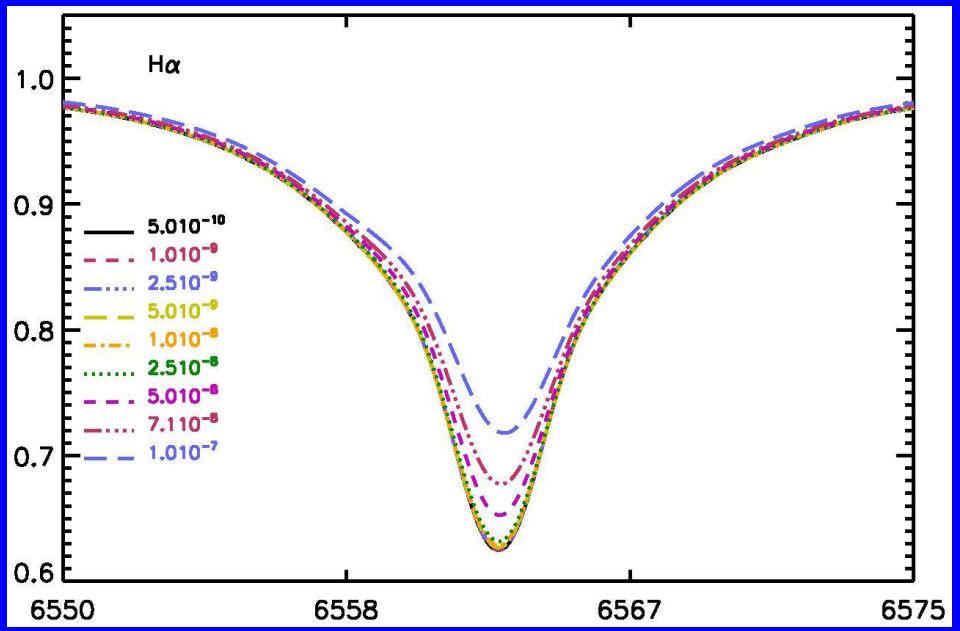
Bα bl/bu=0.90 SL/Bν =11

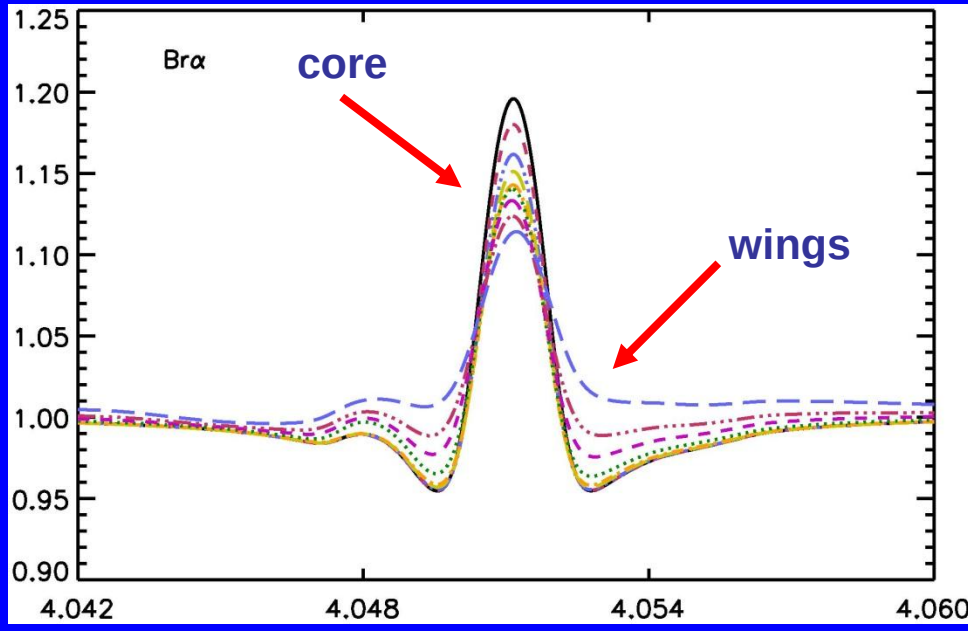
Thin winds ➔ n=4 depopulation at line core.

