Physical conditions in disks and winds around Herbig Ae/Be stars from high-resolution, wide band NIR spectroscopy with GIANO

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The accretion/outflow connection in young stellar objects – Noordwijk, October 27-29 2015

GIANO in a nutshell

- **GIANO is a NIR high-resolution spectrograph mounted at the Nasmyth A focus of the 3.58-m Telescopio Nazionale Galileo (La Palma, Canary Islands)**
- Provides cross-dispersed echelle spectroscopy at a resolution R∼50000 over the 0.95-2.45 μm range in a single exposure
- Almost complete coverage up to 1.72 μm, a few narrow intervals missing above this wavelength (including Brγ …)
- 2 optical fibres (1 arcsec diameter on sky) 3 arcsec apart
- 49 orders
- JHK < 10 (but z<15 for guiding camera)

Three young stars observed during commissioning night of July 30, 2013

Herbig Be star HD200775 (a.k.a. MWC 361)

- **B3 star, 5-15x10^3 $L_\odot$**
- **Double system: primary 10.7 $M_\odot$, secondary 9.3 $M_\odot$**
- **Distance 429 pc, Av 0 1.8 (Rv=3.1) – 3,0 (Rv=5.0)**

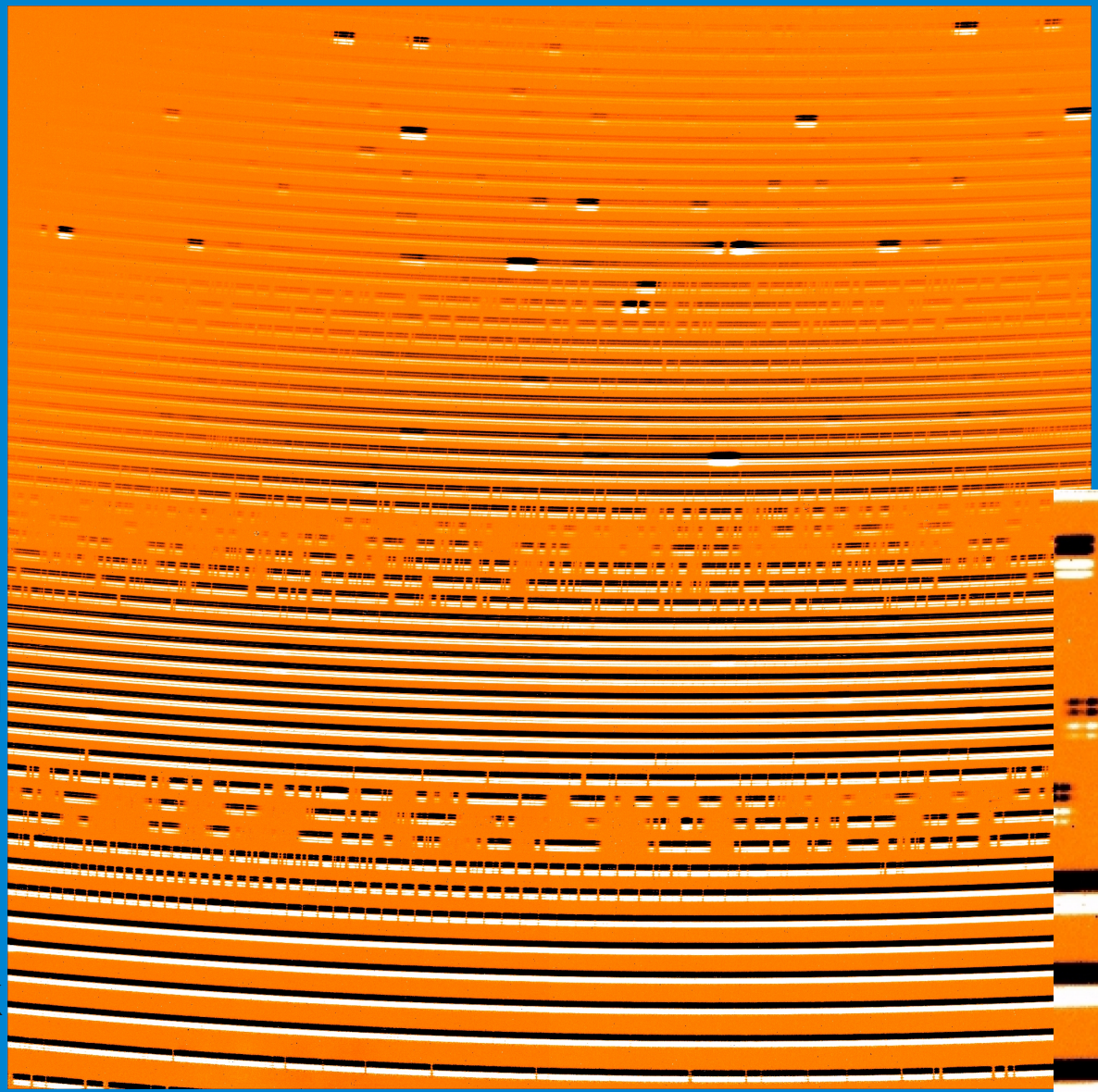
Be star V1478 Cyg (a.k.a. MWC349A)

- **B star, possible LBV, 3x10^4 $L_\odot$**
- **Mass 20 $M_\odot$**
- **Distance 1200 pc, Av = 10-10.7**

Herbig Ae star V1686 Cyg (a.k.a. LkHα 224)

- **B2-F9 star, 257 L**
- **Mass > 3.5 $M_\odot$**
- **Distance 980 pc, Av = 5.22 (Rv = 6,1)**

2D spectrum of V1478 Cyg



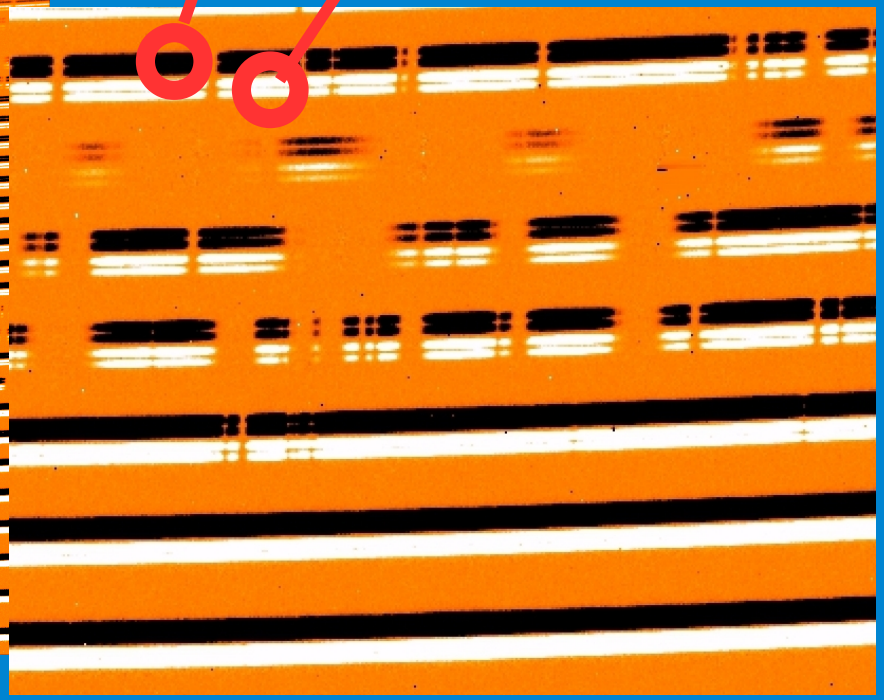
Nodding on fibres:

