

# Emission lines variability of young accreting planets and brown-dwarf companions

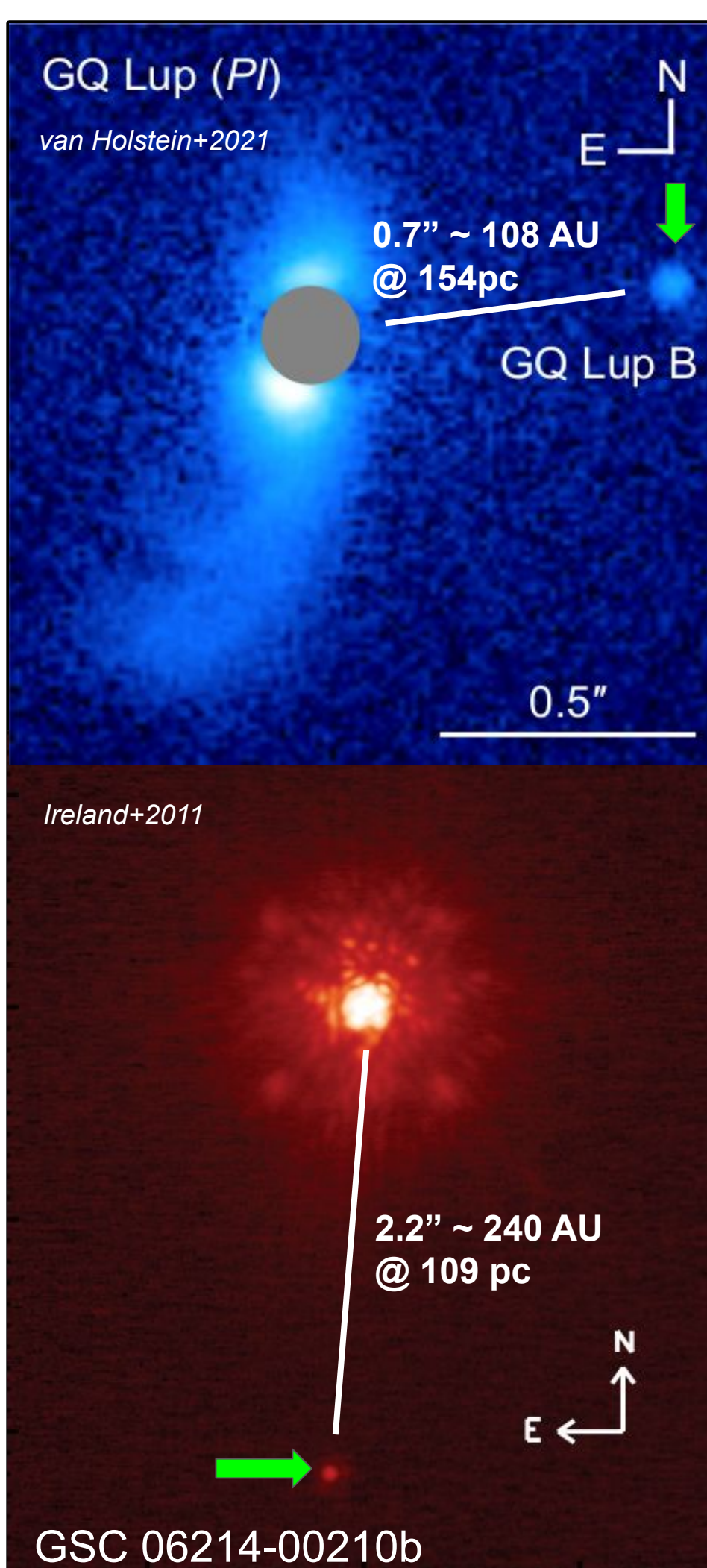
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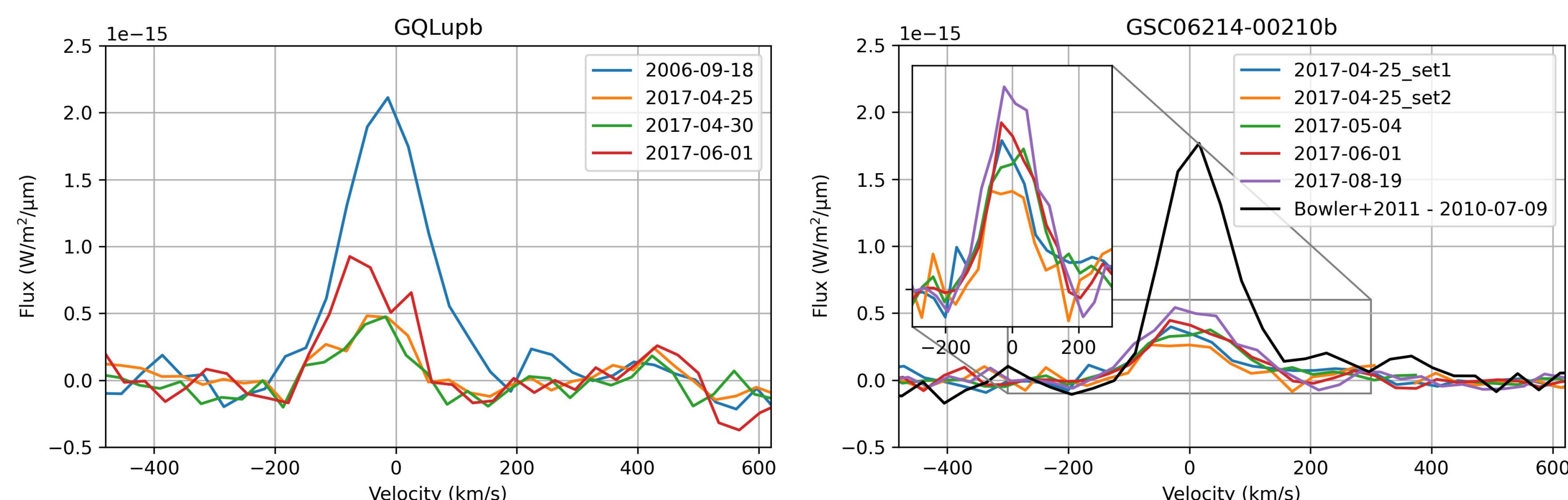
**Abstract** We present the results of a monitoring campaign of the Paschen  $\beta$  emission lines ( $1.28\mu\text{m}$ ) of two accreting  $10\text{-}30M_{\text{Jup}}$  companions with the VLT/SINFONI integral field spectrograph : GQ Lup b and GSC 06214-00210 b. We evidence variability of line intensities and profiles on minutes to years timescales on both objects. These behaviors are reminiscent of rotation-modulated variability observed on CTTS and a signpost of magnetospheric accretion. The line properties are compared to predictions from a scaled-down version of the stellar magnetospheric accretion (MA) models and to the latest disk-driven accretion models of protoplanets nested within circumstellar disks. The line properties of GQ Lup b are reproduced by MA models while those of GSC 06214-00210 b are better fitted by disk-driven accretion models (protoplanets). New MA models with inclined dipoles and monitoring observations at higher spectral resolving powers over one rotation period (1h to several days) could help confirming the mechanisms at play on these two objects. We discuss the implication of our findings for the protoplanet detection based on their line emission (e.g., VLT/MUSE, Magellan/MagAO-X).



