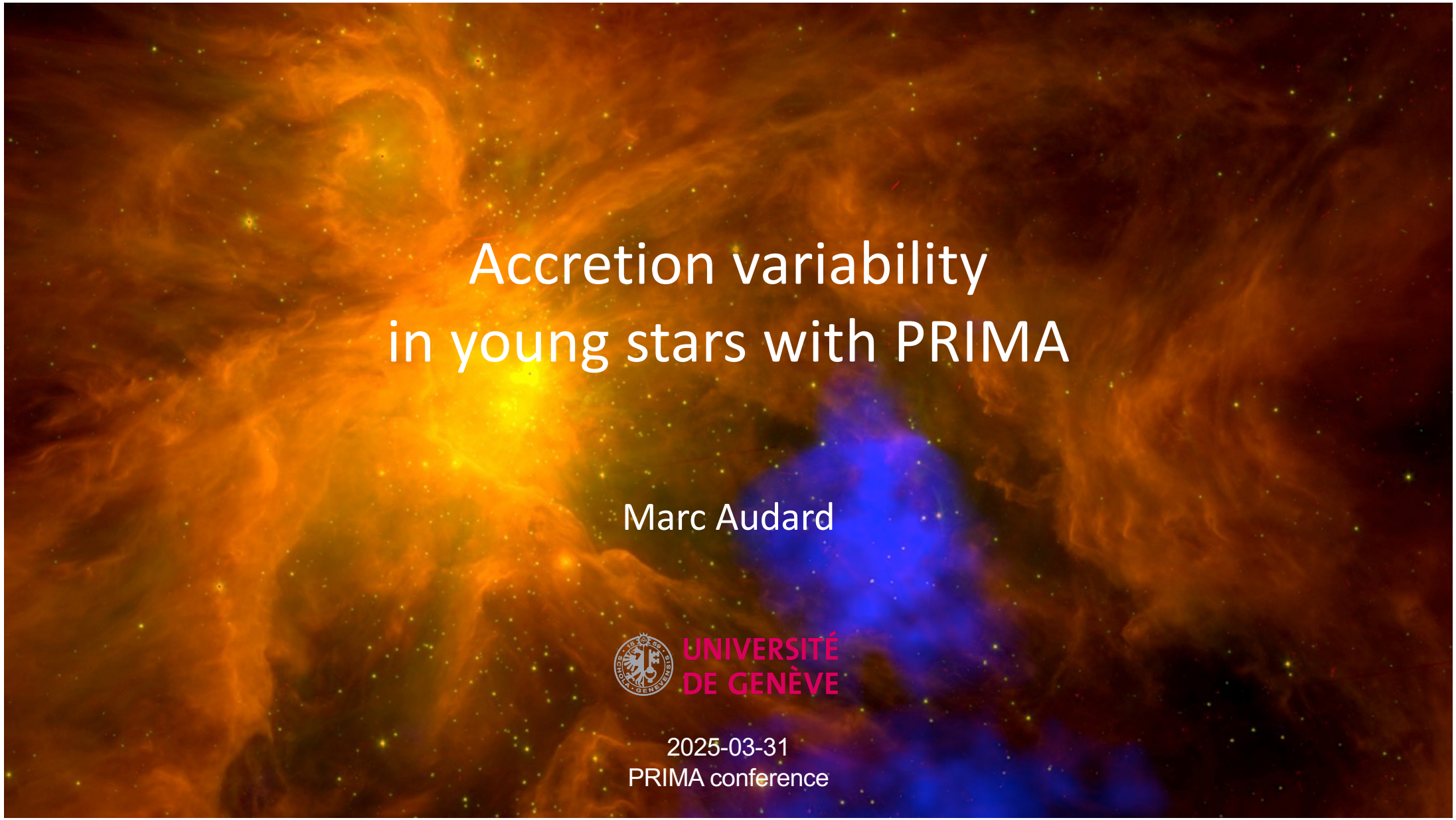


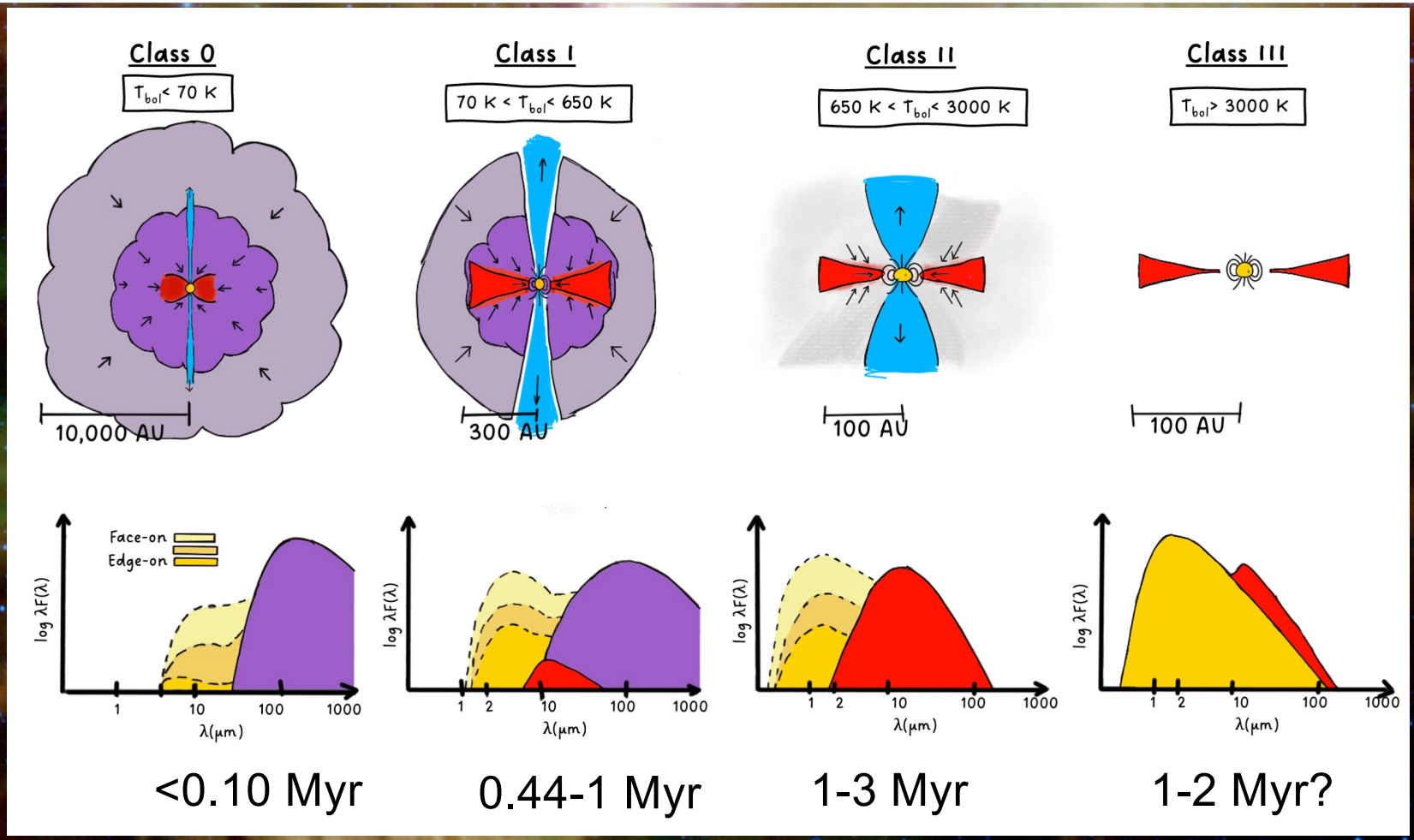
Accretion variability in young stars with PRIMA