Very high sensitivity ➔ valuable diagnostics for Mdot

Potential of IR Lines to constrain Mdot

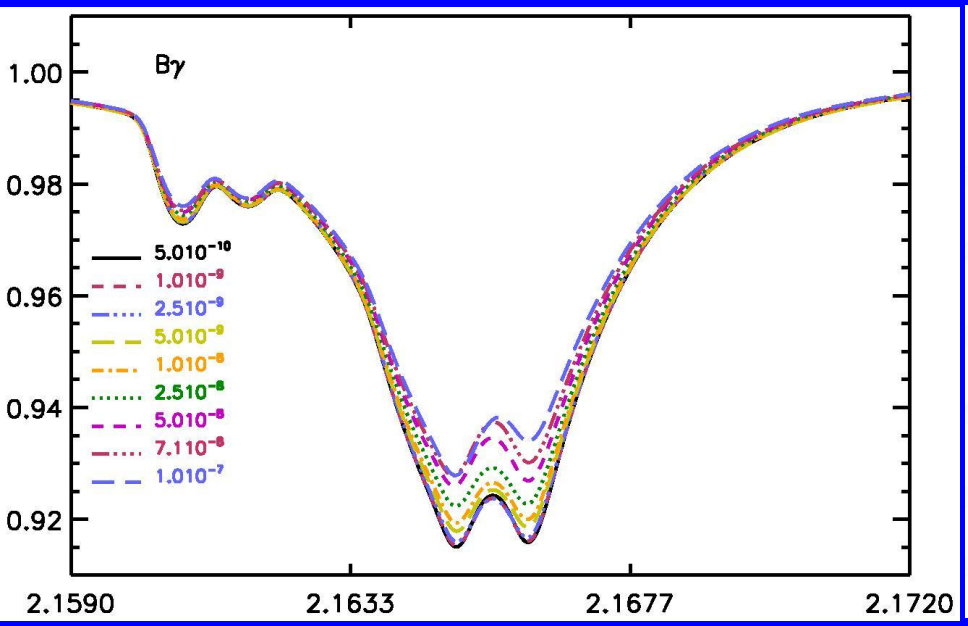
WEAK WINDS

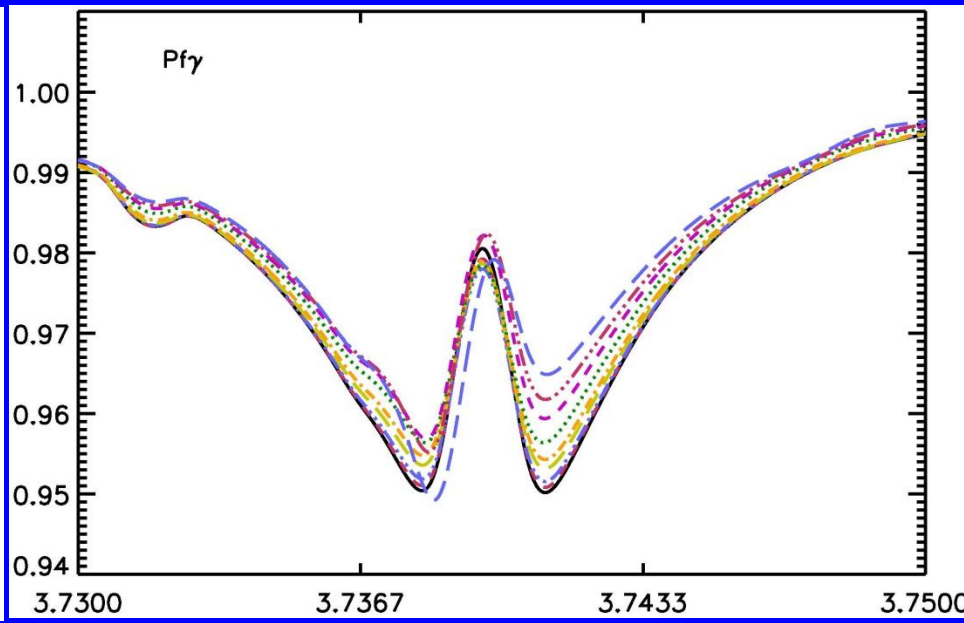




Potential of IR Lines to constrain Mdot

