

Accretion on the PDS 70 planets, a burst-like behavior?

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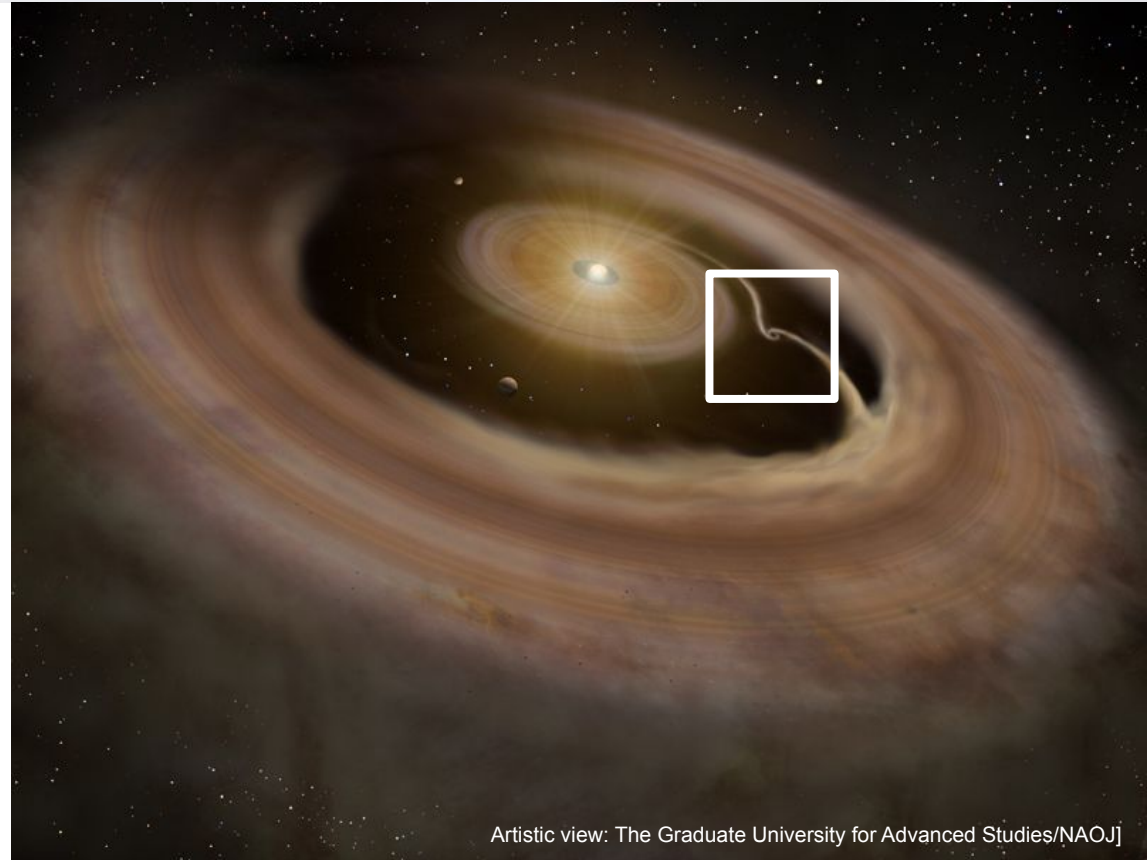


Characterizing accretion phenomena on planetary-mass objects

- Where do planets form?

Planets form within
ProtoPlanetary-Disk (PPD) around
young stars

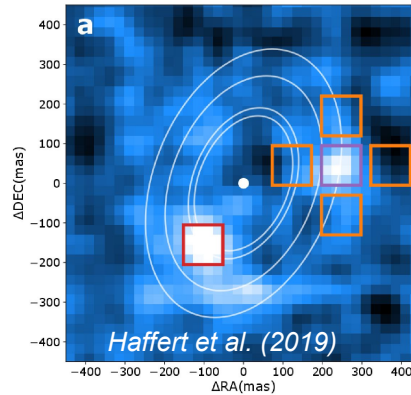
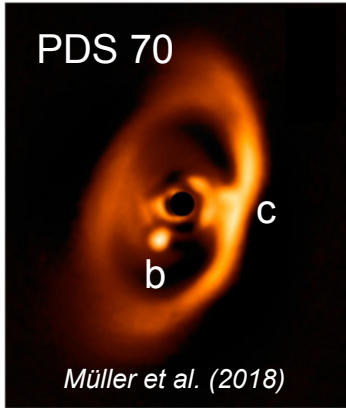
How do planets accrete?



Artistic view: The Graduate University for Advanced Studies/NAOJ

Characterizing accretion phenomena on planetary-mass objects

- The search for accreting planets

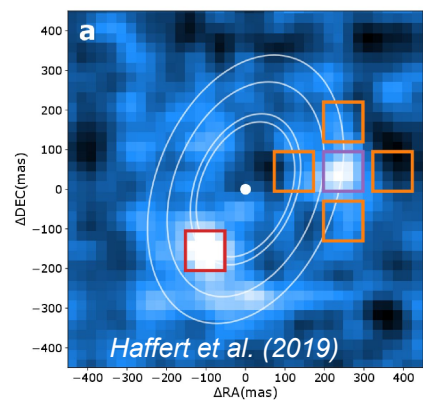
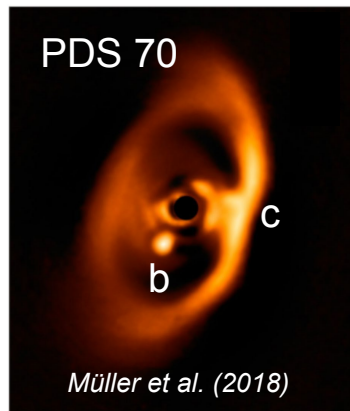


Accreting planets

- Trace the gas dynamics, and allow for testing formation scenarios
- Confirmed as accretors through emission lines (H α , H β , MagAO-X, MUSE)
- Very close separation (0.2-0.3")
- Are very few...

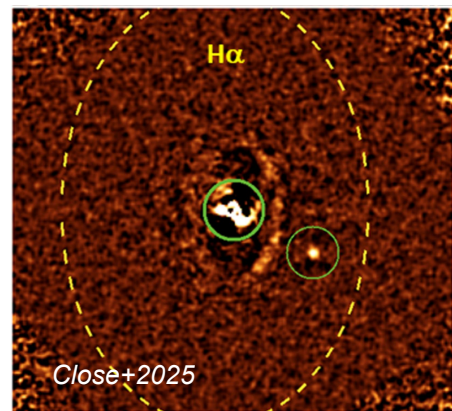
Characterizing accretion phenomena on planetary-mass objects

- The search for accreting planets



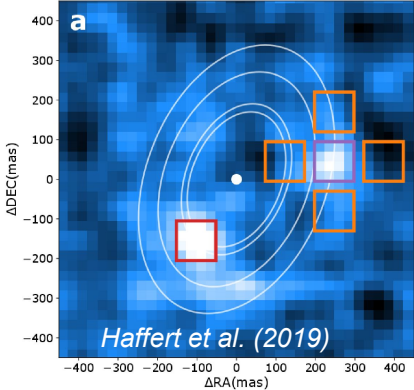
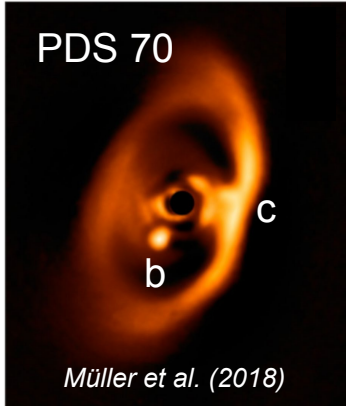
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Characterizing accretion phenomena on planetary-mass objects

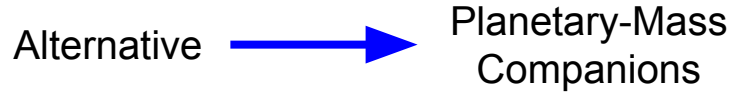
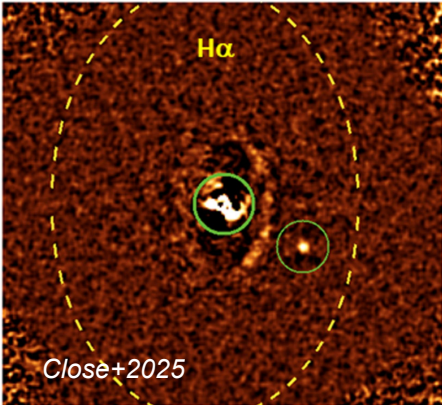
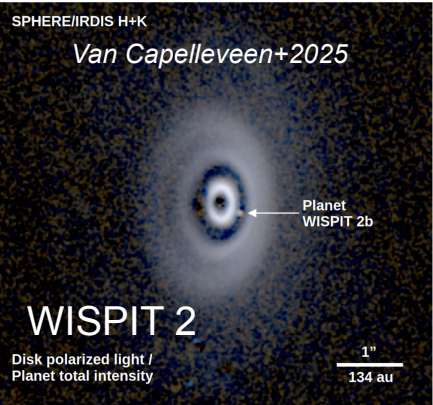
- The search for accreting planets



Accreting planets

- Trace the gas dynamics, and allow for testing formation scenarios
- Confirmed as accretors through emission lines (H α , H β , MagAO-X, MUSE)
- Very close separation (0.2-0.3")
- Are very few...

