An XMM-HST analysis of HD 54879 (O9.7 V): Quantifying the weak-wind problem

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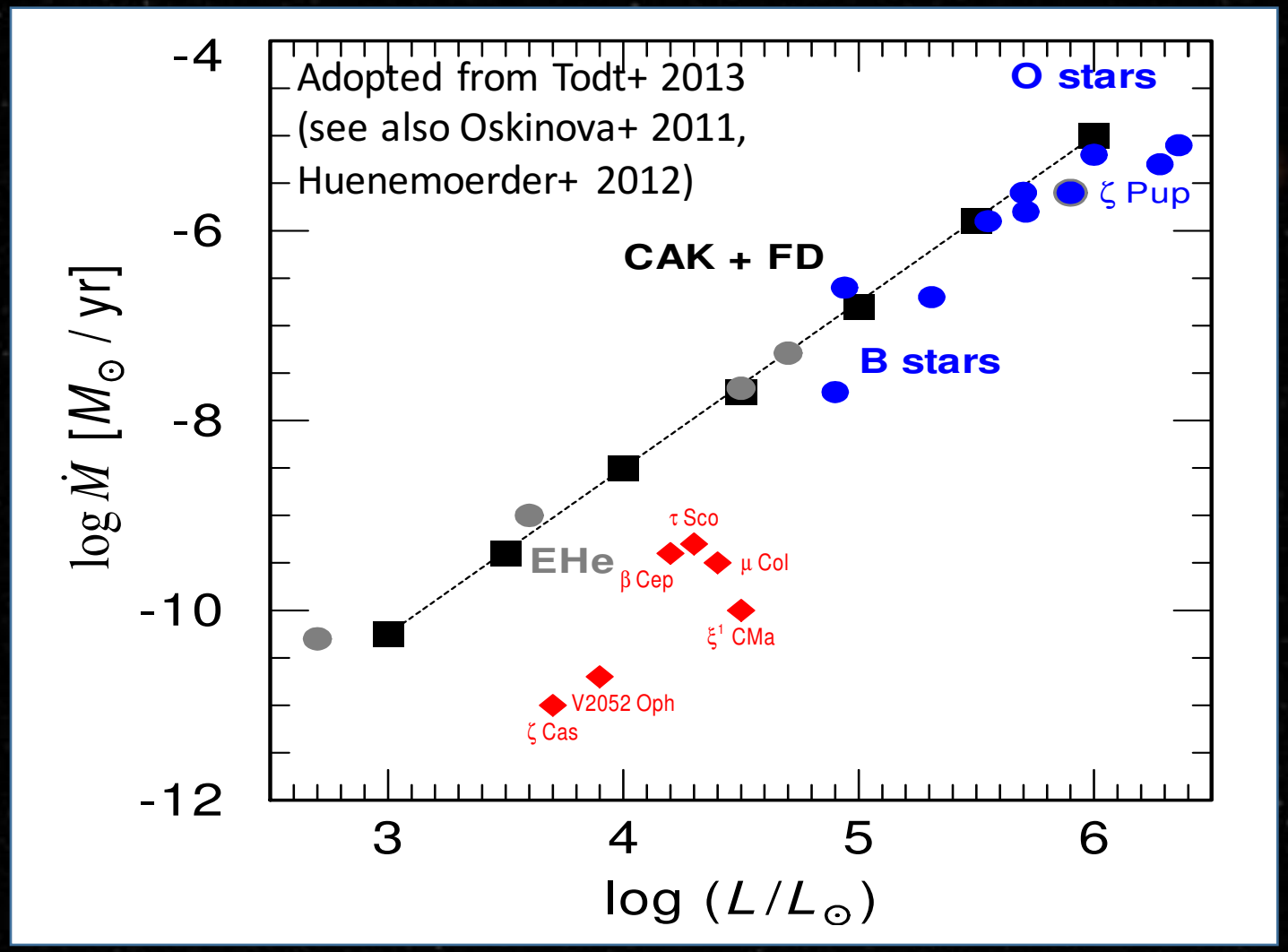
The weak-wind problem



For late OB main sequence stars: $\frac{\dot{M}_{obs}}{\dot{M}_{theory}} \sim 0.01$

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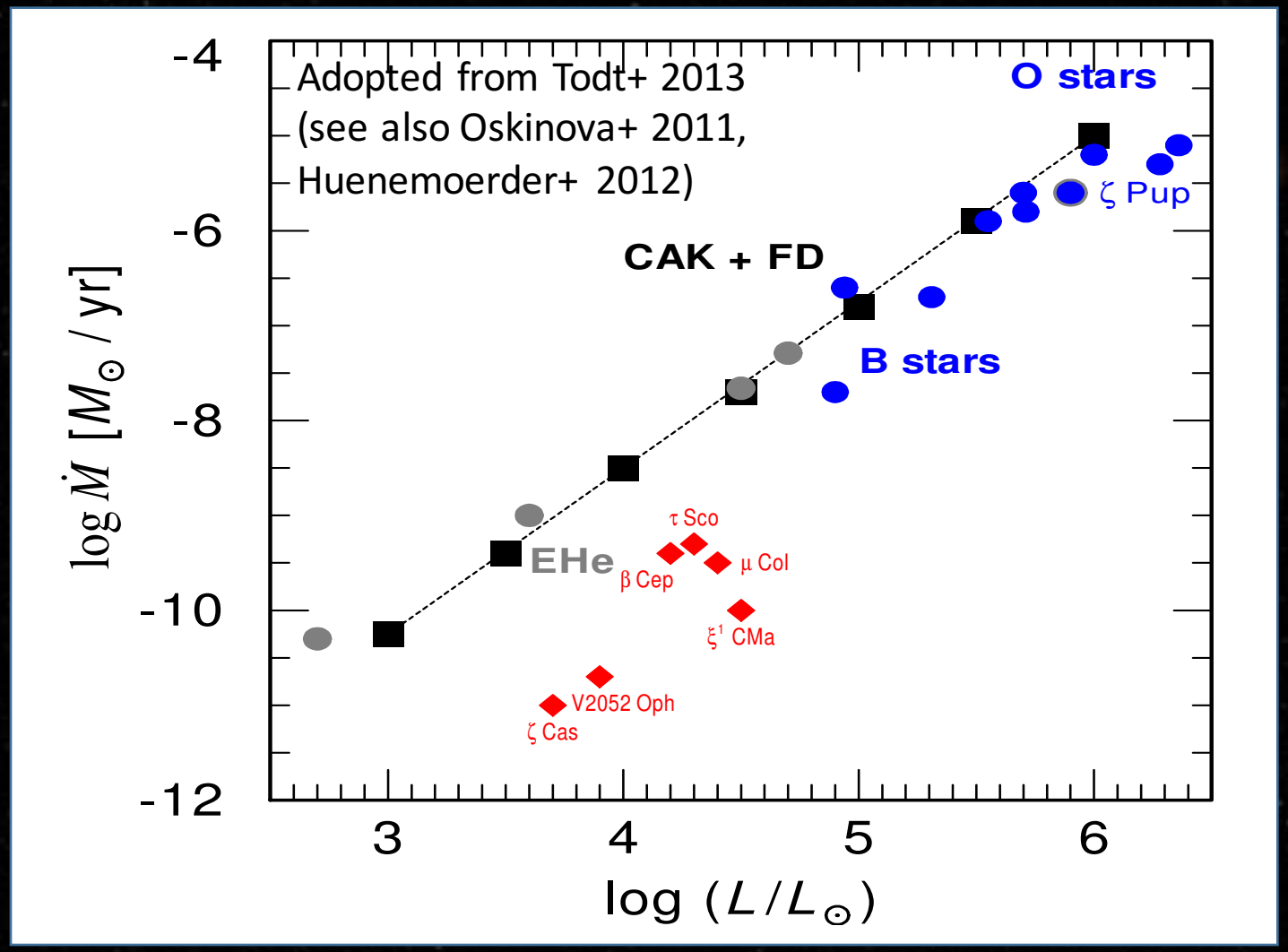

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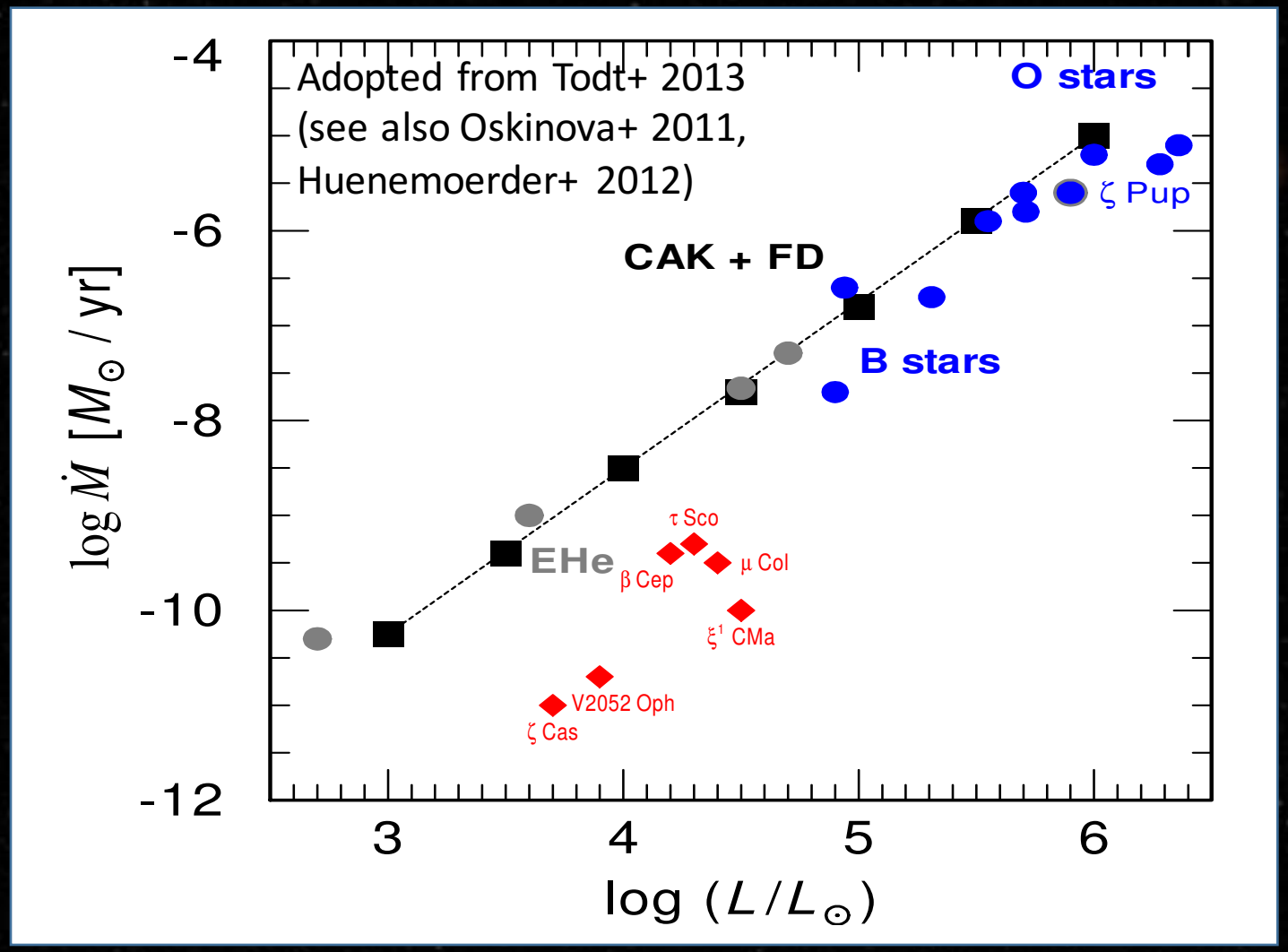