Marc Audard

UNIVERSITÉ DE GENÈVE

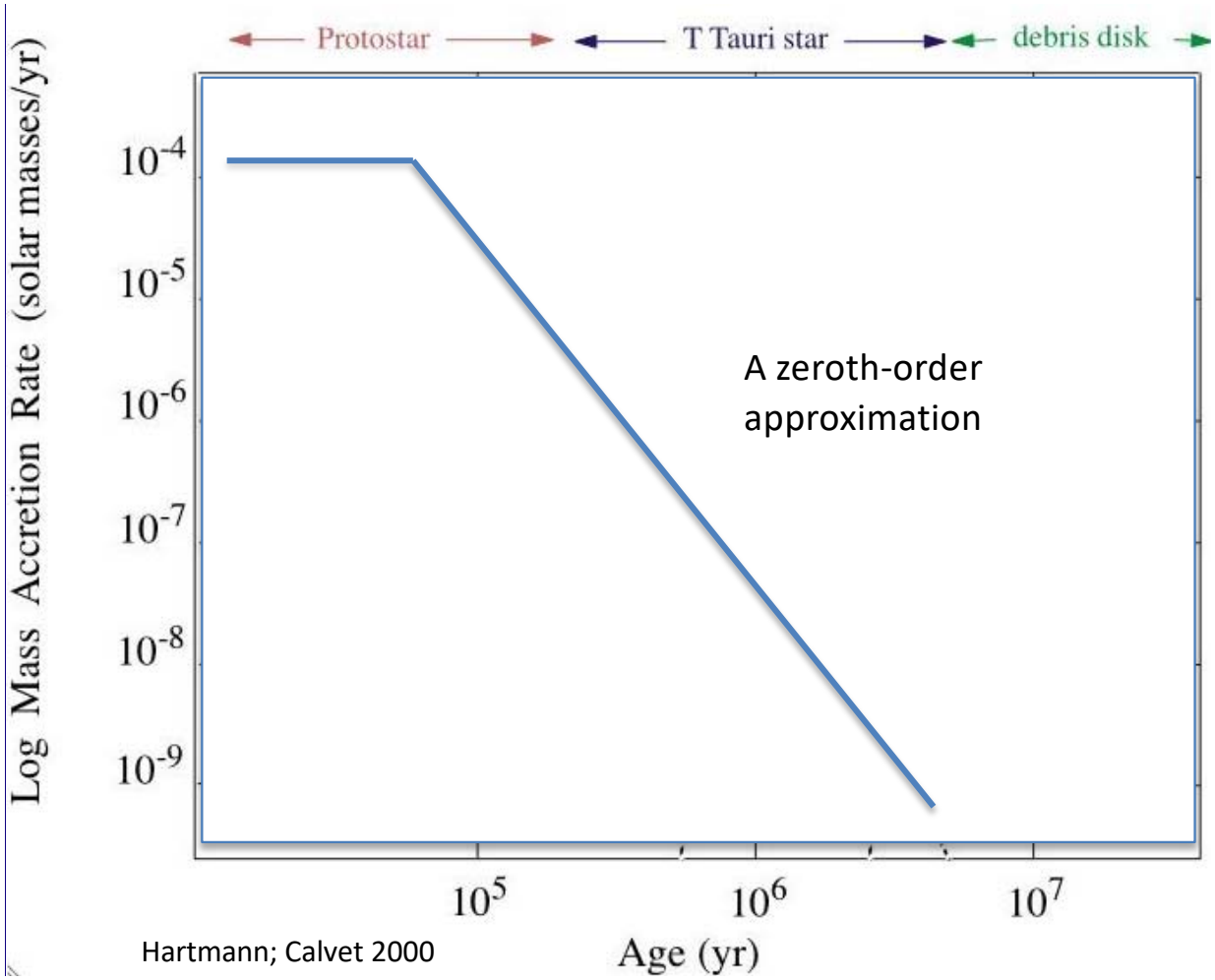
2025-03-31
PRIMA conference

Classification paradigm



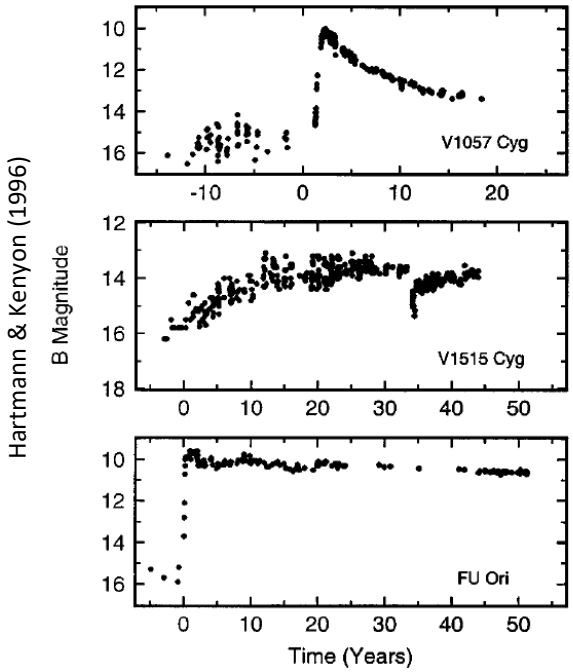
Lada 1987/André 1993; Cartoon by J. Roquette, from Persson (2014)

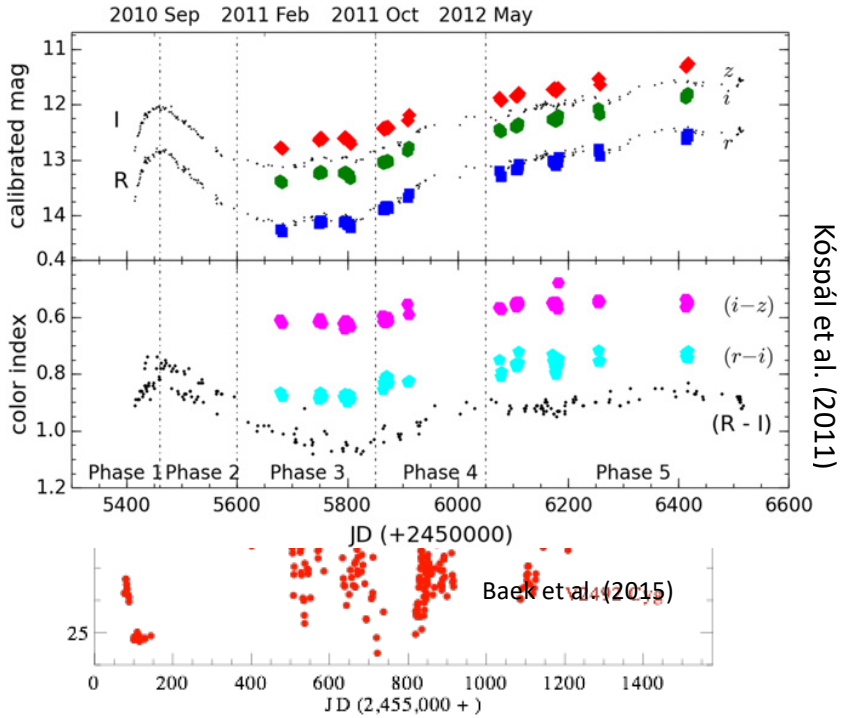
Accretion rate history



Hartmann; Calvet 2000

A wide range of outbursts





Outbursts in last decade have started to blur the distinction between FUors and EXors:

- Outburst luminosities reach intermediate values (e.g., HBC 722 with ≈5-12L_{sun}, V2775 Ori with 51 L_{sun})
- Outburst durations in between those of EXors and FUors (e.g., HBC 722, V1647 Ori, OO Ser)
- Embedded objects with EXor outburst characteristics (e.g., V723 Car, V1647 Ori, V2492 Cyg)

