

Detectability of resolved hydrogen lines from the accretion shock at gas giants and their CPDs

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(Uni Duisburg–Essen, MPIA, Uni Bern)

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Yuhiko Aoyama (Sun Yat-sen University), Inga Kamp (Groningen)



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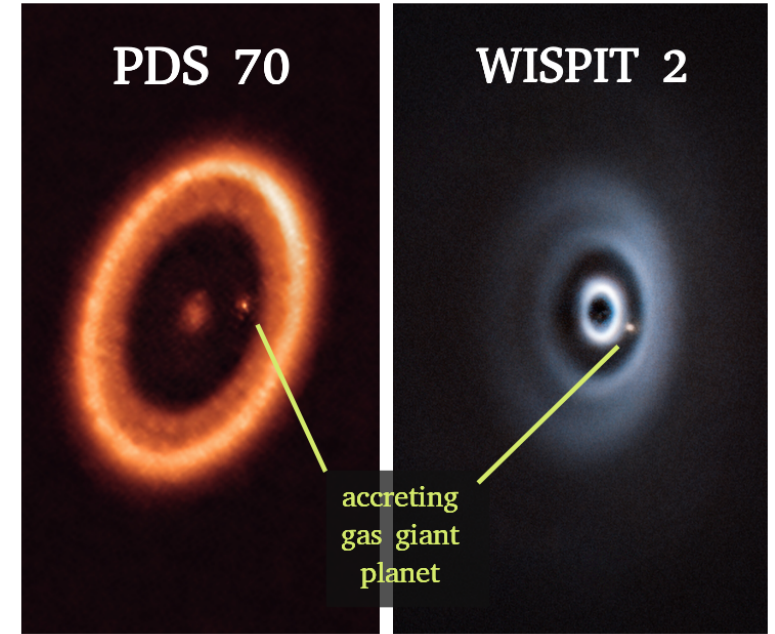
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Planetary-mass accretors in discs

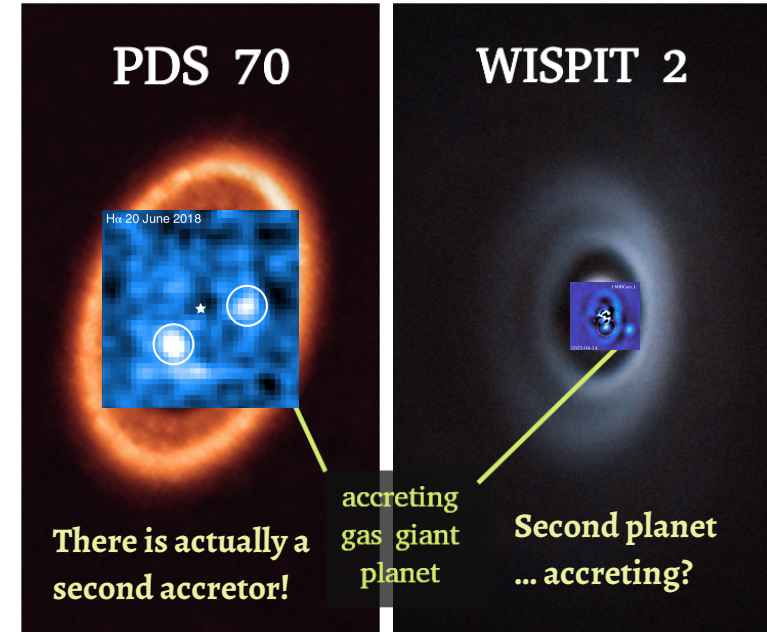
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Benisty et al. (2021), Haffert et al. (2018)
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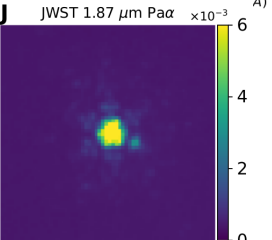
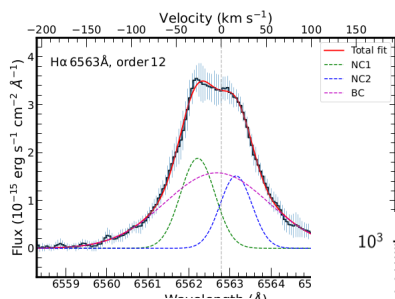
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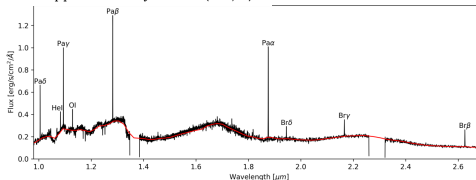
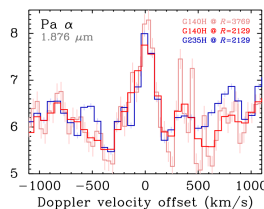
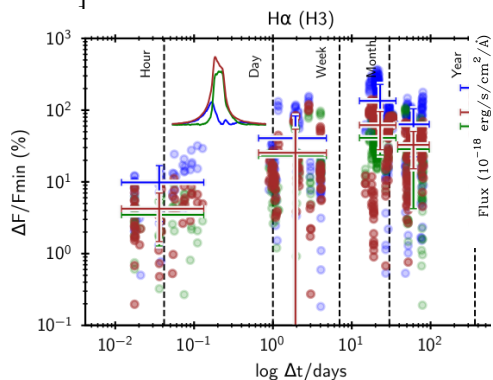
Planetary-mass accretors in discs

- Small numbers still...
- ... but growing!
- There are also some (semi-)isolated accretors

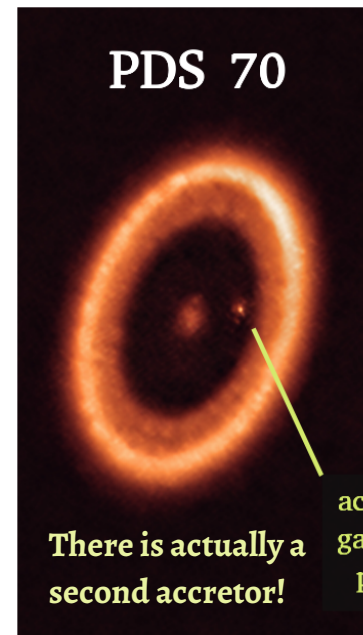
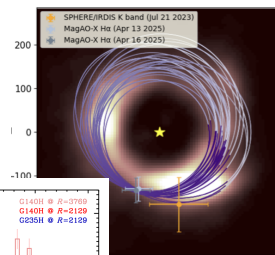


Vila et al. (2025)

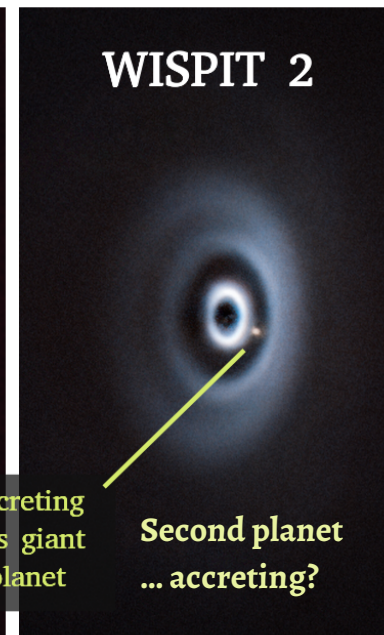
Marleau et al. (2024)
Viswanath et al. (2024, 2026)
Demars et al. (2026)



Li et al. (2025)



There is actually a second accretor!



accreting gas giant planet

Second planet ... accreting?

Benisty et al. (2021), Haffert et al. (2018)
van Capelleveen et al. (2025), Close et al. (2025b)
Lawlor et al. (2026)

Almendros-Abad et al. (2025)

Coming soon...



ELT from VLT



VLT from ELT

Coming soon...

Imager



Coming soon...



High-resolution Spectrograph

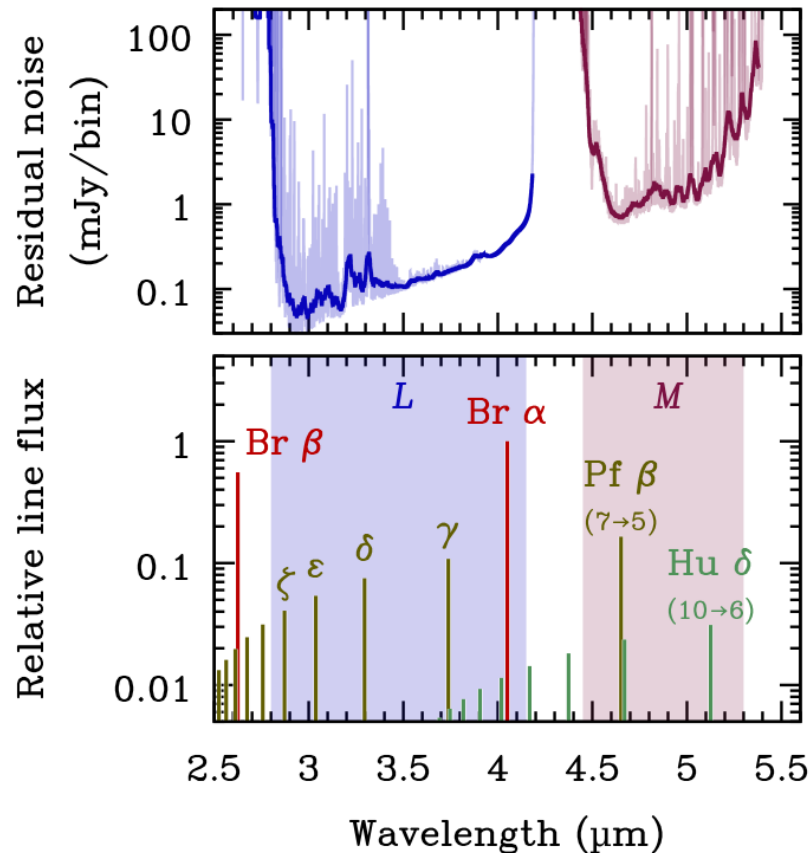


Coming soon...