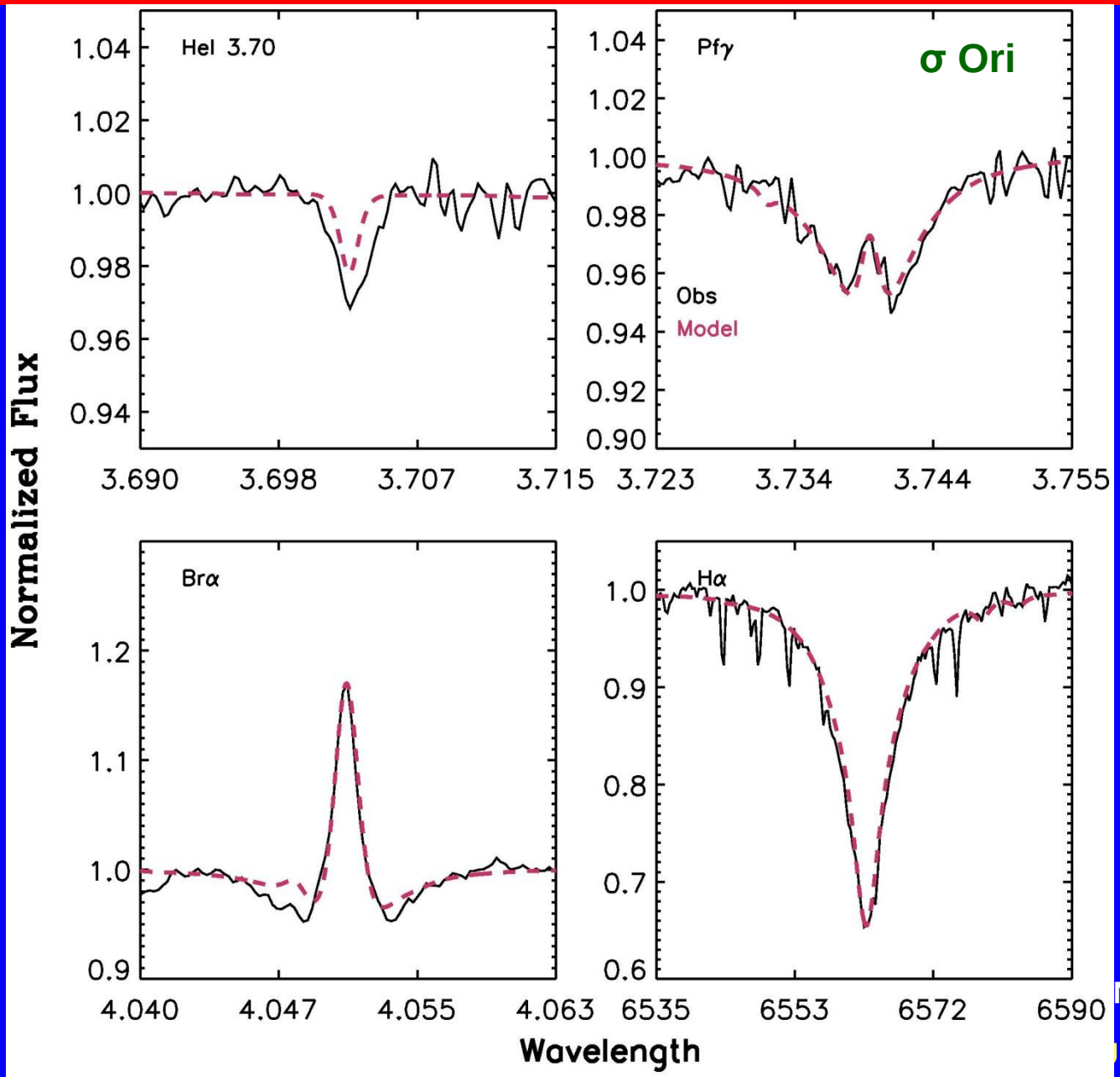
WEAK WINDS





L-Band lines provide reliable constraints on Mdot

Potential of IR Lines to constrain Mdot



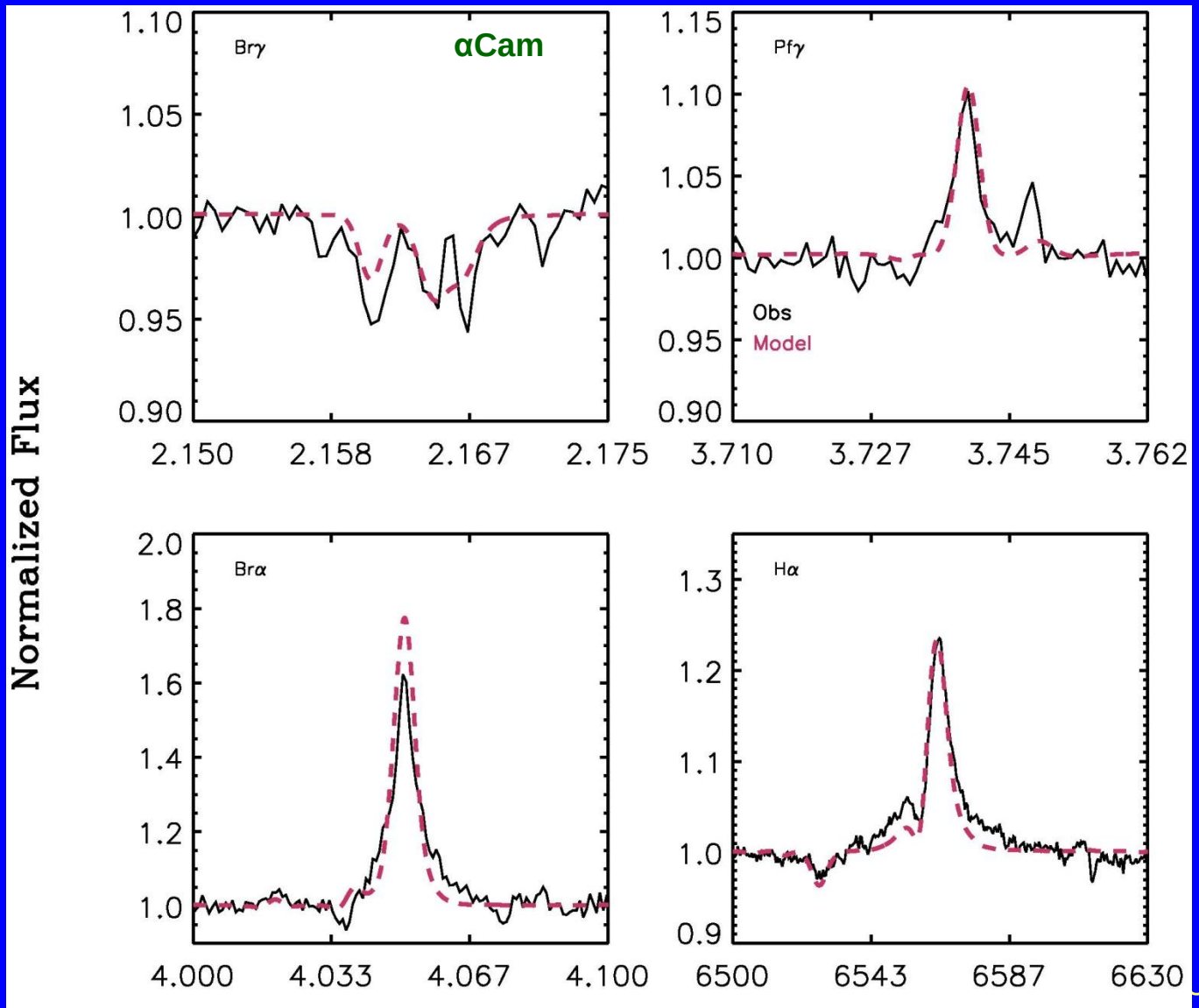
σ Ori O9.5V

Ṁ=2d-10 Msun/yr !