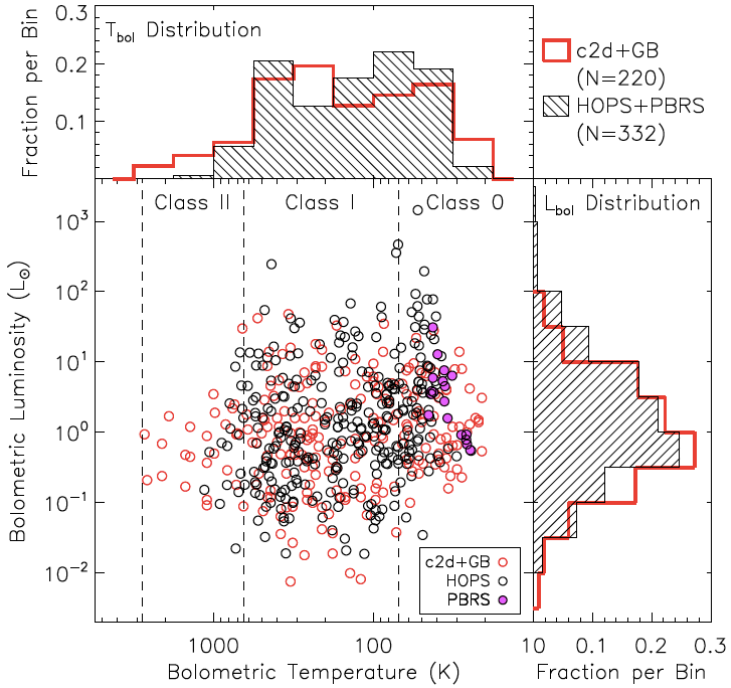
→ A *continuum* of properties of eruptive young stars? (Audard et al. 2014, PPVI review)

See more recent review (PPVII: Fischer et al. 2023)

Solving the protostellar luminosity problem

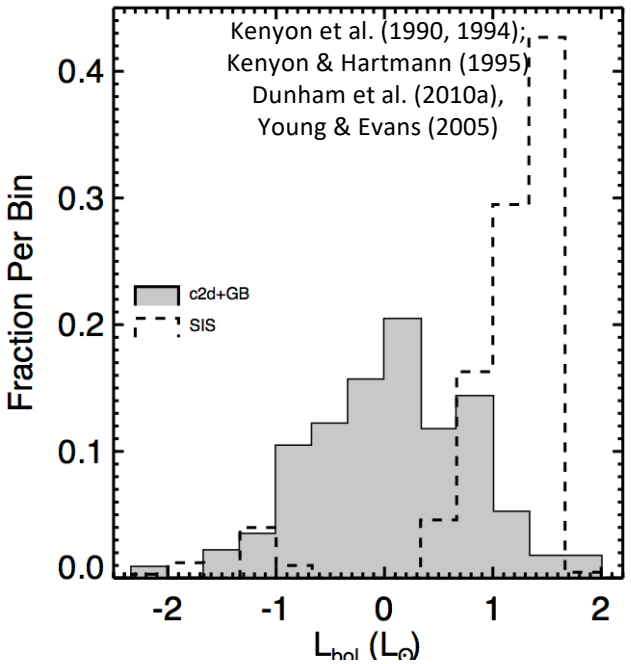
Kenyon et al. (1990, 1994)

Dunham et al. (2014)



$$L = L_* + L_{acc} = \frac{3}{7}\frac{GM_*^2}{R_* t_{KH}} + \frac{GM_*\dot{M}}{2R_*} = L_*\left(1 + \frac{7}{6}\frac{t_{KH}}{t_{acc}}\right)$$

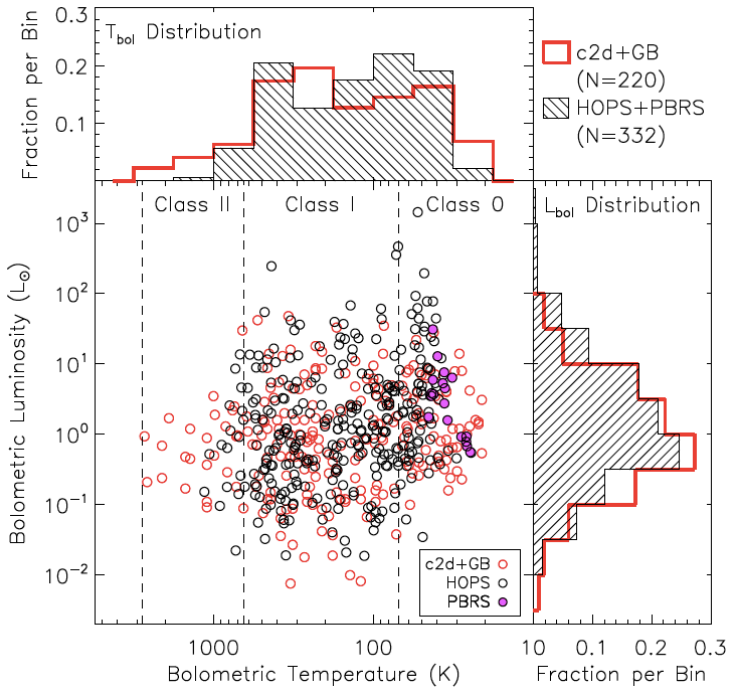
Models of single isothermal sphere with rotation



t_{KH}>t_{acc} in protostars →
L(protostar)>L(T Tau star)
for same mass, in theory

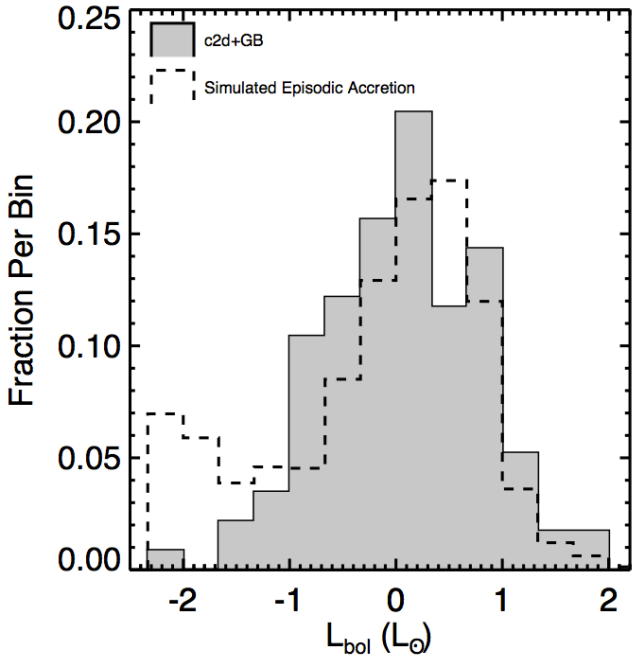
Solving the protostellar luminosity problem

Dunham et al. (2014)