Star on fibre A, sky on fibre B

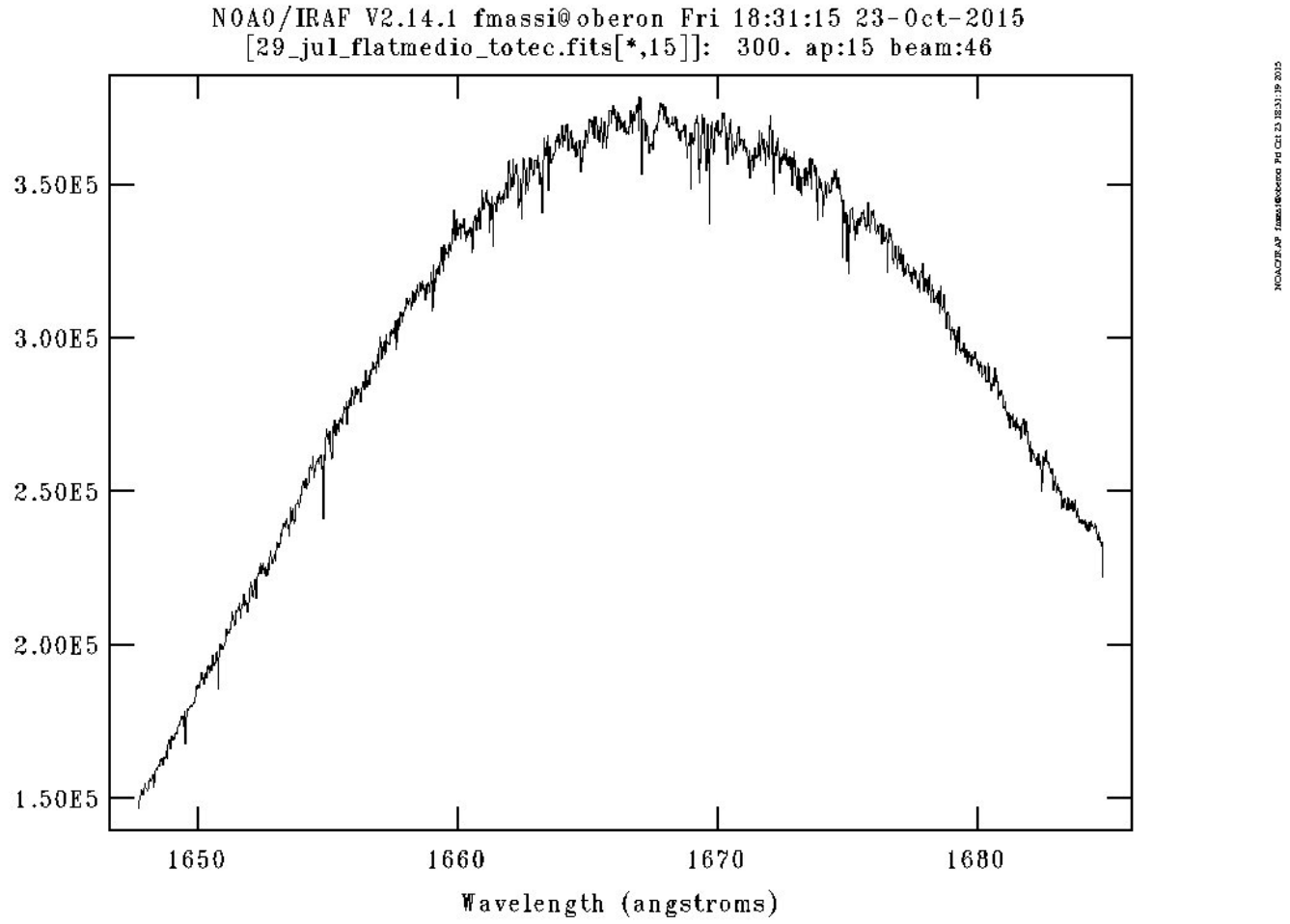
Sky on fibre A, star on fibre B

Fibre B, slicer

Fibre A, slicer



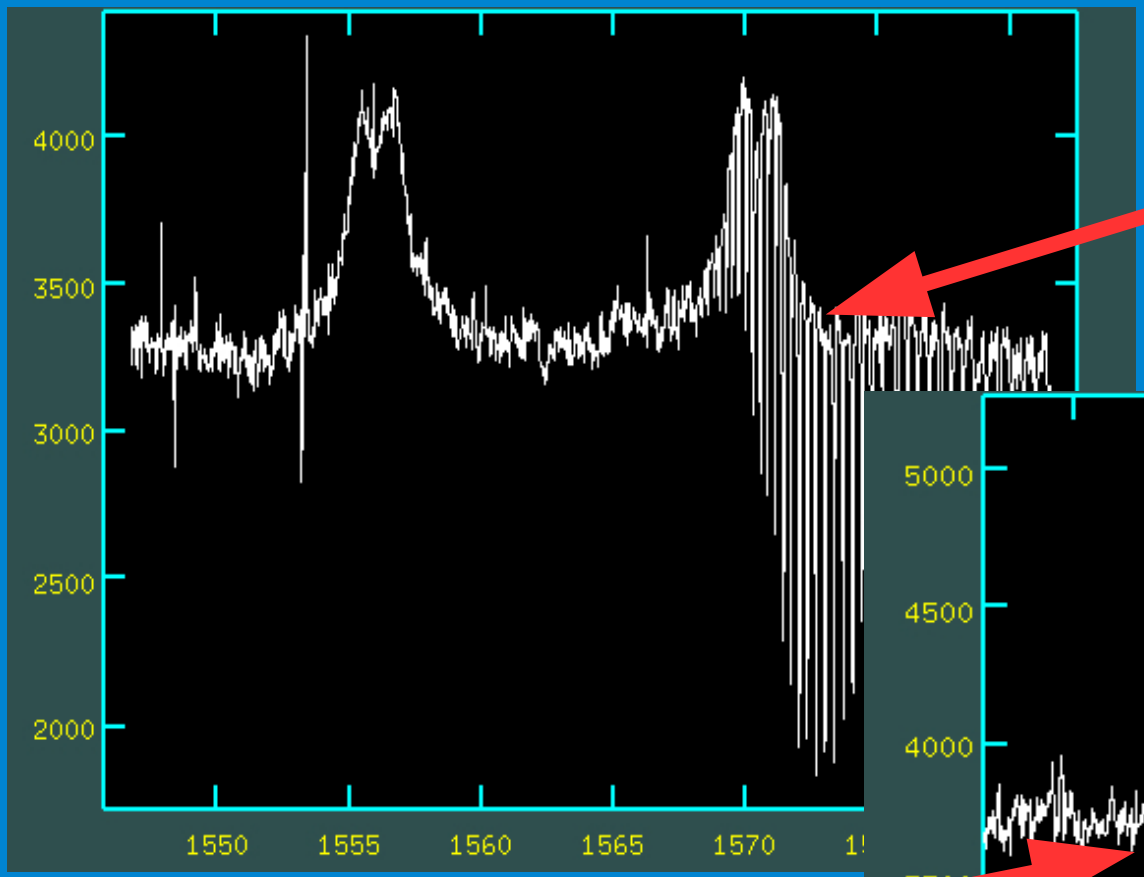
Typical efficiency in single order

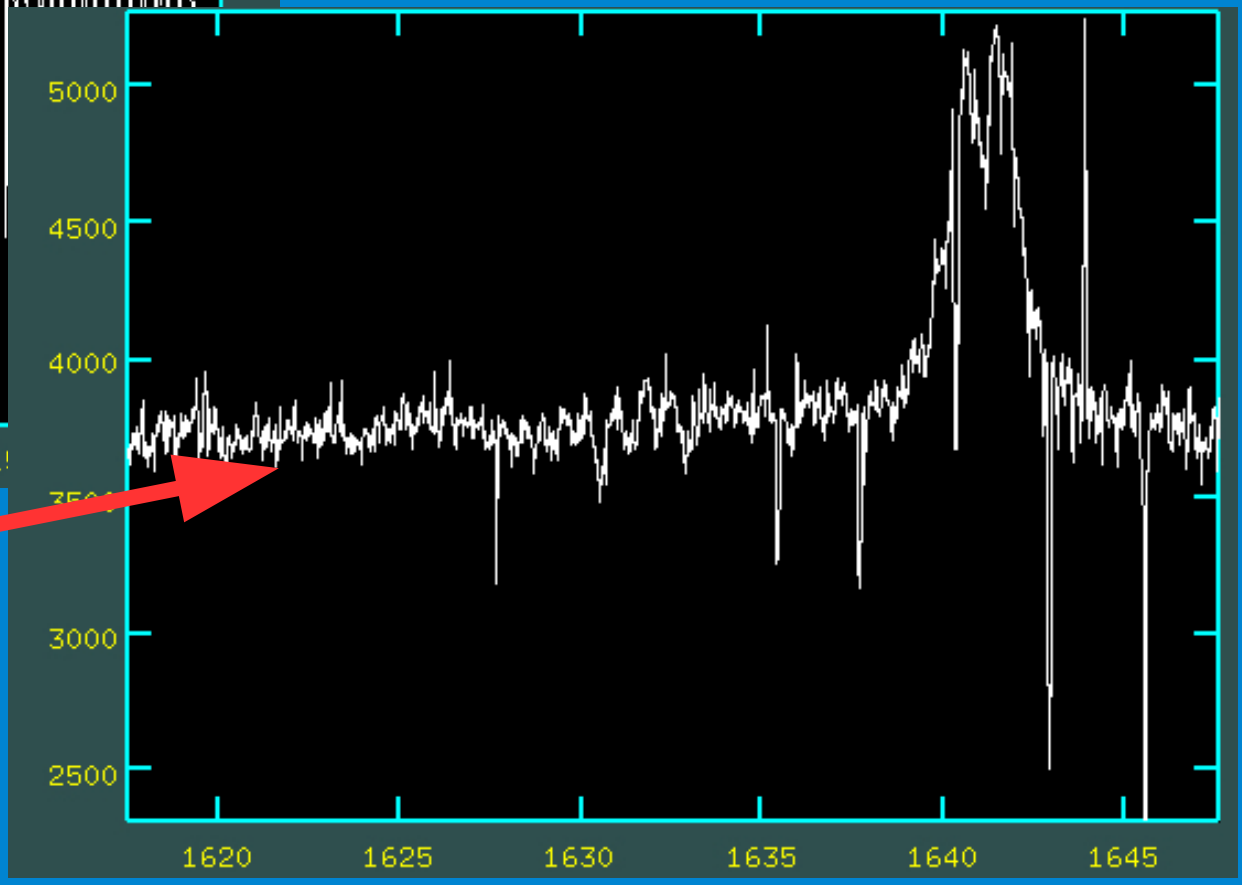