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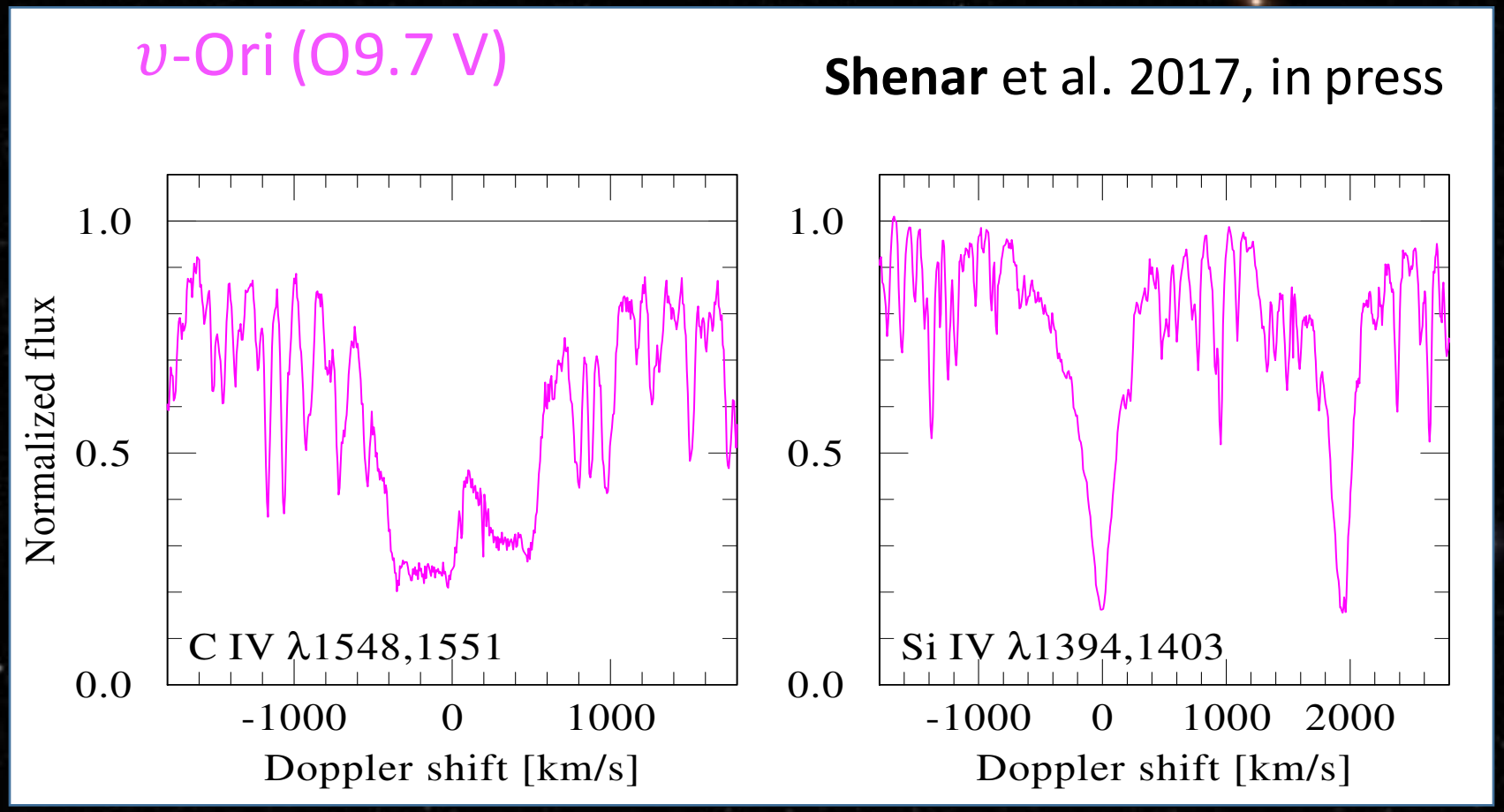
→ Systematic errors in stellar evolution models

→ We do not fully understand stellar winds

Measuring the mass-loss rates of weak-wind stars



Problem:

mass-loss diagnostics Often not present in weak-wind stars!!

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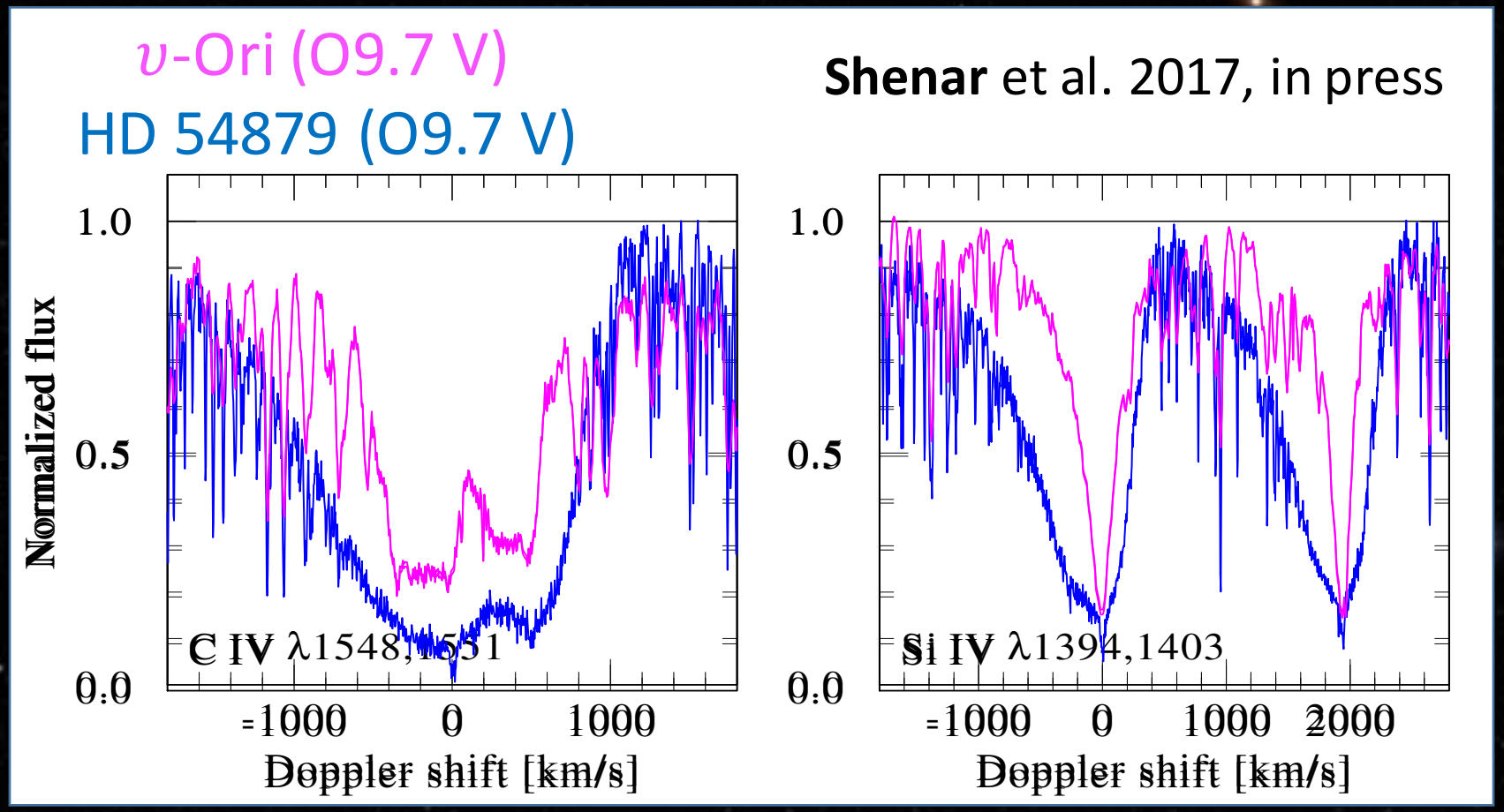