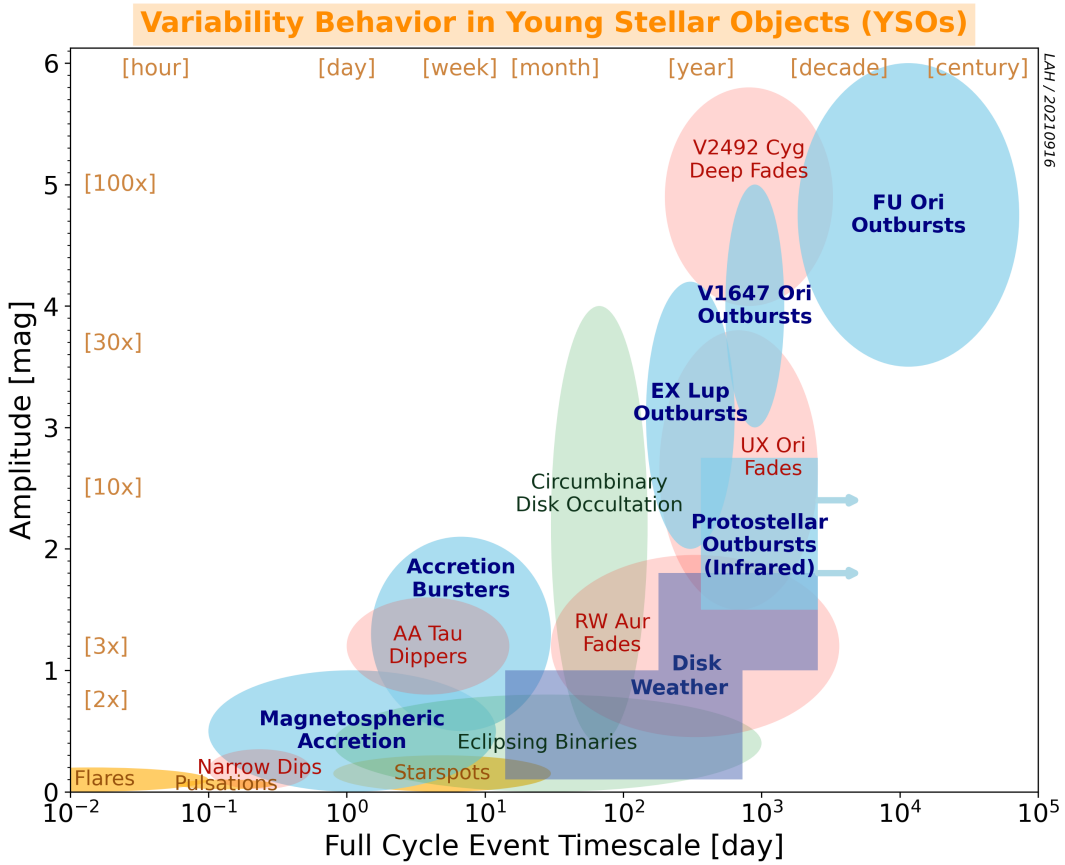
Dunham et al. (2010), Dunham & Vorobyov (2012)

Models with simulated episodic accretion



Episodic accretion may also explain luminosity spread in young clusters
(Baraffe et al. 2009, 2012; Jensen & Haugbølle 2017)

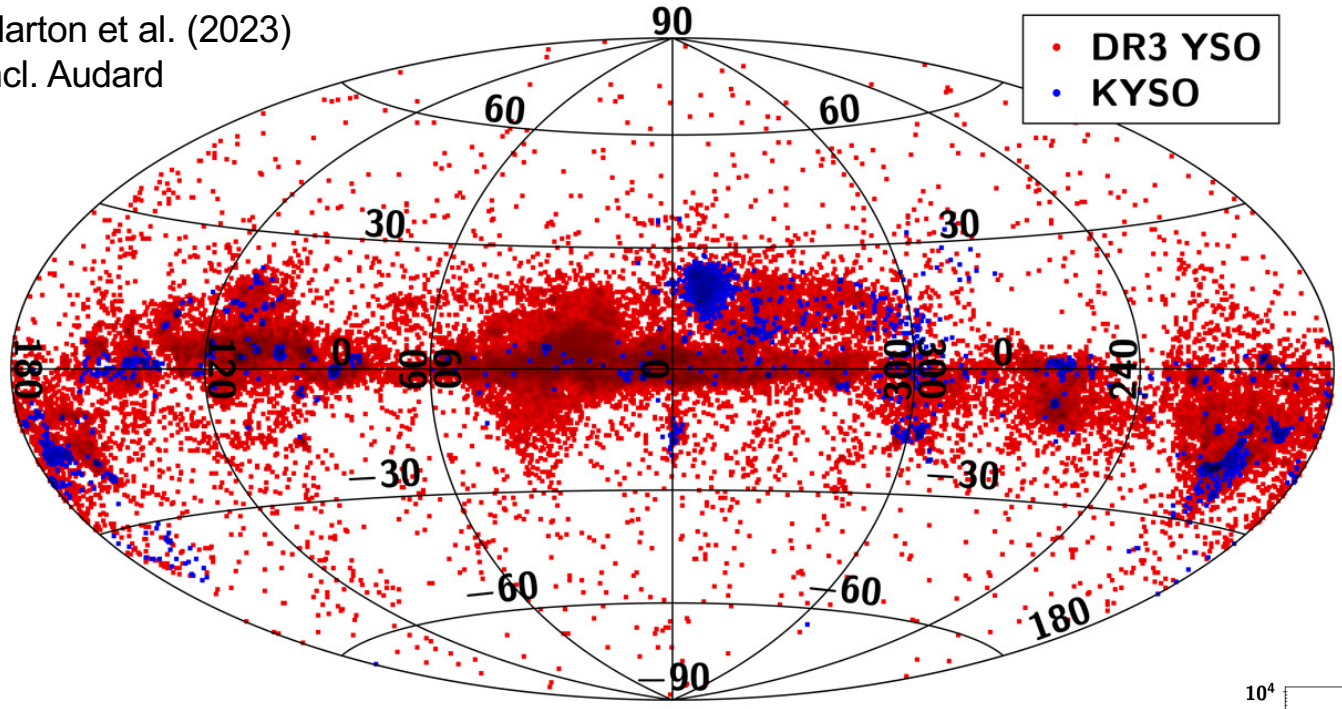
YSO variability

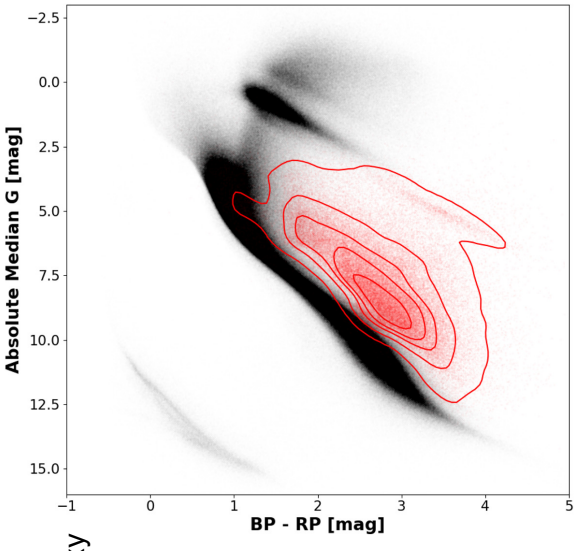


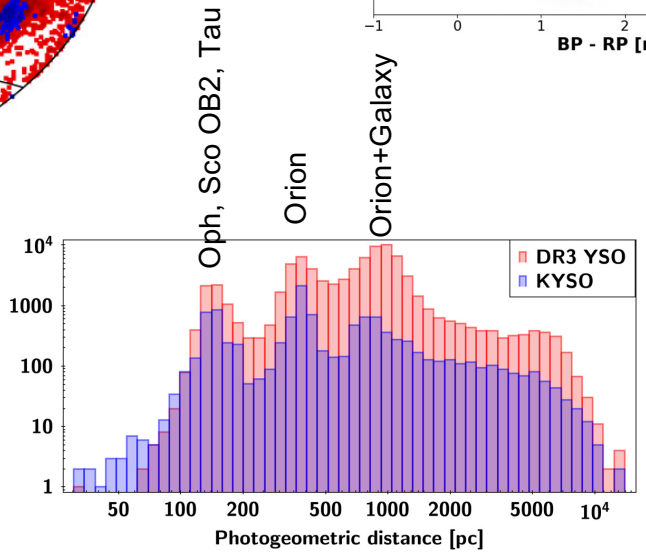
Fischer et al. (2023), based on Hillenbrand & Findeisen (2015)