Only 3 known accreting planets, in 2 systems



Characterizing accretion phenomena on planetary-mass objects

- The search for accreting planets

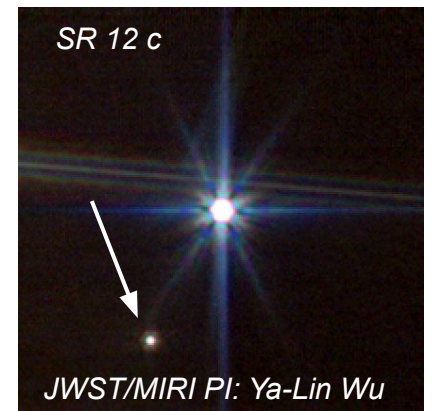
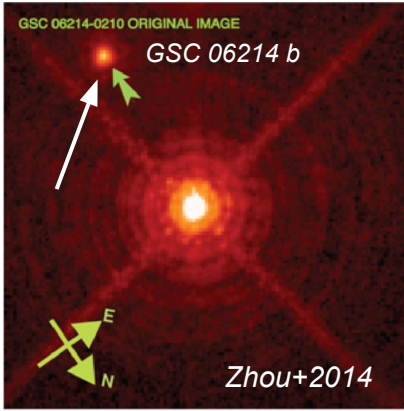
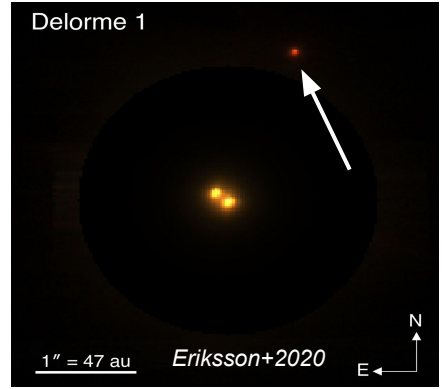
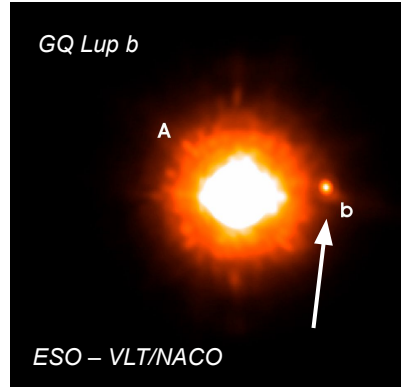
Planetary-Mass Companions

- Slightly more massive (10–20 M_{Jup})
- Wider orbit (0.7–40")
- Emission lines as accretion tracers
- Confirmed gas reservoirs (circumplanetary-disks)

They are:

- The **low-mass end of brown-dwarfs**
- Serve as **proxies for accreting planets**

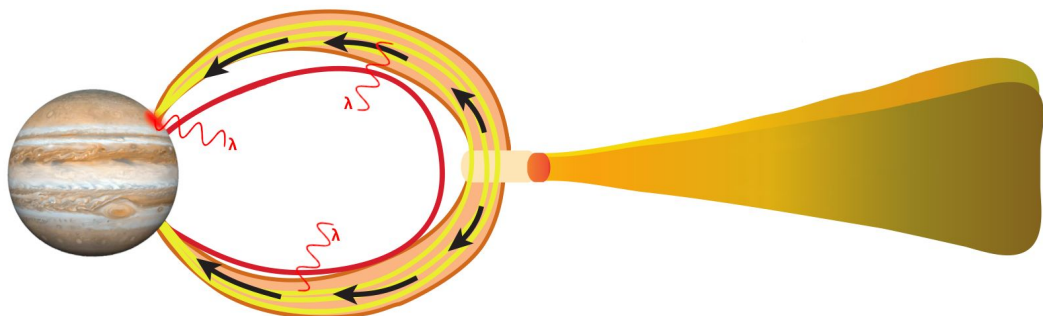
Where are the emission lines coming from?



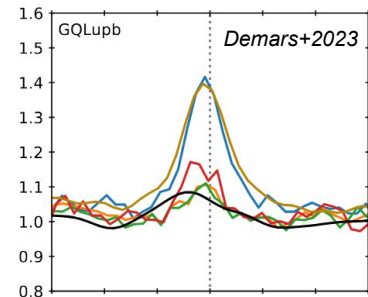
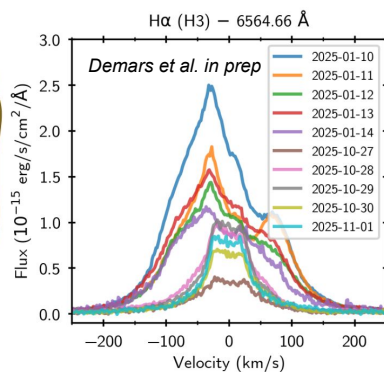
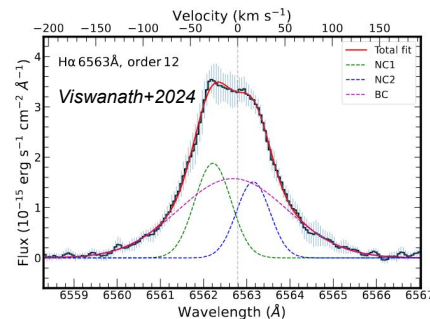
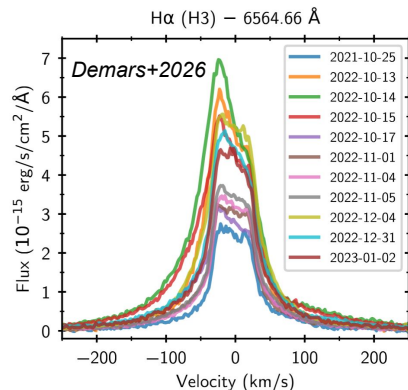
Where are emission lines coming from?

Planetary-Mass Companions

- Constraints from line profiles
- Magnetospheric accretion + shock (+activity?)
- ENTROPY team in France: Bonnefoy, Demars, Viswanath, Dougados



adapted from Hartmann+2016



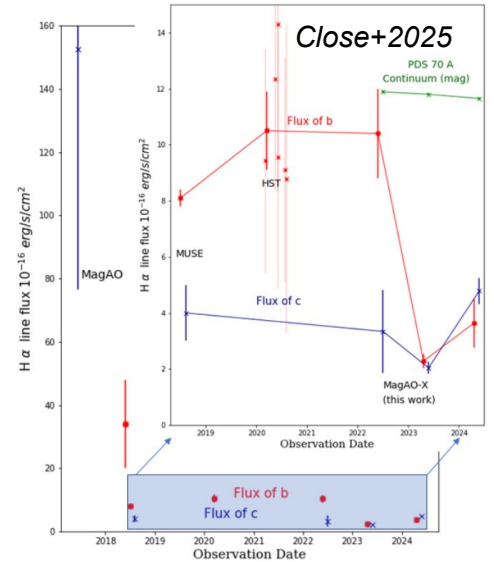
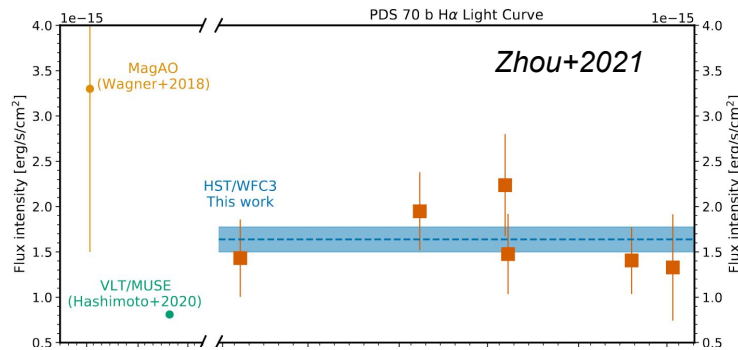
Where are emission lines coming from?