Problems:

Telluric absorption lines

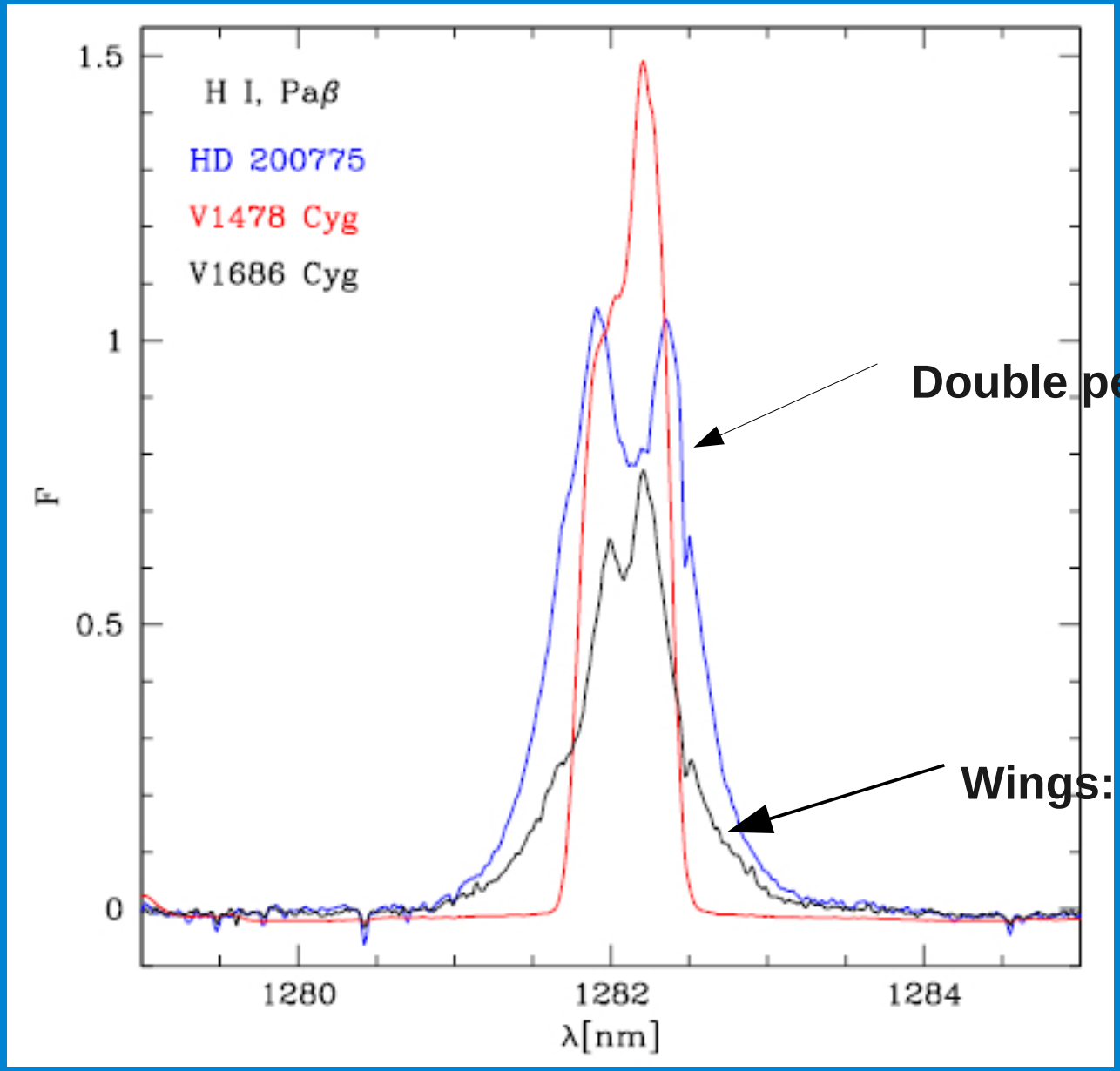
Corrected using telluric star spectrum Hip 89584 (O6.5 V) observed on July 29
Fit Gaussians to lines, normalise to continuum --> g(λ), then multiply target spectrum by $g(\lambda)^w$