The Gaia DR3 YSO catalogue

Marton et al. (2023)
incl. Audard





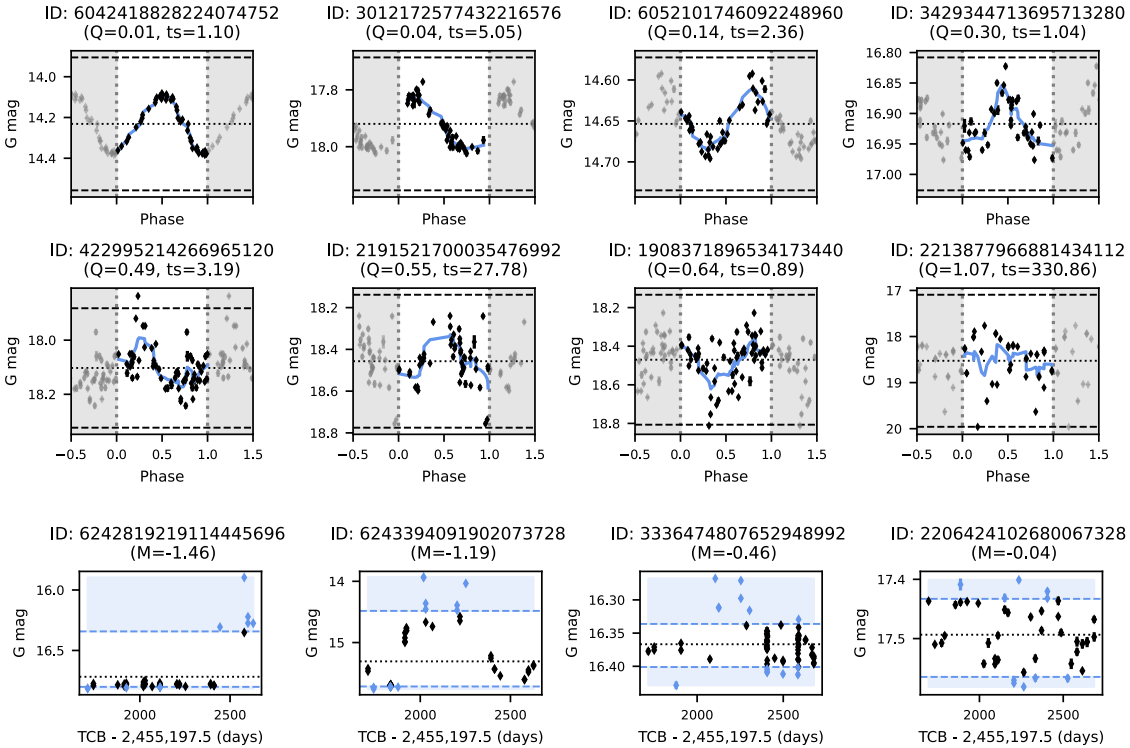


79,375 candidates, about 40k new

Comparison of Gaia samples with optical/IR catalogues
(e.g., Marton+ 2019, Grossschedl+ 2018, Kuhn+ 2021)

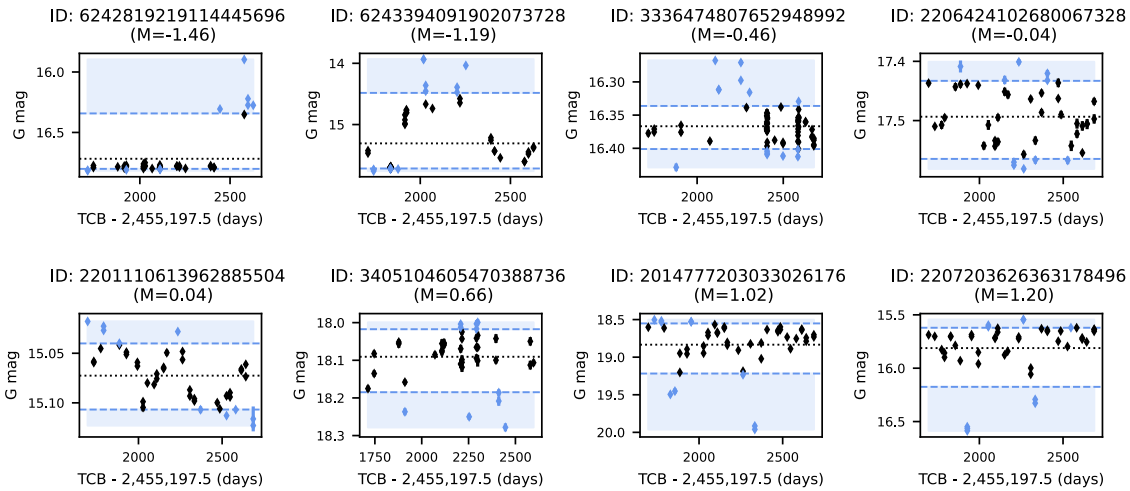
Optical variability

Periodicity



Q=0 → seriodic
Q>>0 → Stochastic

Asymmetry



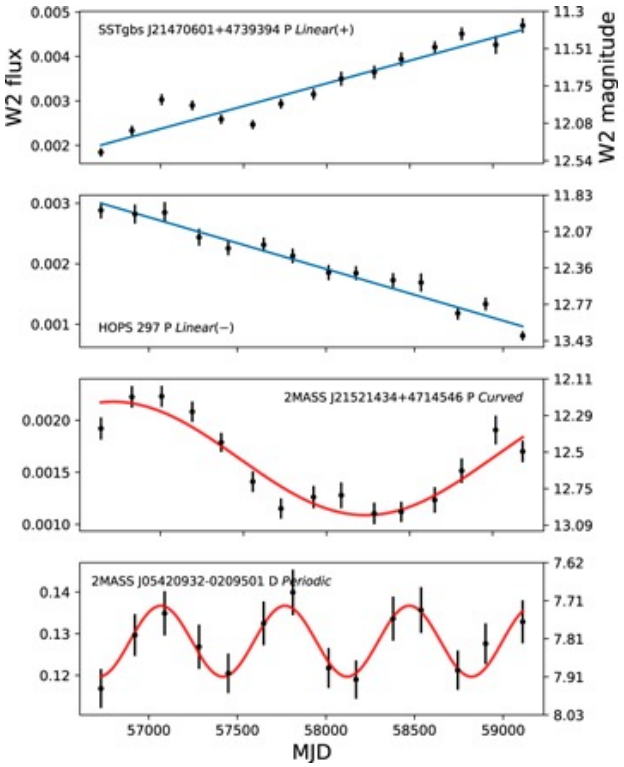
Accretion processes are stochastic and asymmetric

M=0 → symmetric
|M|>0 → asymmetric
(burst or dipping)

Mas, Roquette, Audard et al. (2025) submitted

IR + sub-mm variability

Park et al. (2021)