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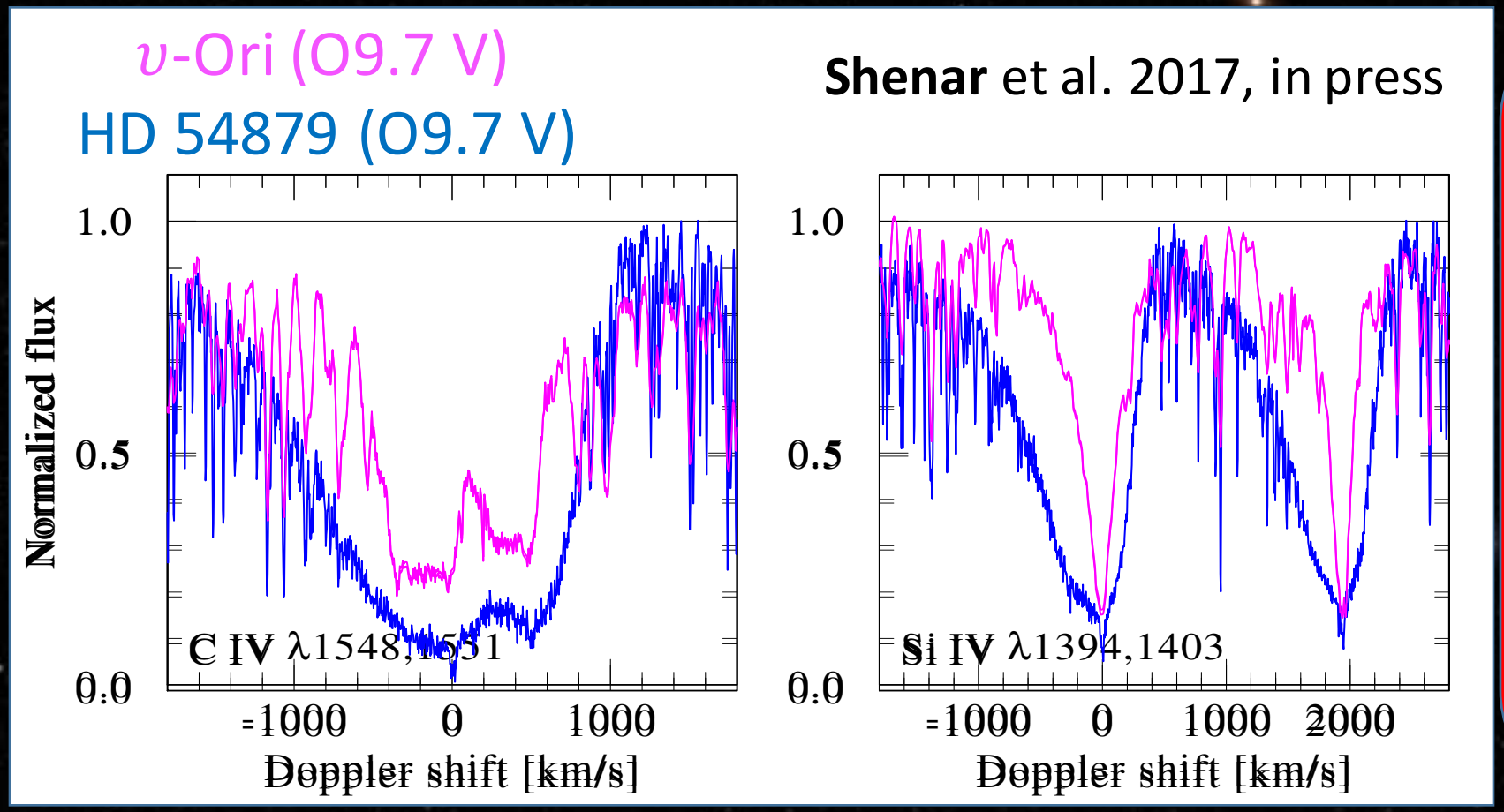
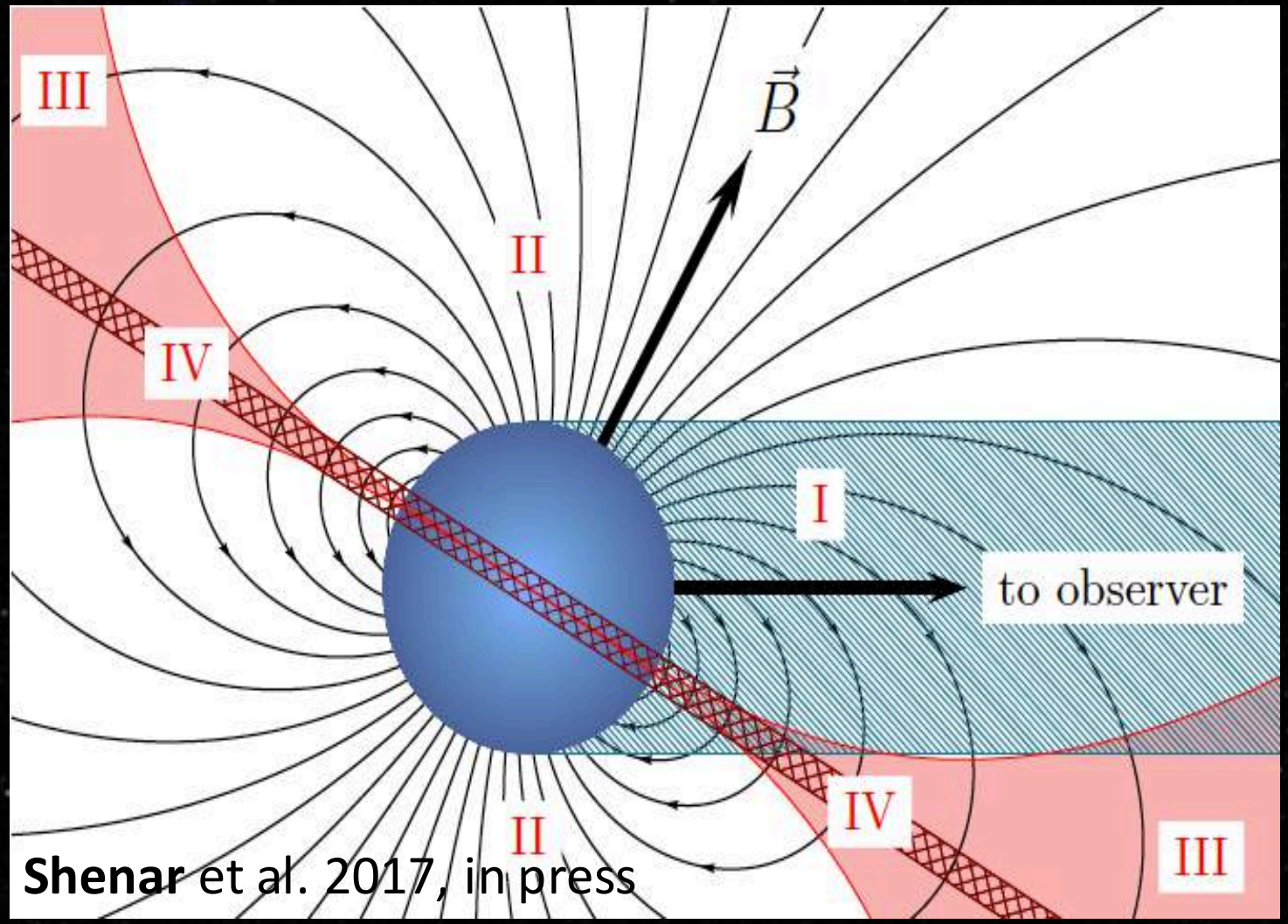


The difference?
You guessed it…
Magnetic fields!

$|B_z| \sim 600\ G$
$B_d \geq 2\ kG$
(Castro+ 2015, BOB collaboration)

The magnetically confined wind model



Shenar et al. 2017, in press

- Wind outflow confined in loops up to Alfen radius
- Goes back to Weber & Davis 67, extended by Babel+Montmerle 1997, ud-Doula+Owocki 2002, (see talk by A. David-Uraz!)
- Shock-zone builds due to collision at mag. Equator (see recent review by Ud-Doula + Naze 2016)

A comprehensive XMM-HST study

1. X-rays: study the shocked wind (40 ks exposure, low-res spectrum)

2. UV: Study the magnetically confined wind
(3 exposures within a night, high-res spectrum)

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The Potsdam Wolf-Rayet (PoWR) code

- Non-LTE model atmosphere code (Hamann et al. 2006)
- Applicable for hot stars with expanding atmospheres (OB, WR, …)
- Accounts for: line blanketing, clumping, X-rays..... But.....
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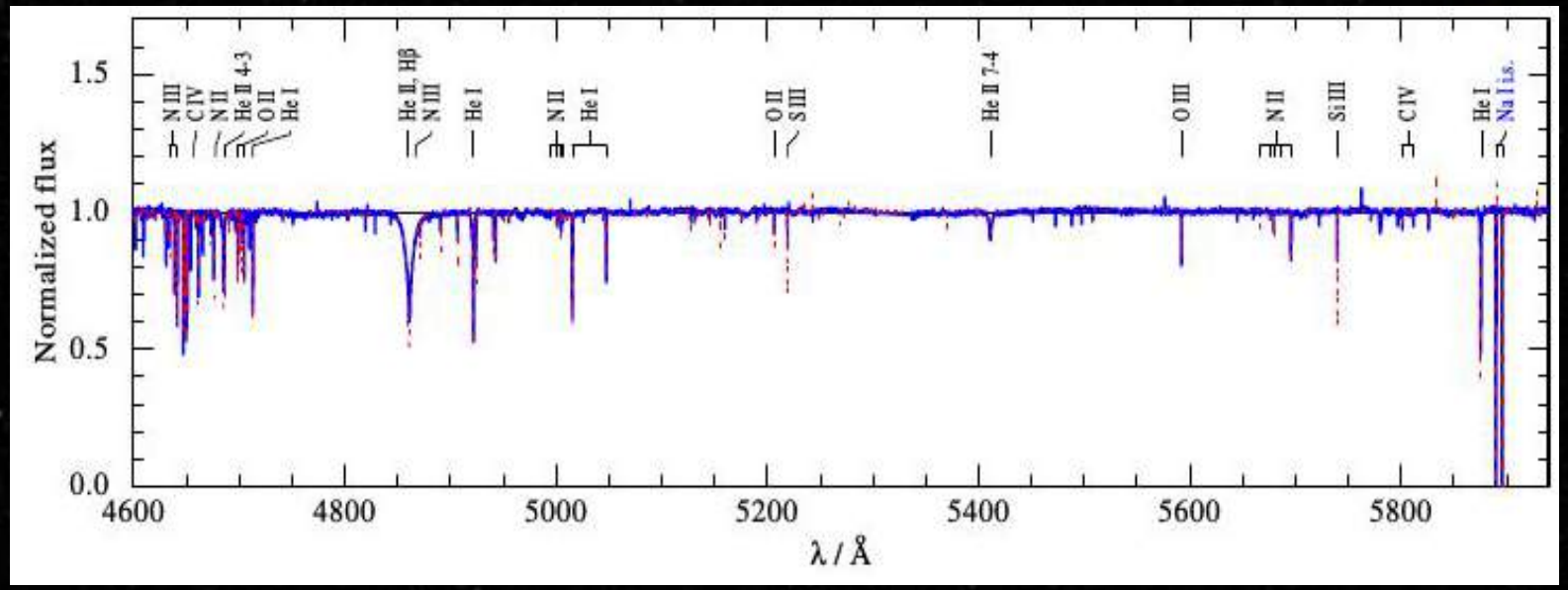
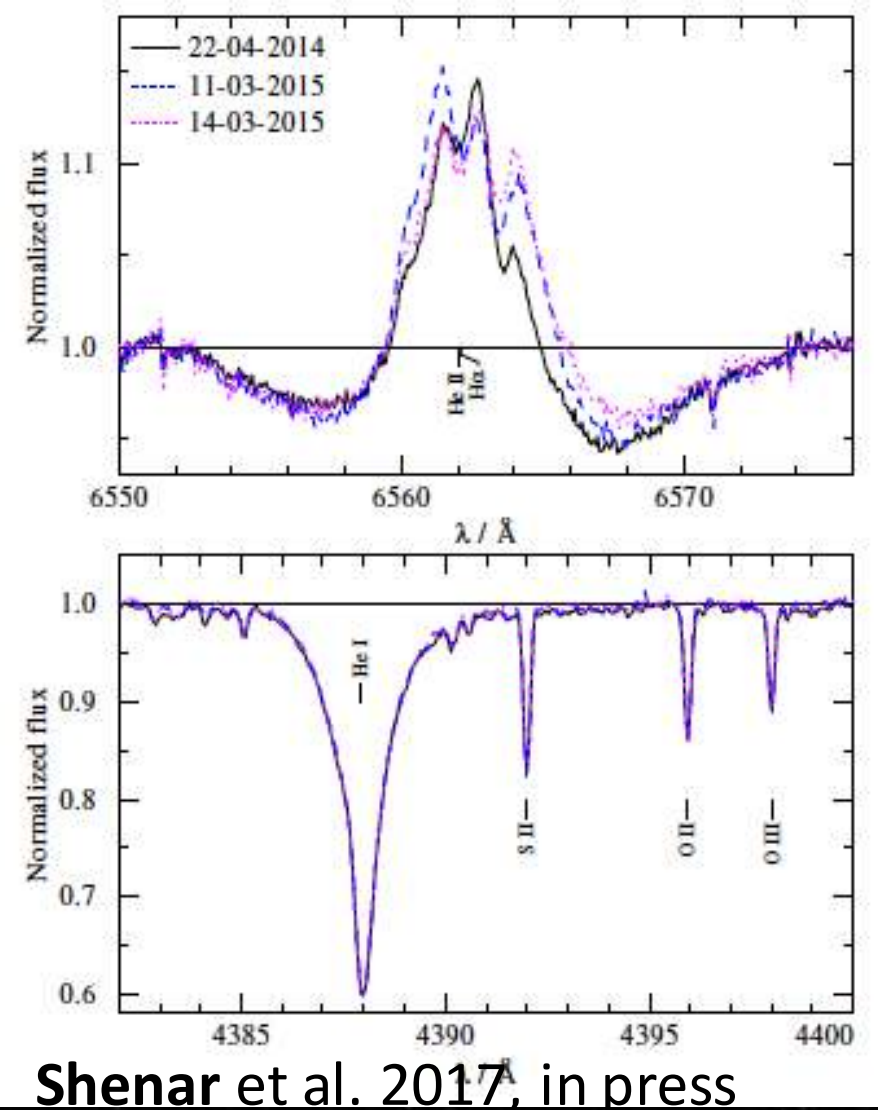


Stellar parameters:

T, log g, L, $\dot{M}, v_\infty,$ $v \sin i$, …

HD 54879: the photosphere



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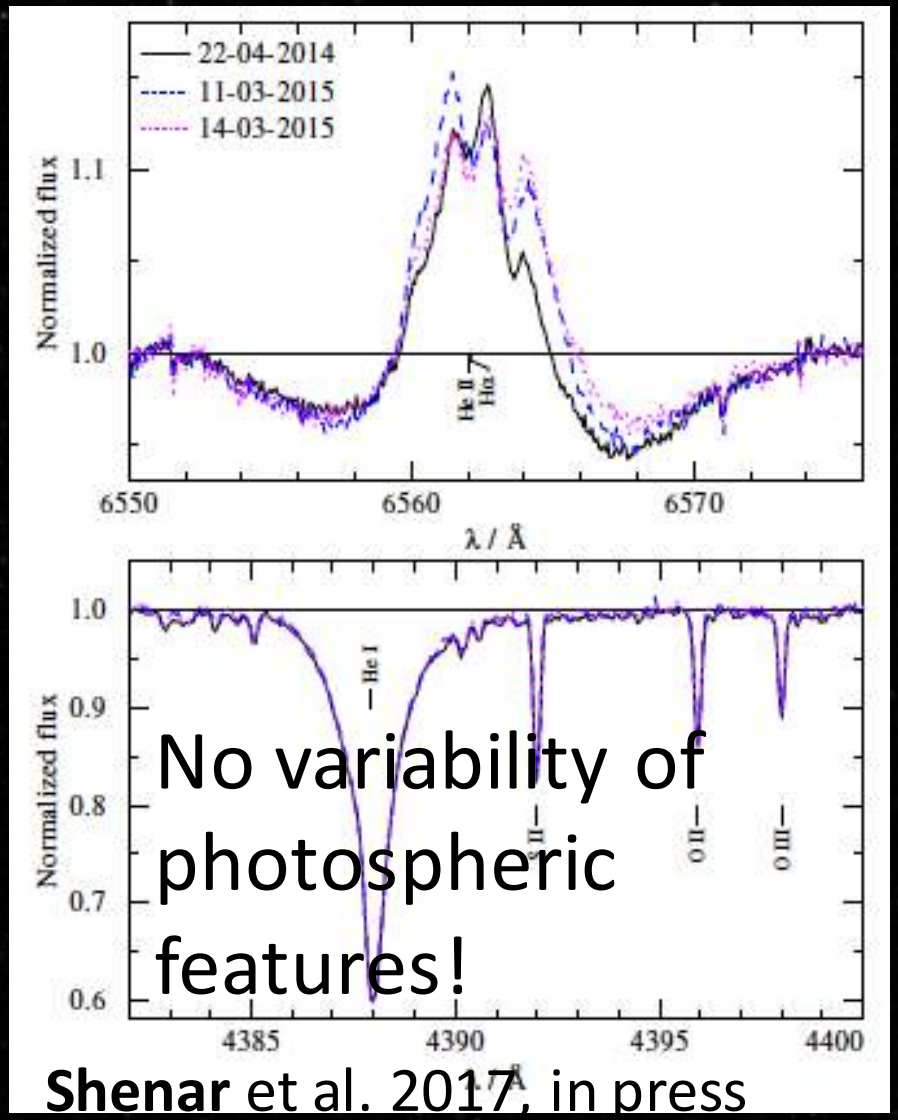

No variability of photospheric features!

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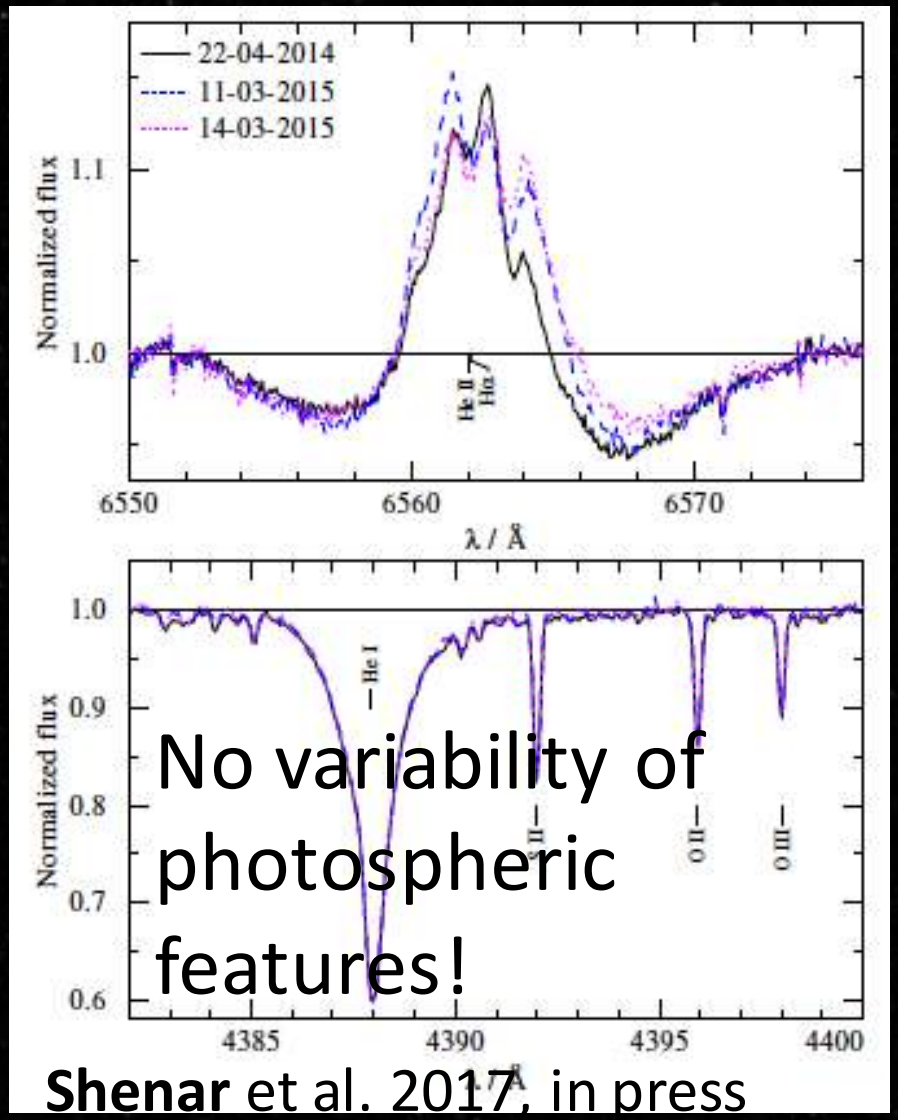

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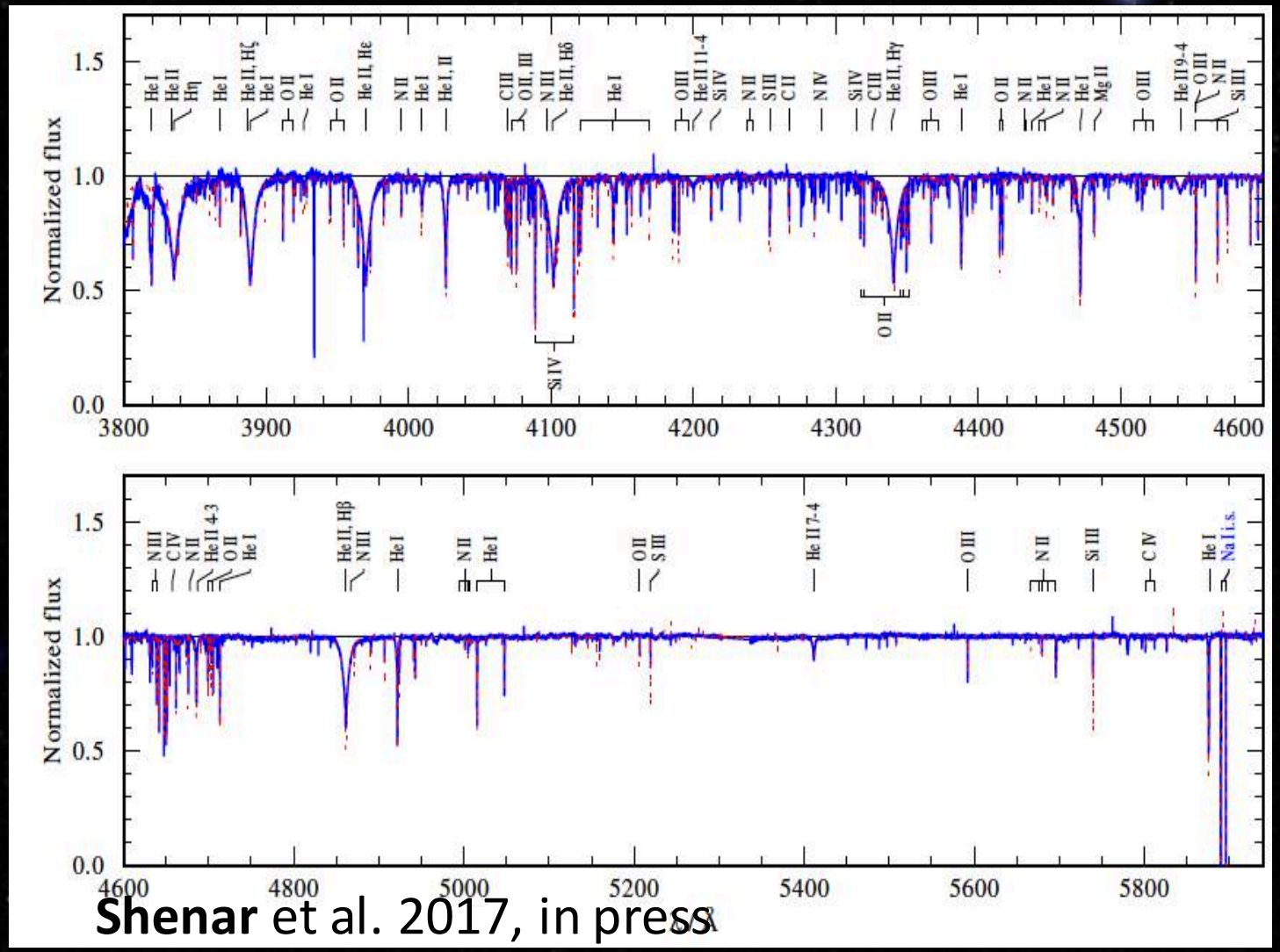