Najarro, Hanson & Puls 2011

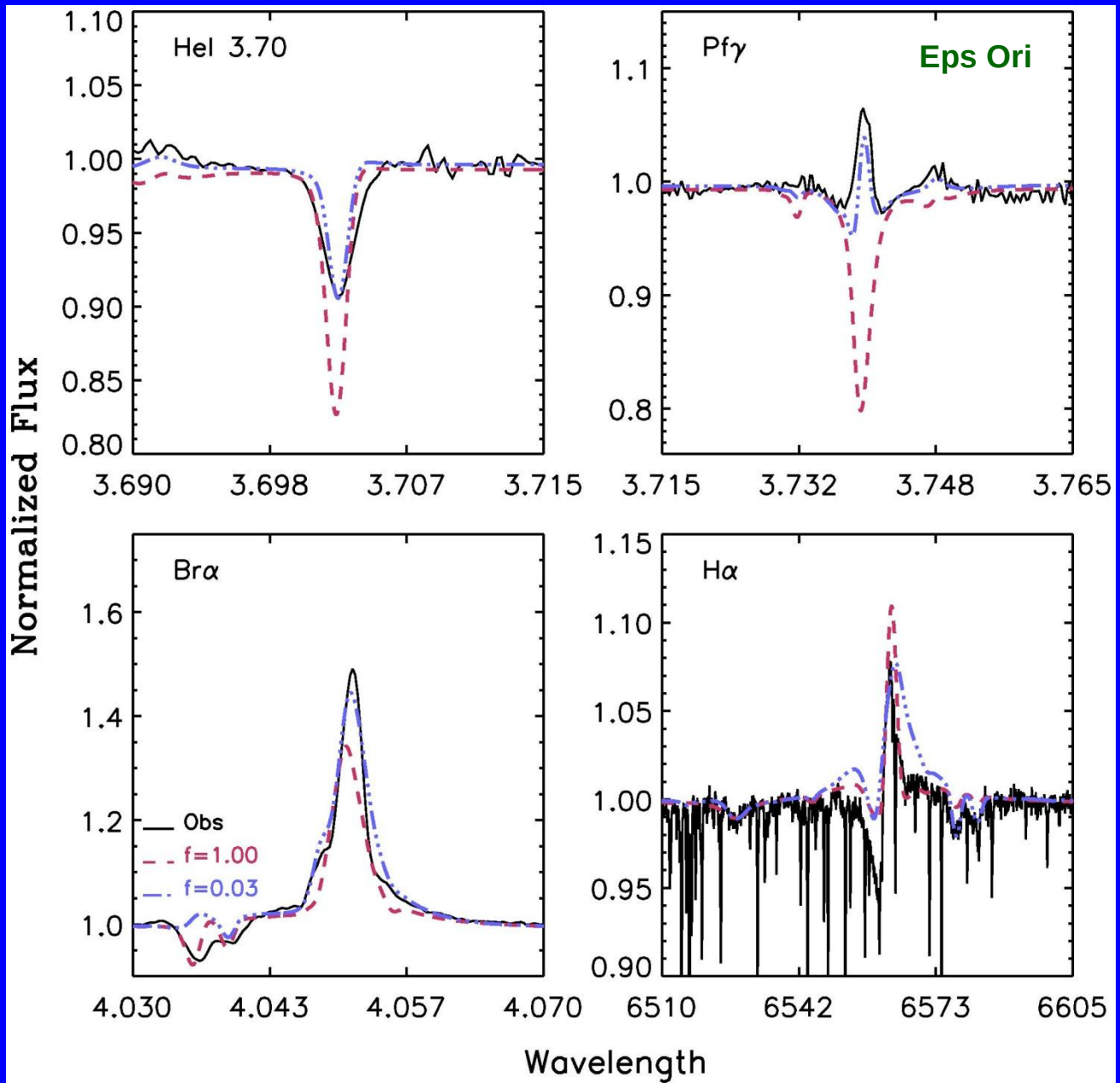
Potential of IR Lines to constrain Mdot

DENSE WINDS



Najarro, Hanson & Puls 2011

Potential of IR Lines to constrain Mdot

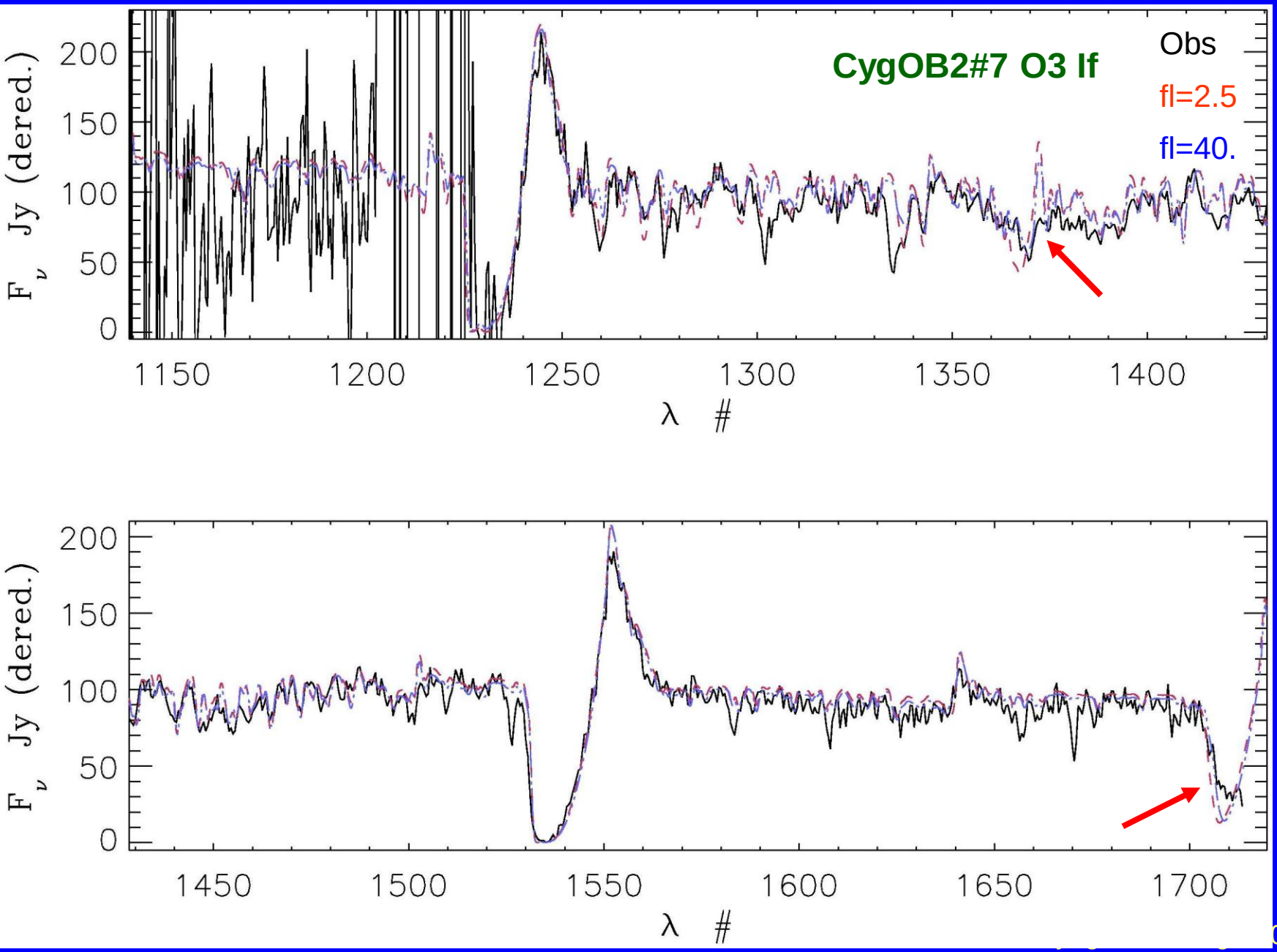