Accreting planets (PDS 70 b/c, WISPIT 2 b)

- Lines **too faint** for resolved line profiles
- Lines **too faint** for accurate line ratios
- Lines are **known to be variable!**

Line profiles and ratios may be accessible during bright events

Need for constraints on variability



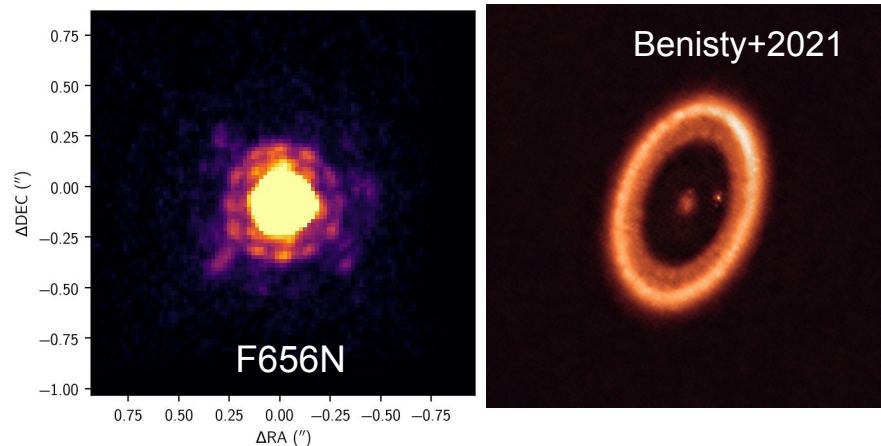
HST/UVIS2/F656N: PDS 70 – Ha monitoring

PDS 70

- 0.98 M_{\odot} , 5 Myr star
- Host to a protoplanetary disk
- Two planets within a gap:
 - PDS 70 b: 2–4 M_{Jup}
 - PDS 70 c: 1–3 M_{Jup}

HST observations

- **UVIS2/F656N** imaging campaign (Ha)
- **36 visits** (1 visit = ~45mins), divided in:
 - 6 epochs in 2020
 - 4 epochs in 2024
 - 1 epoch in 2025



PDS 70 – Stellar and disk subtraction

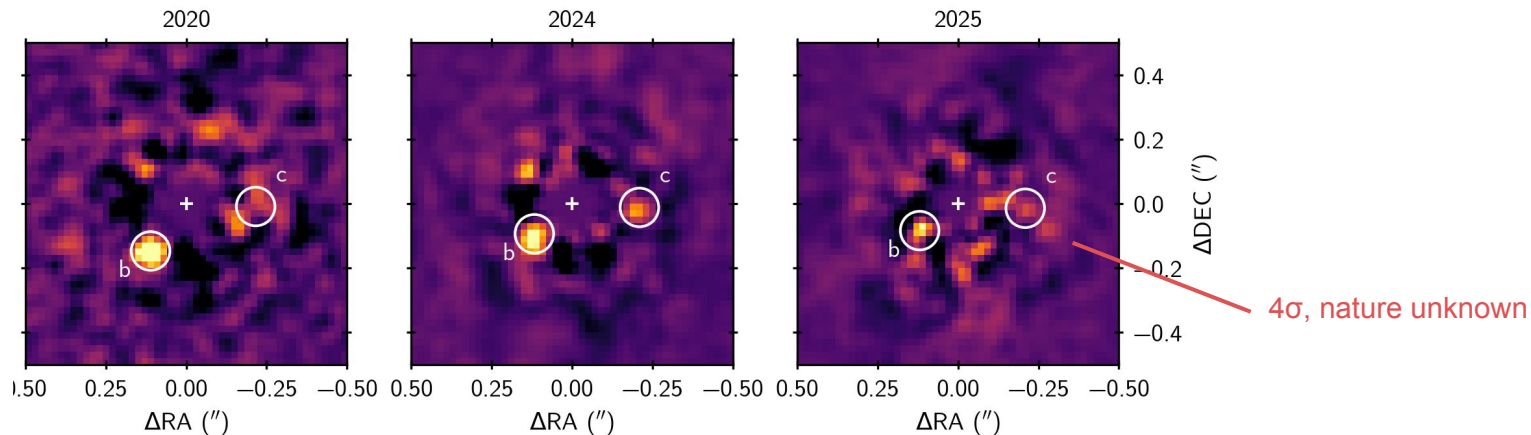
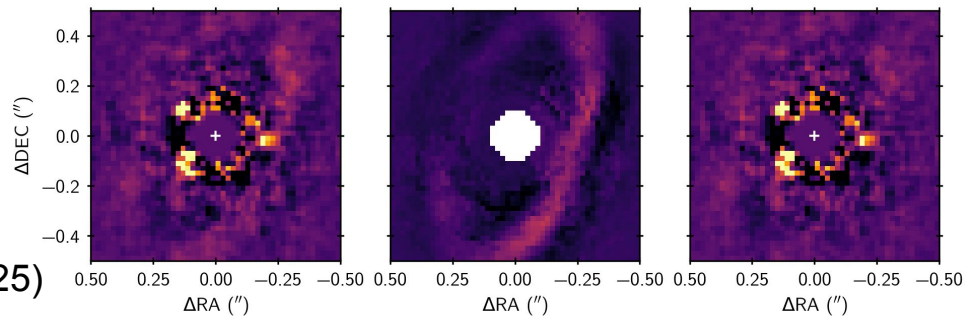
Stellar subtraction with pyKLIP

- ADI+RDI reduction
- Parameters optimized per planet/epoch
- Grid search for optimal parameters

Disk modeling

- Asymmetric geometric model (Blakely+2025)
- Forward-modeling of the ADI distortion

Disk subtraction



PDS 70 – Planets light curve

Smallest binning

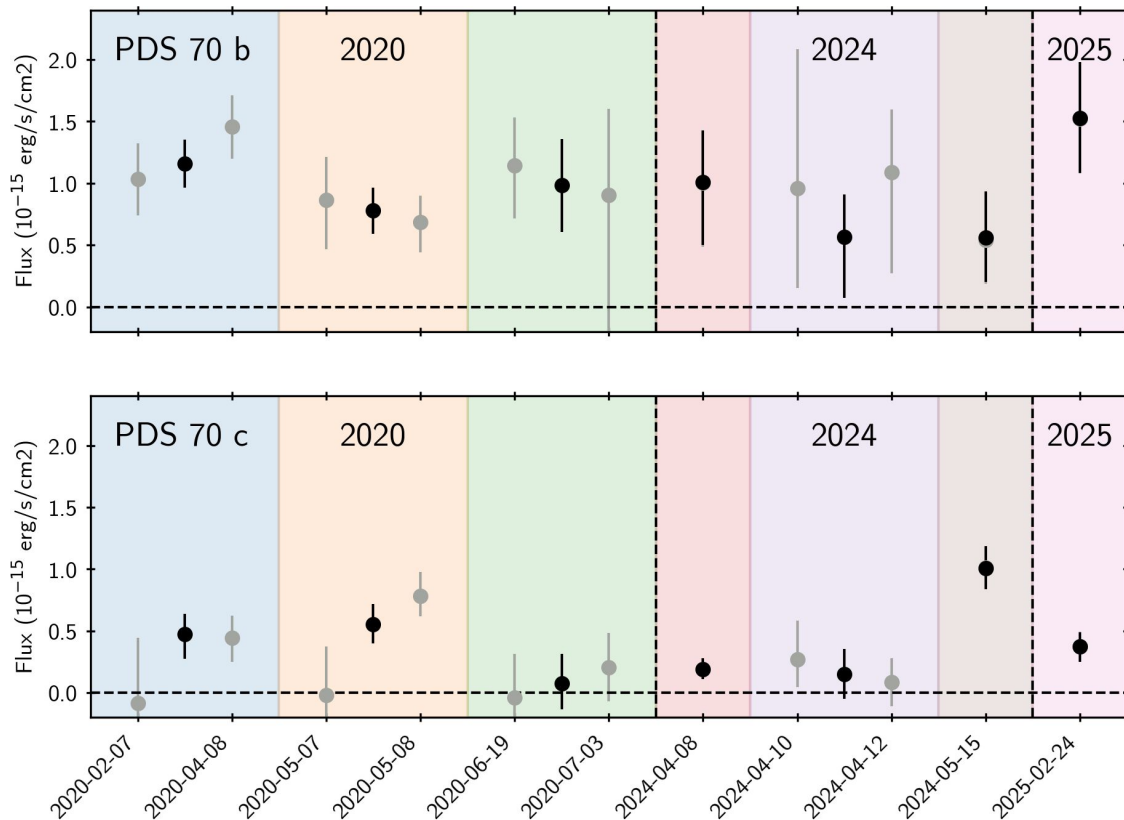
- 1 night (gray)
- 2 nights (black)

Variability

- Stable flux over months timescales
- Baseline consistent with previous observations (Close+2025)

2025-02-24

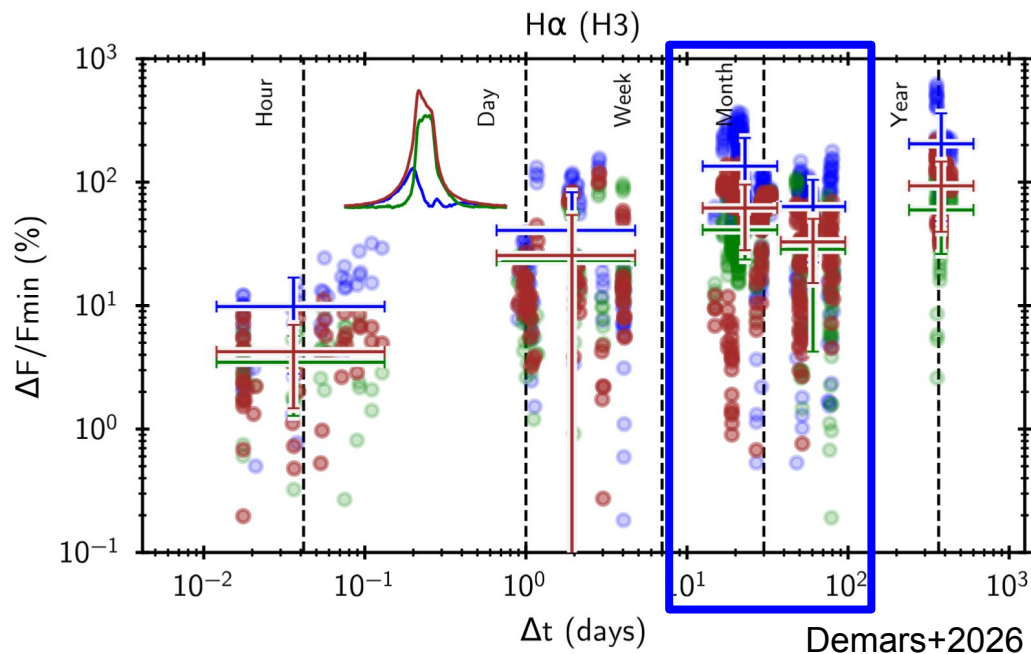
- 10 hours sequence
- No obvious variability (S/N too low)