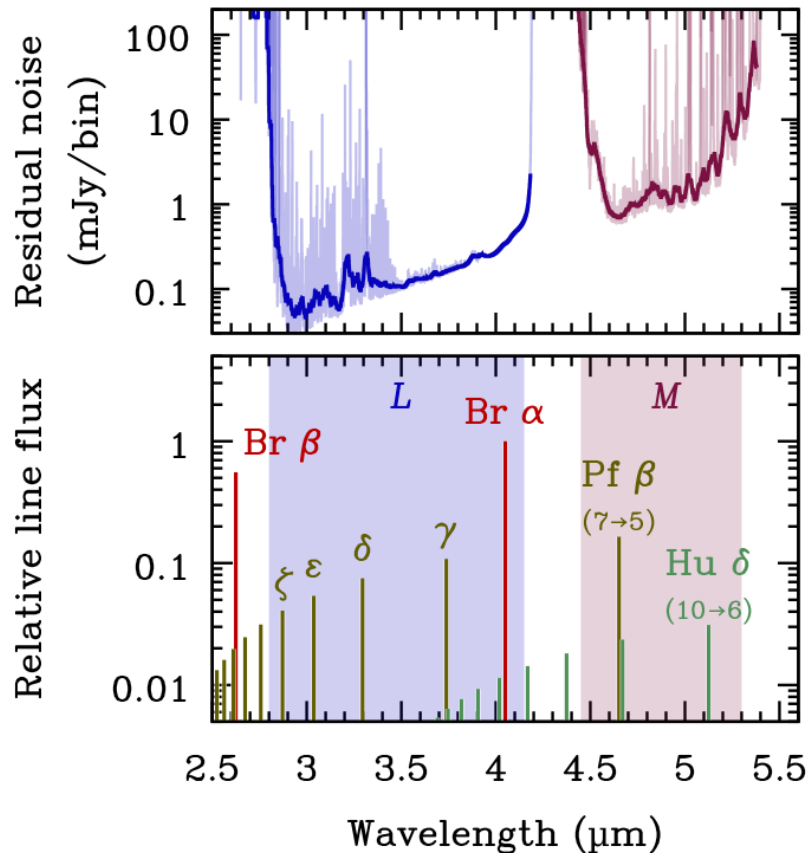
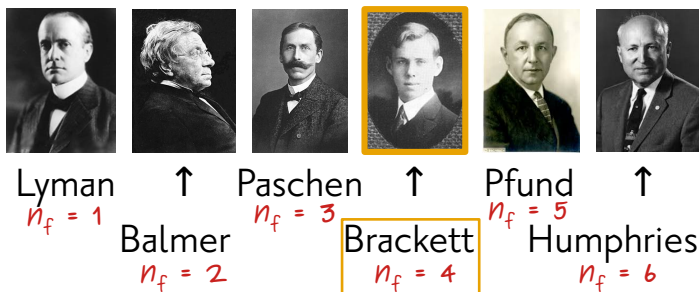
Coming soon...

- The ELT: Extremely Large Telescope
- First light: 2029–2030
- METIS: first-generation, $R \sim 10^5$



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- First light: 2029–2030
- METIS: first-generation, $R \sim 10^5$
- Study accreting planets! Main: Brackett alpha

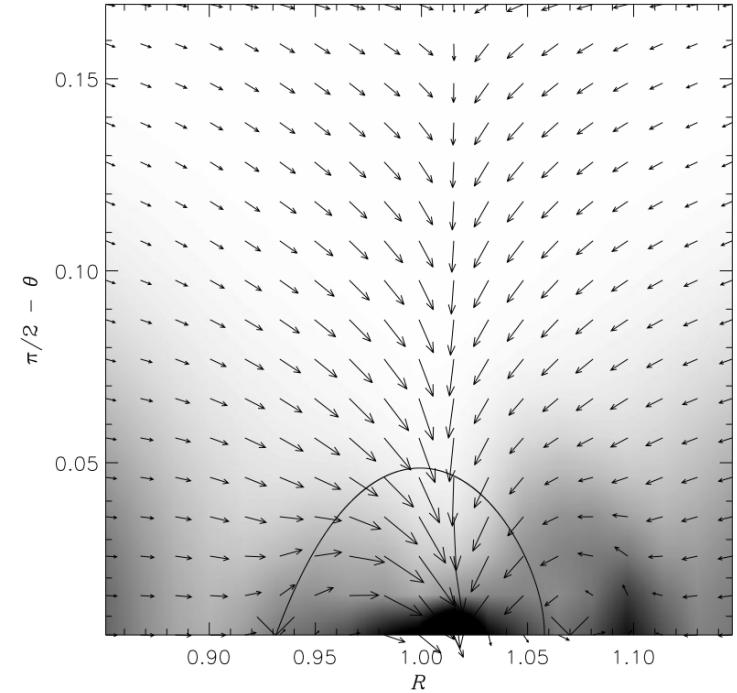


Our goals and methods

- Predict spectral shape of emission lines
- Focus on gap-opening planets in discs

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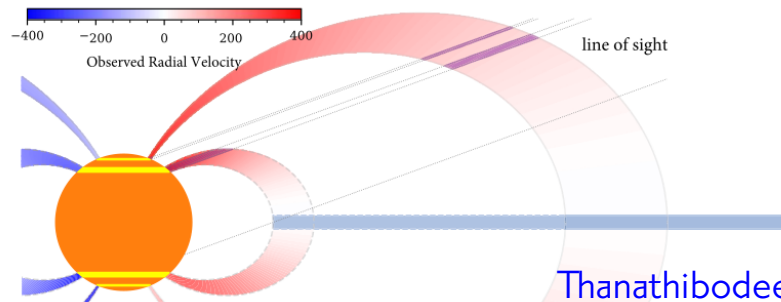
Kley, D'Angelo & Henning (2001)

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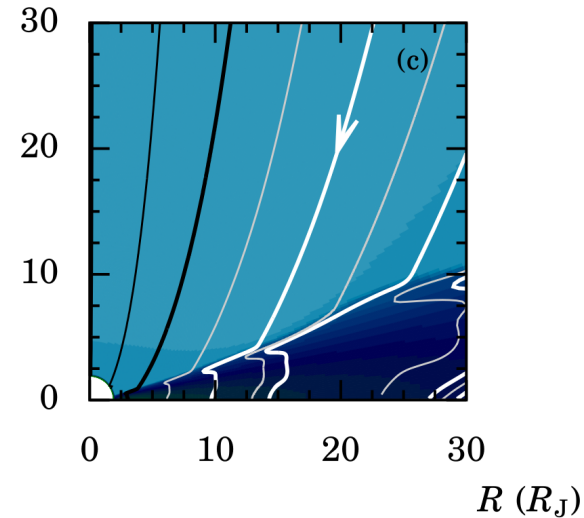
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Thanathibodee et al. (2019)

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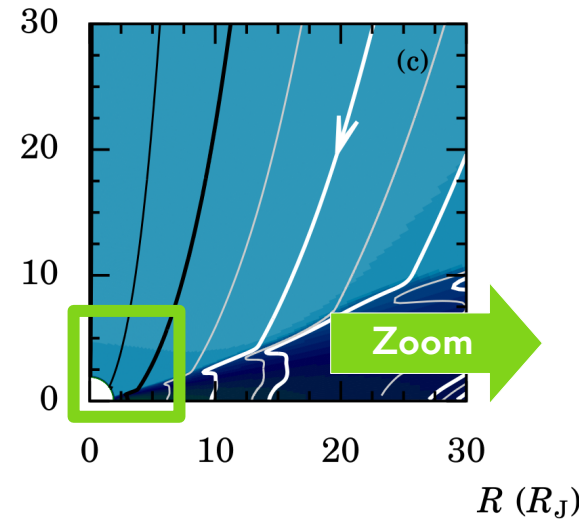
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Marleau et al. (2023)