Linear +

Linear -

Curved

Periodic

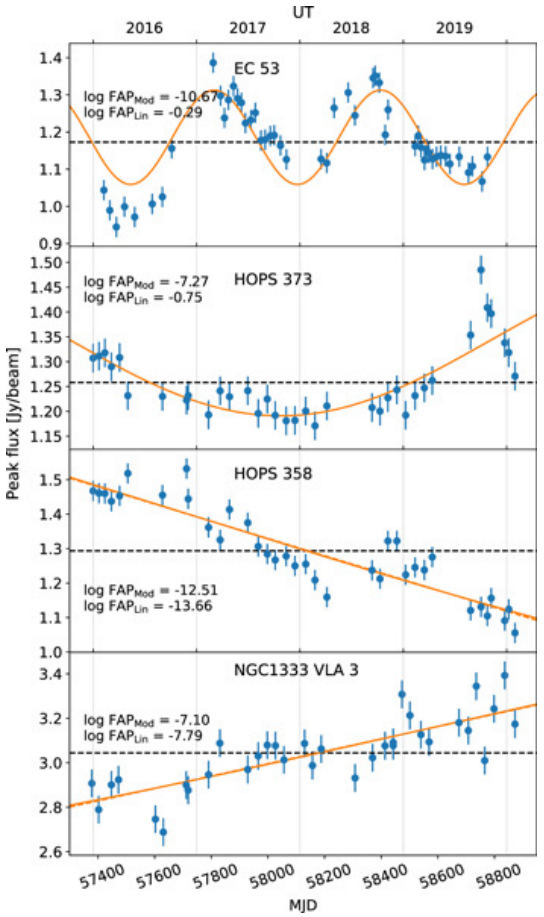
WISE

Periodic

Curved

Linear -

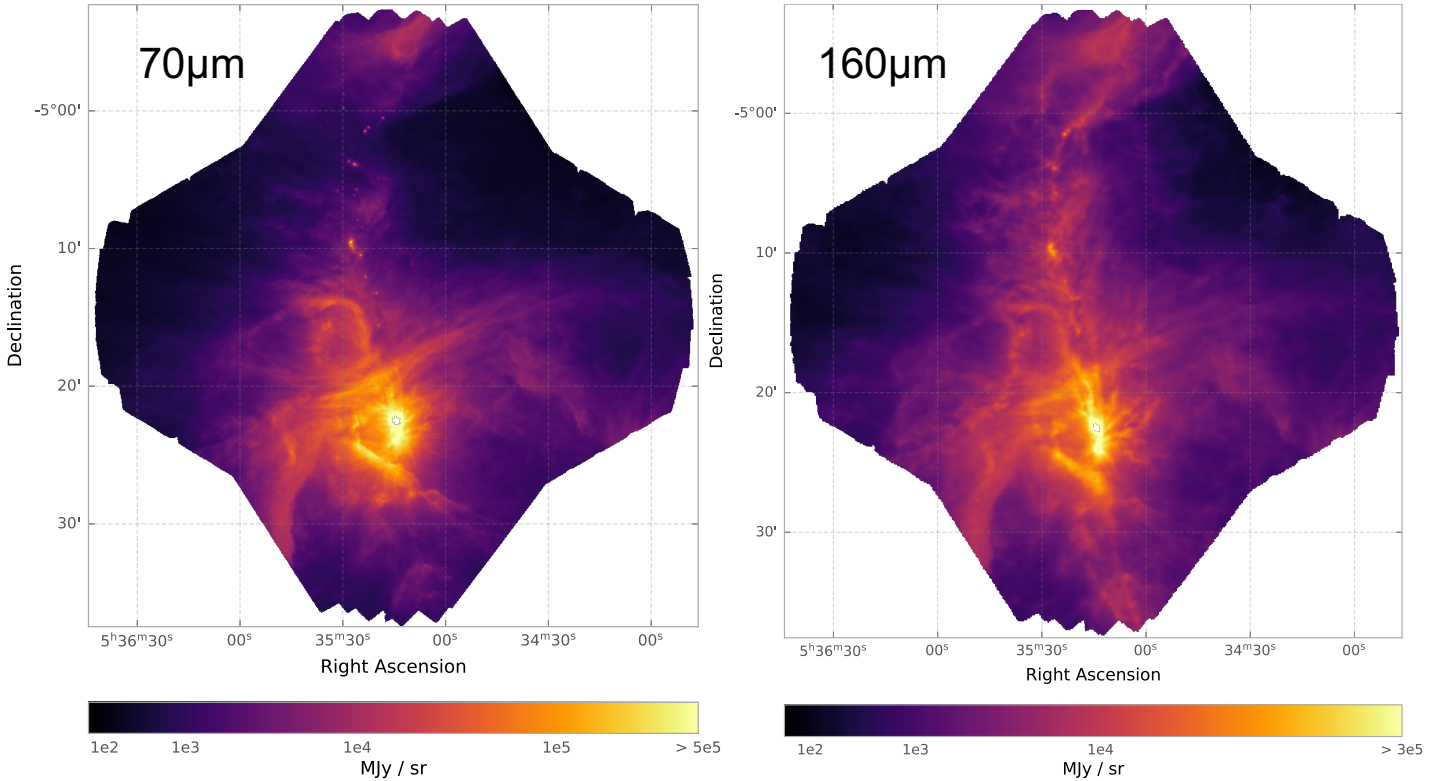
Linear +



JCMT

Lee et al. (2022)

FIR Orion Nebula monitoring

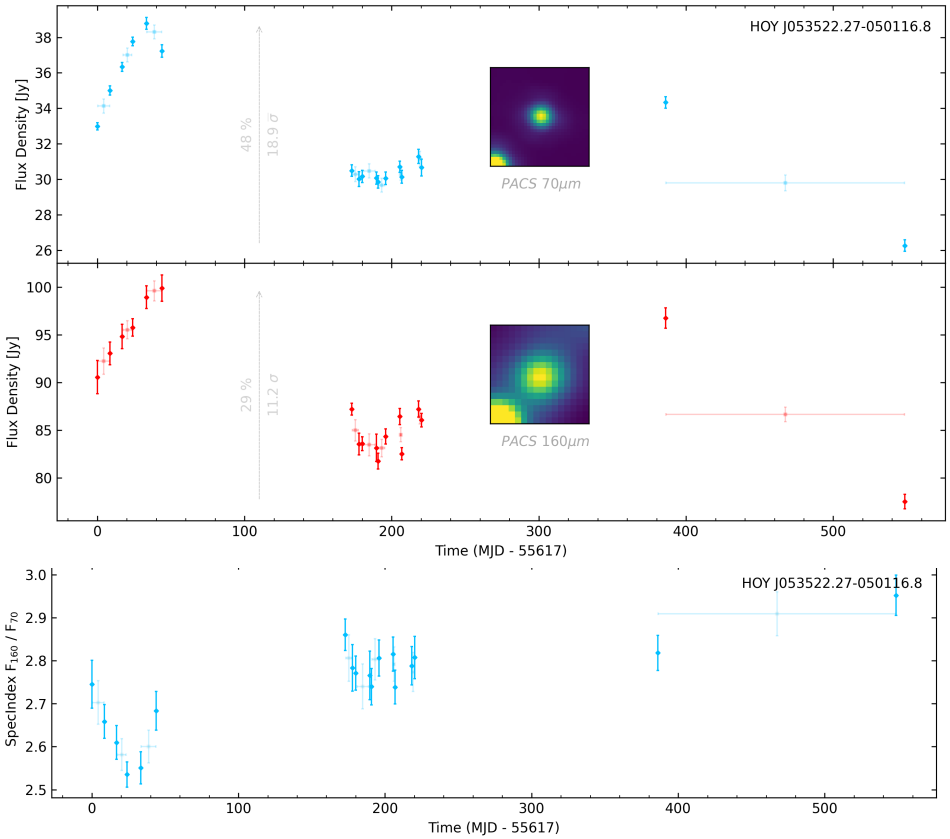


Billot, Audard, et al. (2025)

- 38 point-like sources with reliable 70μm flux density
- 18 observations of single 35'x35' region centered on ONC
- Constant speed of 20"/s in zig-zag pattern
- Coverage from 2011-02-25 to 2012-08-27
- PI: N. Billot, OT1_nbillot_1