PDS 70 – Variability diagrams

Comparison to similar targets (PMCs)

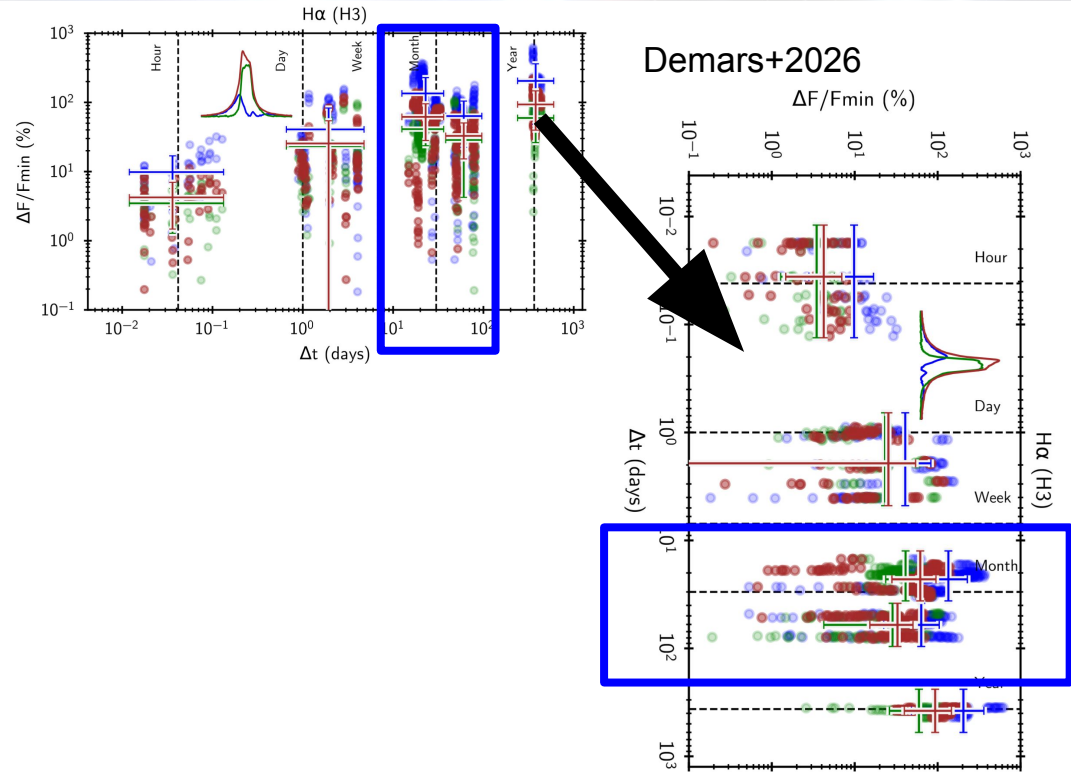
- Only Delorme 1 (AB)b has similar H α weekly/monthly sampling



PDS 70 – Variability diagrams

Comparison to similar targets (PMCs)

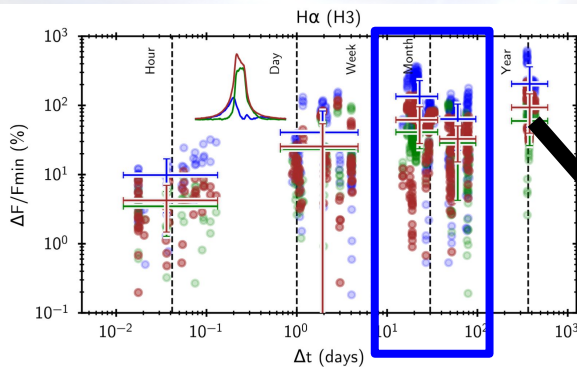
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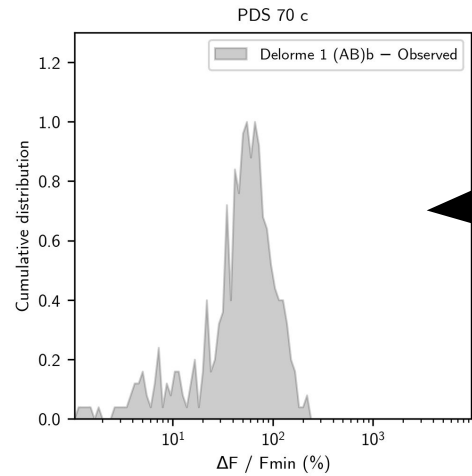
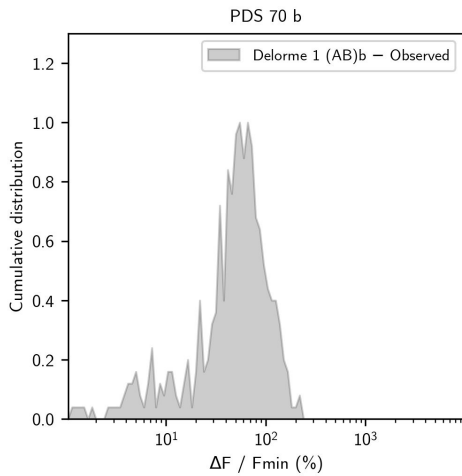
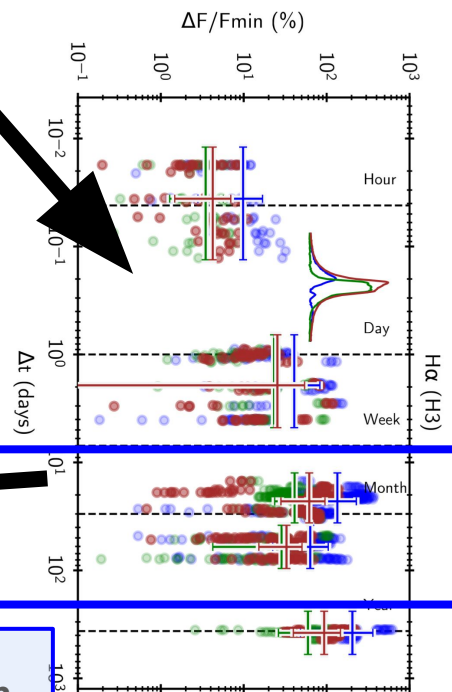
PDS 70 – Variability diagrams

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Demars+2026



Make histogram

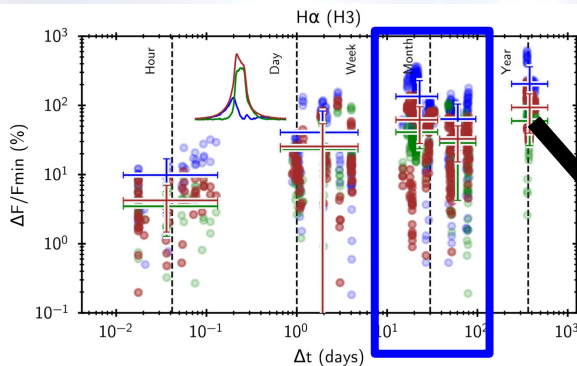
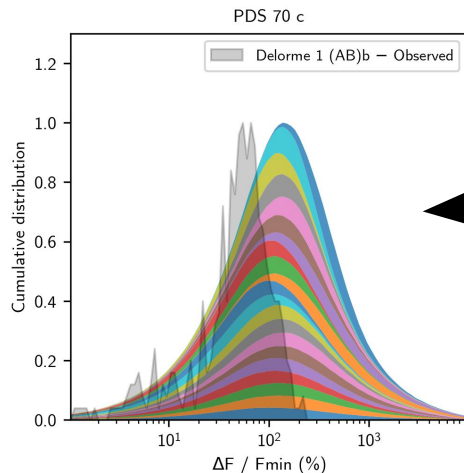
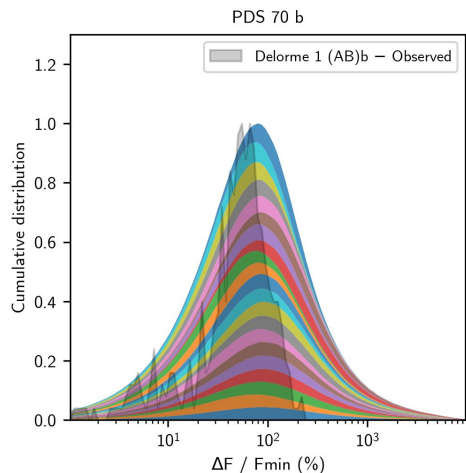
PDS 70 – Variability diagrams