## 1. Observing program

- **J band** observations with SINFONI/VLT
  - 1.1-1.4  $\mu\text{m}$  @  $R=2360$
  - **Paschen  $\beta$  line** @  $1.282\mu\text{m}$
- **GQ Lup b** :  $10\text{-}30 M_{\text{Jup}}$  companion to a 2-5 Myr CTTS star ( $0.7M_{\odot}$ )
- **GSC 06214-00210b** :  $14 M_{\text{Jup}}$  companion to a 15 Myr K-type star ( $0.9M_{\odot}$ )
- **Probing hours to years timescales**
  - New monitoring data (2017) : hours to months timescales
  - “Historical” epochs (Keck/OSIRIS, VLT/SINFONI, Gemini/NIFS) : years to decade timescales
- **Custom algorithm to remove the stellar line contamination and photospheric emission**

## 2. Line profiles



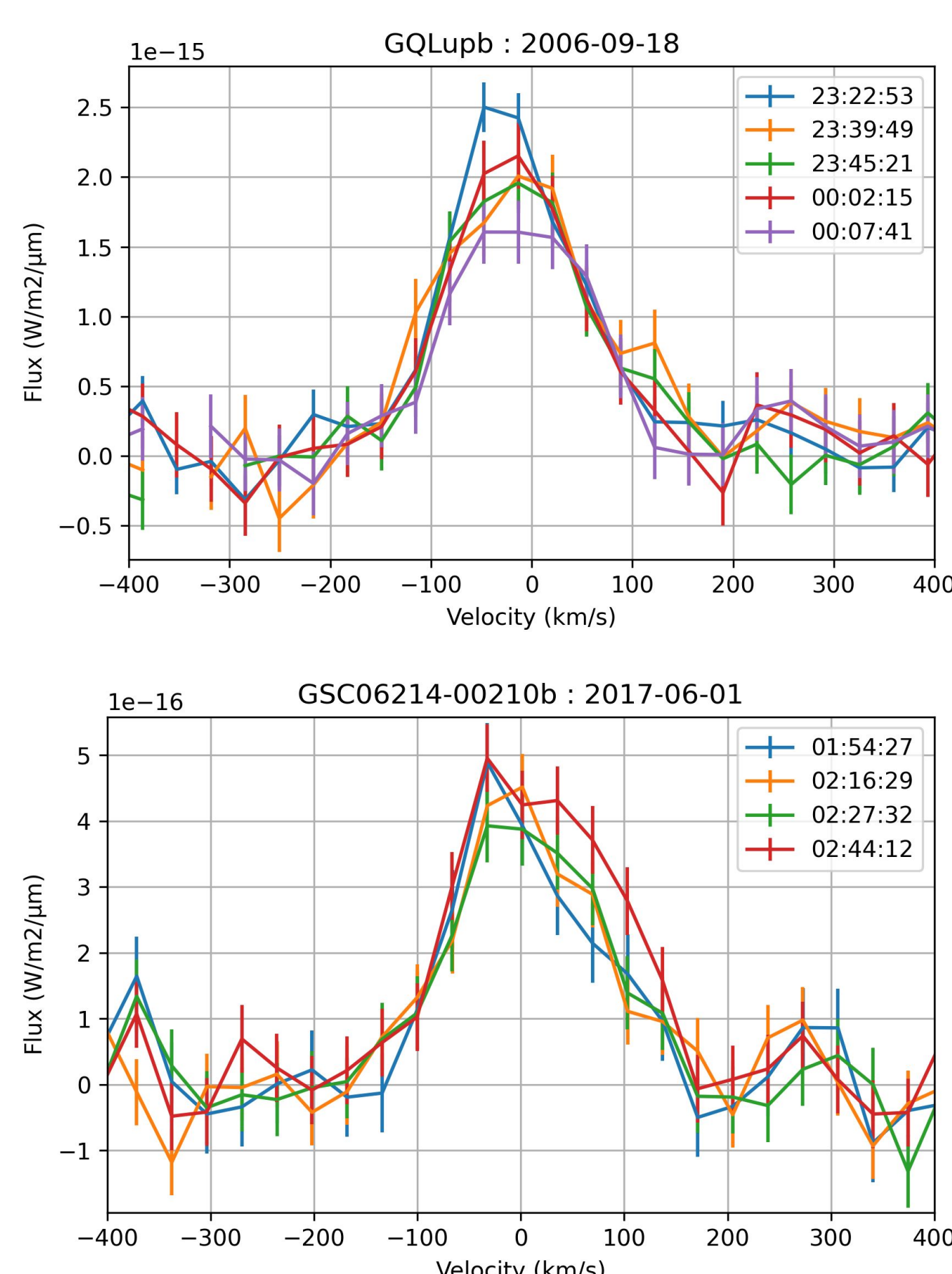
- Lines are **marginally resolved!** 1.2 times the LSF for GQ Lup b and 1.3-1.5 times for GSC 06214b
- **Blue-shifted lines** for GQ Lup b
- **Centered and asymmetric lines** for GSC 06214b

➡ Reminds of CTTS profiles !