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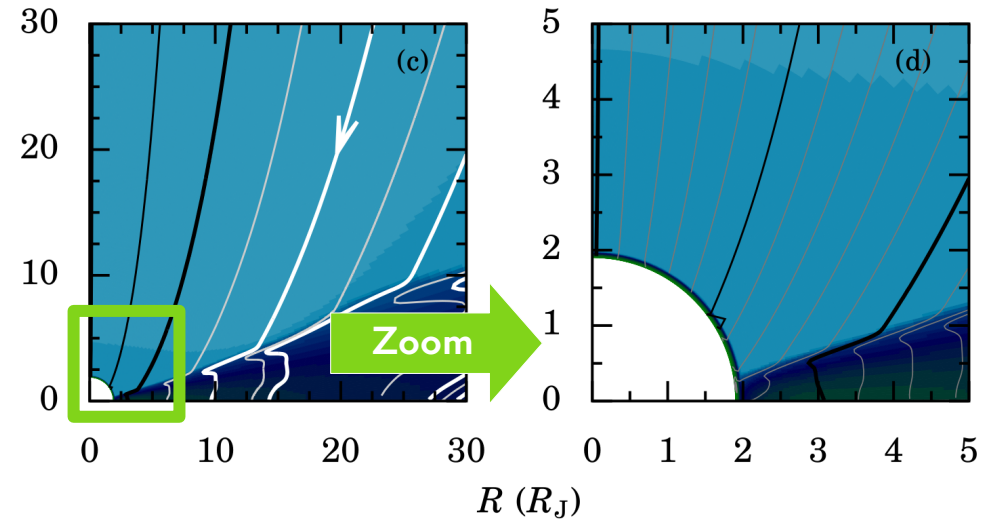
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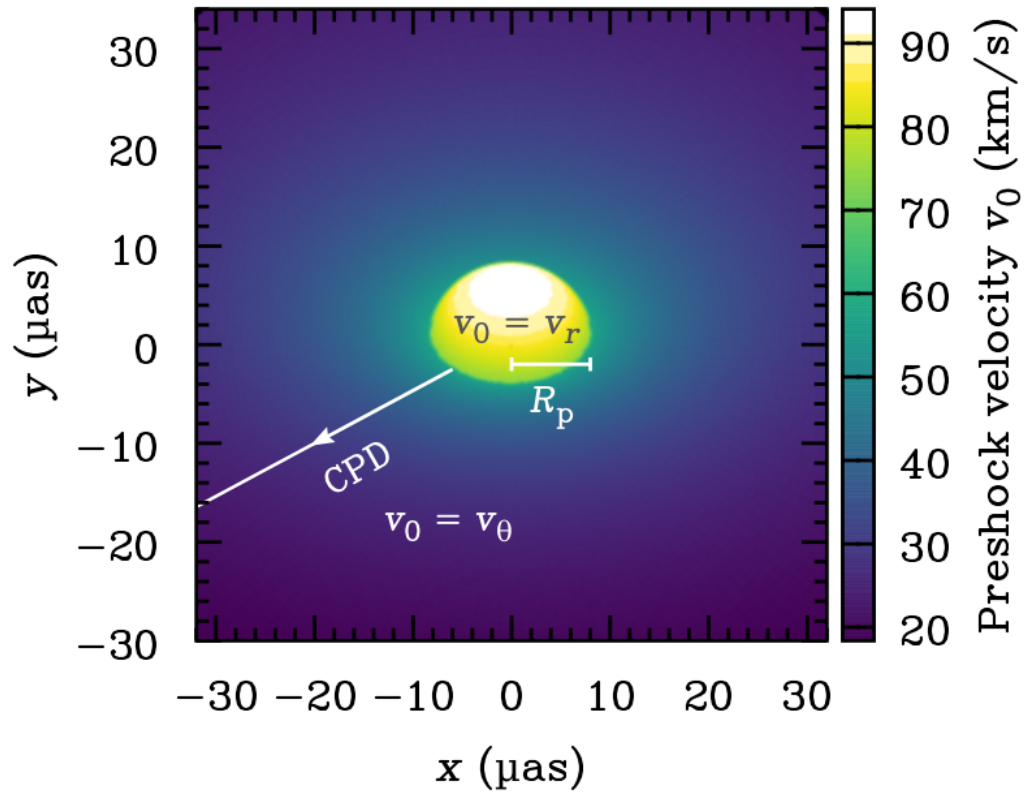
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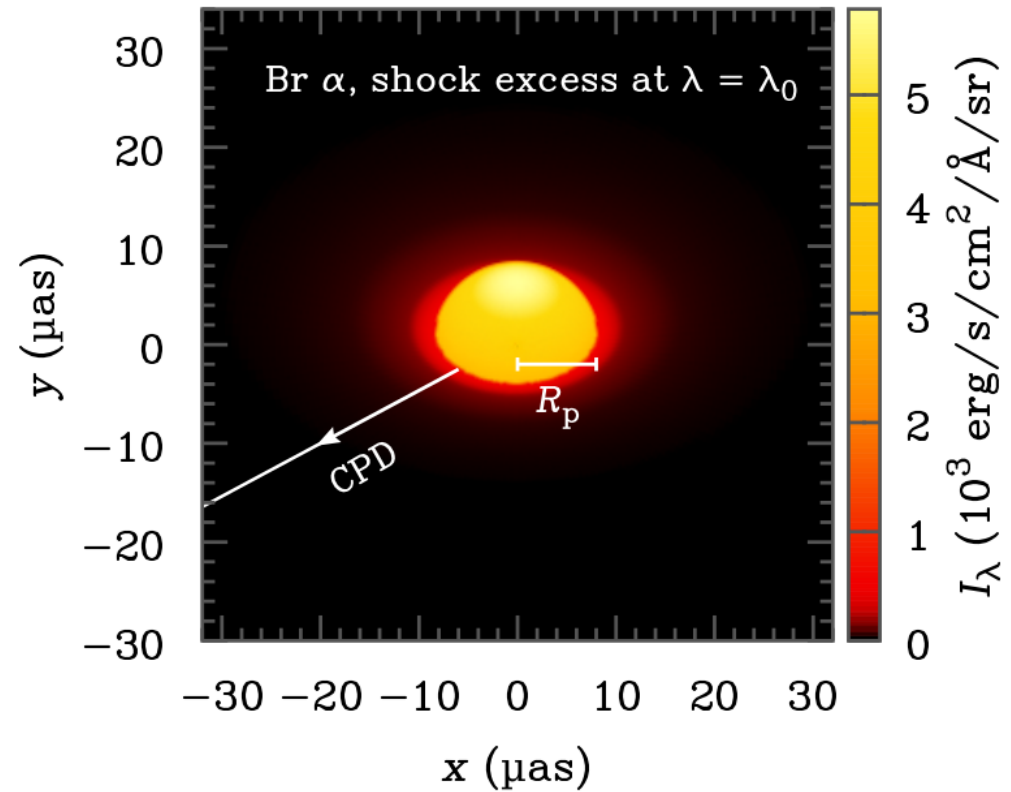
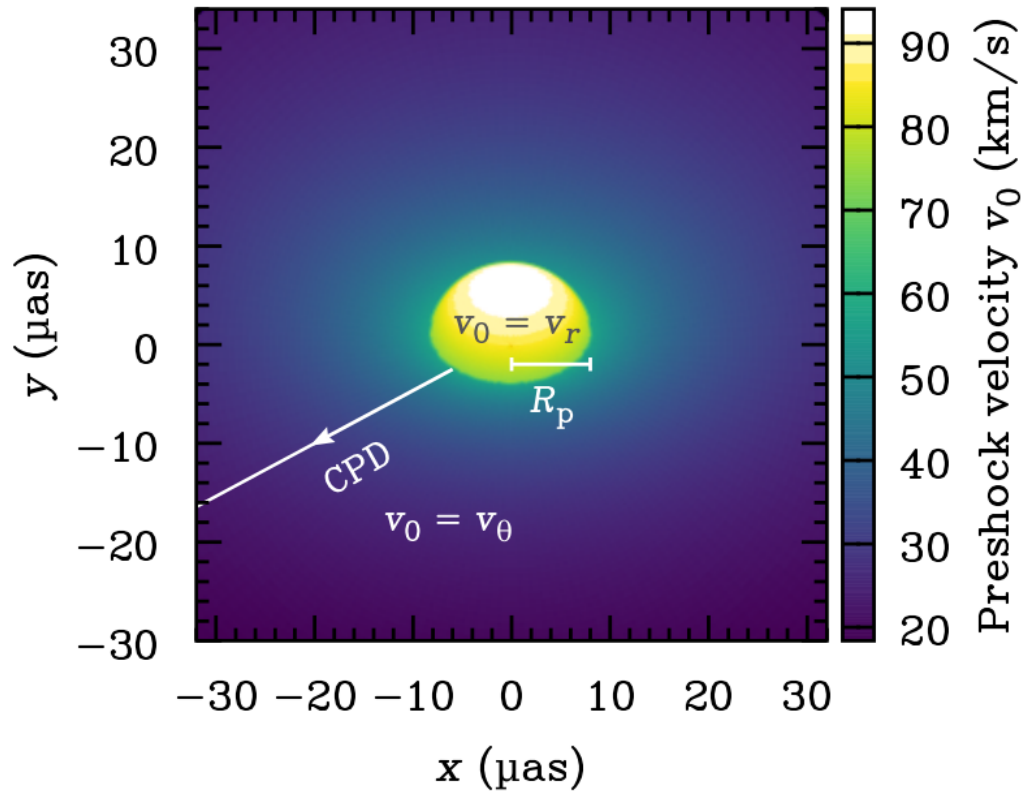


Marleau et al. (2023)

Line-emitting regions

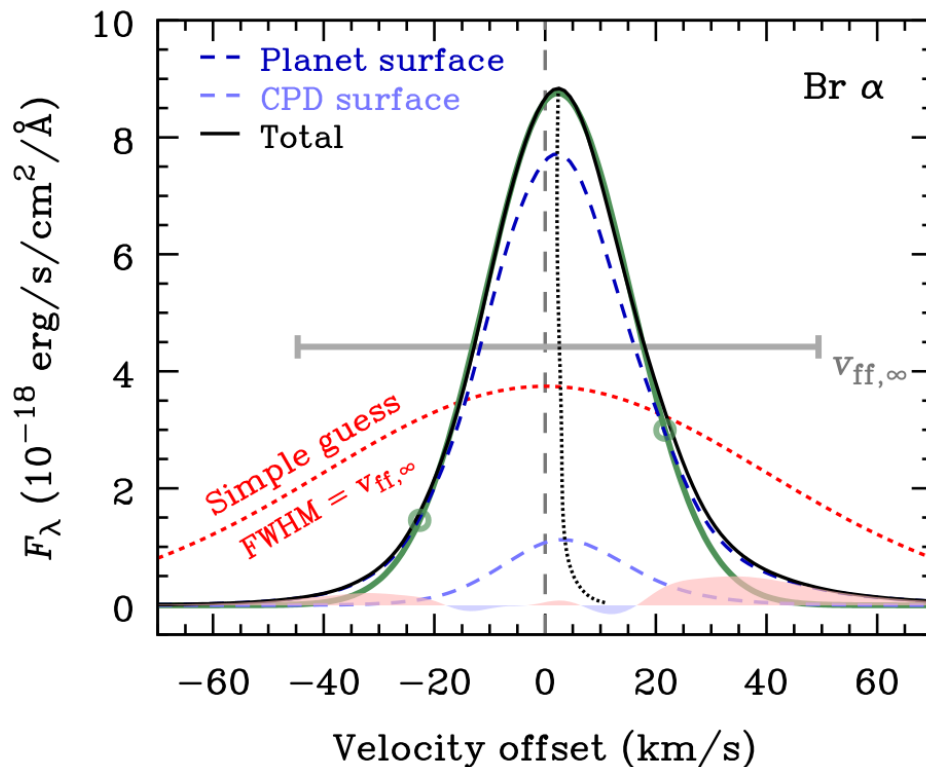


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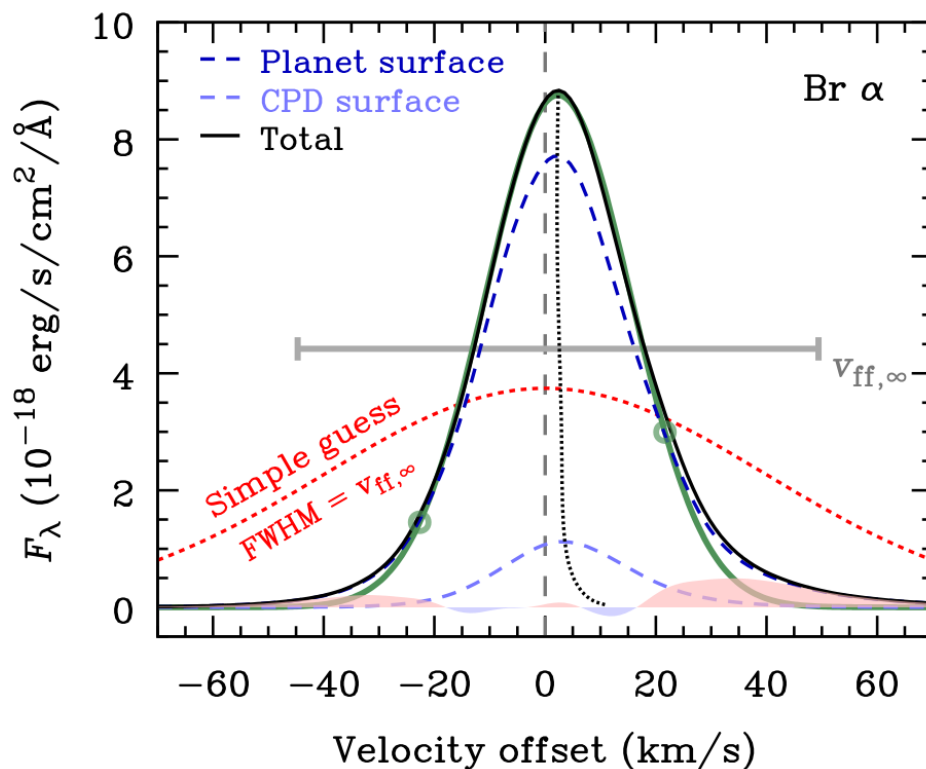
Spatially-integrated line profile