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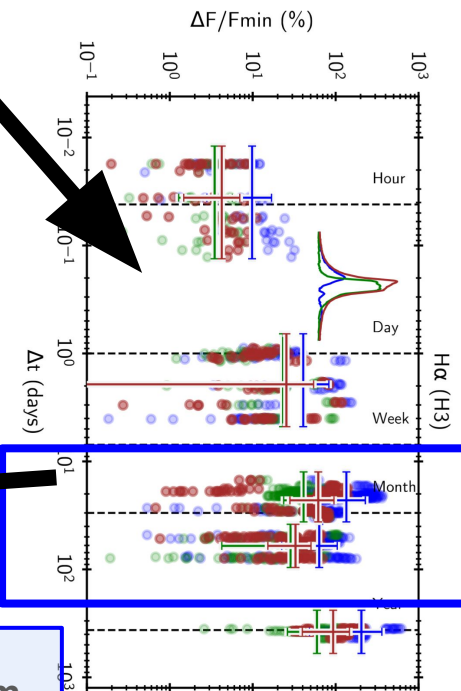
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Average variability

- PDS 70 b: 72%
- PDS 70 c: 151%



Demars+2026



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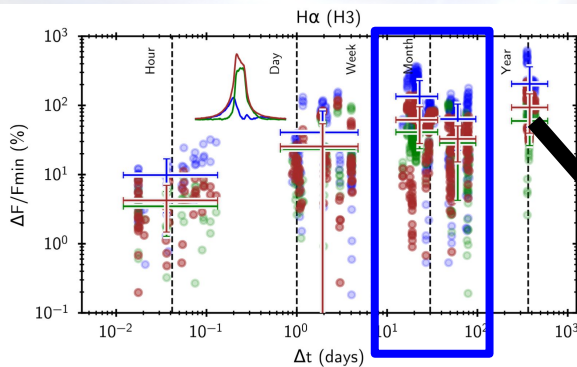
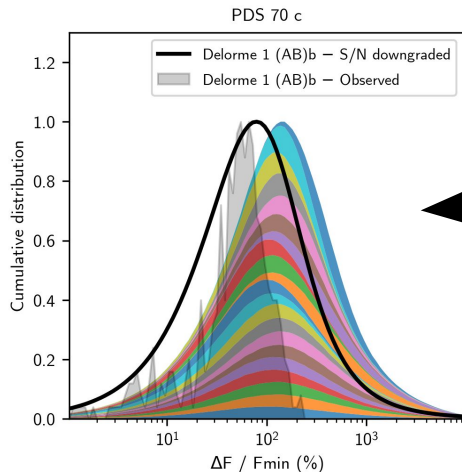
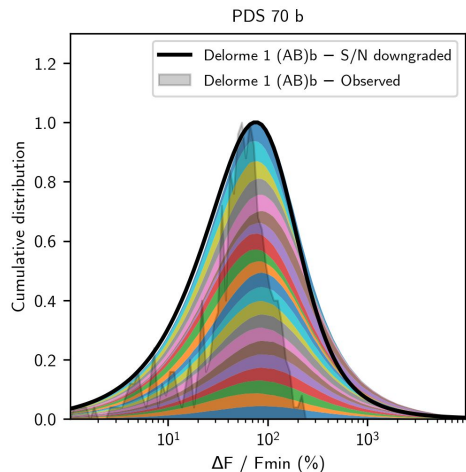
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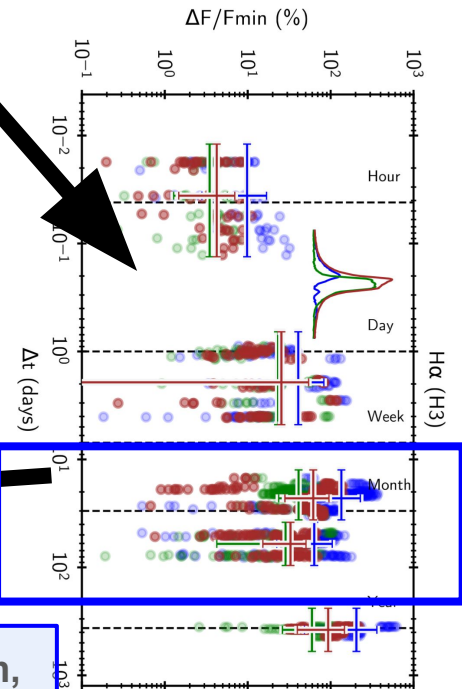
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Demars+2026

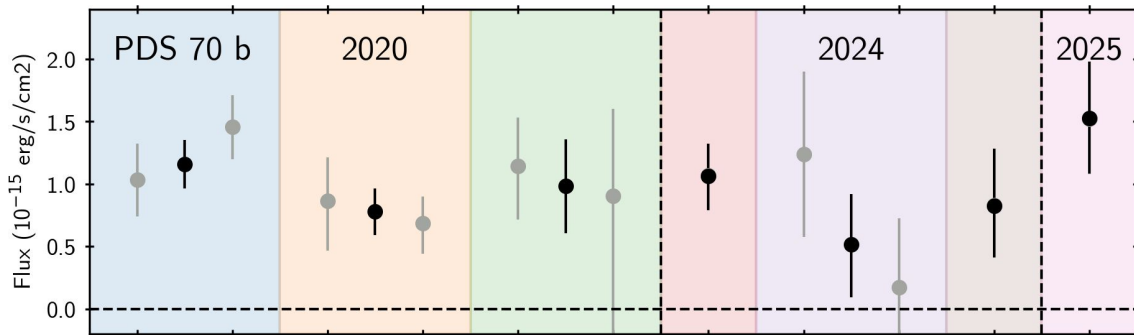


Make histogram,
downgrade S/N

PDS 70 – PDS 70 c outburst

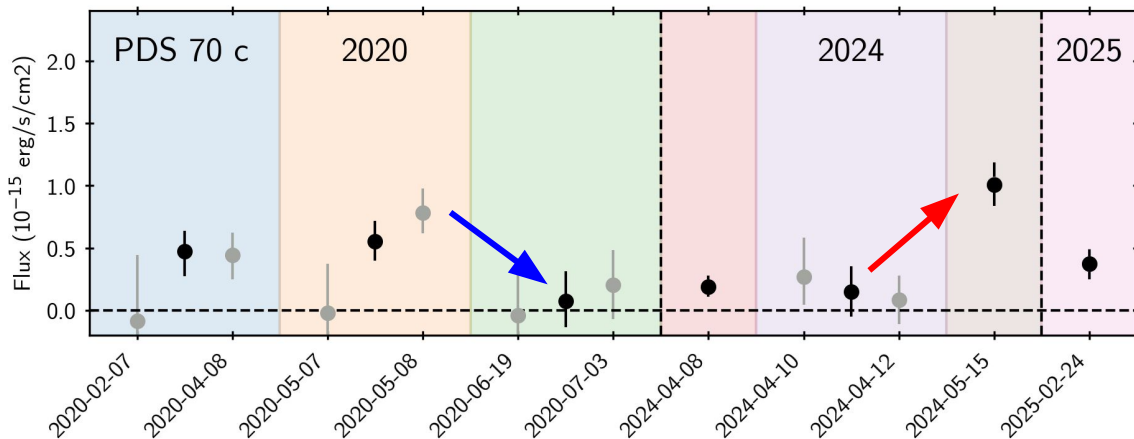
PDS 70 b

- Flat light-curve
- Consistent with previous studies (Close+2025)



PDS 70 c

- Mostly flat light-curve
- **Drop-off** between epochs May and July 2020
- **Outburst** event between epochs April and May 2024

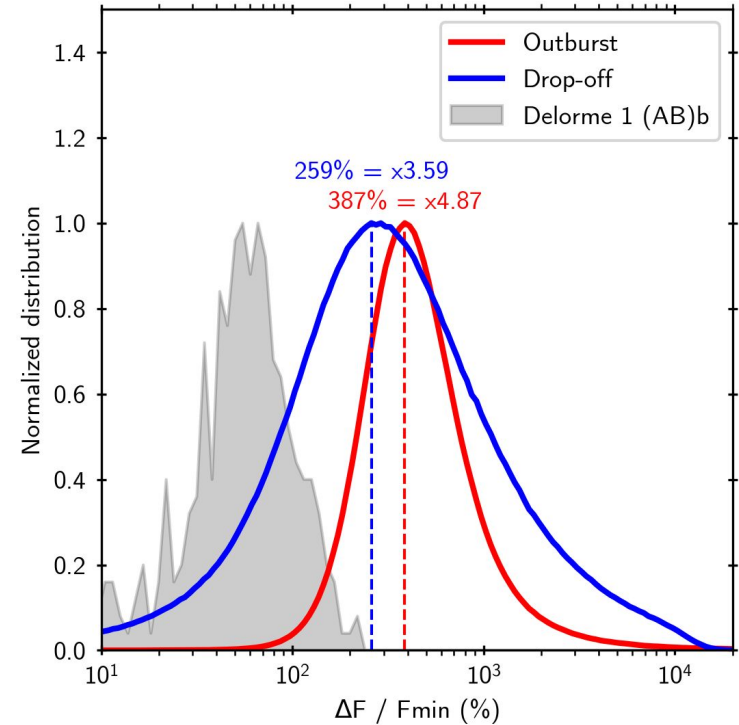
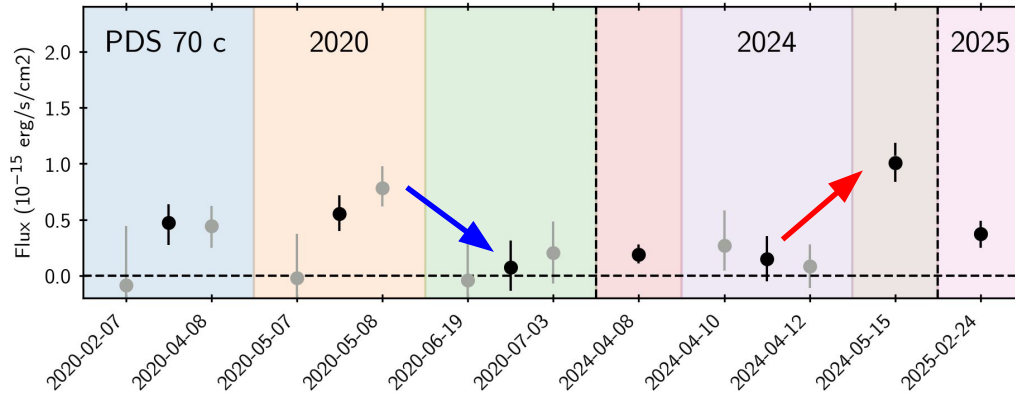