MODAL NOISE (fibres!) degrades signal-to-noise

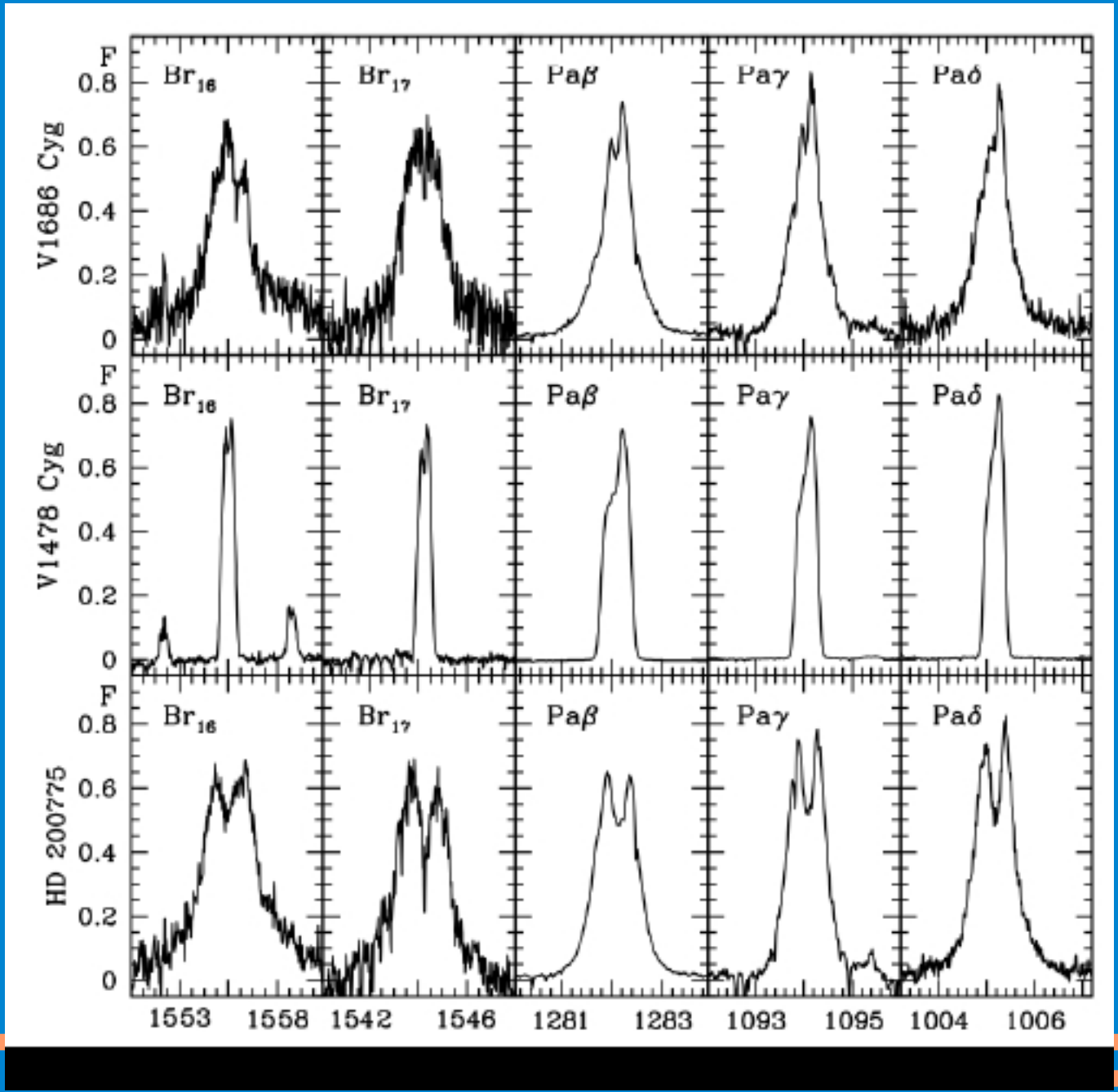
Line profile comparison: Paβ



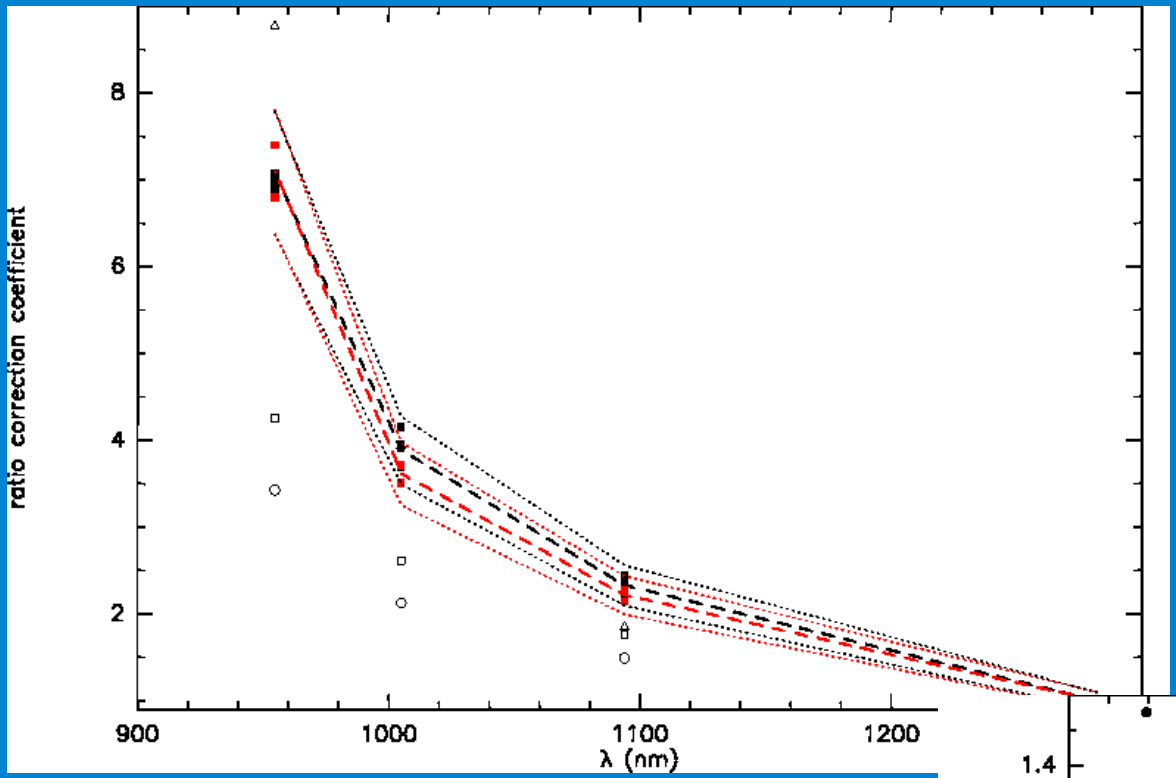
Double peaks: disk?

Wings: winds?