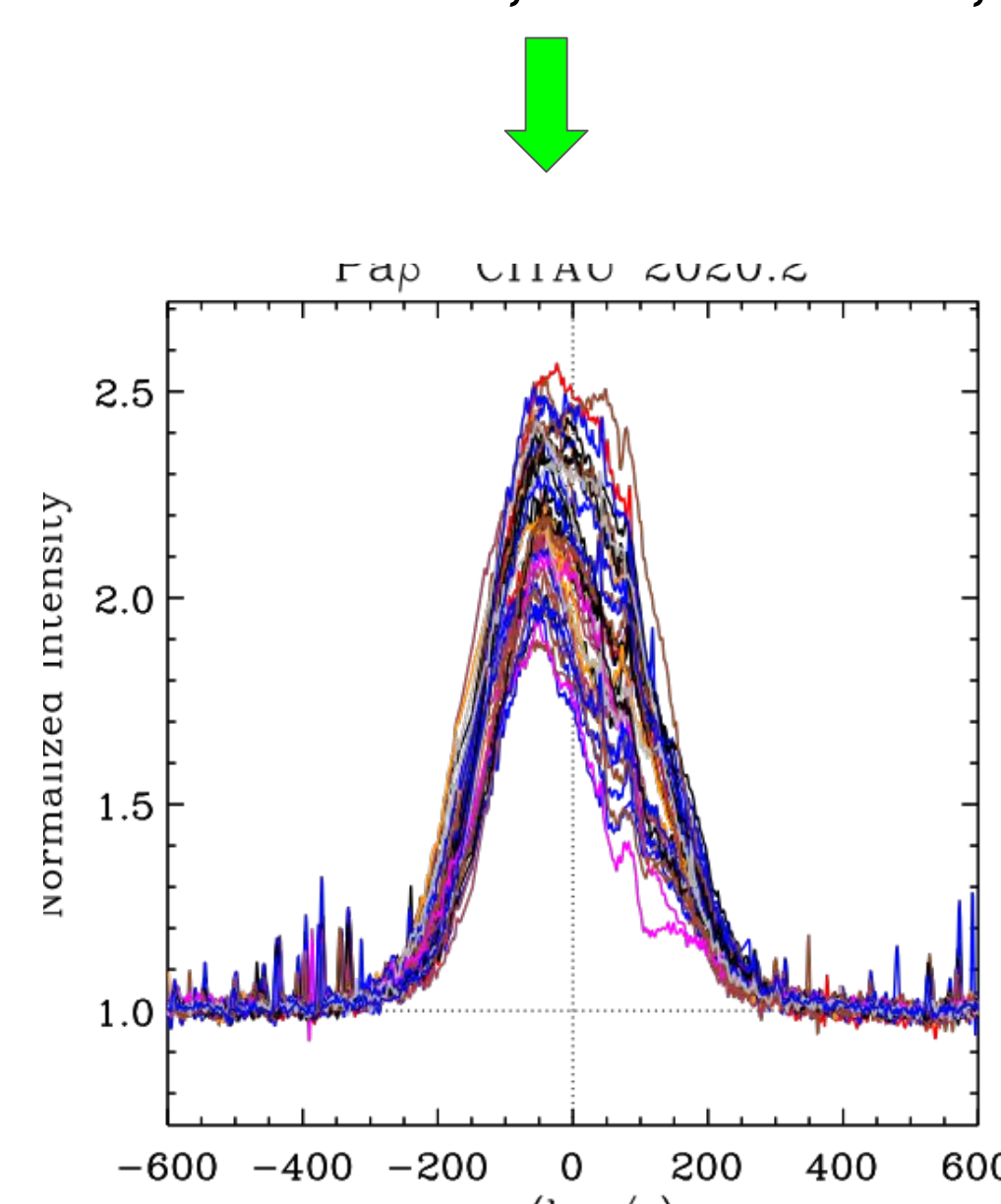
## 3. Short timescales variations

Two types of behaviors:

- **Intensity variation**: seen on 1 epoch of GQ Lup b, and 3 epochs of GSC06214b.
- **Red wing variation**: seen on 1 epoch of GSC06214b. This is a feature that is similar to Pa  $\beta$  lines of T Tauri stars