- Narrow line: FWHM ~ 30 km/s
- ... much less than **free-fall velocity**



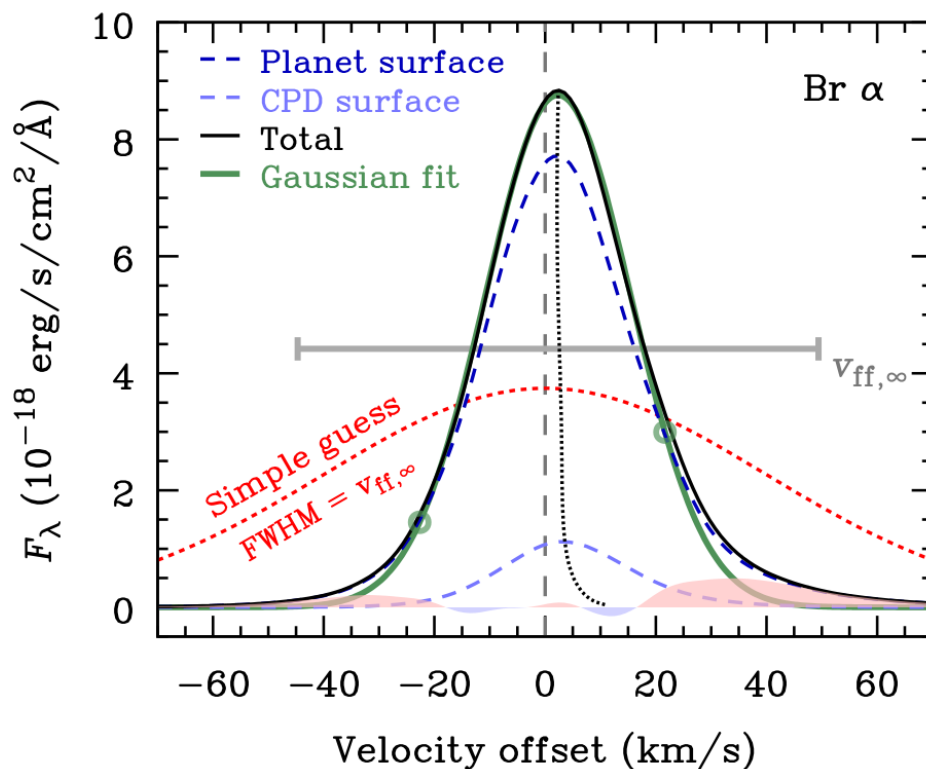
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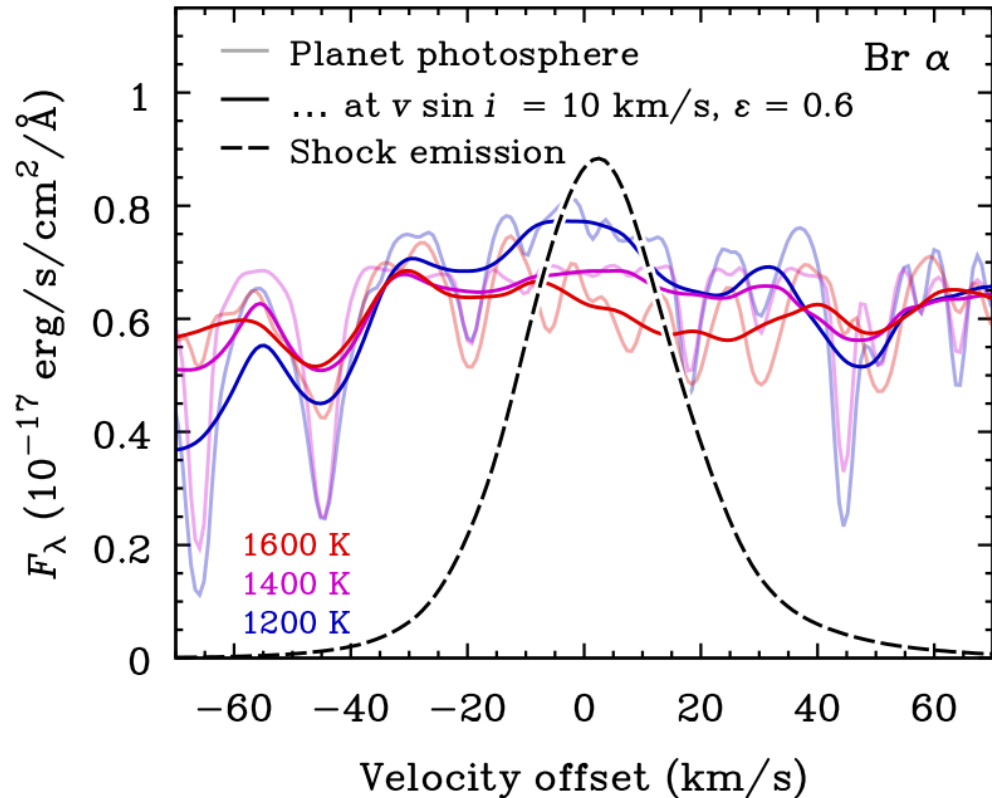


Spatially-integrated line profile

- Narrow line: FWHM ~ 30 km/s
- ... much less than **free-fall velocity**
- Shift of +2 km/s $\leftarrow$ postshock emission
- Slight asymmetry only in wings
- Gaussian core, broader wings



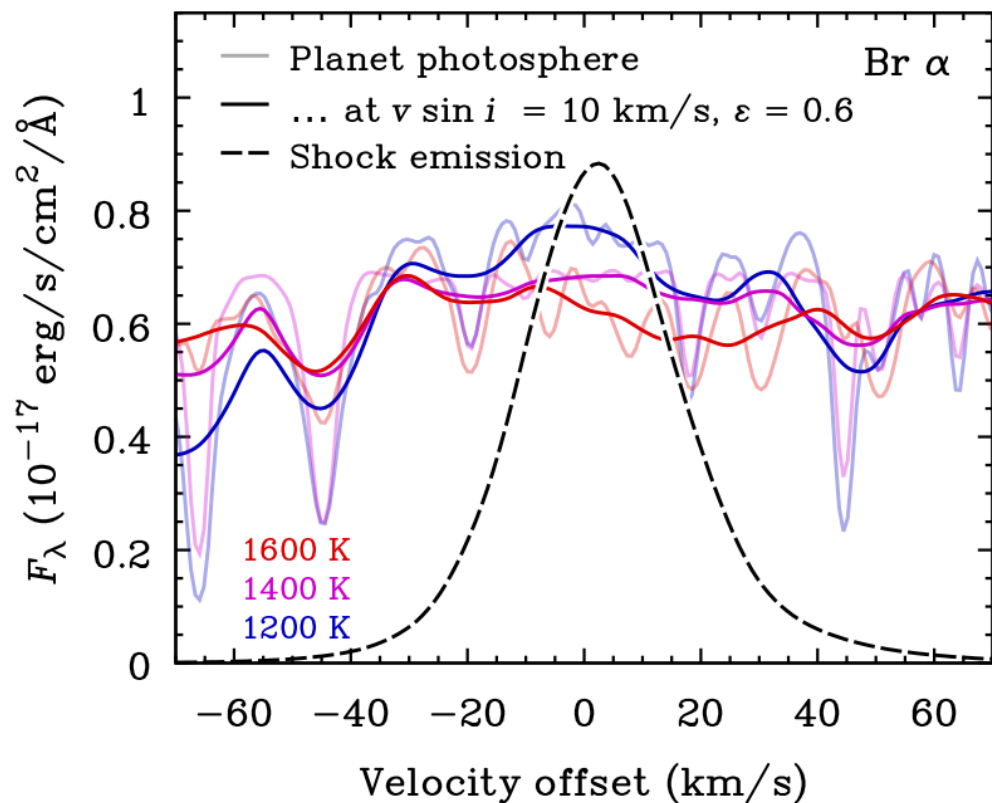
Photosphere: “noise”



Line peak similar to continuum

- Good! Could have been much weaker
- This is for fiducial parameters; could be a bit more favourable