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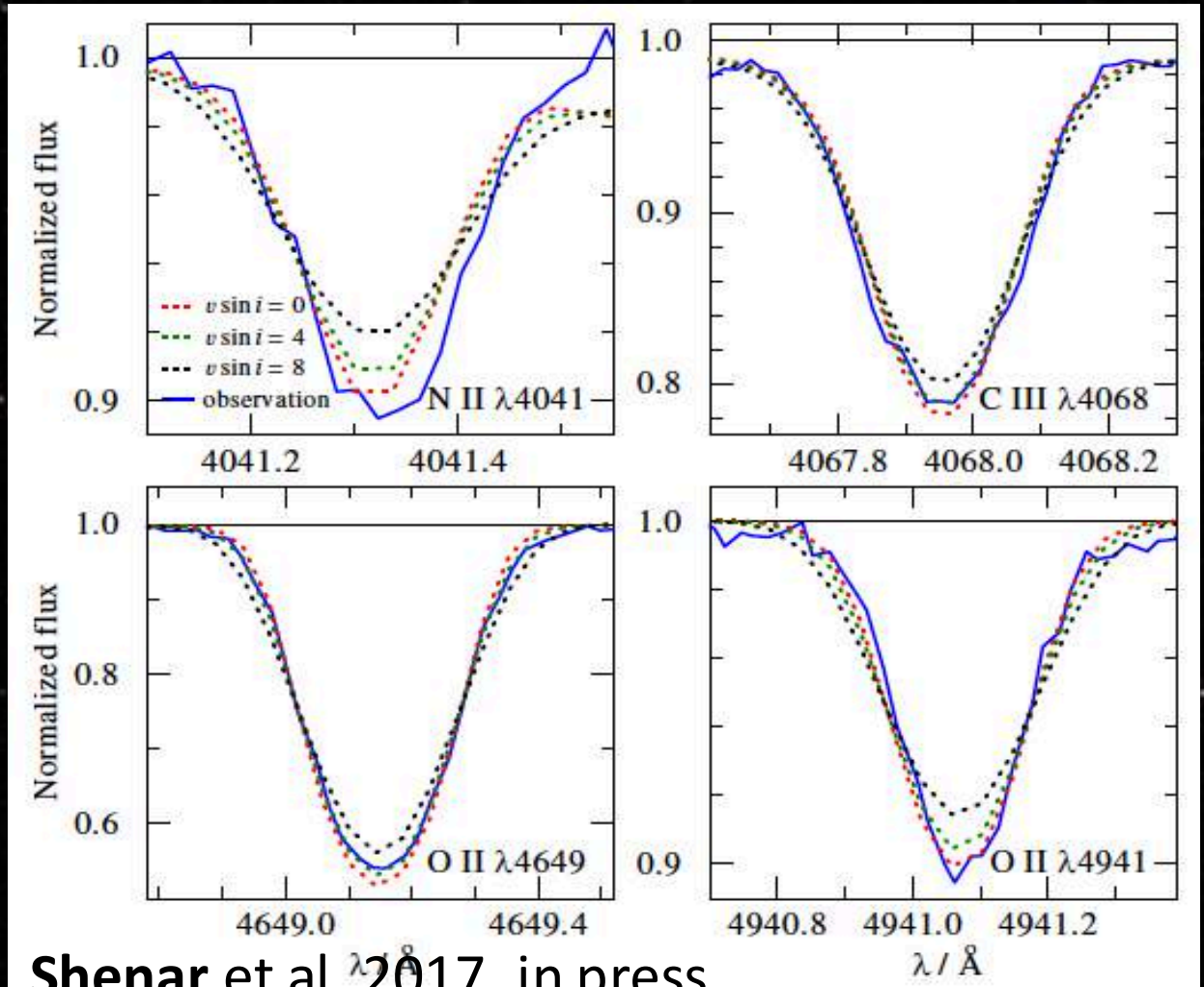
HD 54879: the photosphere

- Stellar parameters typical for O9.7 V:

  T = 30.5 kK, log g = 4.0, L = 4.45 Lsun

  But…

- $v \sin i,\ v_{\mathrm{mac}}, v_{mic} < 4$ km/s
- N, C abundances subsolar (~factor 3)



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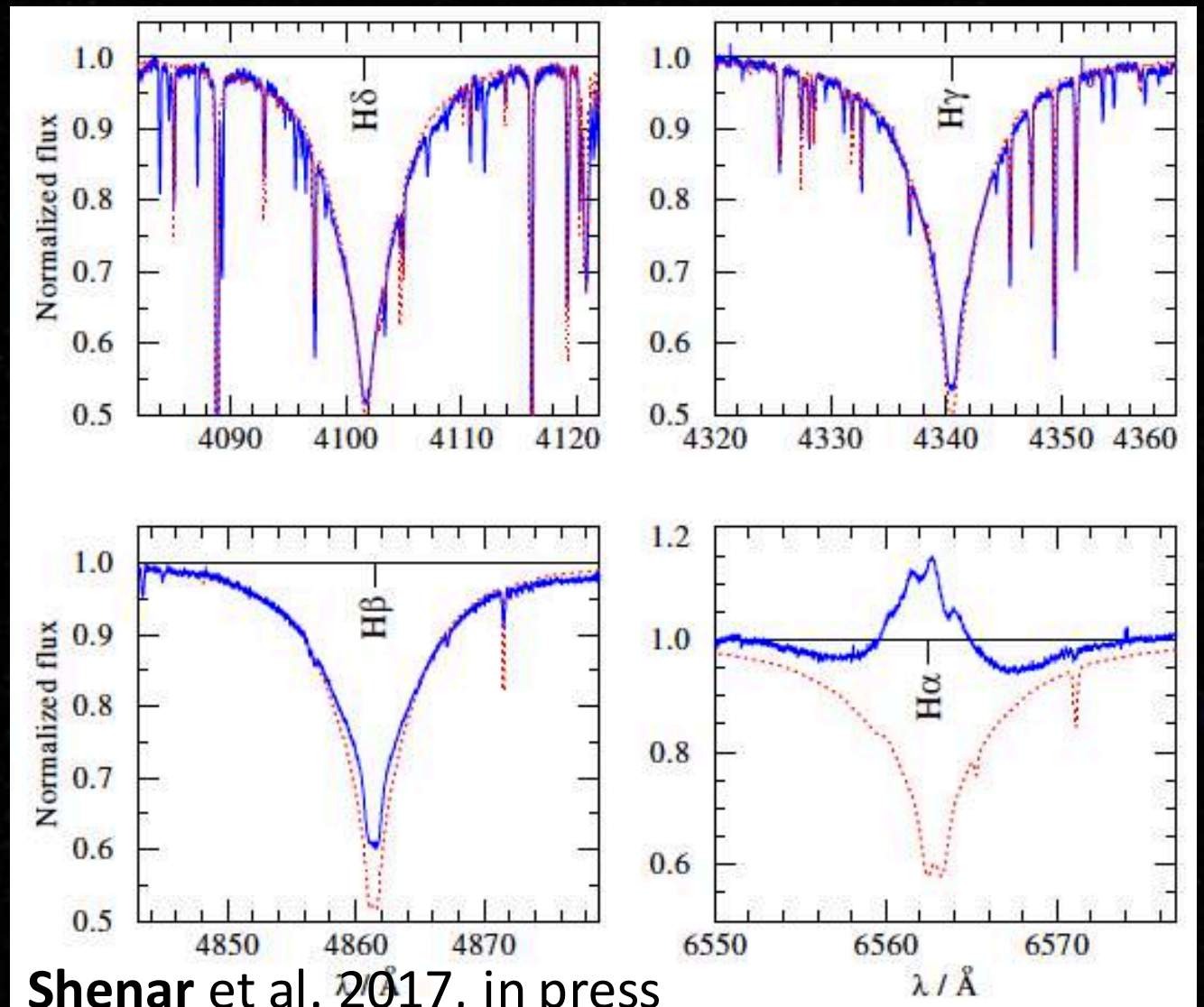

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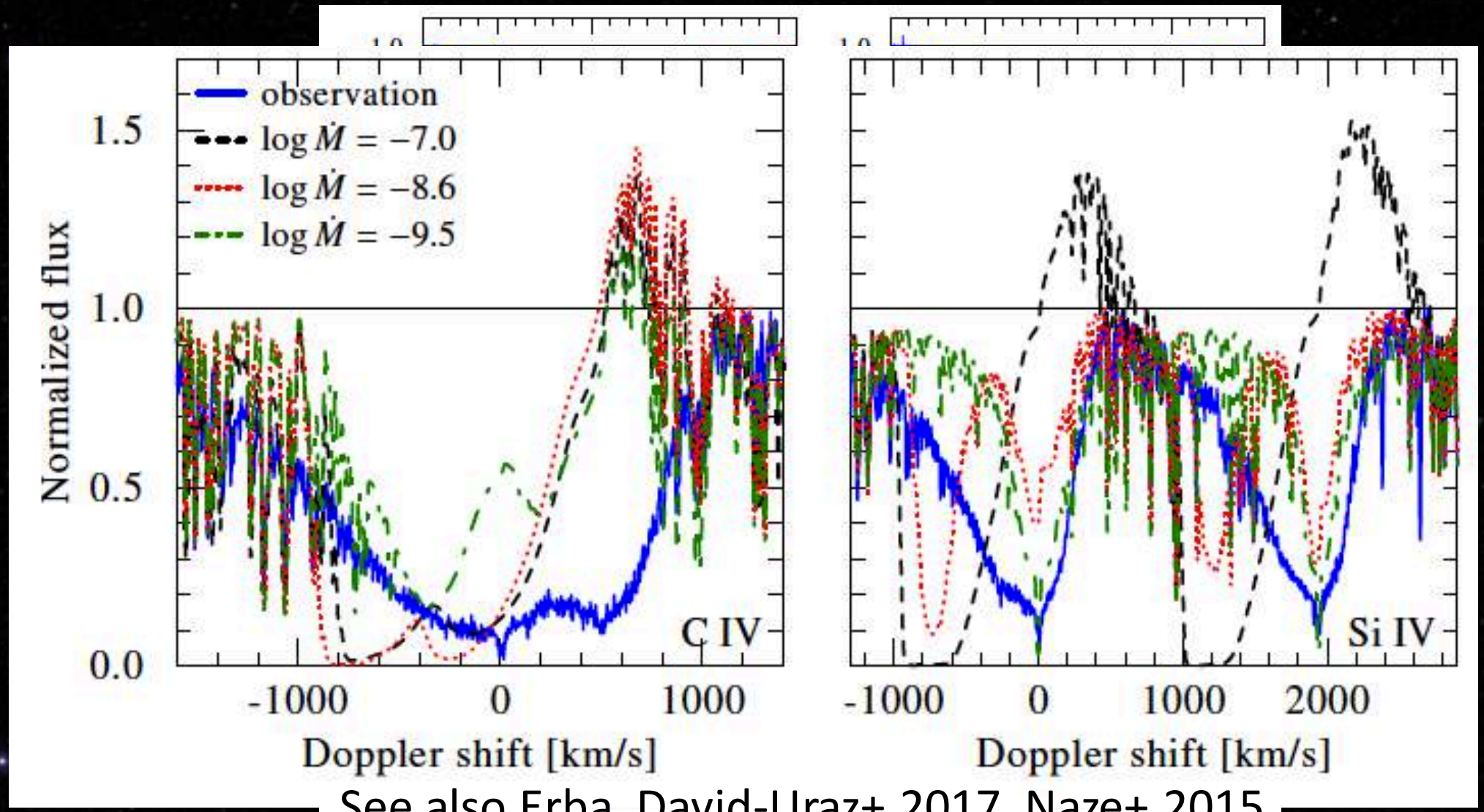