Line profile comparison: Brackett and Paschen lines



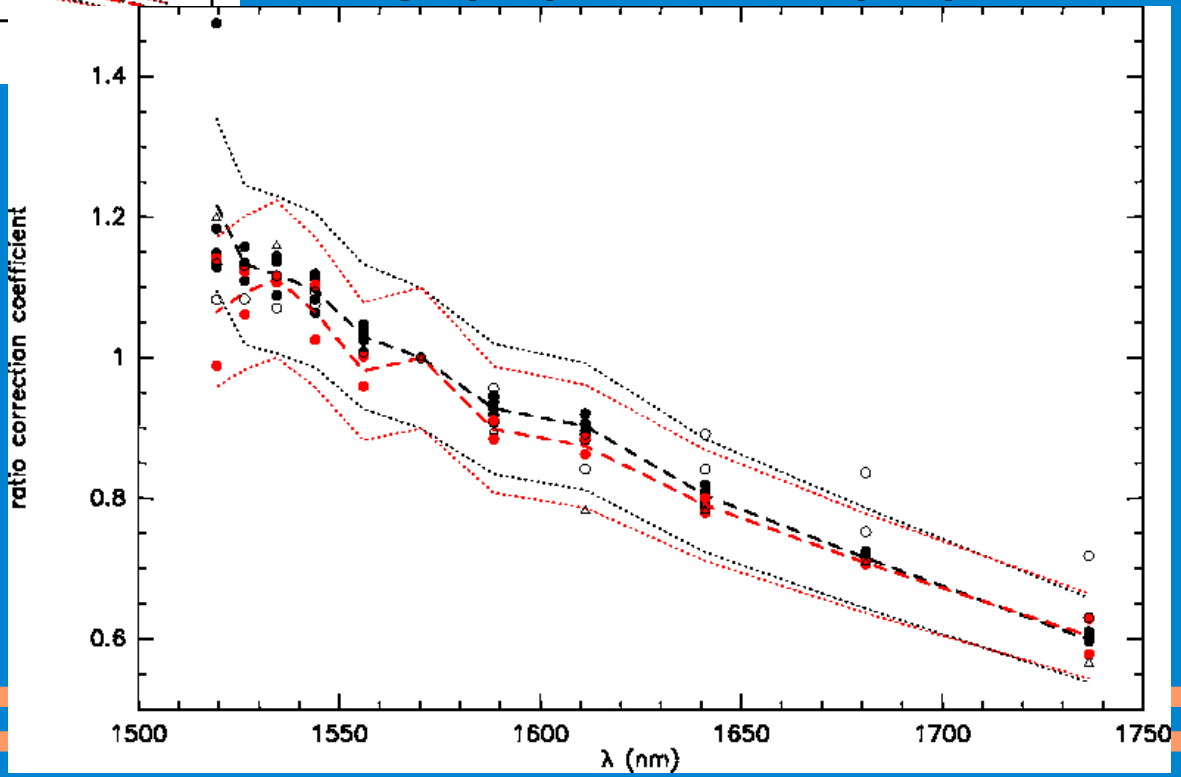
Line ratios calibrations



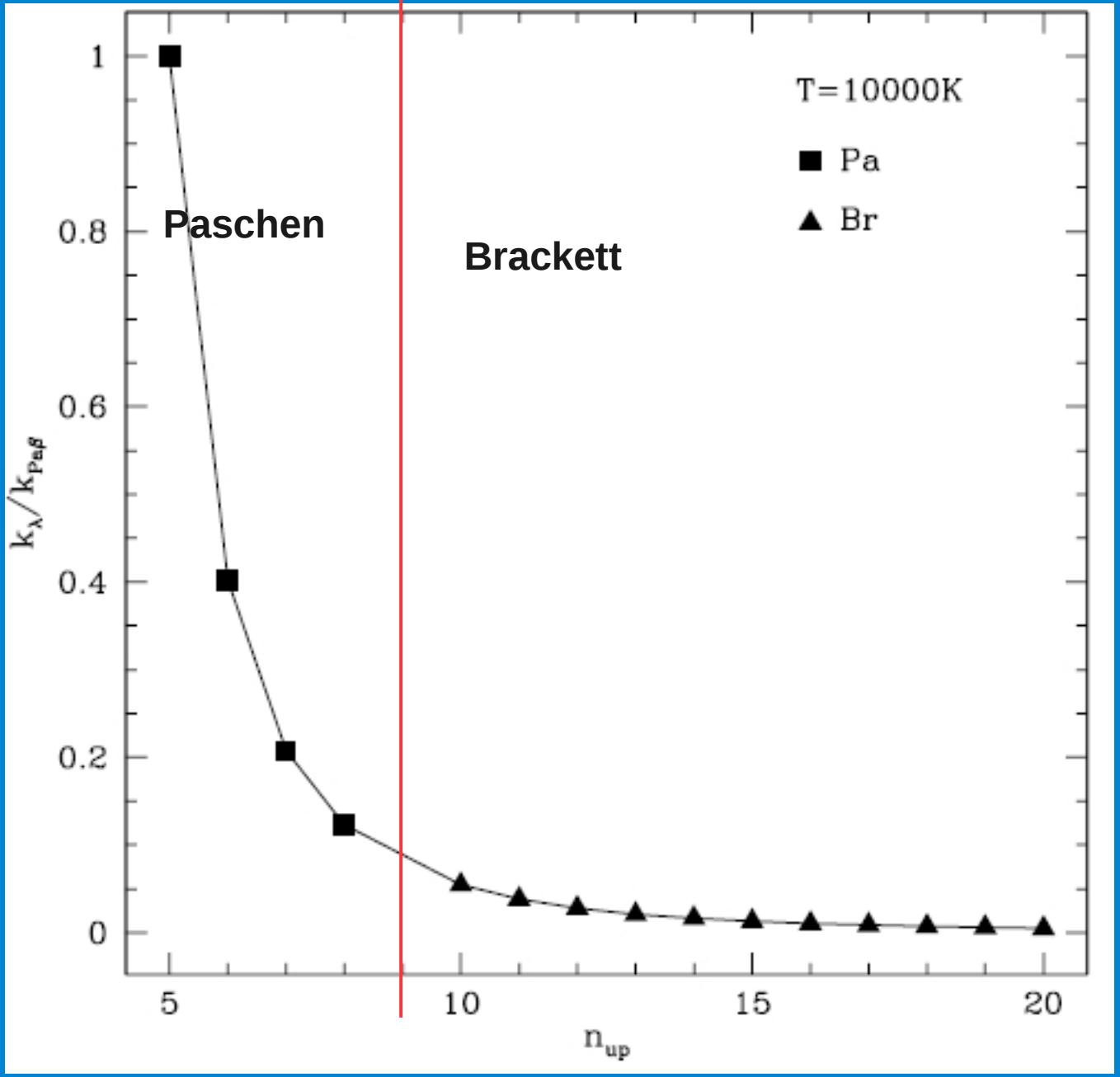
Use continuum spectrum (from 2MASS photometry)

Problems: target variability

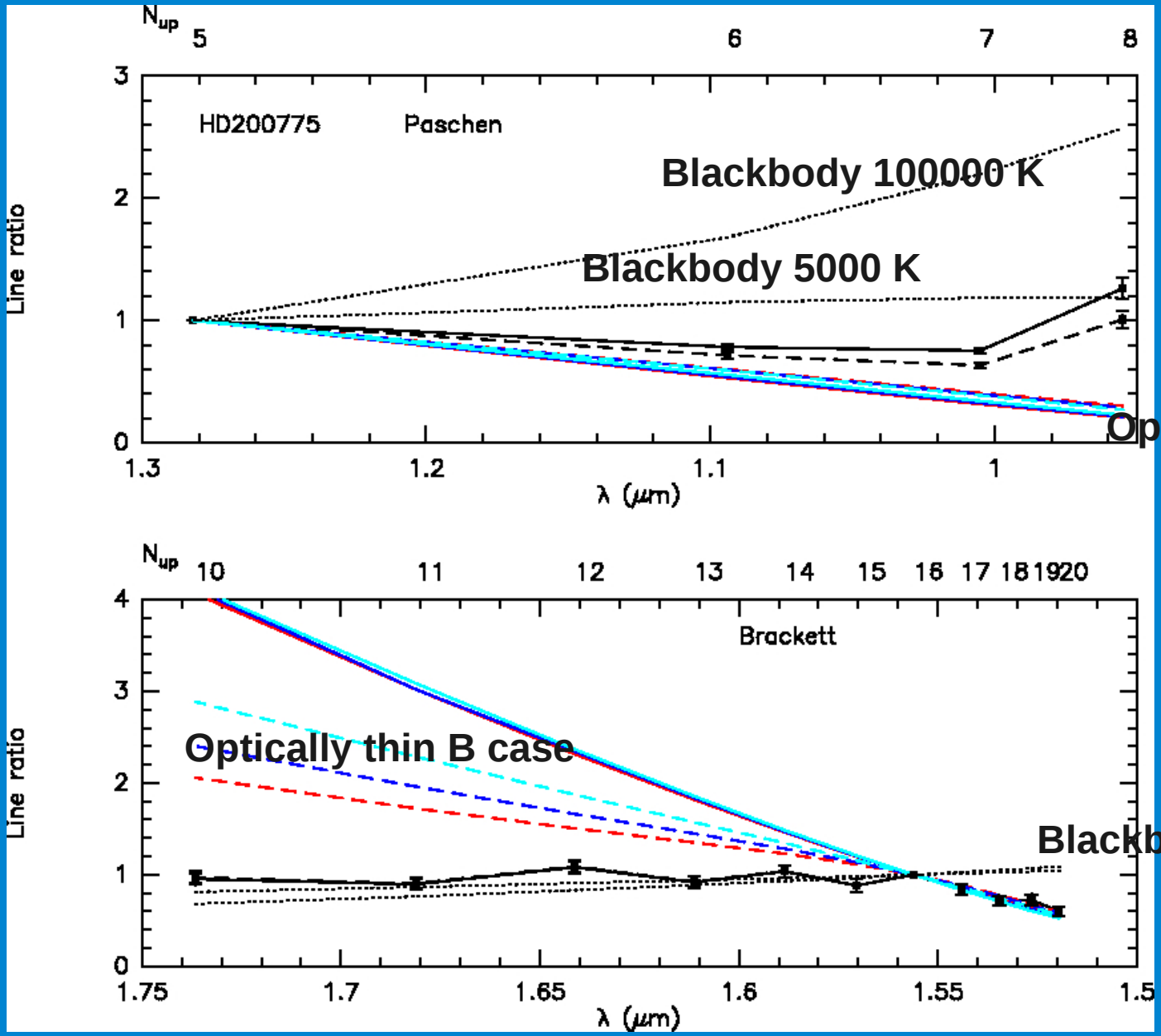
Calibrators:
July 29:
telluric standard Hip 89584(O star)
Vega (A star)
HD 188001 (O7 Iabf)
HD190429A (O4 If)
July 31:
Vega (2 spectra 7 hrs apart)