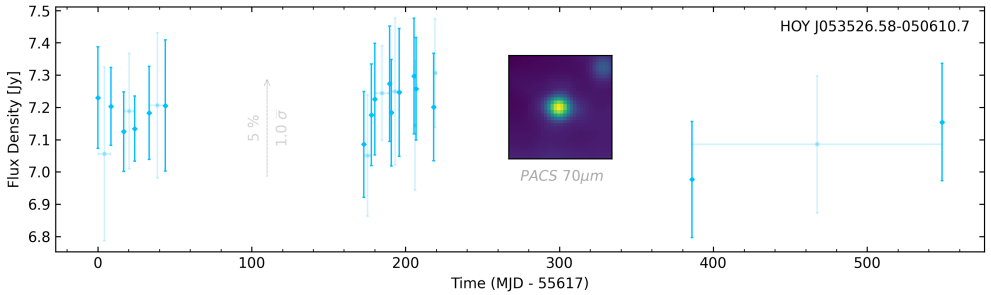
Far-infrared variability in protostars

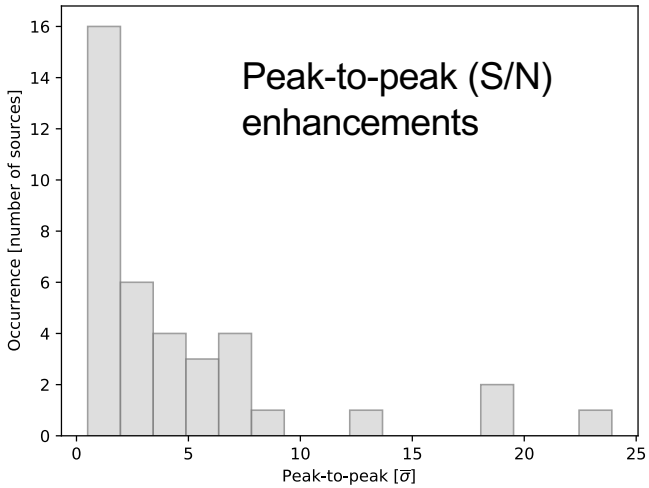
Variable protostar



Billot, Audard, et al. (2025)

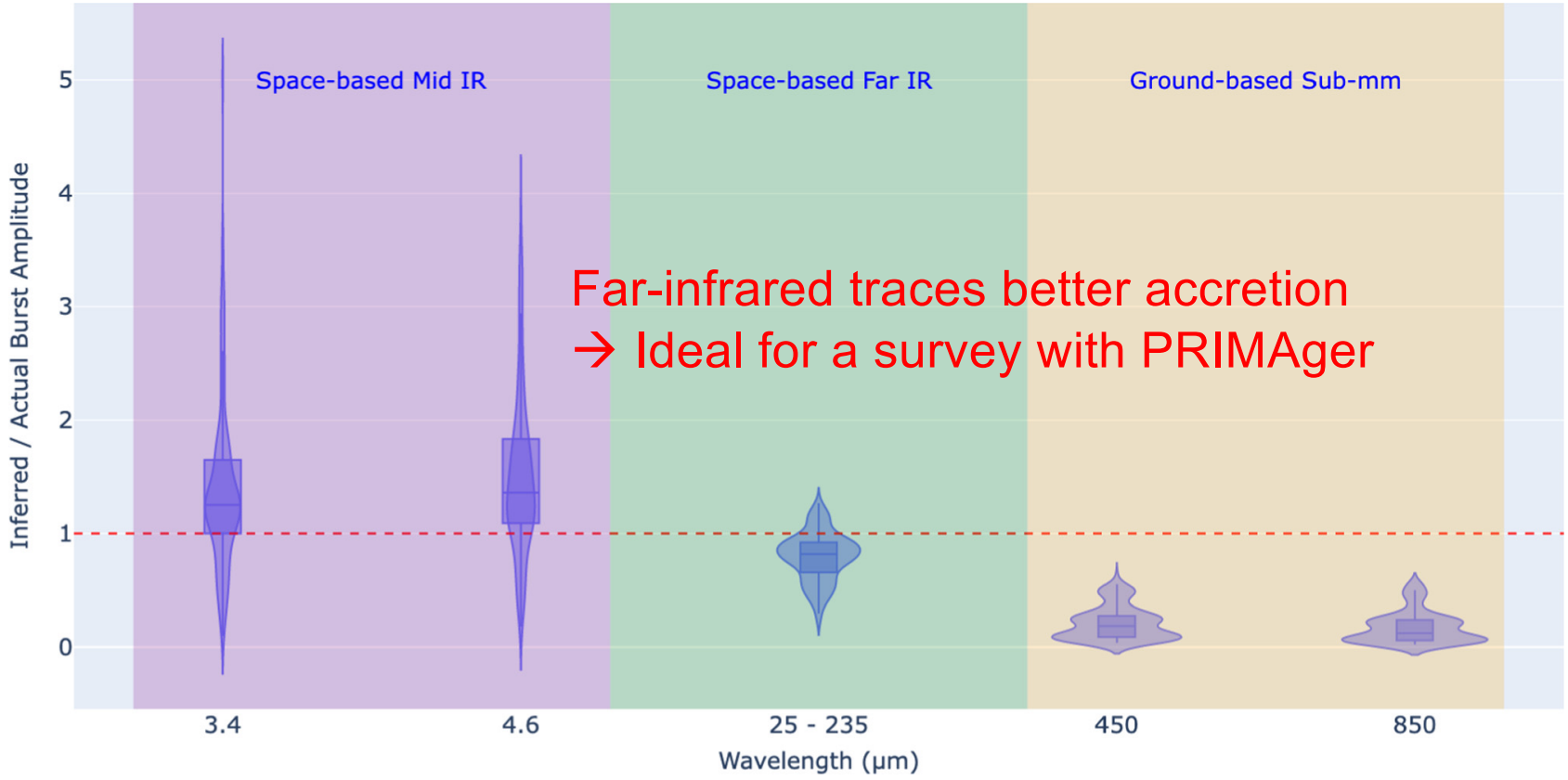
Non-variable protostar





Significant and frequent variability detectable in protostars

Far-infrared as tracer of accretion



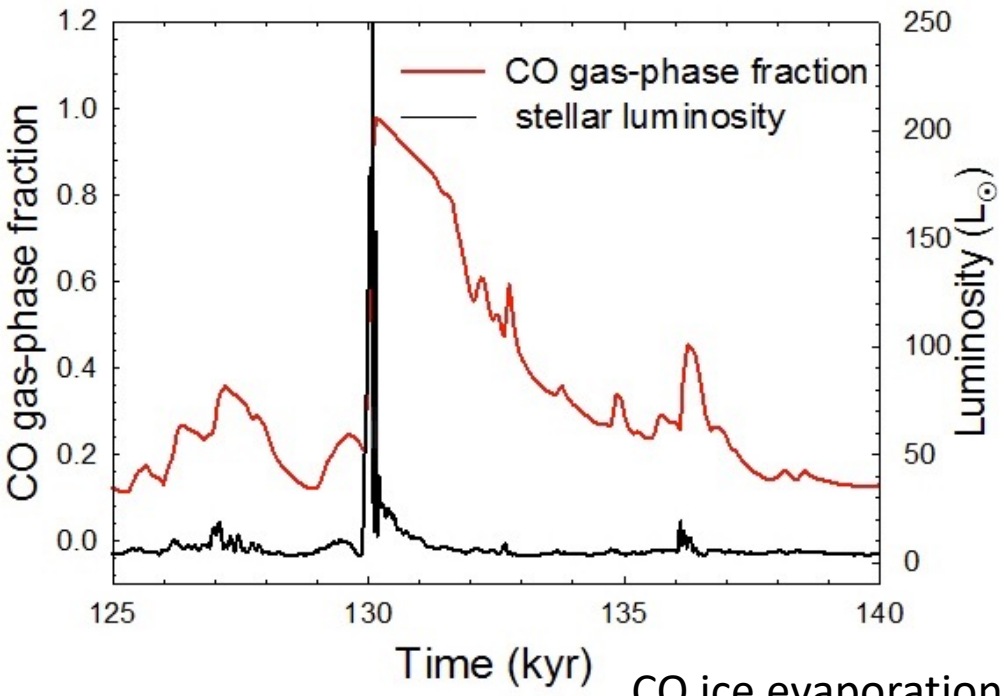
Complementary to accretion tracers in UV (e.g., UVEX)