See also Erba, David-Uraz+ 2017, Naze+ 2015

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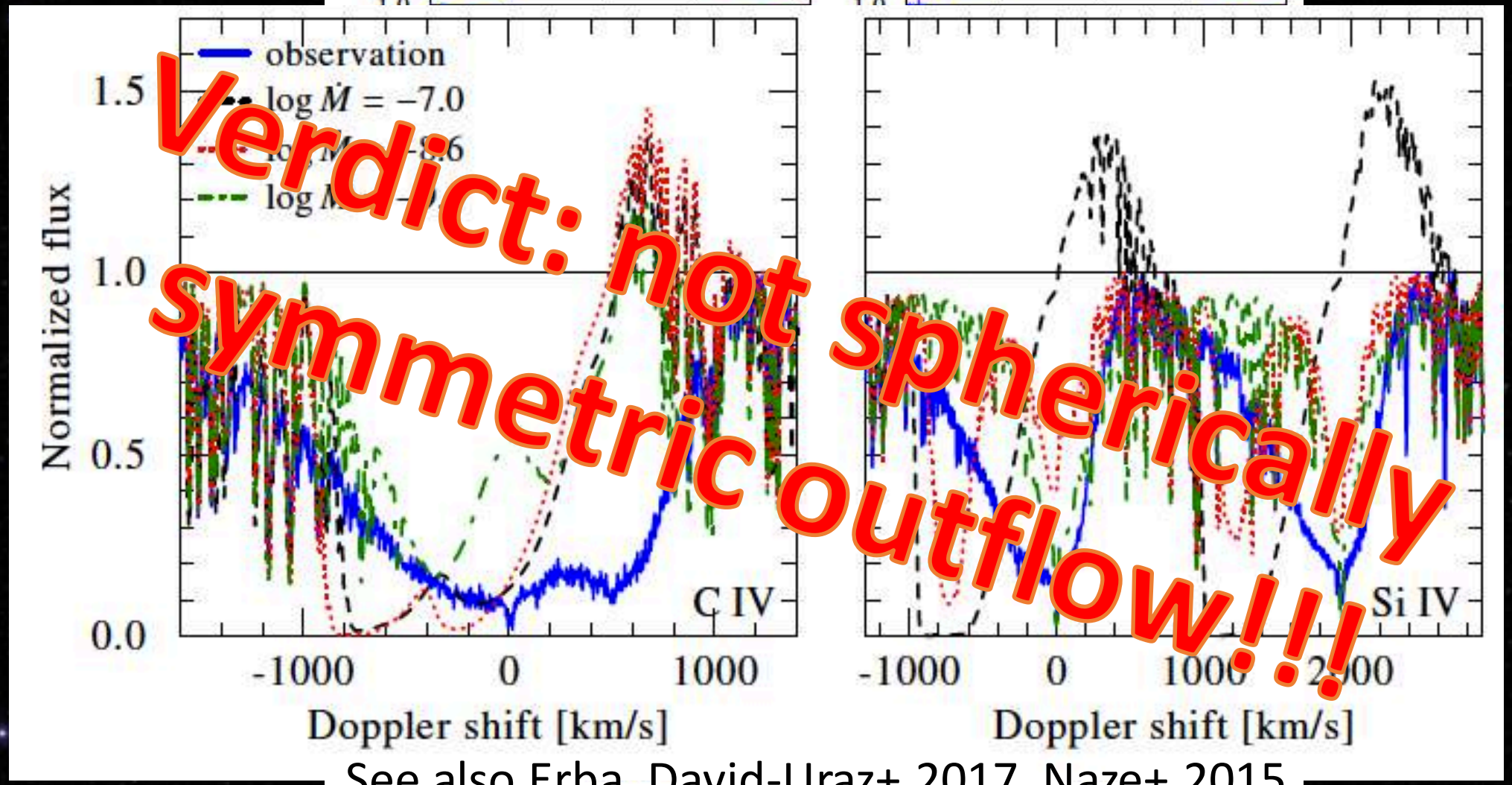

Verdict: not spherically symmetric outflow!!!

See also Erba, David-Uraz+ 2017, Naze+ 2015

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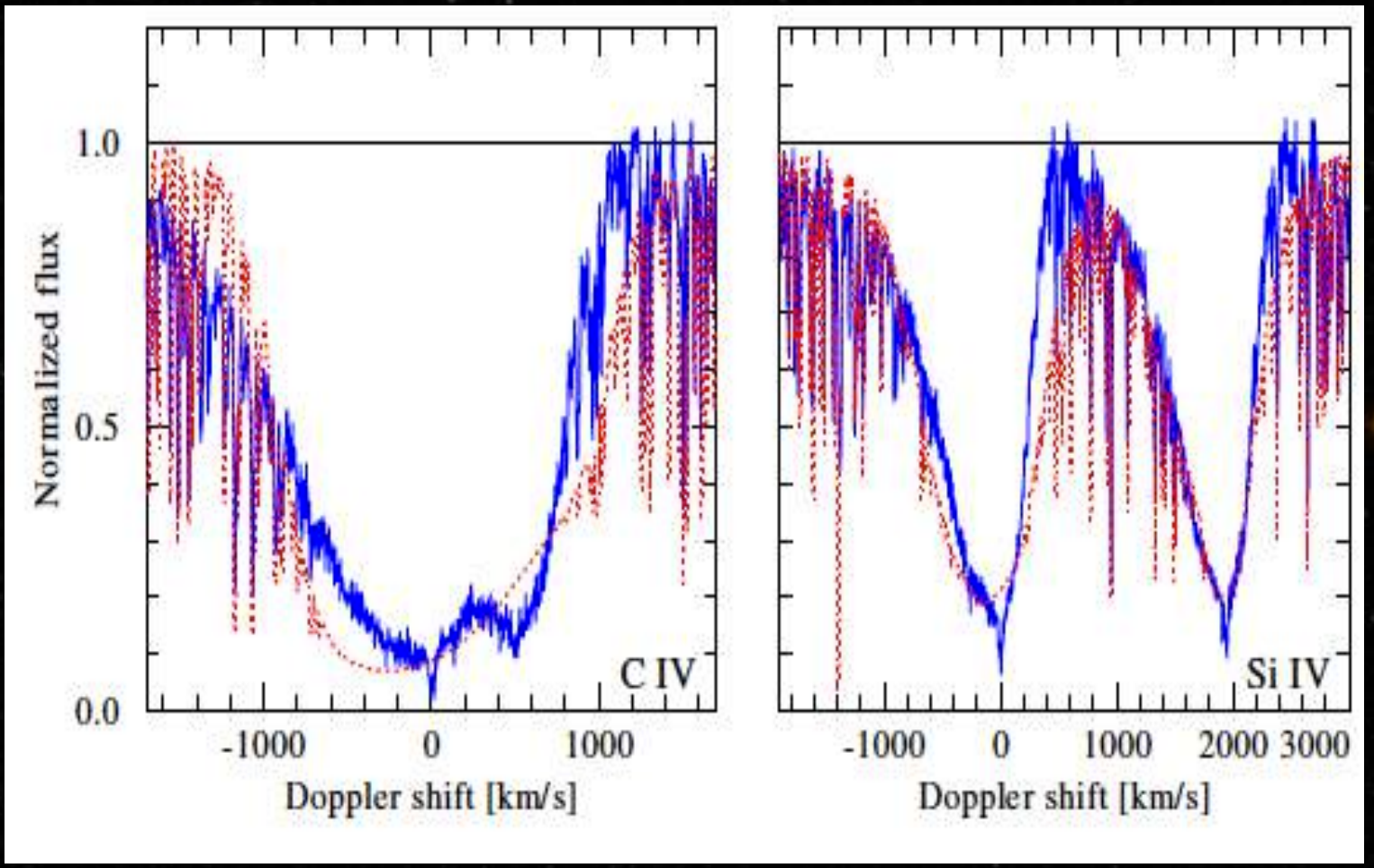

Resonable fit:

1. $v_{\mathrm{mic,\ wind}}$= 500 km/s
2. $\log \dot{M} = -8.8\ [\frac{L_\odot}{\mathrm{yr}}]$
3. $v_\infty = 300$ km/s

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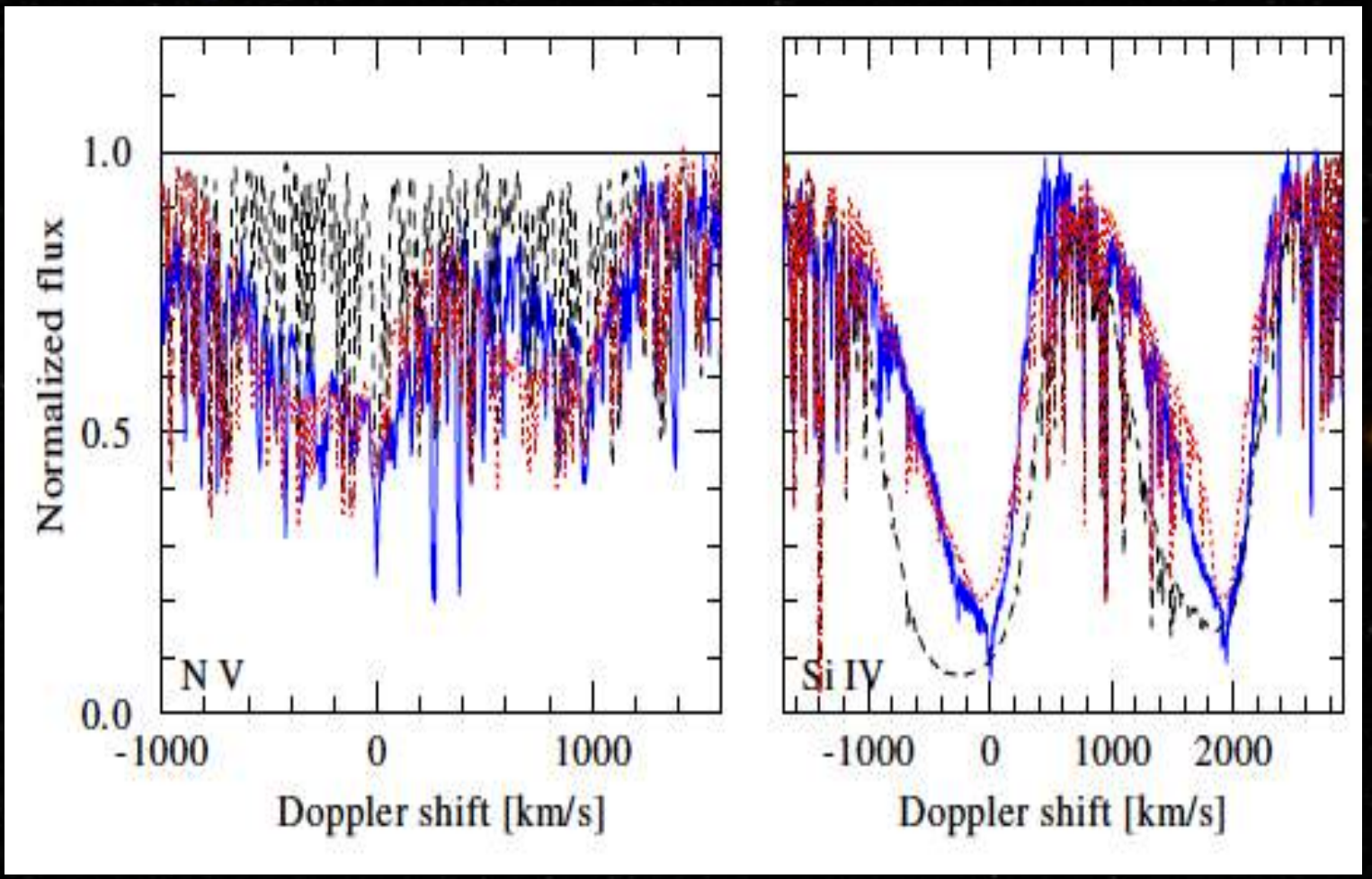