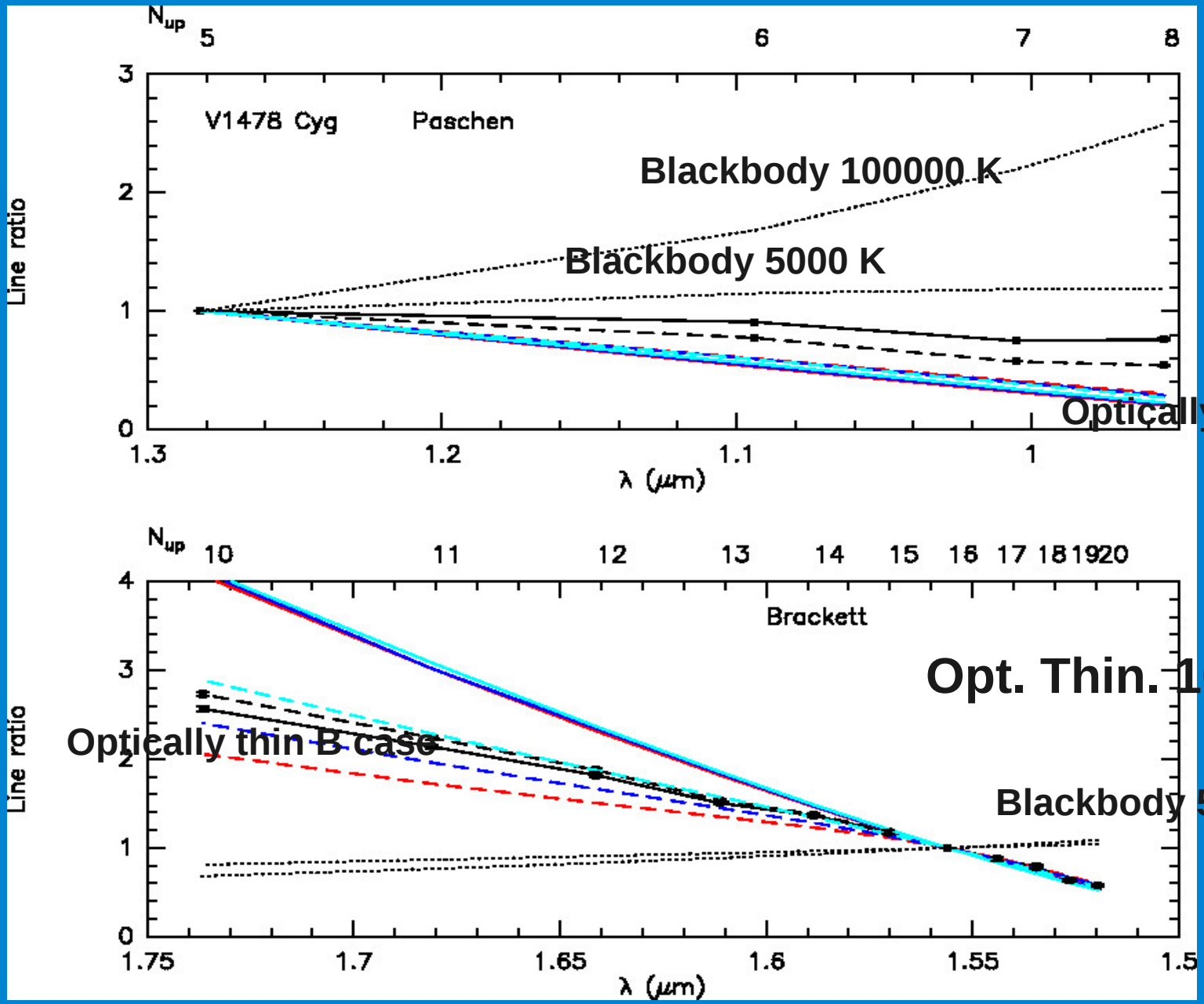
Line opacity, LTE,10000 K, normalized to Paβ