Fischer et al. (2023b), see also PRIMA GO Book, Battersby+

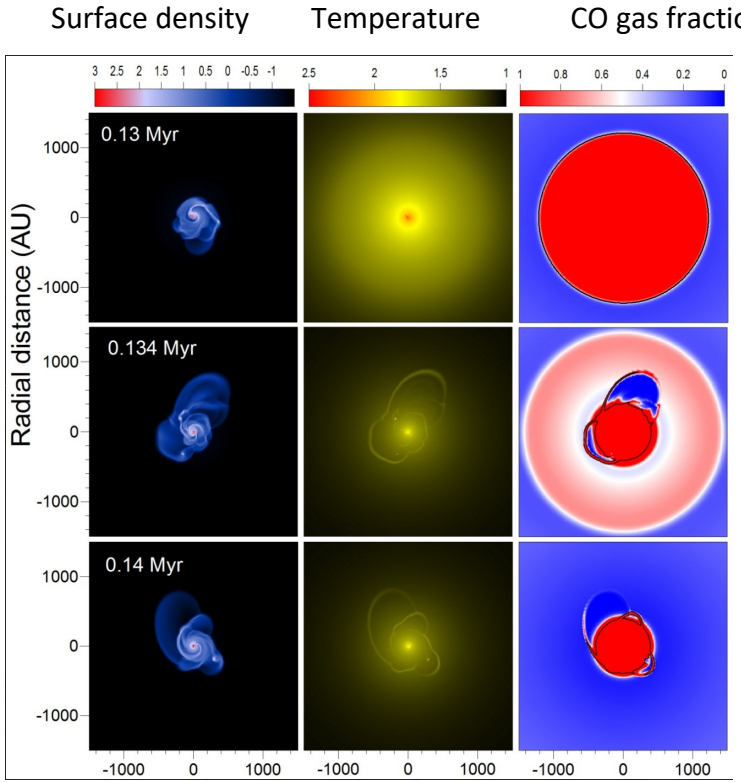
Outburst chemistry

Episodic accretion events can evaporate ice frozen onto grains

→ CO, CO_2, N_2H^+, HCO^+, H_2CO time tracers

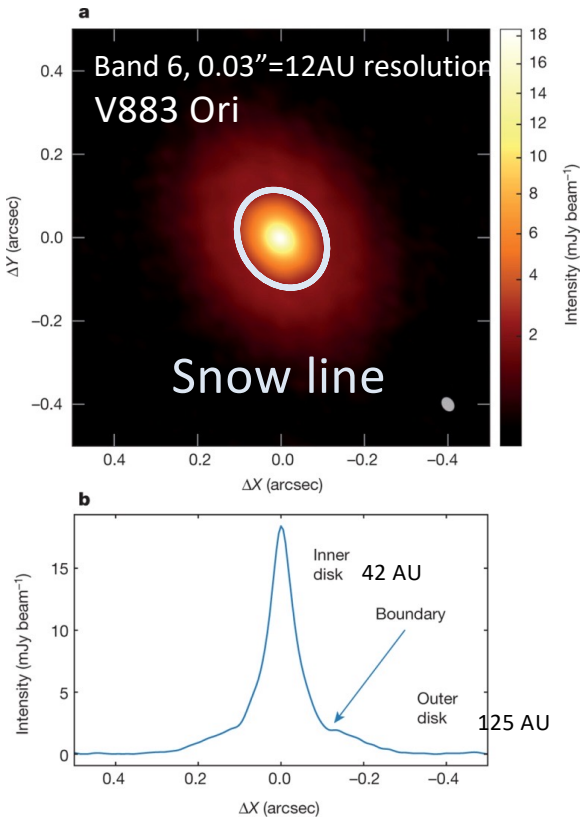


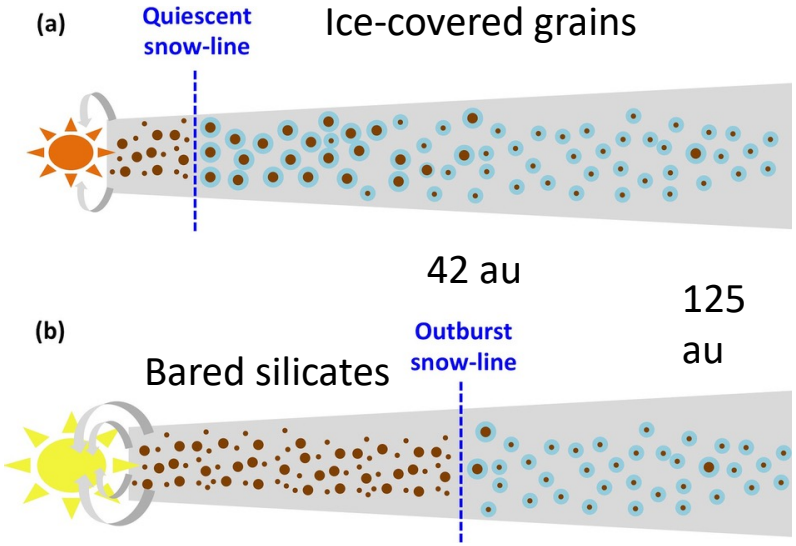
Vorobyov et al. (2013)



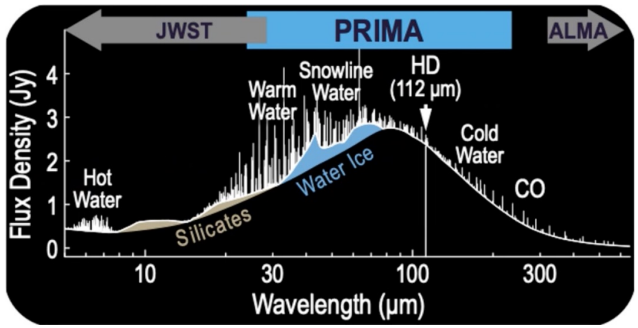
CO ice evaporation in the inner envelope (1000-2000 au)

Snow line





L A Cieza *et al. Nature* **535,** 258–261 (2016) doi:10.1038/nature18612



See also Banzatti et al. (2015); Schoonenberg et al. (2017); Hsie et al. (2019); Liu et al. (2021), Vorobyov et al. (2022)

→ Accretion variability with PRIMA/FIRESS

Conclusion

- Accretion in young stars is variable
- Far-infrared regime traces accretion better
- Episodic accretion modifies the disk chemistry
- Snow lines move, ices evaporate

- Young stars are ideal targets for PRIMA to probe accretion variability and its impact on the PP disk

Opportunities in Switzerland

- Swiss SNF Postdoc fellowship
  - independent project 2 years. Similar to Marie Curie fellowship
  - 0-8 yrs after PhD
  - Call 1 Dec 2025 TBC

Feel free to talk to me!

- Swiss SNF Ambizione fellowship
  - independent project up to 4 years
  - Can ask for PhD student
  - < 4 yrs after PhD
  - Call 4 Nov 2025