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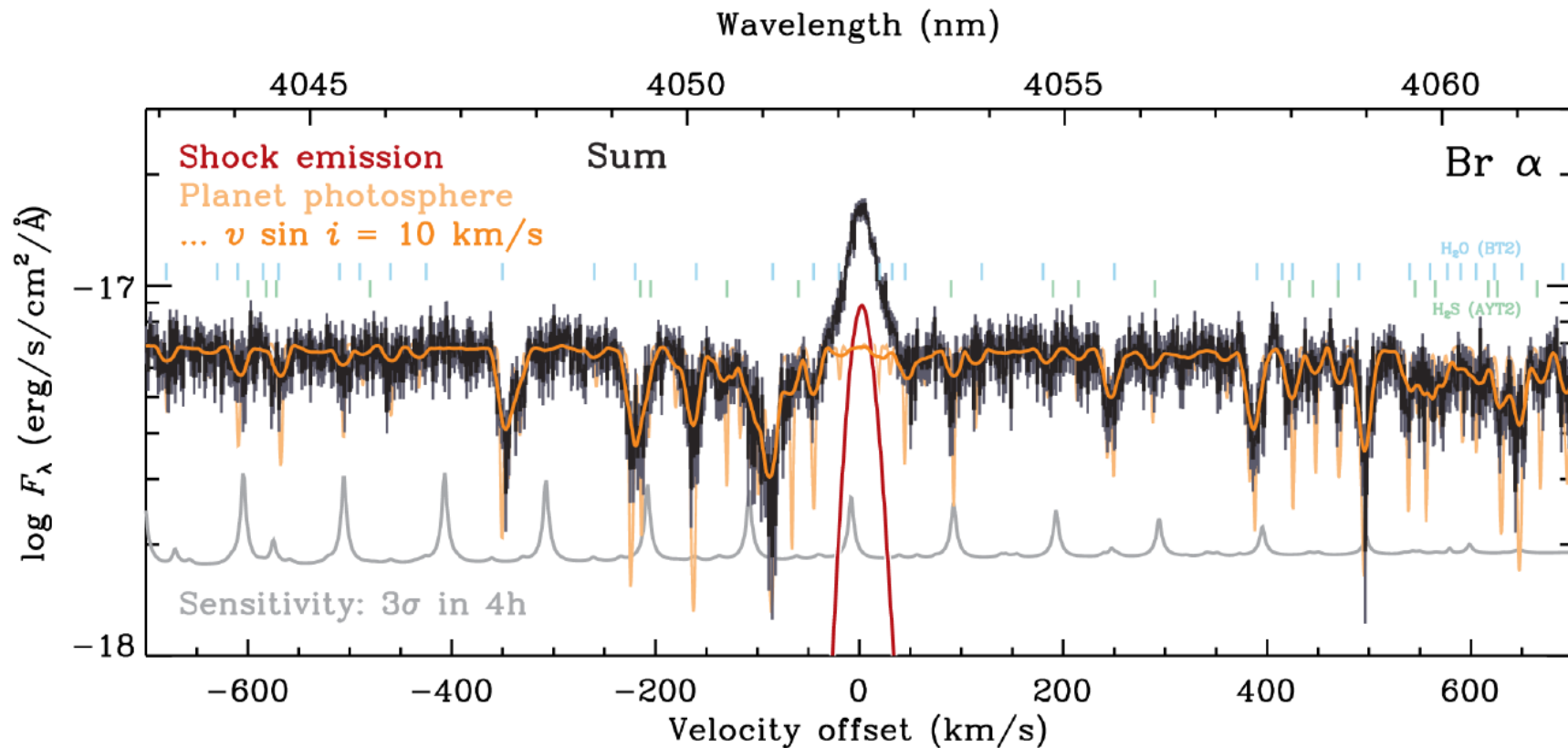
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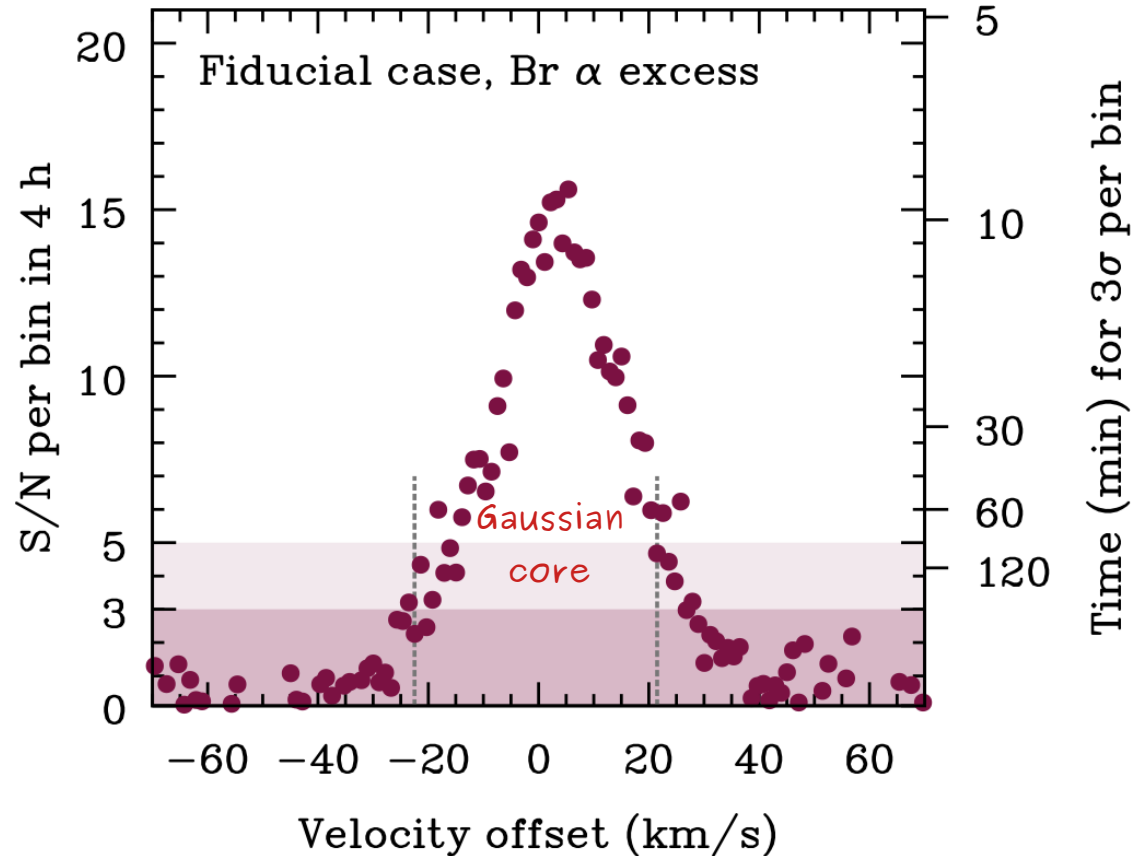
Rotational broadening:
smooths only the photosphere!

→ helps

Simulated spectrum with noise

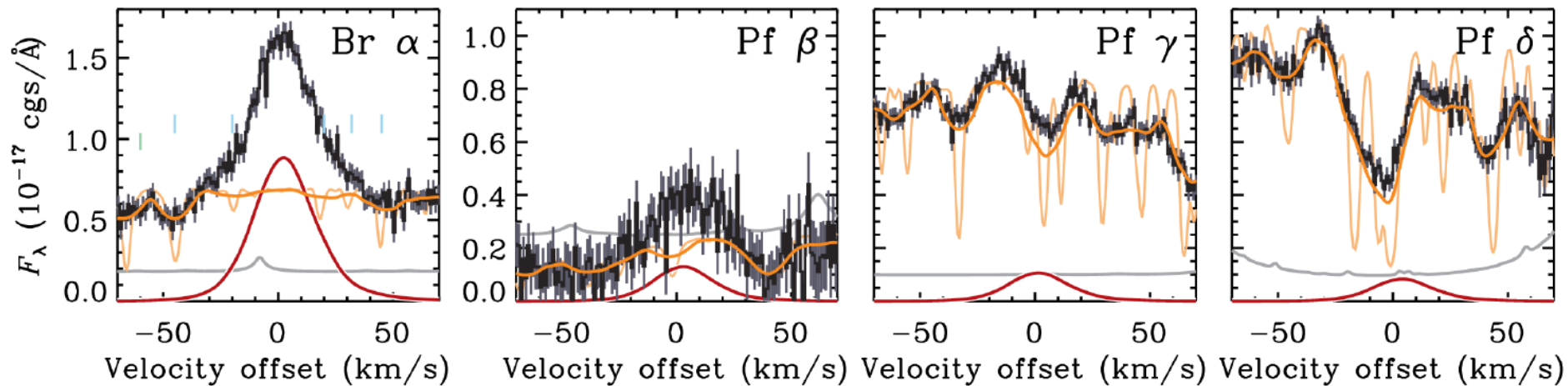


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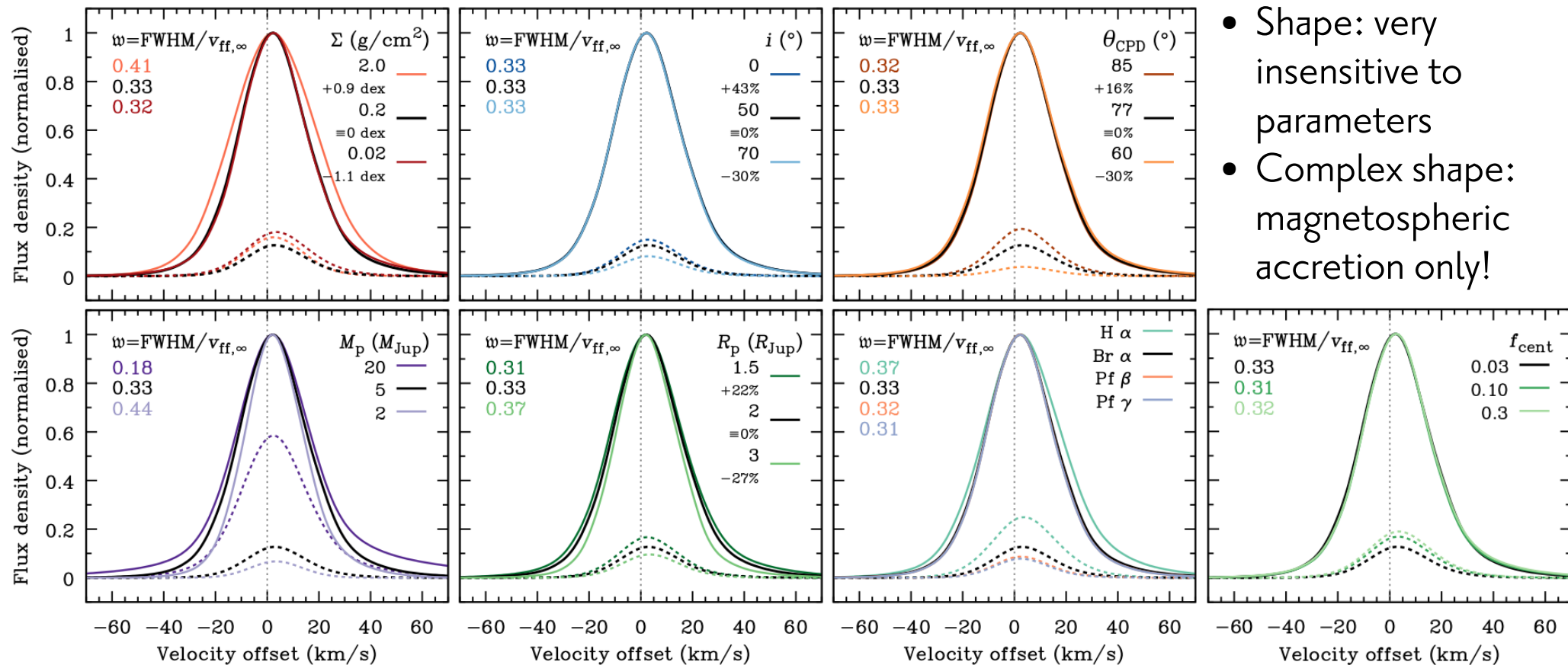