DENSE WINDS

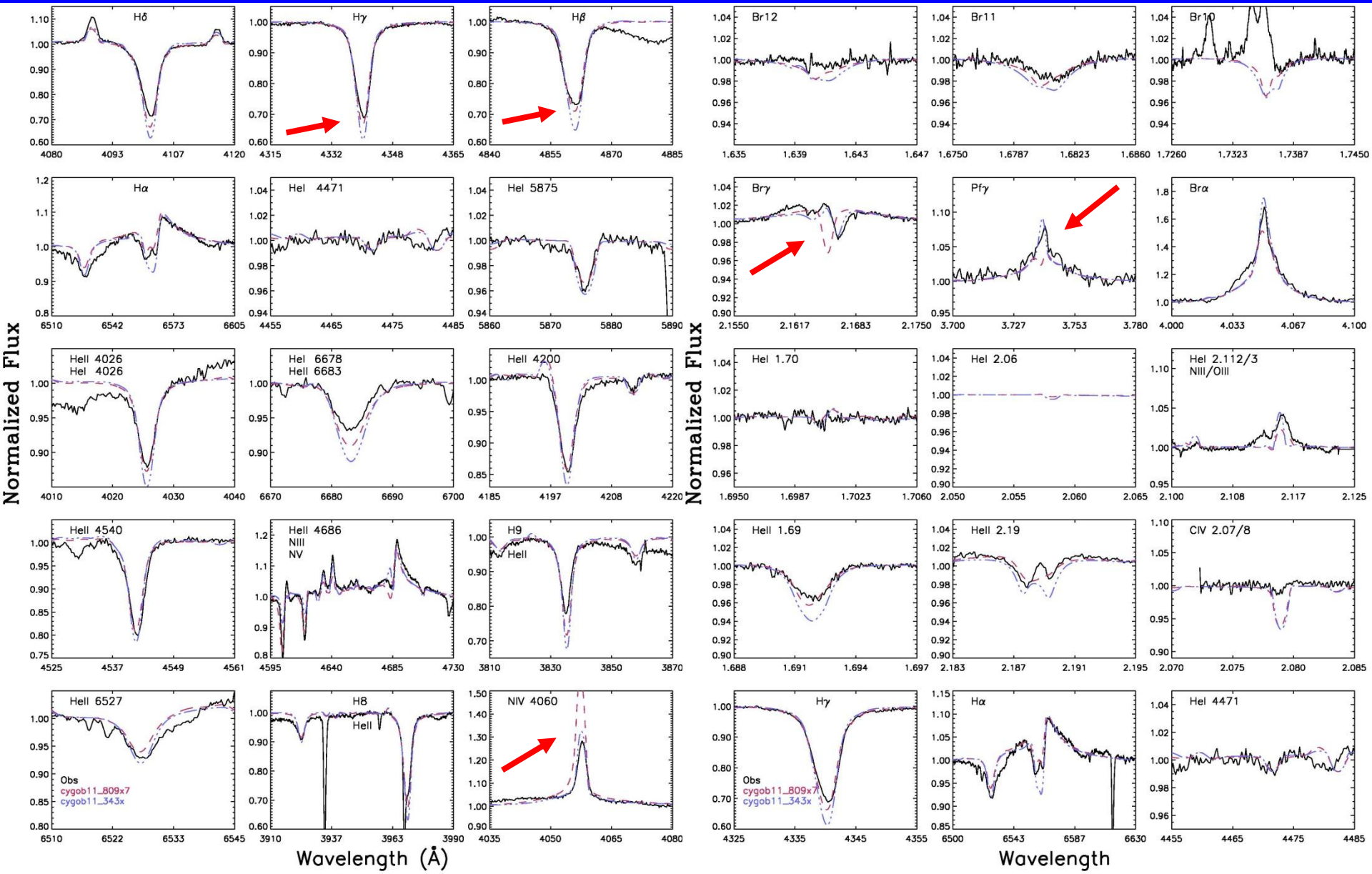
CLUMPING

Najarro, Hanson & Puls 2011

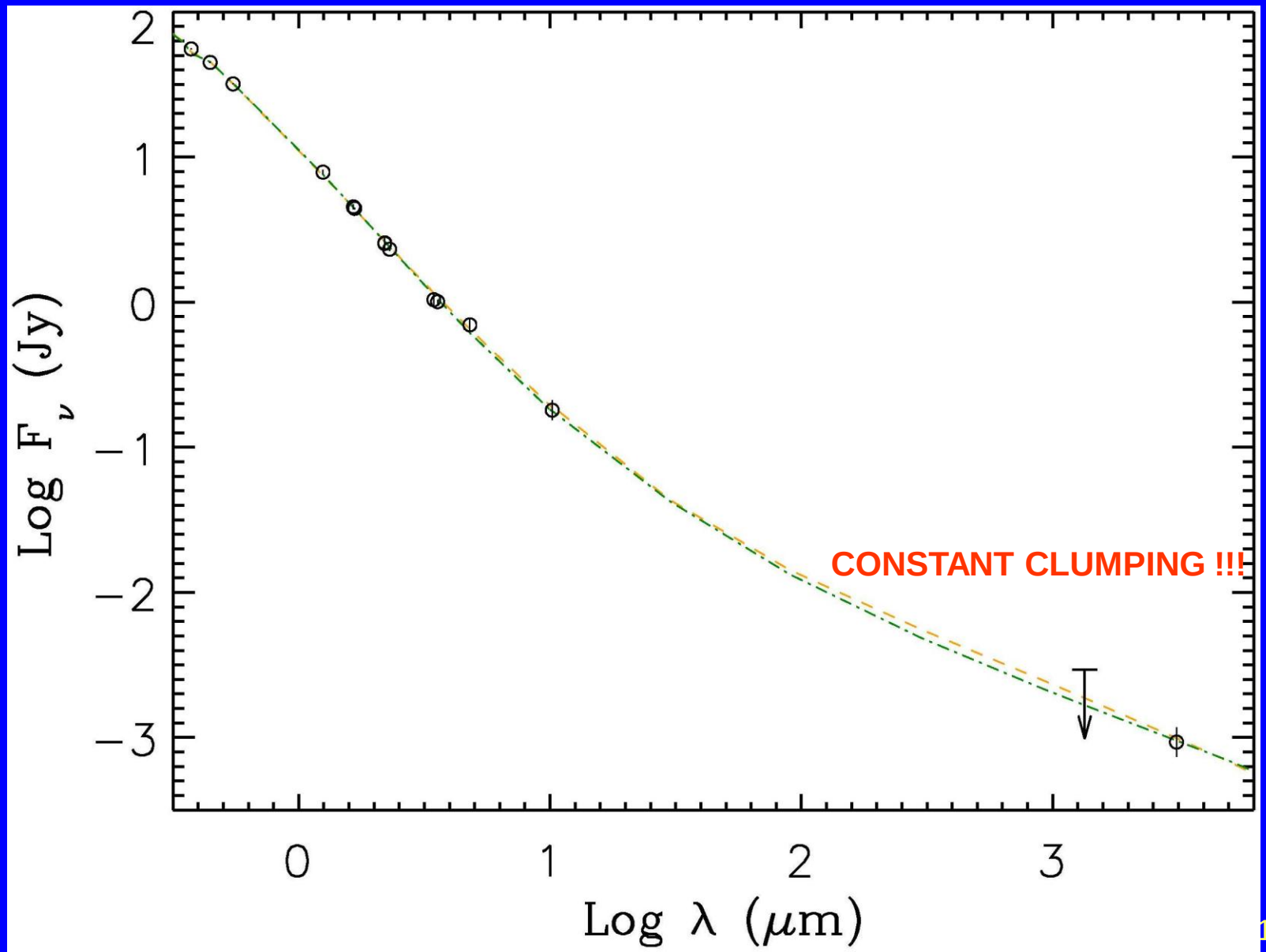
Multi-wavelength study: CygOB2 #7



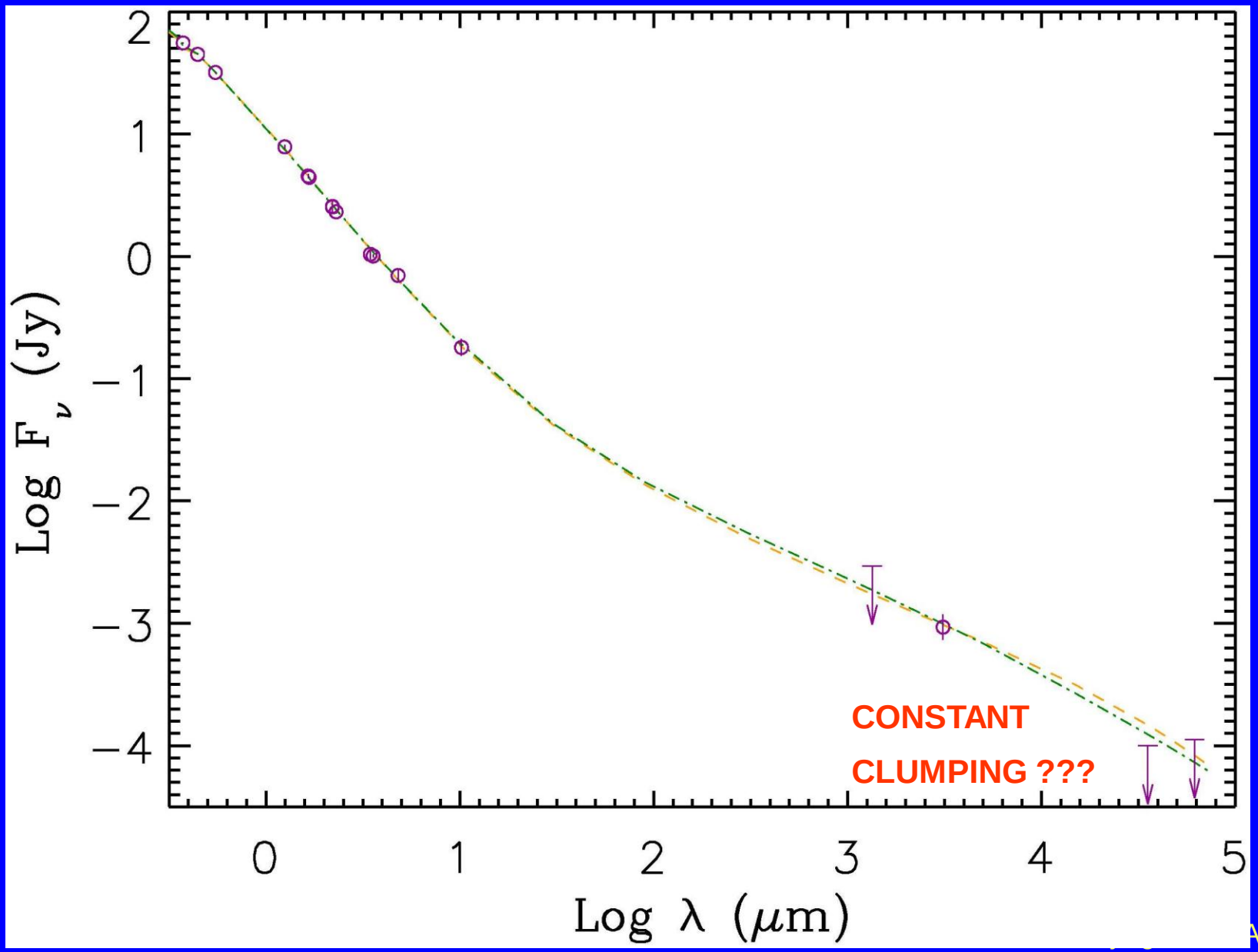
Multi-wavelength study: CygOB2 #7