PDS 70 – PDS 70 c outburst

PDS 70 c

- **Drop-off** within 2 months
- **Outburst** within 2 month, **must drop-off** within 8 months

Such variability has never been observed on these timescales even on wide-orbit companions!

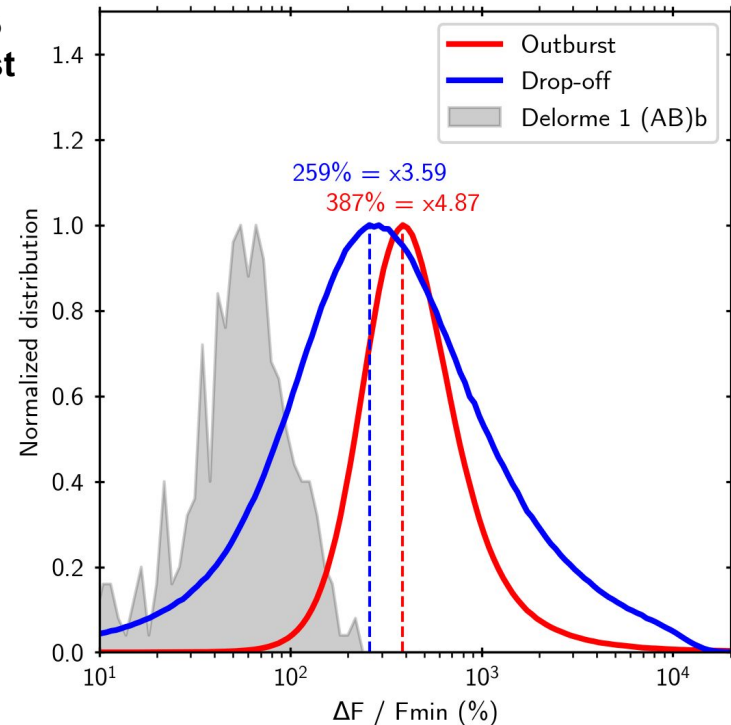
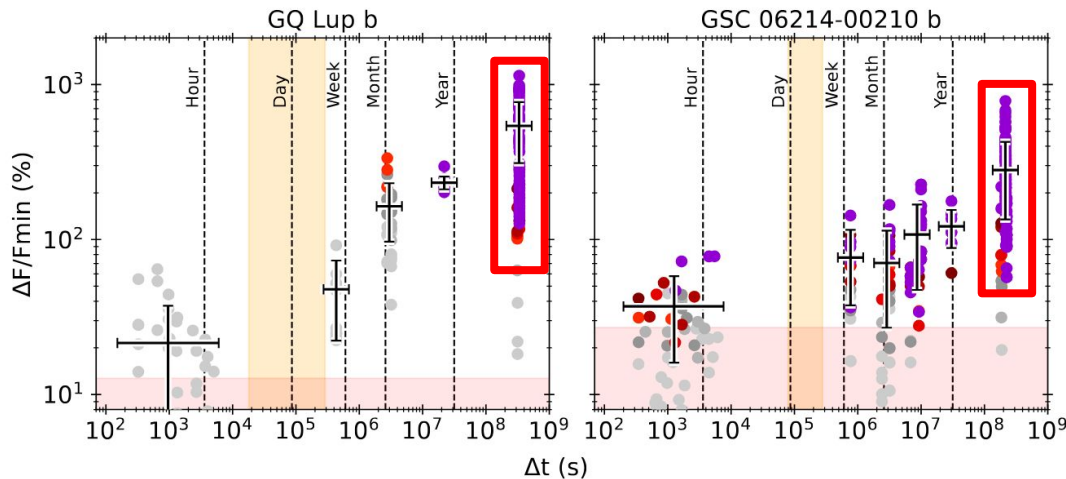


PDS 70 – PDS 70 c outburst

BUT! Outbursts **have been observed** on **decades timescales** in **Pa β**

- GQ Lup b and GSC 06214 b were **first observed** in an **outburst**
- There are **no constraints** or their **duration** either

Is this outburst a **once-in-a-while thing**? Or **did we miss them** in previous observations?



Demars+2023

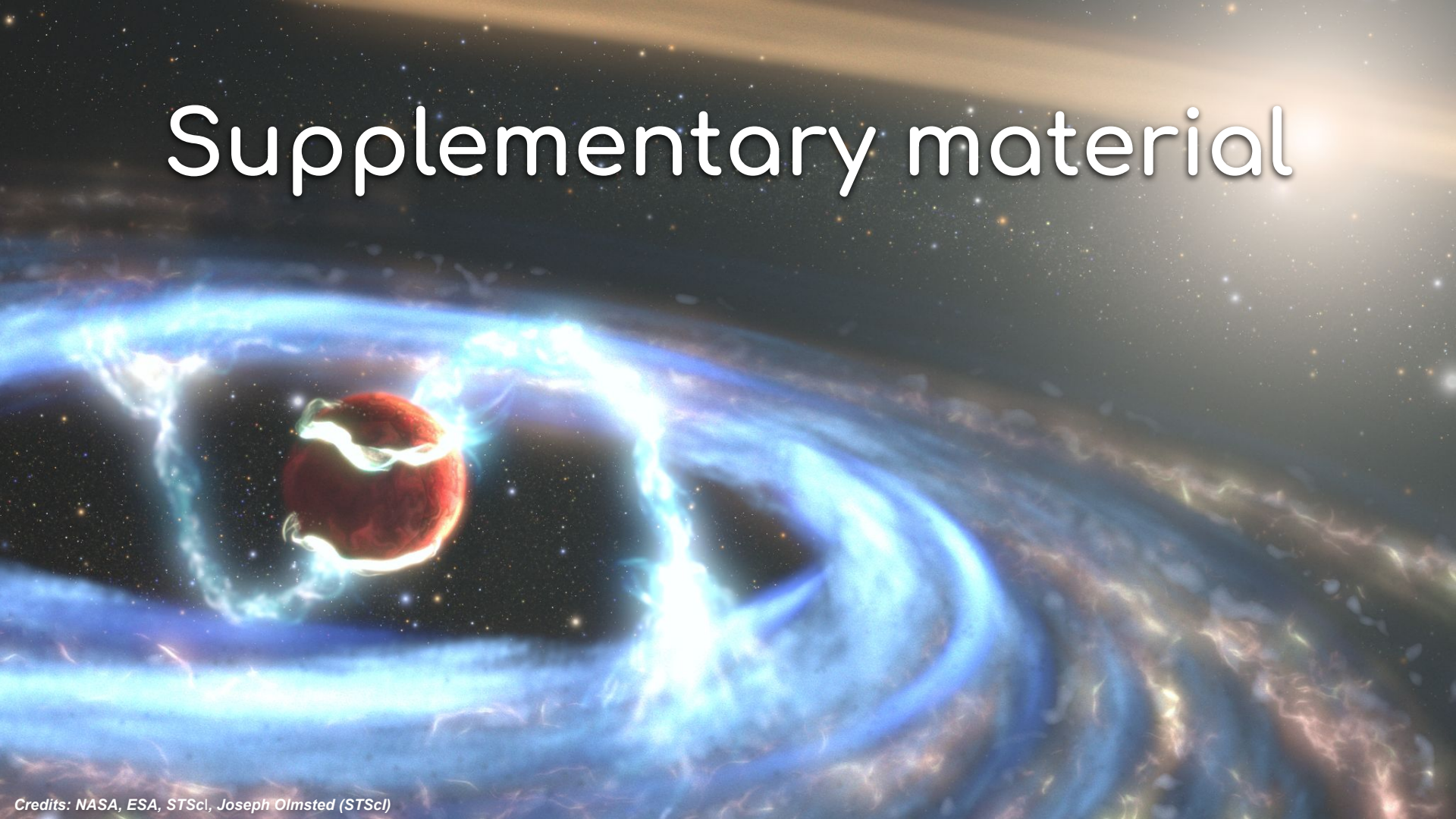
PDS 70 b/c accretion – Summary

- **Understanding variability** is necessary for future **characterizing accretion mechanisms** on accreting planets
 - **Bright events** may allow for **line-profile** characterization
- **No obvious variability behavior difference** between PDS 70 b and c
 - We still note **surprising similarity** between PDS 70 b and **Delorme 1 (AB) b**
- An **outburst event** detected on **PDS 70 c**, that might be **akin** to those observed on **wide-orbit companions**