Other lines accessible to METIS

*Other hydrogen lines:
Not very detectable (but worth a try)*

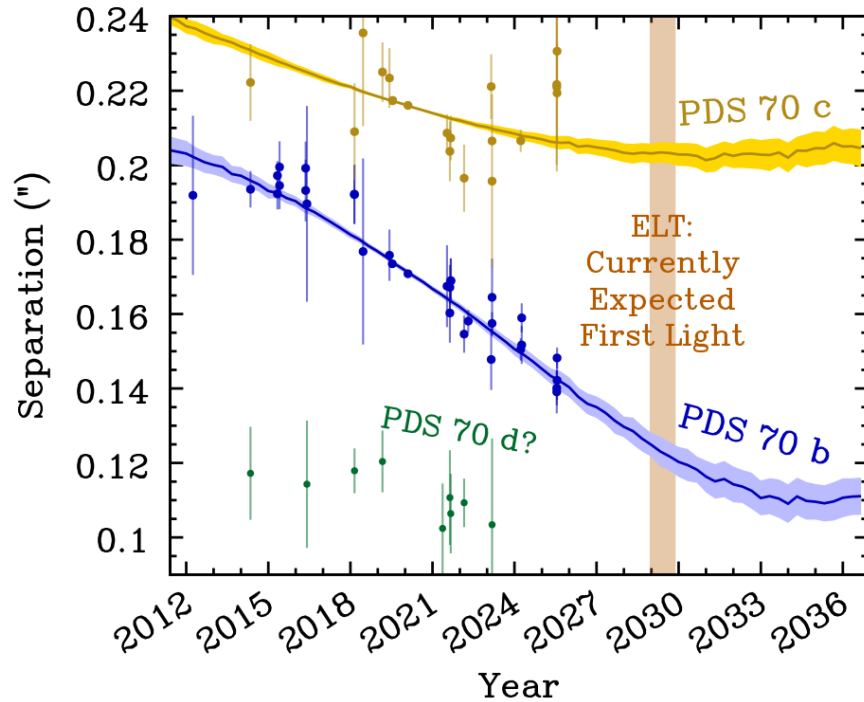


Line shape: ~insensitive to parameters

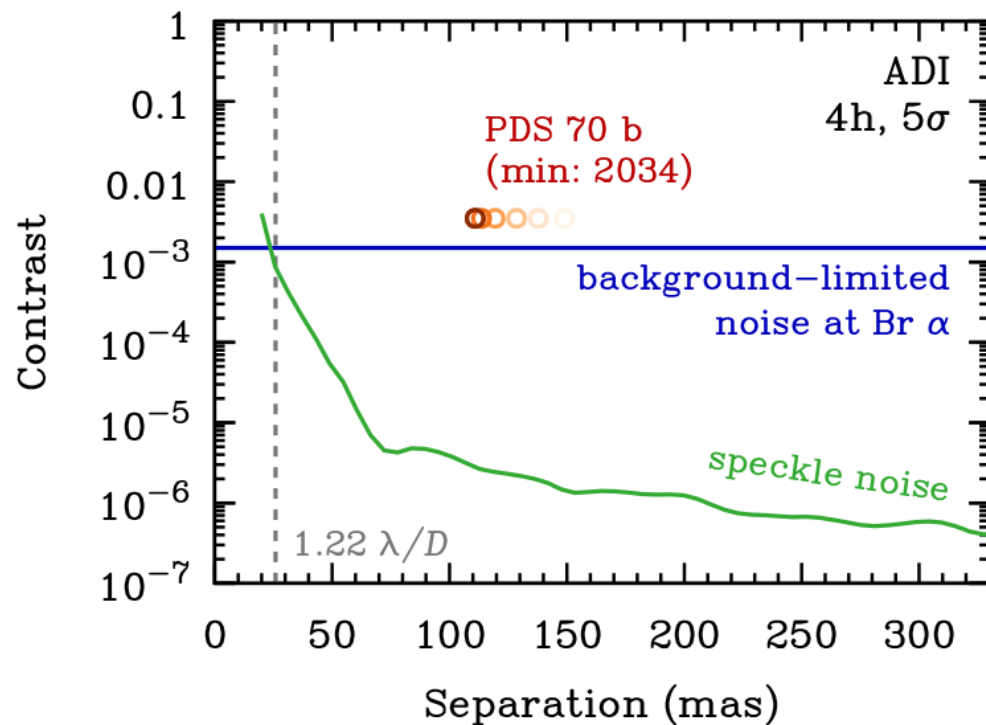
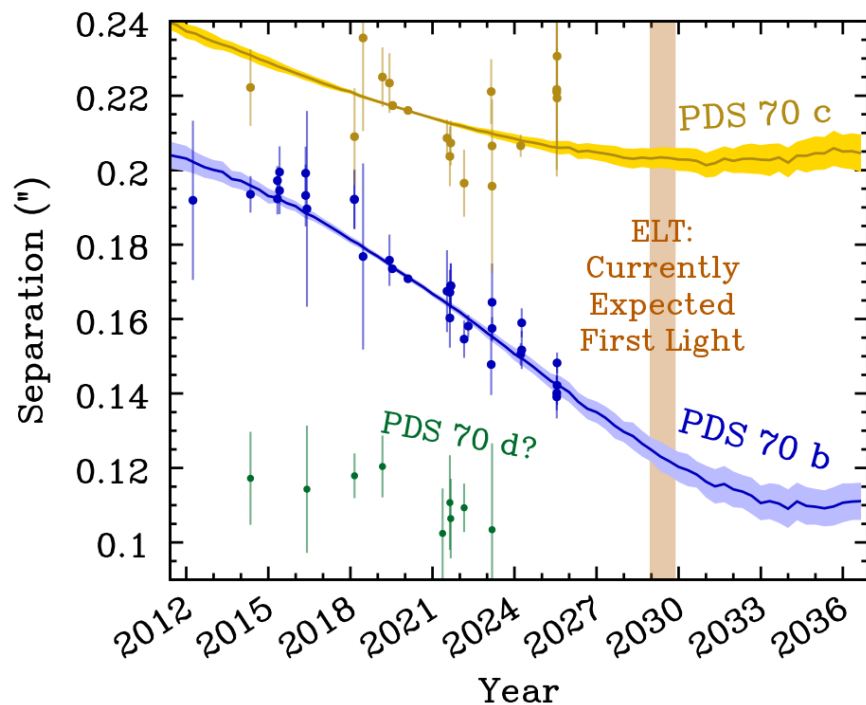


- Shape: very insensitive to parameters
- Complex shape: magnetospheric accretion only!

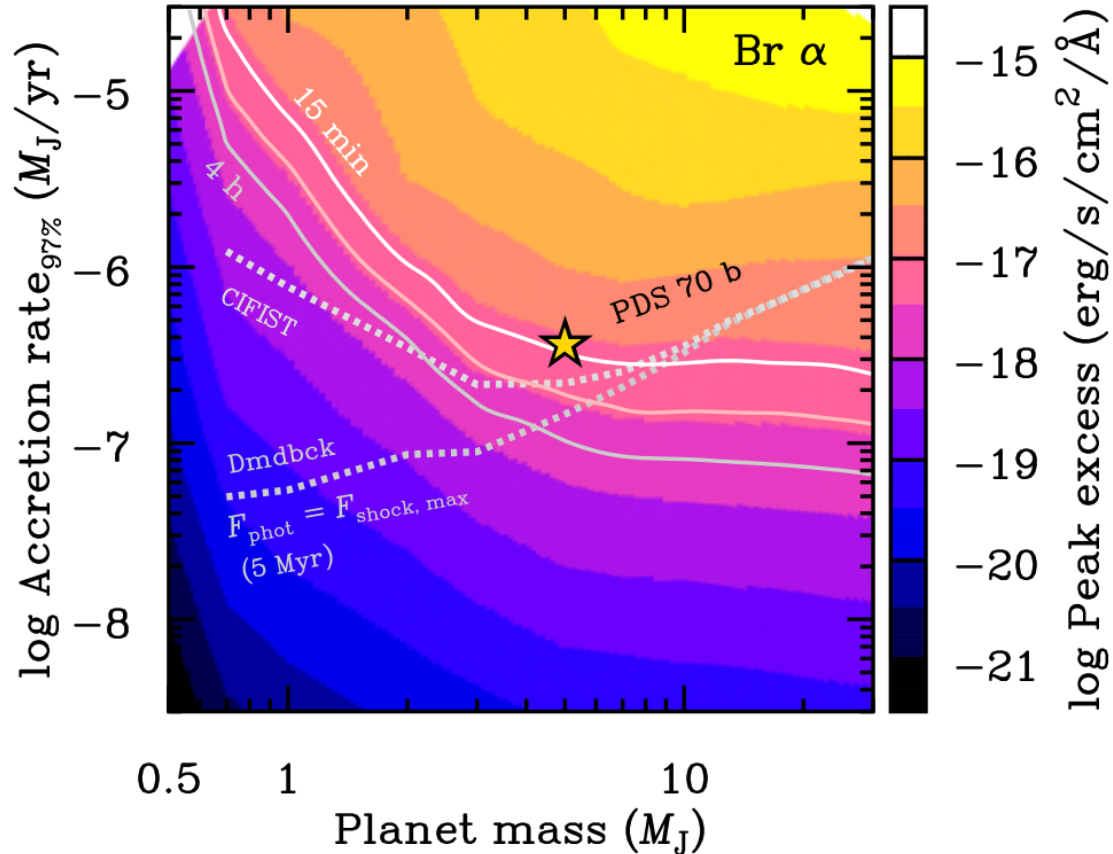
Stellar contribution?