Multi-wavelength study: CygOB2 #7

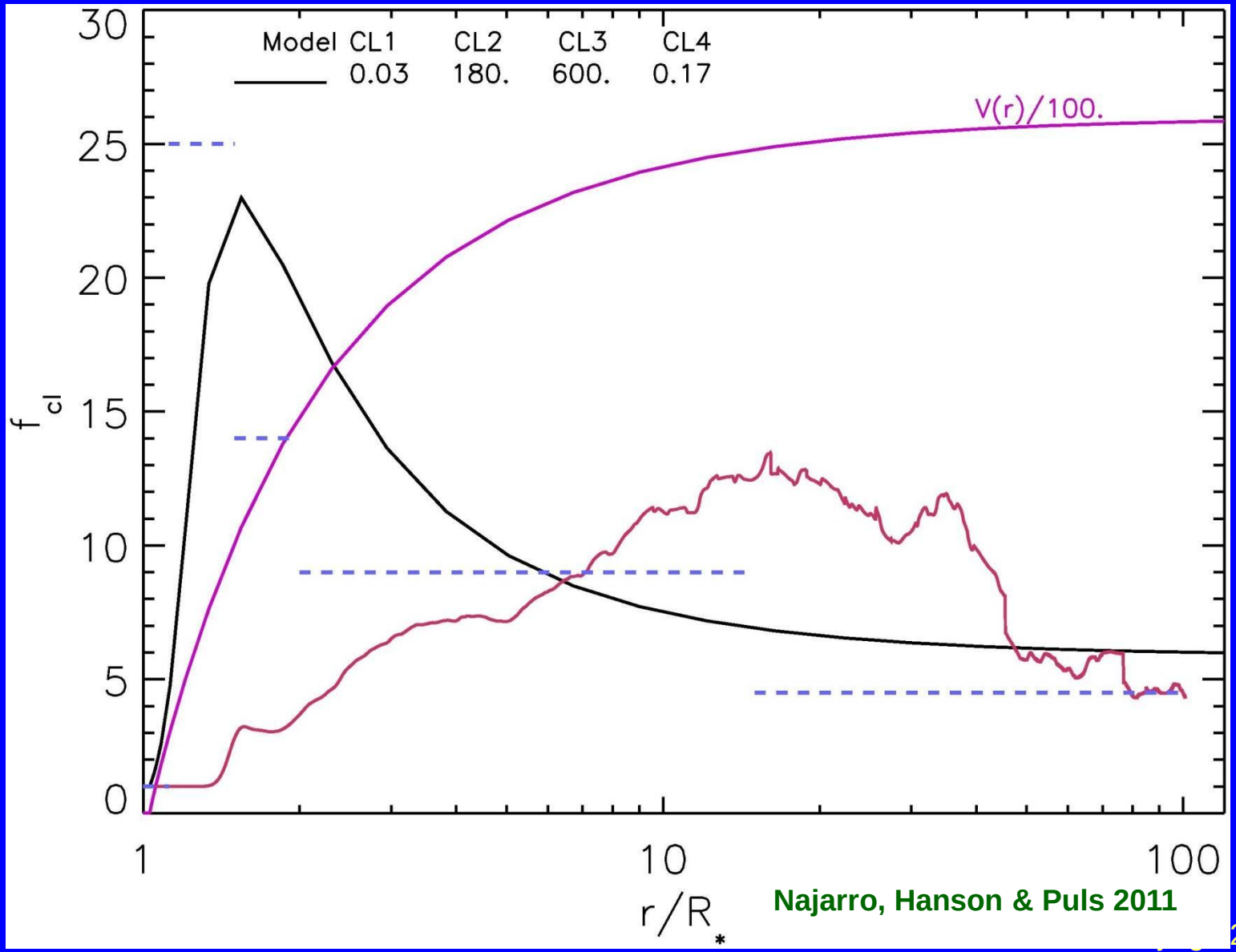


Constant Clumping?



CygOB2 7

Multi-wavelength results: Clumping structure of Zeta Puppis



Najarro, Hanson & Puls 2011

Conclusions

Potential of L-Band spectroscopy for $\dot{M}$ estimates:

- **Dense Winds:**
  - **Bα → intermediate wind**
  - **Pfγ → inner wind**
  - **When combined with other indicators (multiwavelength studies) → wind clumping structure**

- **Weak Winds:**
  - **Bα → reliable diagnostic tool to constrain $\dot{M}$**
  - **Strong reaction of the emission core to low $\dot{M}$ values**
  - **Wings behavior similar to Hα core**

Bα → primary diagnostic tool to measure very low mass-loss rates