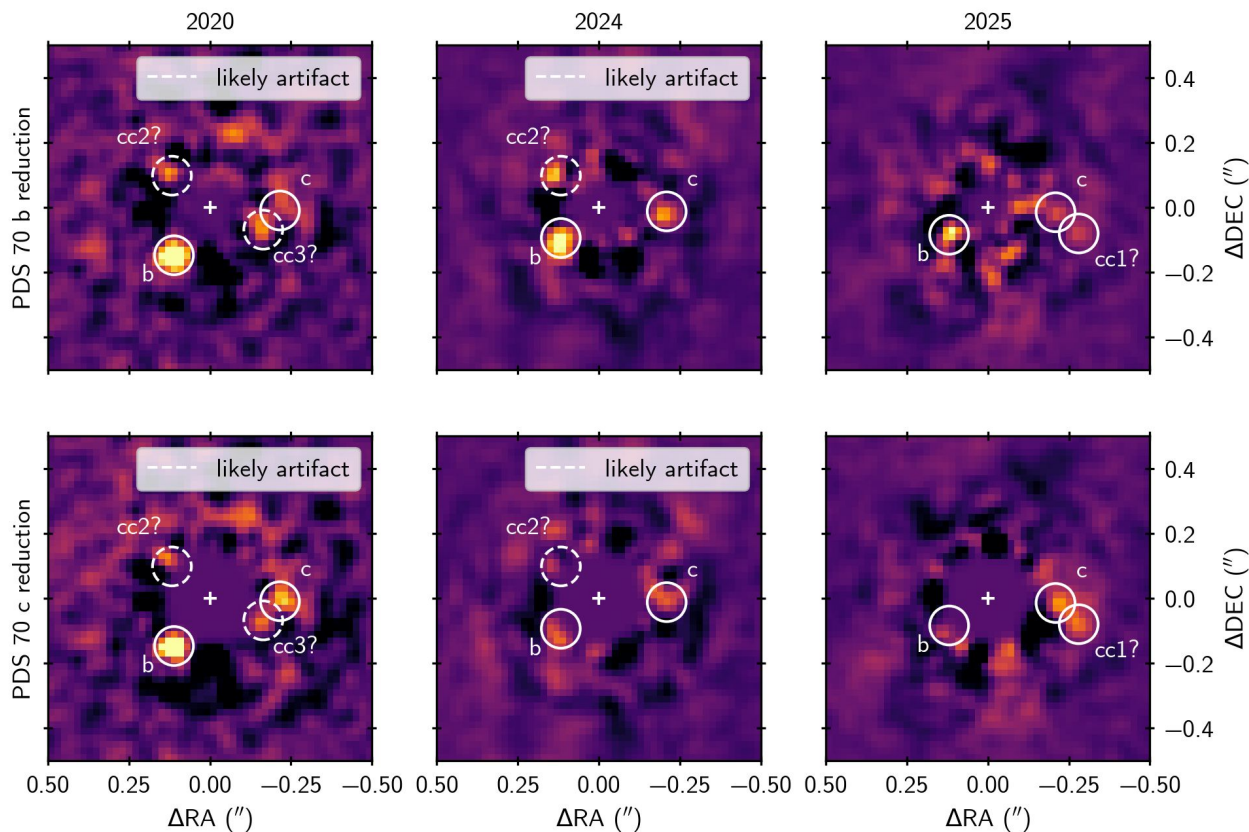
Check your **bingo**: we need **more follow-up observations** to quantify the **occurrence rate** and **duration** of these events!



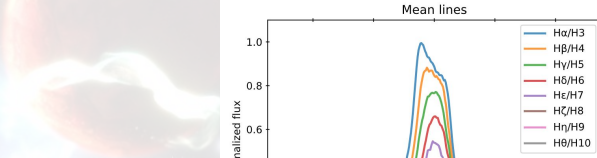
Supplementary material



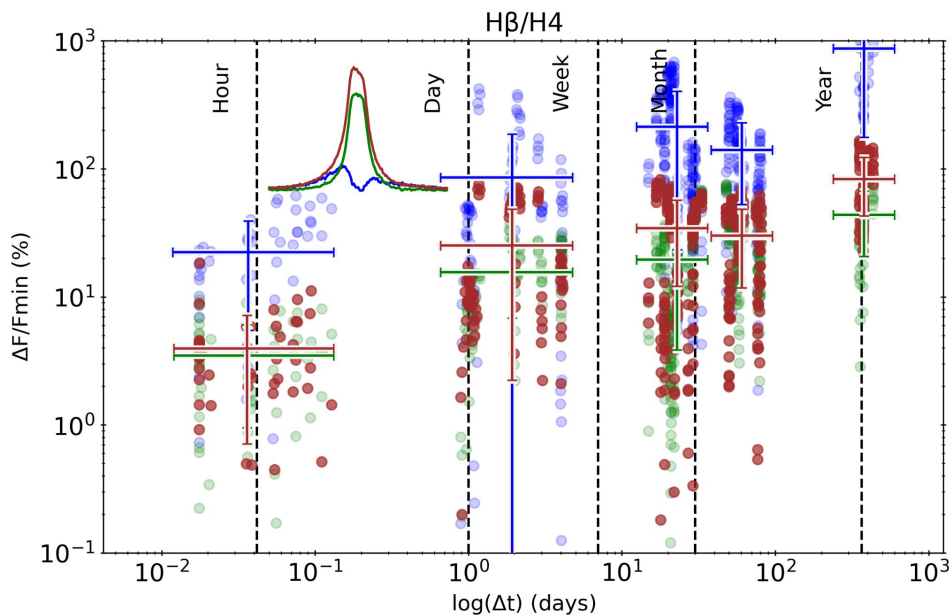
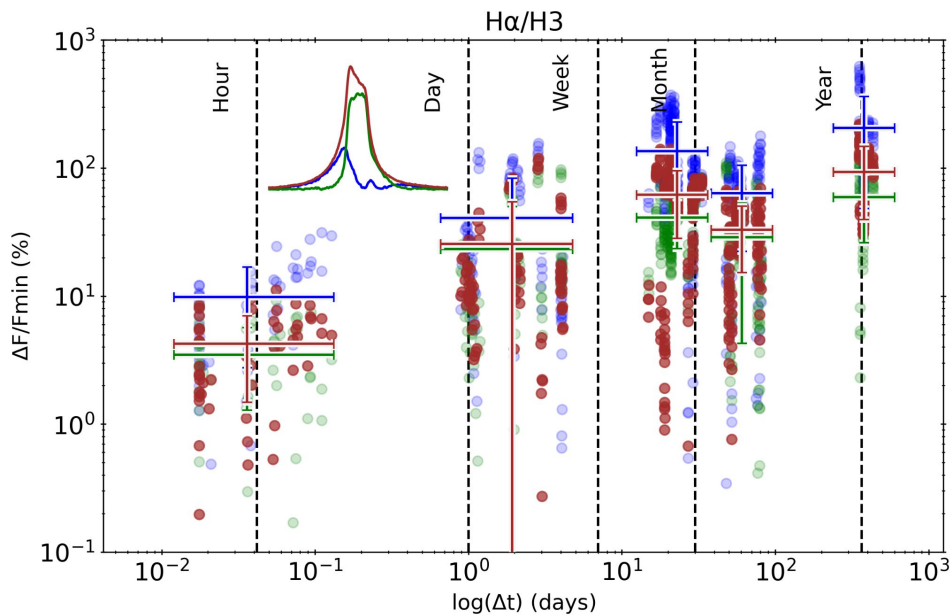
PDS 70 all reductions



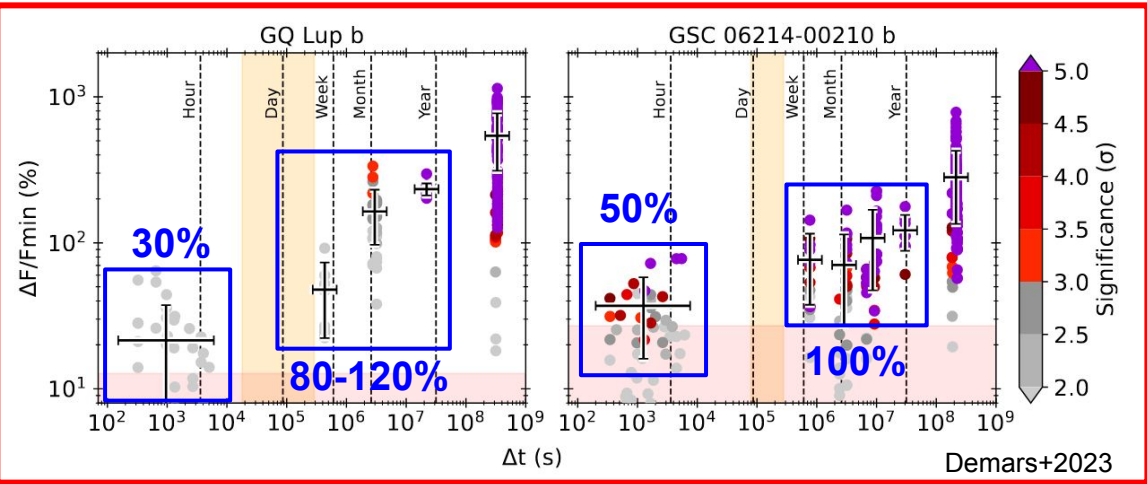
Delorme 1 (AB)b - Variability Timescales