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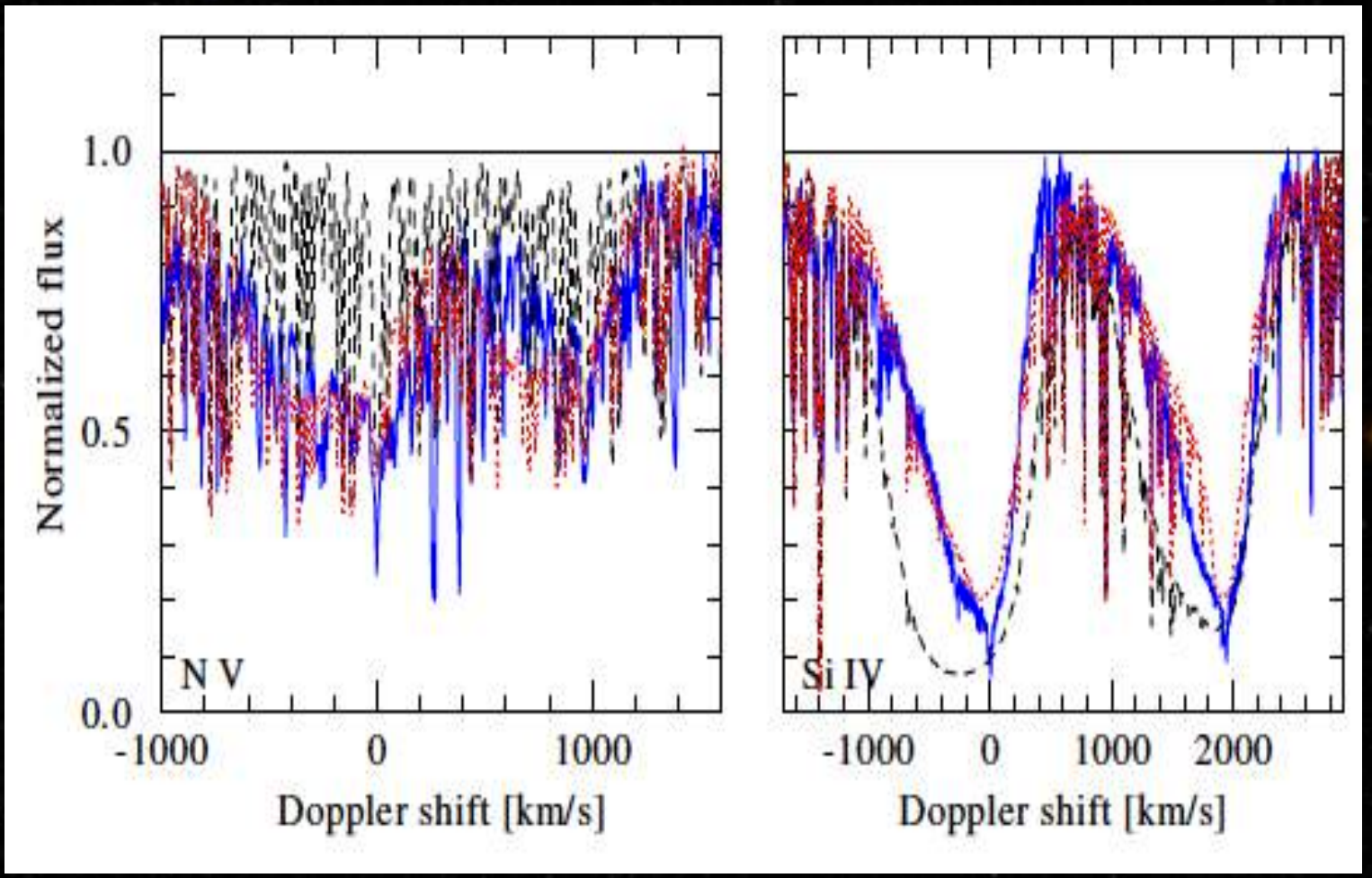

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However:
nonesense in →
nonesense out

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"wind" parameters → density stratification $\rho(r)$

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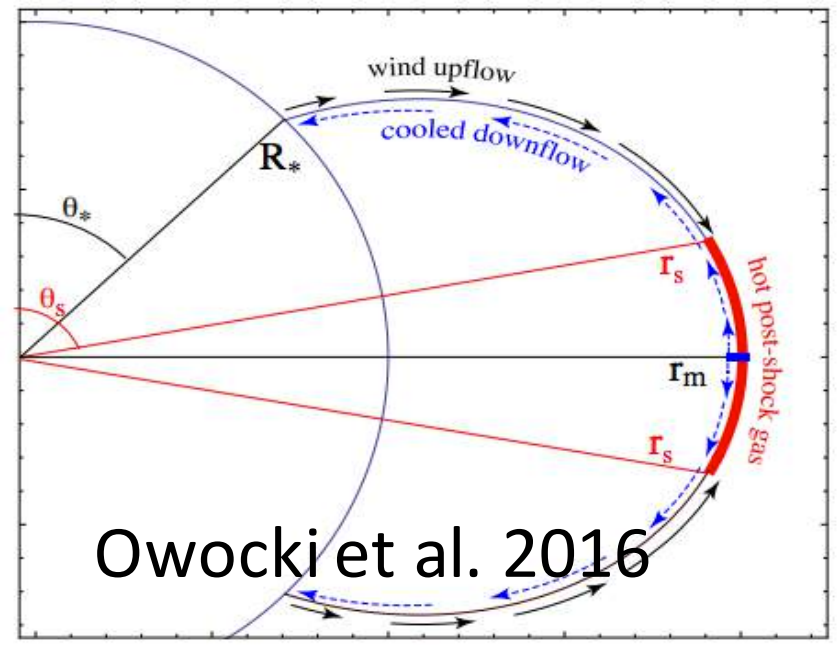
Analytical solution by Owocki et al. 2016 → $\rho(r, \boldsymbol{\theta}, v_\infty, R_*, \dot{M}_{B=0})$



Owocki et al. 2016

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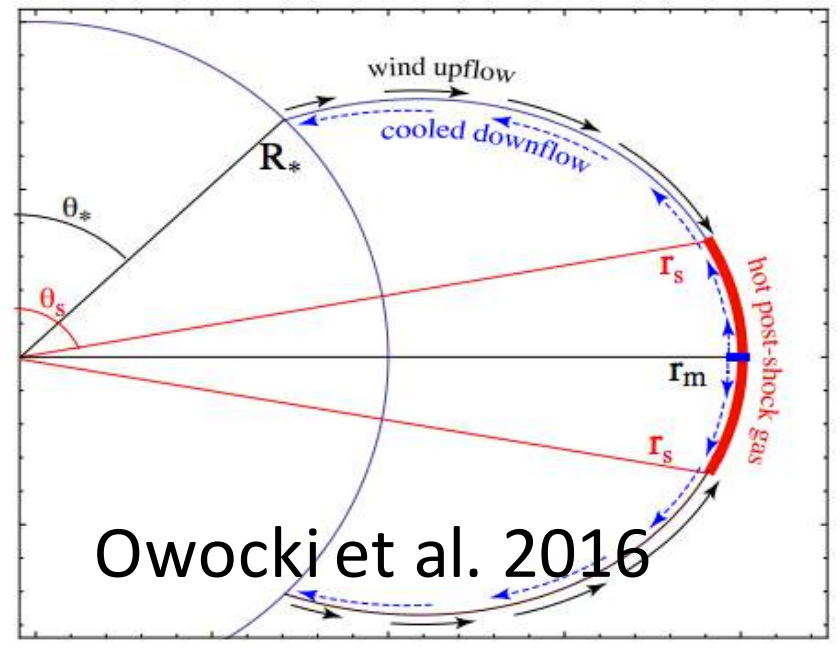

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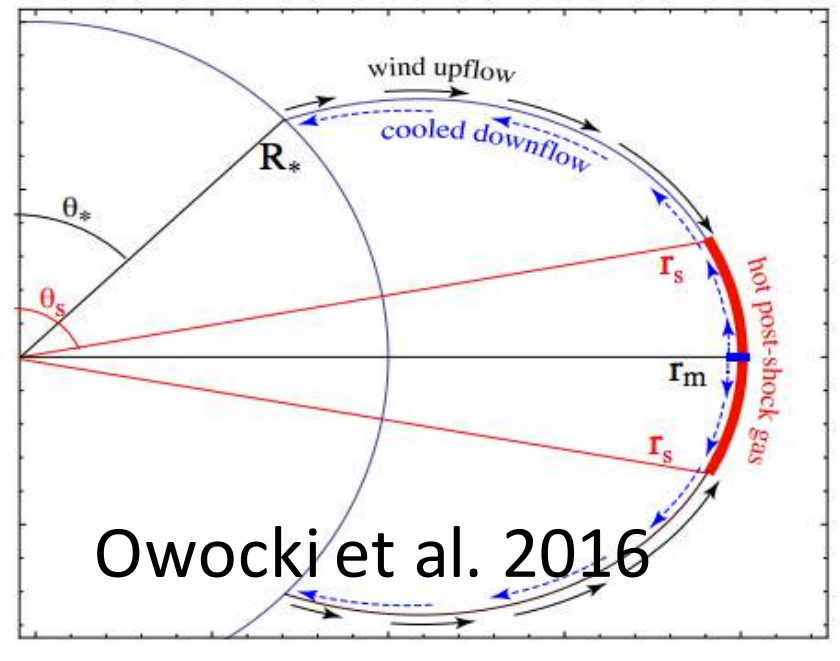

- $\log \dot{M}_{B=0} = -9.0\ [\frac{M_\odot}{\mathrm{yr}}]$
- ~1.5 dex lower than predicted (Vink+ 2000)
- Comparable with weak-wind stars (e.g. Marcolino + 2009)
- Implies $r_A > 12\ R_\odot$; $\log \dot{M} < -10.2\ [\frac{M_\odot}{\mathrm{yr}}]$

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- Multiwavelength (X-ray, UV, optical) spectral analysis of HD 54879
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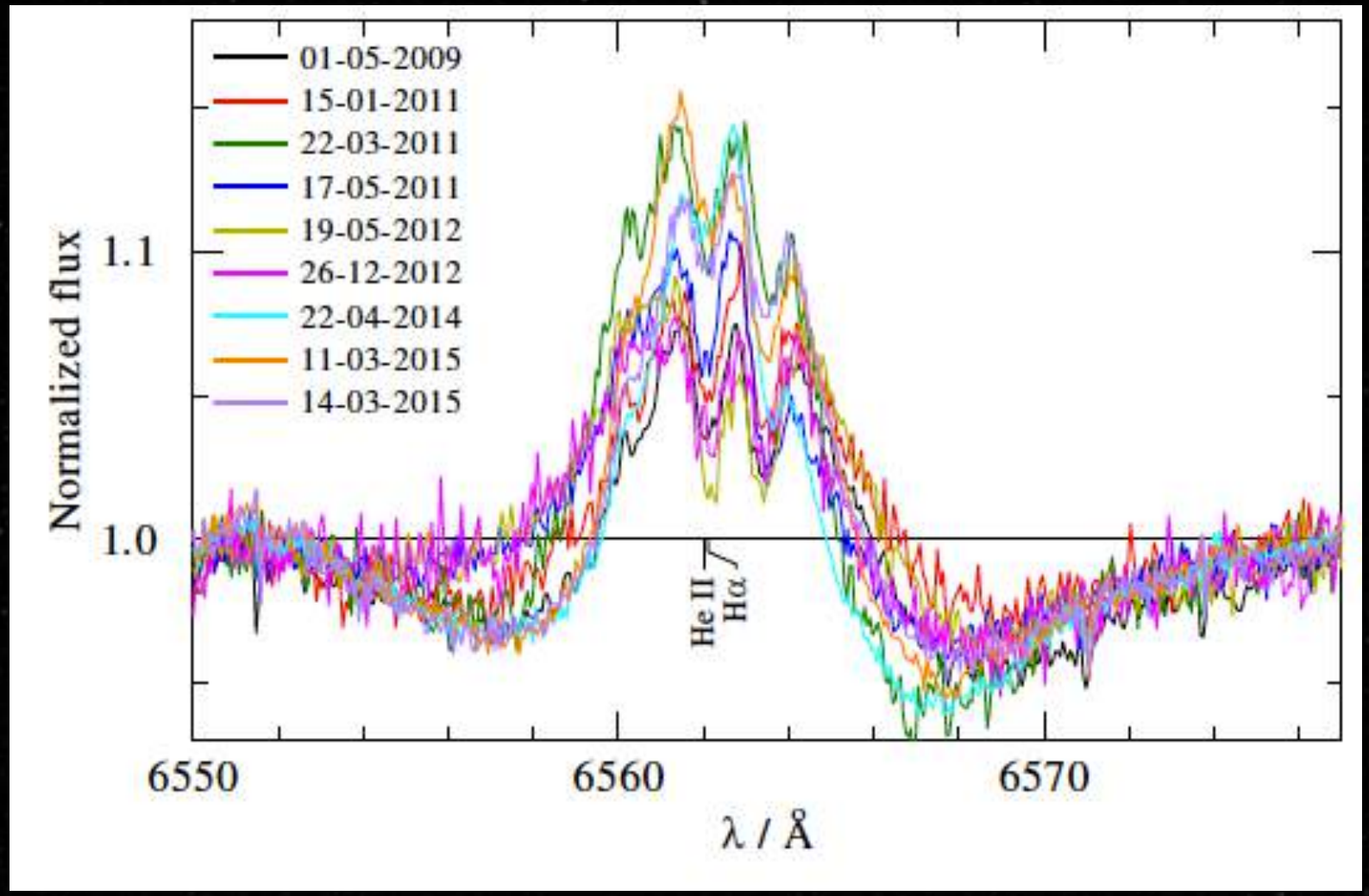
A motivation for your next proposal for magnetic stars:
"magnetic stars help to quantify the weak-wind problem"