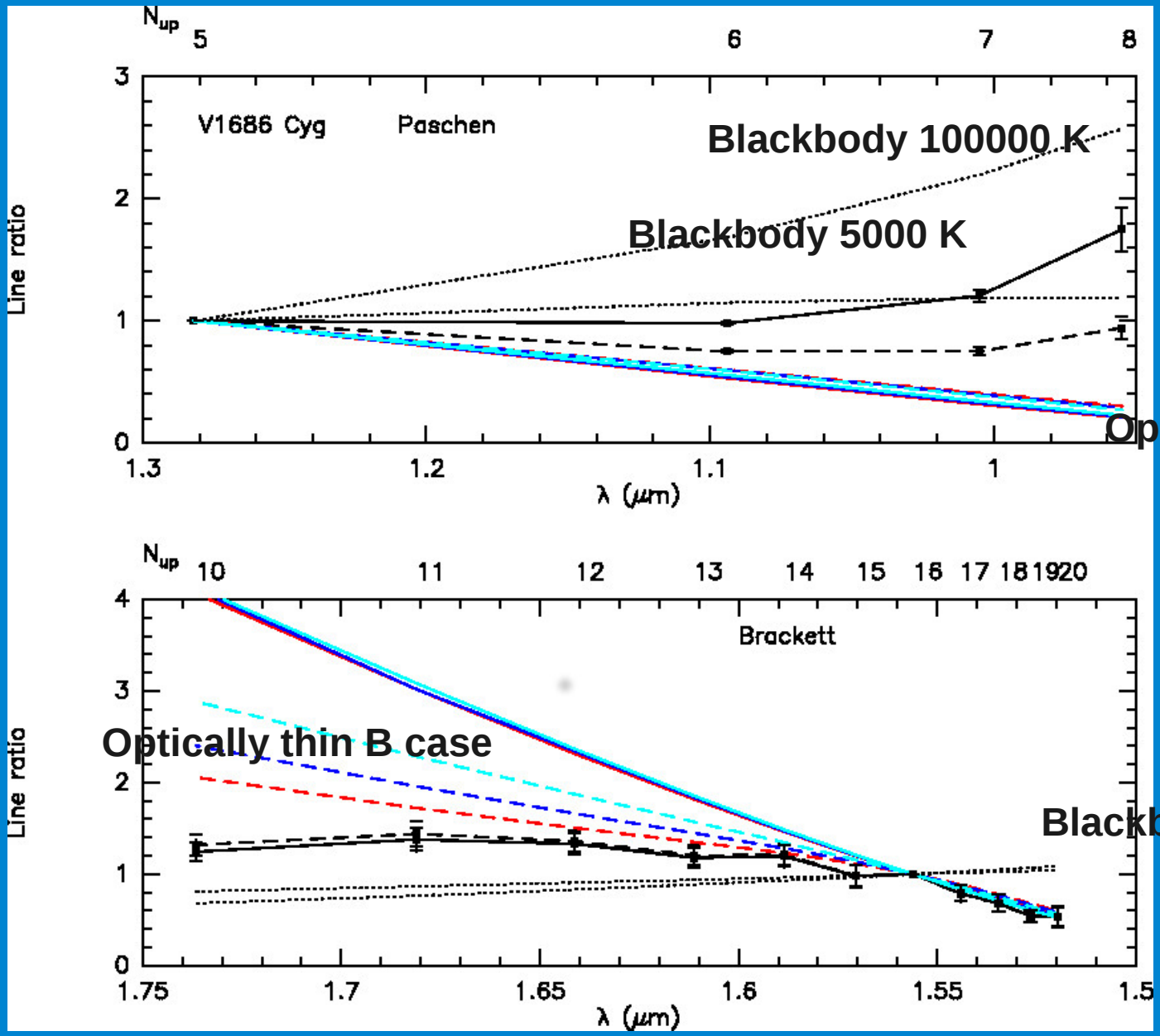
HD200775 line ratios



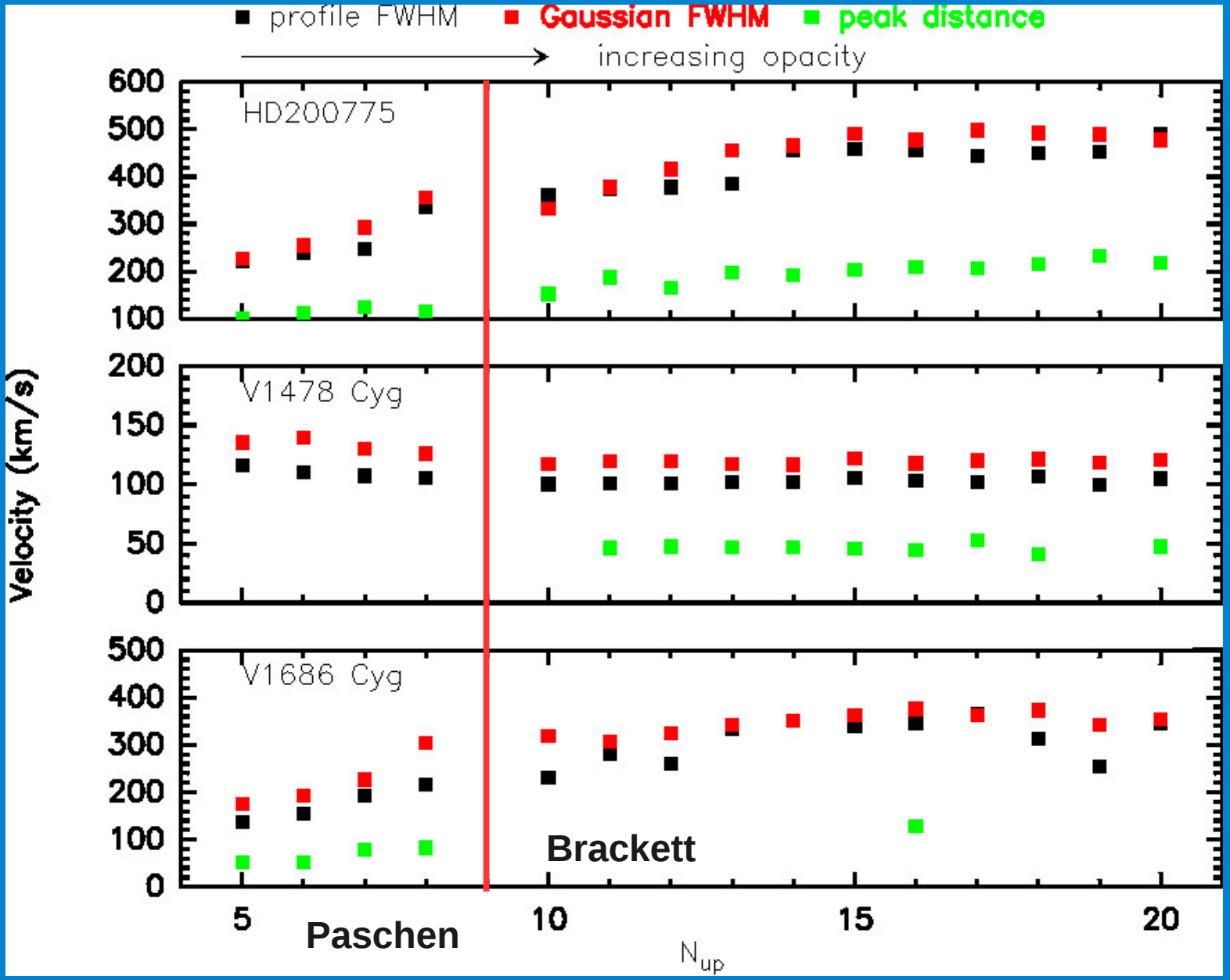
V1478 line ratios



V1686 line ratios

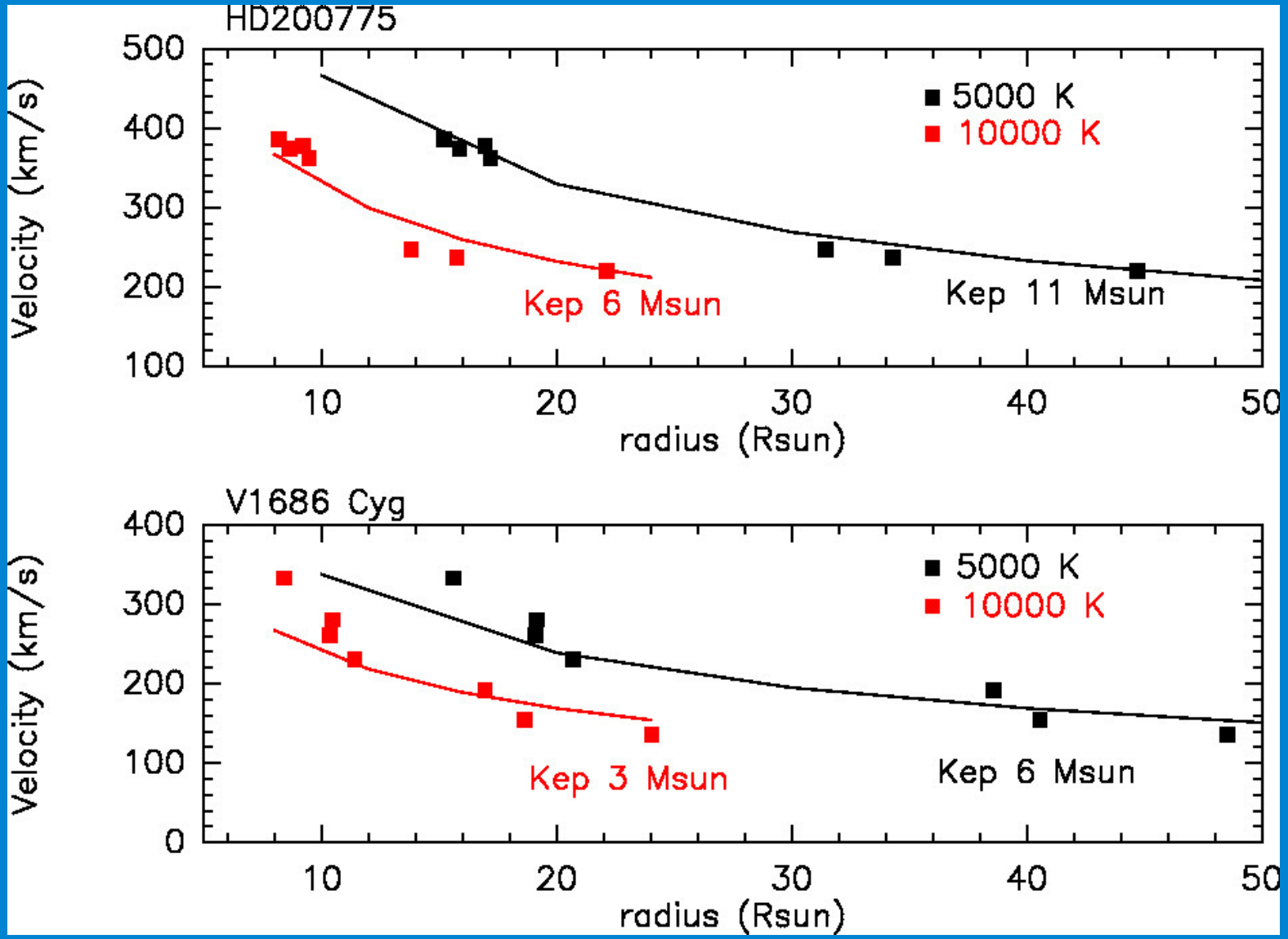


Line widths vs. line opacity



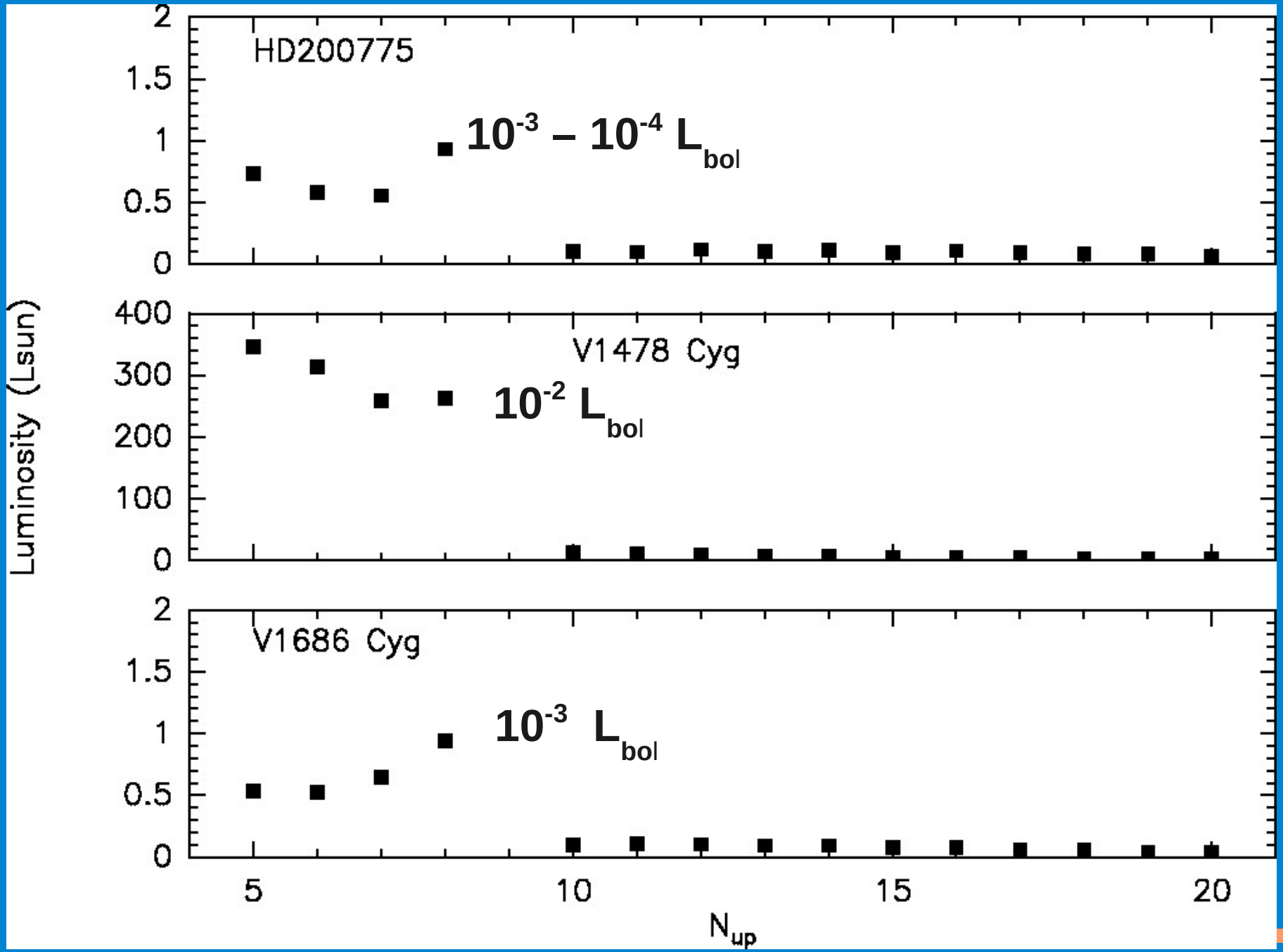
Distance to star vs. ine widths

Assuming lines optically thick: $F_\lambda = \pi (R/dist)^2 B(\lambda,T) \Delta\lambda$

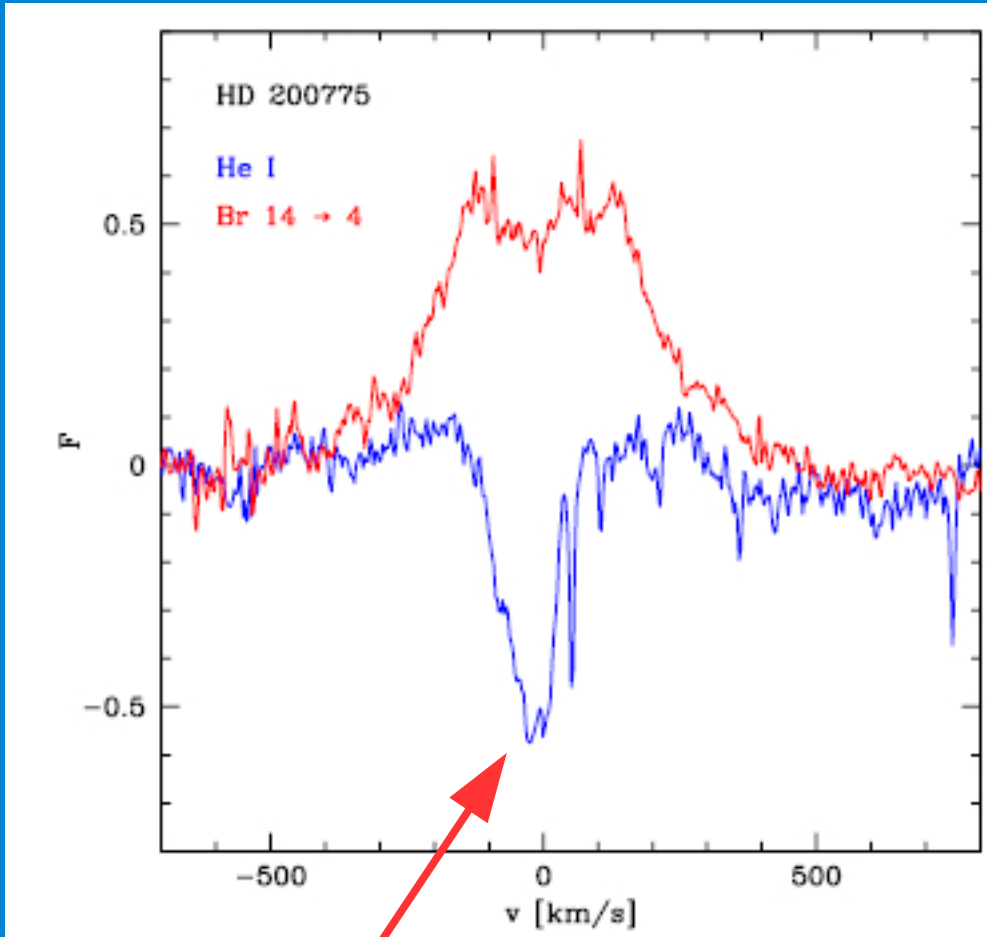


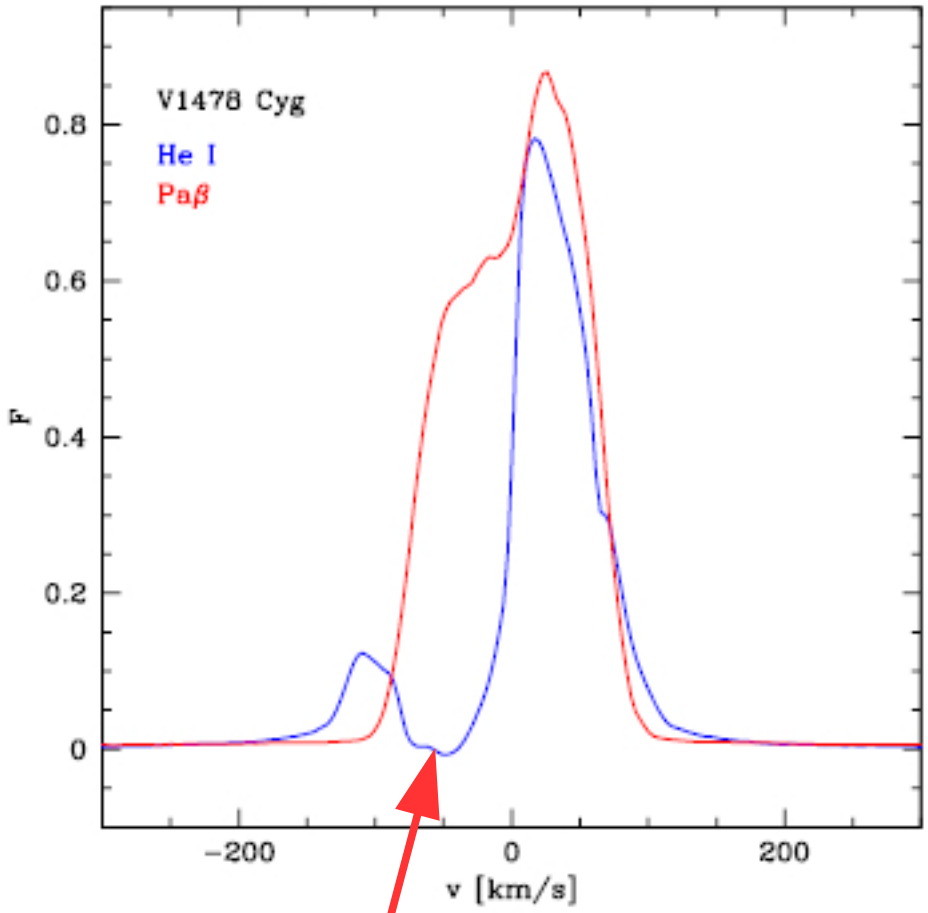
$M_\odot \sin^2 i$

Line luminosity



HeI 1.083 µm: wind tracer (Edwards et al. 2006)





In absorption, blueshifted

Self-absorbed line blueshifted dip
Consistent with disk wind 75 km/s

SUMMARY

- Herbig stars HD200775 and V1686 Cyg: Paschen and lowest Brackett lines originate in region close to a disk. Wings in profiles indicate winds
- V1478 Cyg: Brackett lines optically thin originate in a dense (10^{8} cm^{-3}) hot (10000 K) gas. Picture consistent with ionised disk wind from almost edge-on disk (e.g. Martin-Pintado et al. 2011). Paschen lines optically thick and self-absorbed
- High-resolution allows in-depth line profile analysis, wide band allows multiple line analysis avoiding problems inherent with source variability
- New GIANO-telescope interface (GIARPS) available soon: no fibres ---> no modal noise!