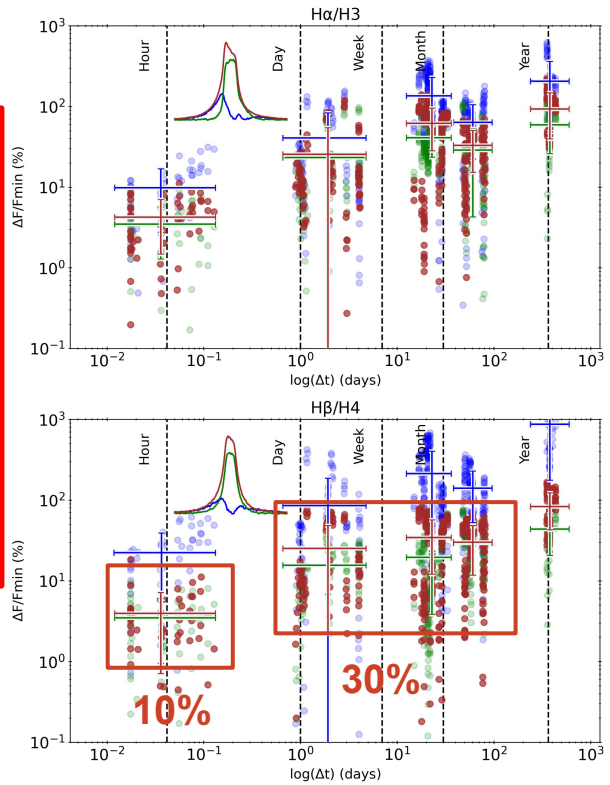
- Lines have a small variability amplitude at the ~hour timescale
- H β variability reaches a ~30% plateau at days to months timescales, whereas it is more chaotic for H α



Delorme 1 (AB)b - Variability Timescales

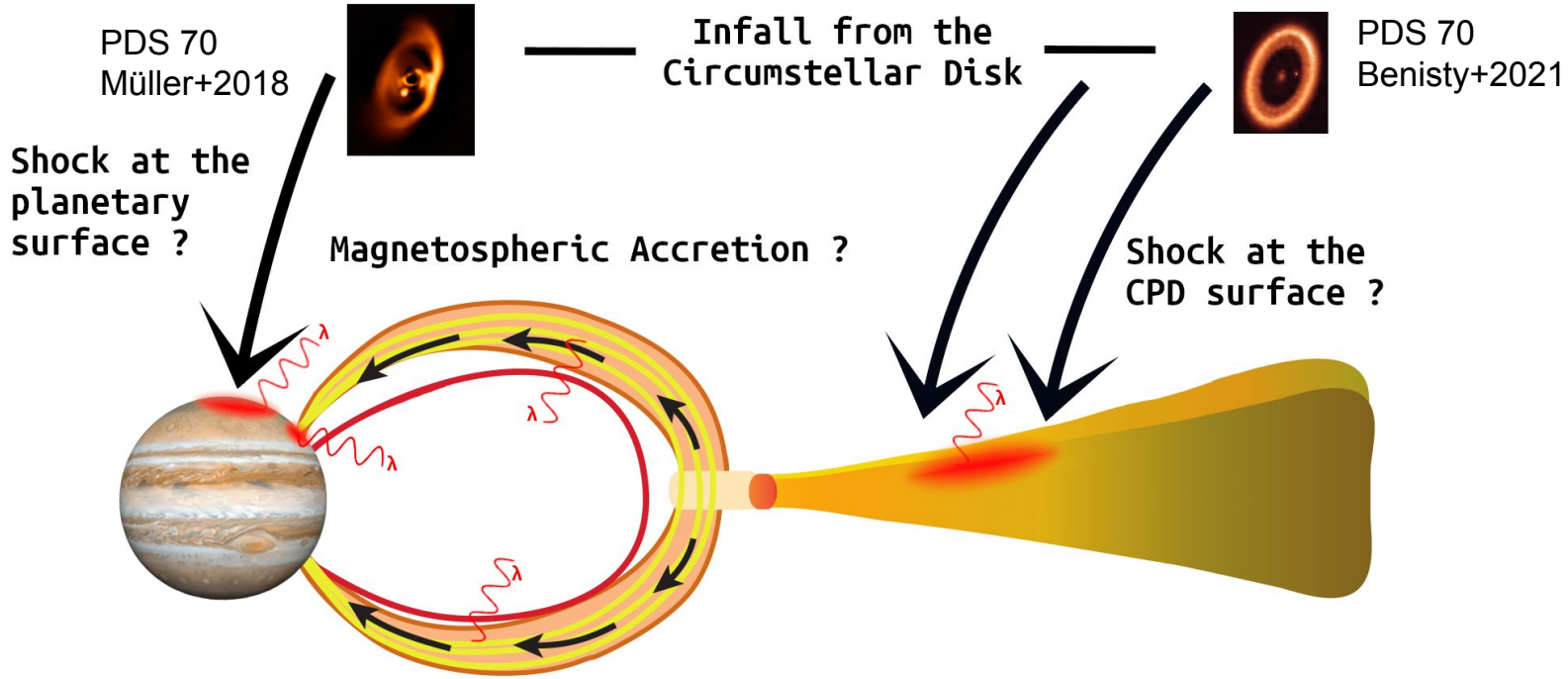


Variability amplitude ≤ 1 year of Delorme 1 (AB)b is much less than observed at Pa β on younger objects



Characterizing accretion phenomena on planetary-mass objects

- A variety of accretion models



*adapted from
Hartmann+2016*

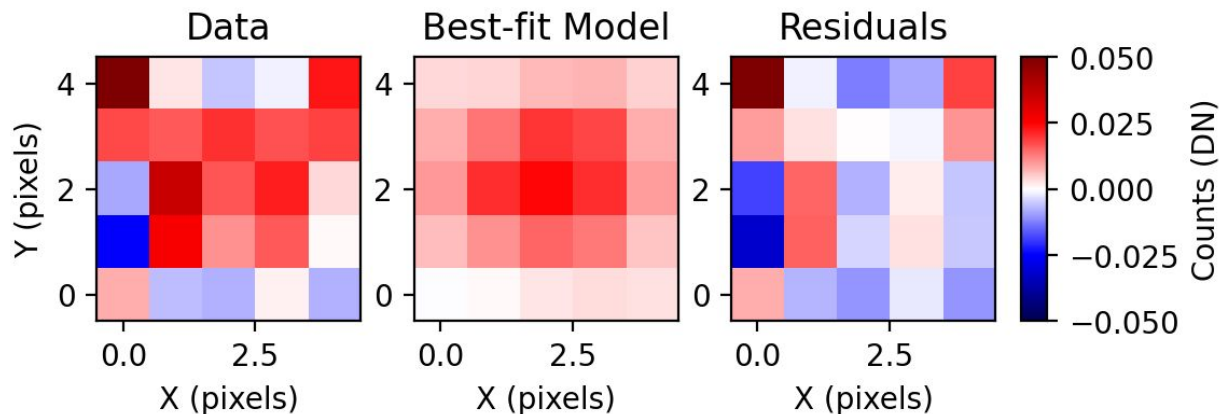
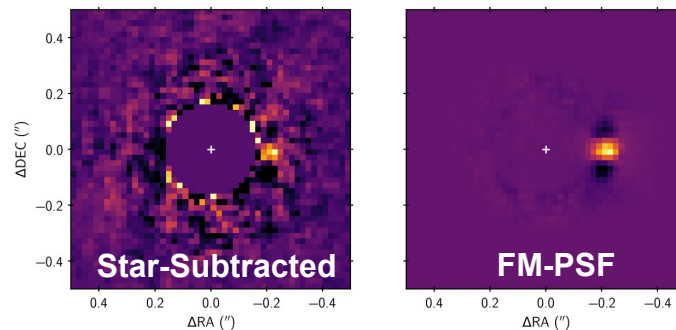
PDS 70 – Planets recovery

Flux recovery with pyKLIP-FM

- Forward-modeling of the planet PSF
 - Positive-negative imprints from ADI
- MCMC fit with emcee

Disk modeling

- Asymmetric geometric model
- Forward-modeling of the ADI distortion



HST/UVIS2/F656N: PDS 70 – Ha monitoring

Most data already published, so what's new?

- 2020 data: Zhou+2020
- 2024 data: Zhou+2025

Re-analysis of individual epochs

- What is the **smallest binning** that still yields **meaningful results**?

Planets are variable: they may have **bright lines on sub-epochs**, which is missed in averaged data