HD 54879: variability



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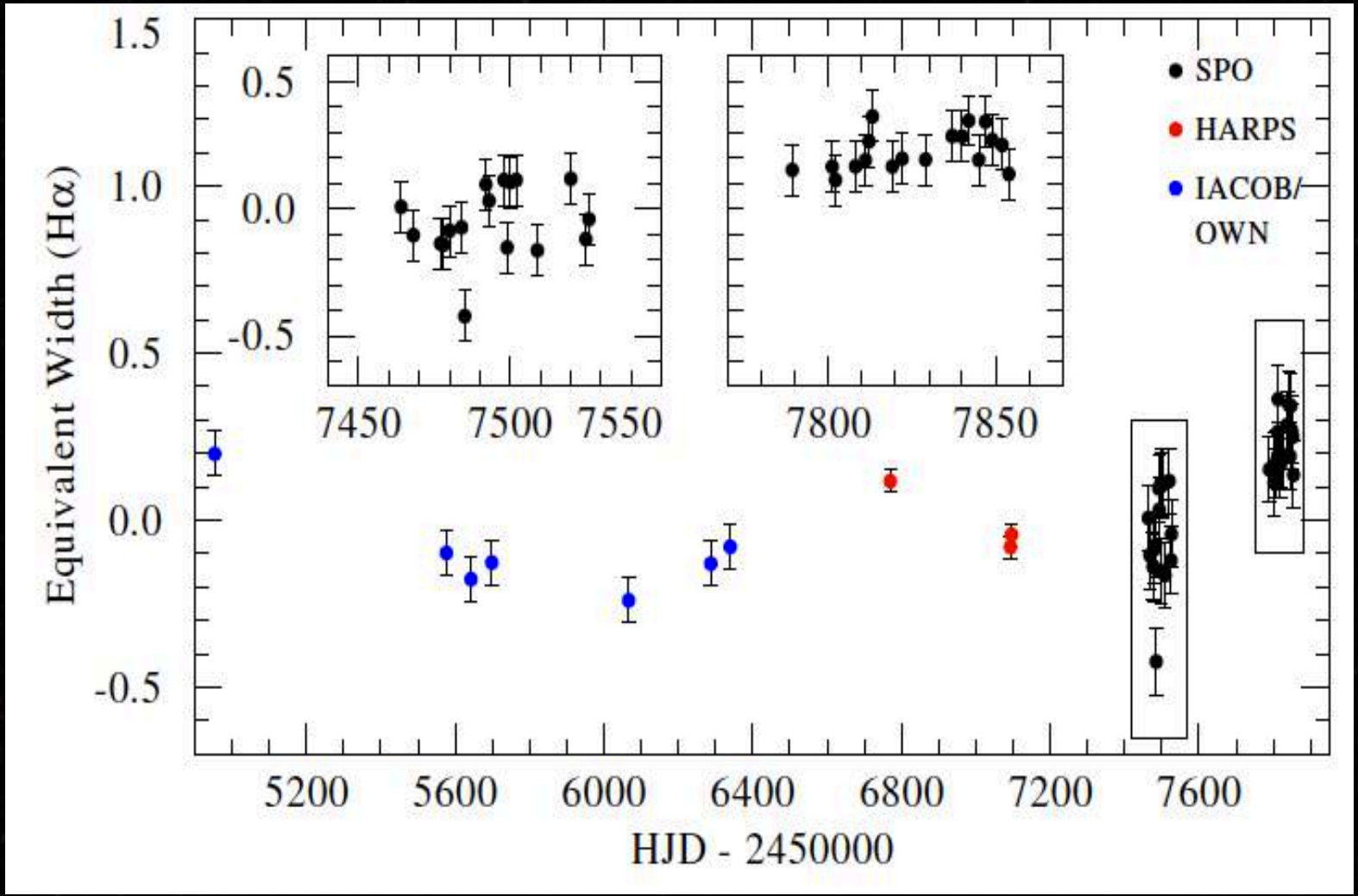


HD 54879: what we already know

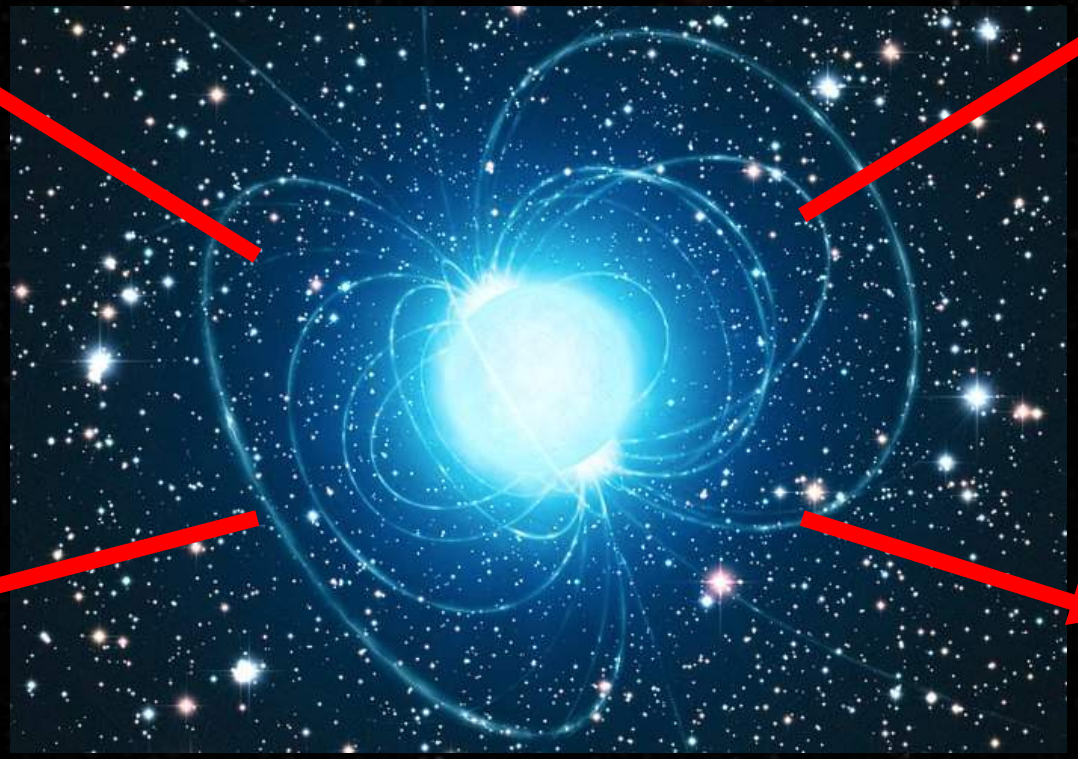
O9.7 V
V ~ 7.65
D ~ 1300 pc

D ~ 1000 pc

$v \sin i, v_{mac} < 4$ km/s

$v \sin i = 7$ km/s
v_{mac} =8 km/s

Castro + 15, BOB collaboration



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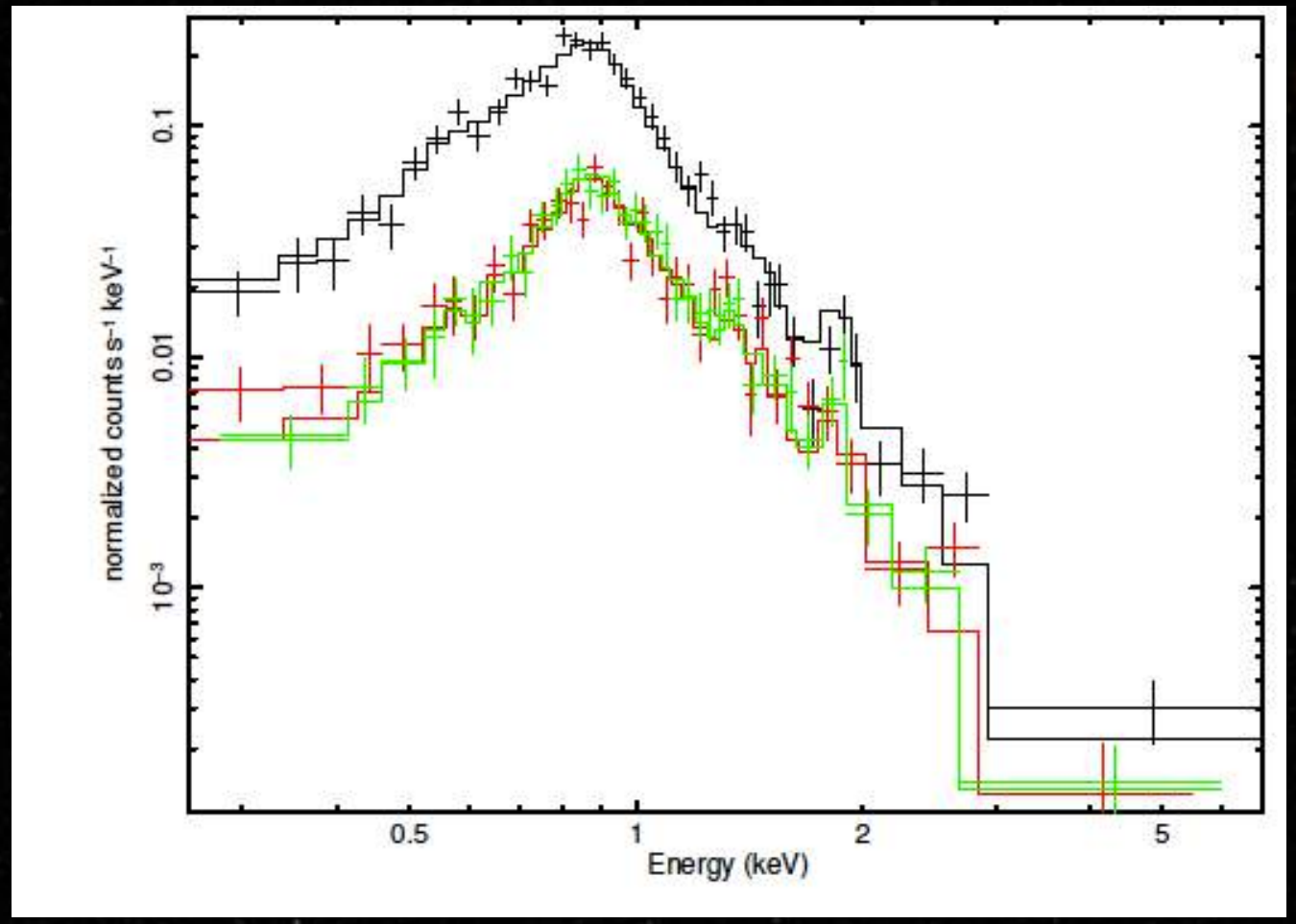
$\log g \sim 4.0\ [cgs]$

HD 54879: X-rays



Multi temperature model:

$$6.2\ \mathrm{MK} < T_{\mathrm{X-rays}} < 20\ \mathrm{MK}$$

$$L_{\mathrm{X-ray}} \approx 10^{32}\mathrm{erg/s}$$

$$\frac{L_{\mathrm{X-ray}}}{L_{Bol}} = -6$$ (X10 than average!)

→ X-ray excess due to collisions at magnetic equator