Stellar contribution? No

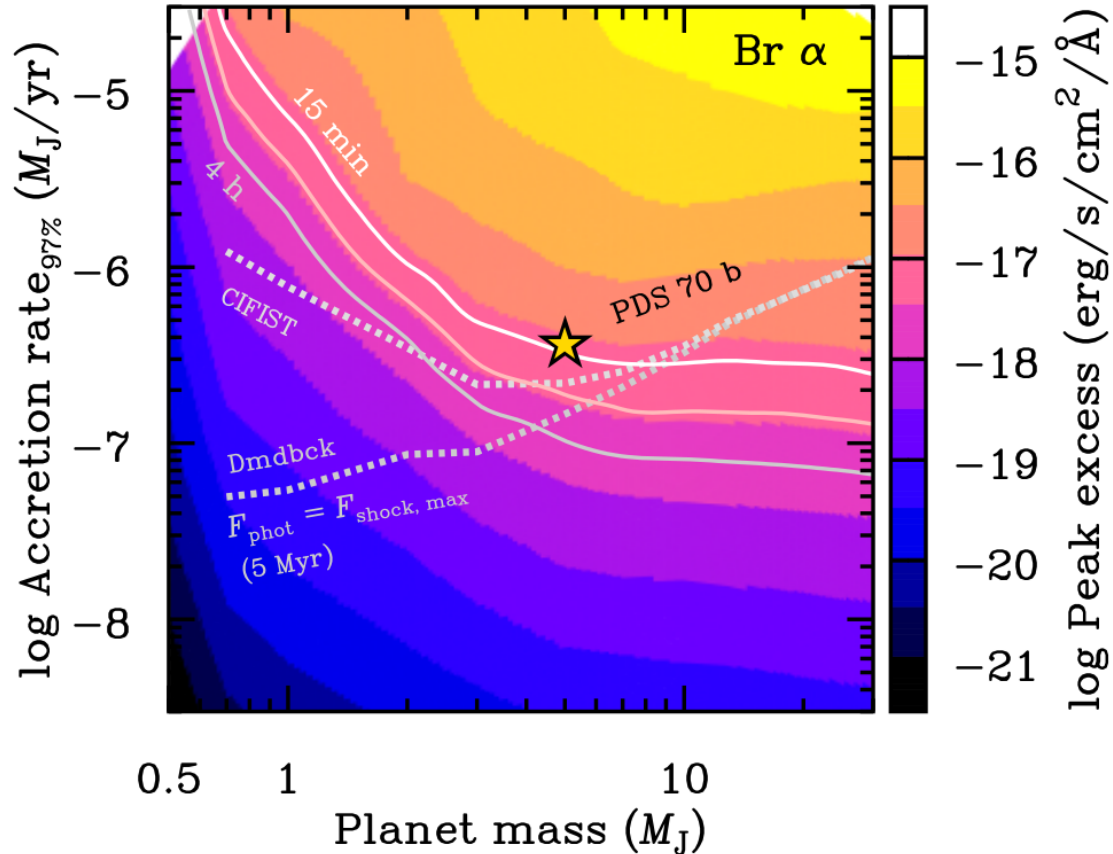


Detectability as $f(M, \dot{M})$



- Peak line flux (colour) depends more on accretion rate than mass
- Contours: time for 3 σ detection
- PDS 70 bc, WISPIT 2 b: similar

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- Dashed line: $F_{\text{phot}} = F_{\text{shock}}$

Summary

- Calculated line emission from shock at super Jupiters observable with METIS
- Shock at planet (dominates) + CPD surface → integrate spatially to get line shape
- Shock emission can produce only smooth, narrow, Gaussian-core lines



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- Planetary spin smooths photosphere $\rightarrow$ shock line stands out
- PDS 70 b detectable at peak S/N ~ 14 per bin in 4 h (!)
- Other targets: WISPIT 2, *Gaia* DR4 discoveries...



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e-mail: gabriel.marleau@mpi-a.de

² Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany
³ Division of Space Research & Planetary Sciences, University of Bern, Sidlerstr. 5, 3012 Bern, Switzerland

⁴ Division of Physics Research & Planetary Sciences, Guangdong 519082, People's Republic of China

⁵ School of Physics and Astronomy, Sun Yat-sen University, Guangdong 519082, People's Republic of China

⁶ Kapteyn Astronomical Institute, University of Groningen, PO Box 800, 9700 AV Groningen, The Netherlands

Received – / Accepted –

ABSTRACT

Context. For fewer gas giants have been caught in their accretion phase than mature ones are known. Extremely Large Telescope (ELT) will be able to observe gas giants. We focus on the



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Danke für eure
Aufmerksamkeit!



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ABSTRACT

Context. For fewer gas giants have been caught in their accretion phase than mature ones are known. Extremely Large Telescope sensitivity and a smaller inner working angle than tools up to now, which should increase search for accreting gas giants. We focus on the

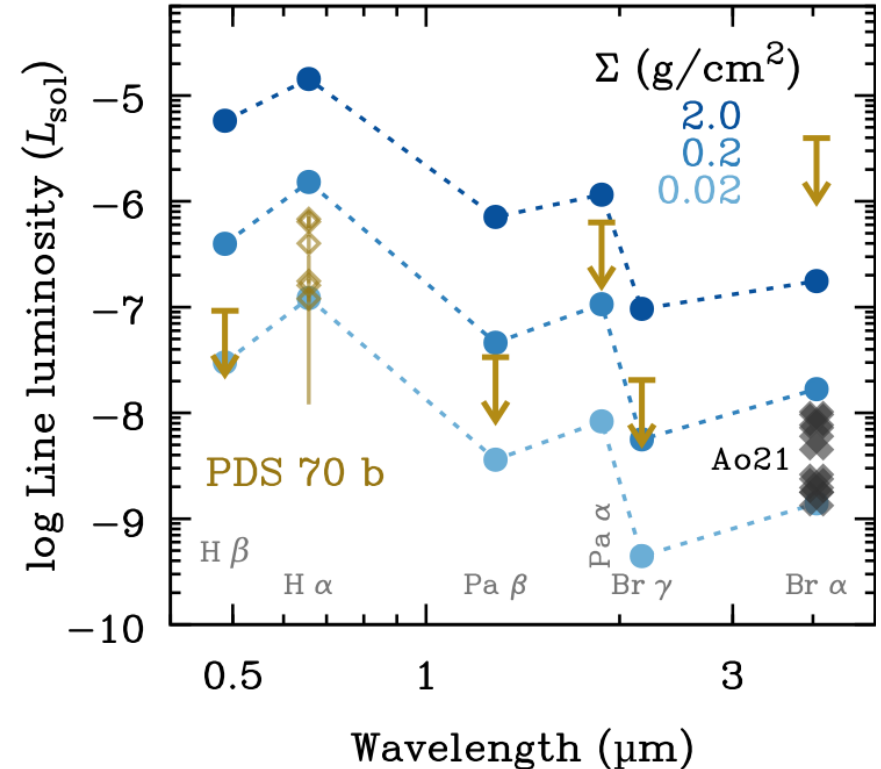


Extra slides

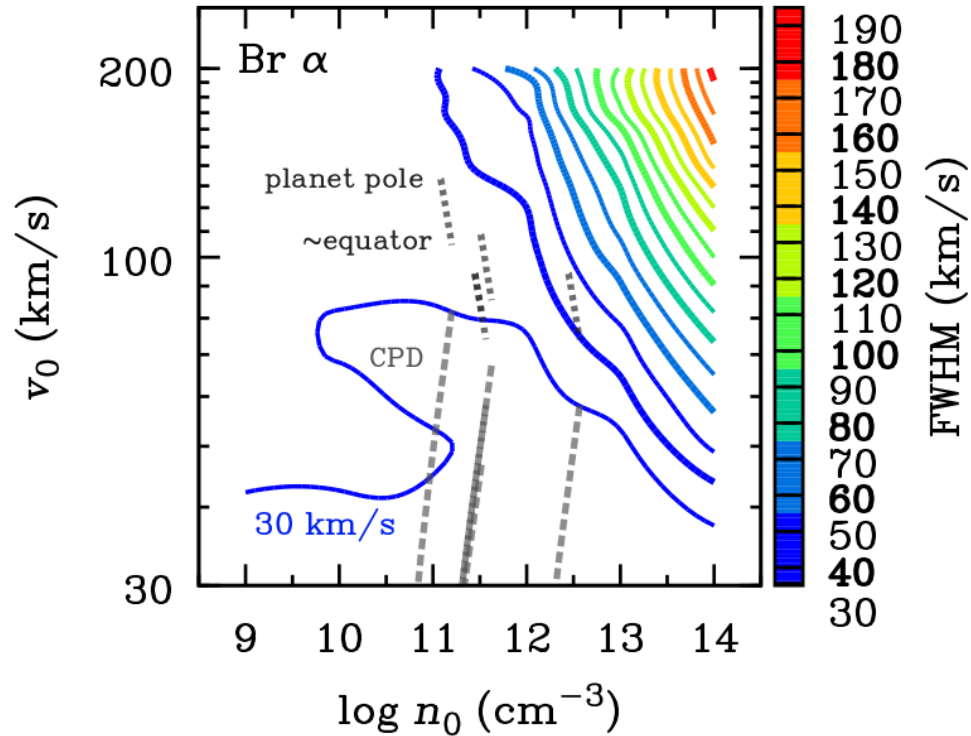
Fiducial parameters

Nominal case: PDS 70 b, ~WISPIT 2 b

<i>Planet intrinsic parameters</i>	
Mass	$M_p = 5 M_J$
Radius	$R_p = 2 R_J$
Effective temperature ^a	$T_{\text{eff}} = 1400 \text{ K}$
Surface gravity ^a	$\log g = 3.5$
Projected rotation speed ^a	$v \sin i = 10 \text{ km s}^{-1}$
<i>CPD parameters</i>	
Relative centrifugal radius	$f_{\text{cent}} = R_{\text{cent}}/R_{\text{Hill}} = 0.03$
CPD opening angle ^b	$\theta_{\text{CPD}} = 77^\circ$
<i>System and observer parameters</i>	
Stellar mass	$M_\star = 0.9 M_\odot$
PPD surface density in gap ^c	$\Sigma = 0.2 \text{ g cm}^{-2}$
Distance to observer ^d	$d = 113.4 \text{ pc}$
Viewing inclination	$i = 50^\circ$

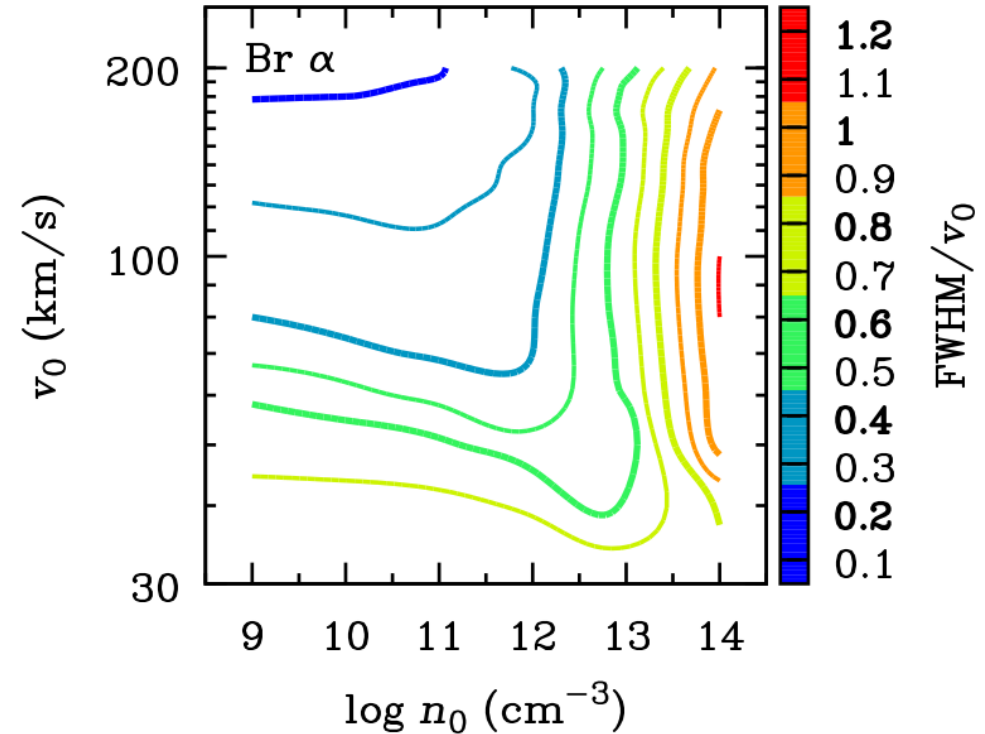
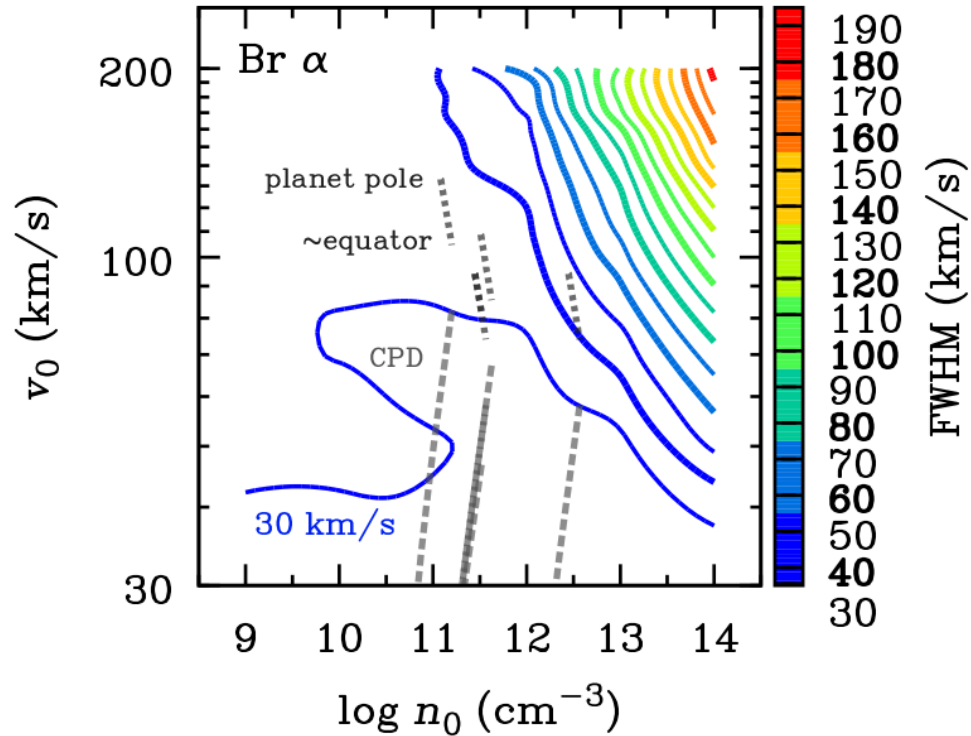


Shock model: Line widths



Marleau et al. (2025)
but directly based on models of
Aoyama et al. (2018)

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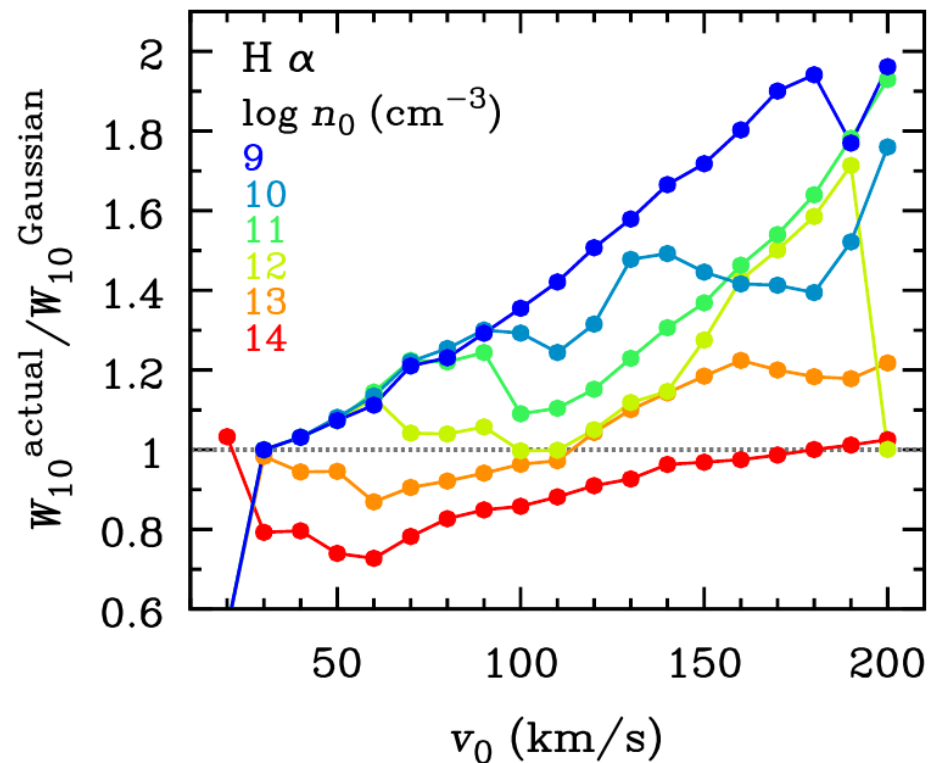
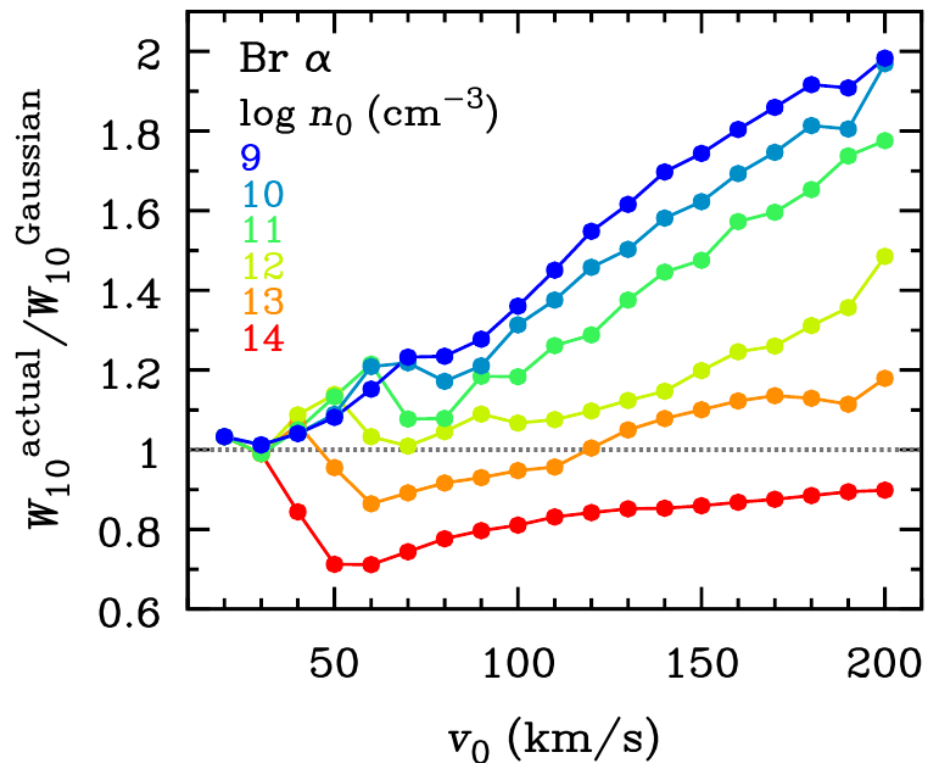


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Shock model: Wings

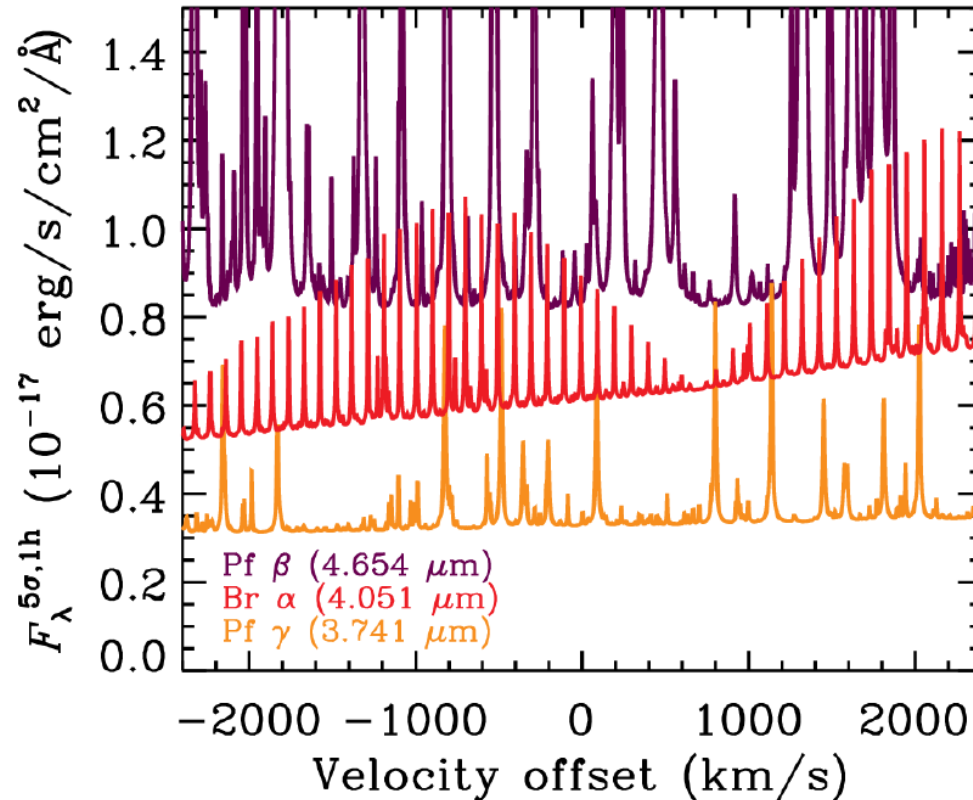


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Telescope+detector sensitivity



Photospheric contribution