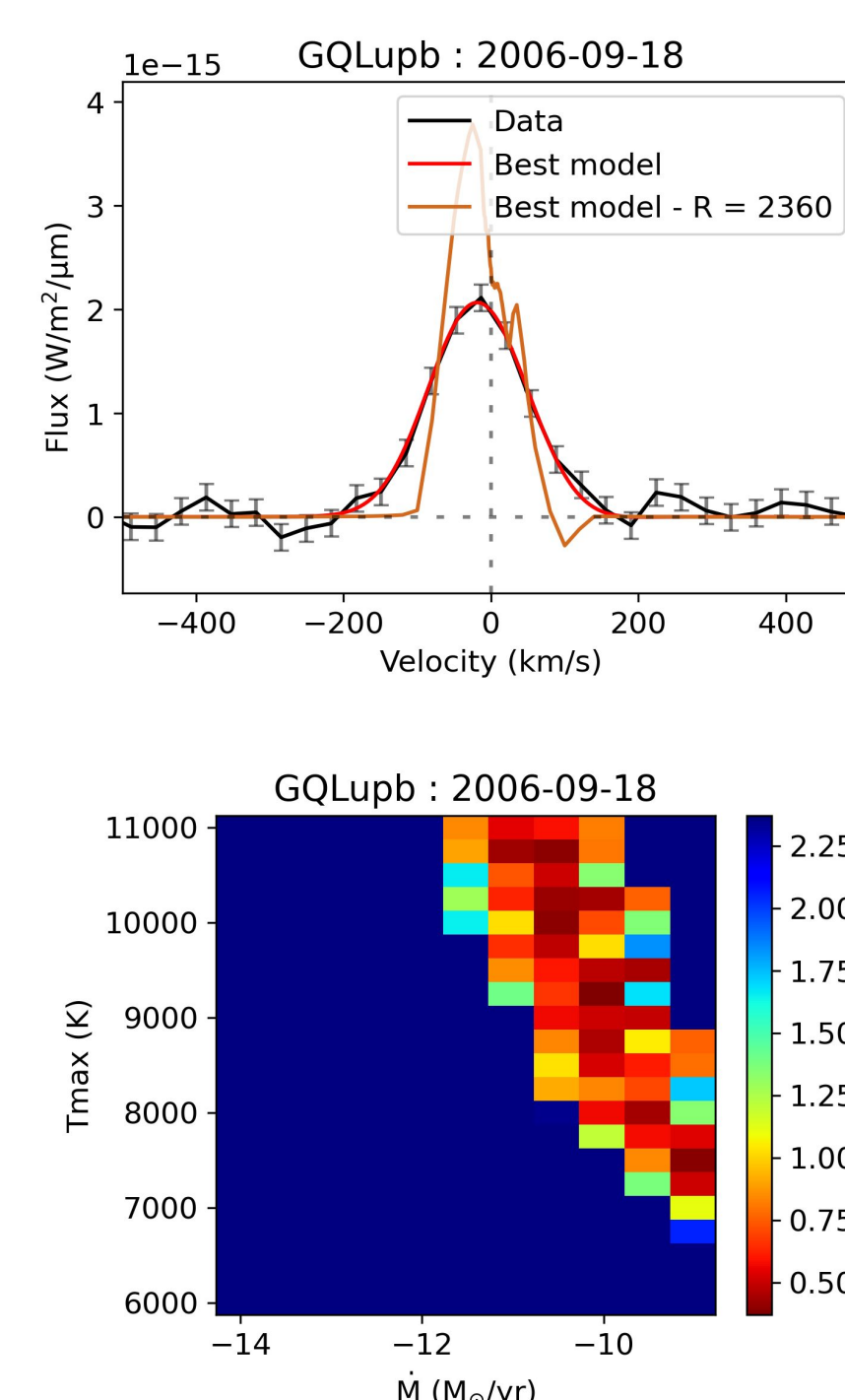
Reminiscent of CTTS too!  
(*SPirou obs of CI Tau; De Sousa et al, in prep.*)



## 4. Comparison to models

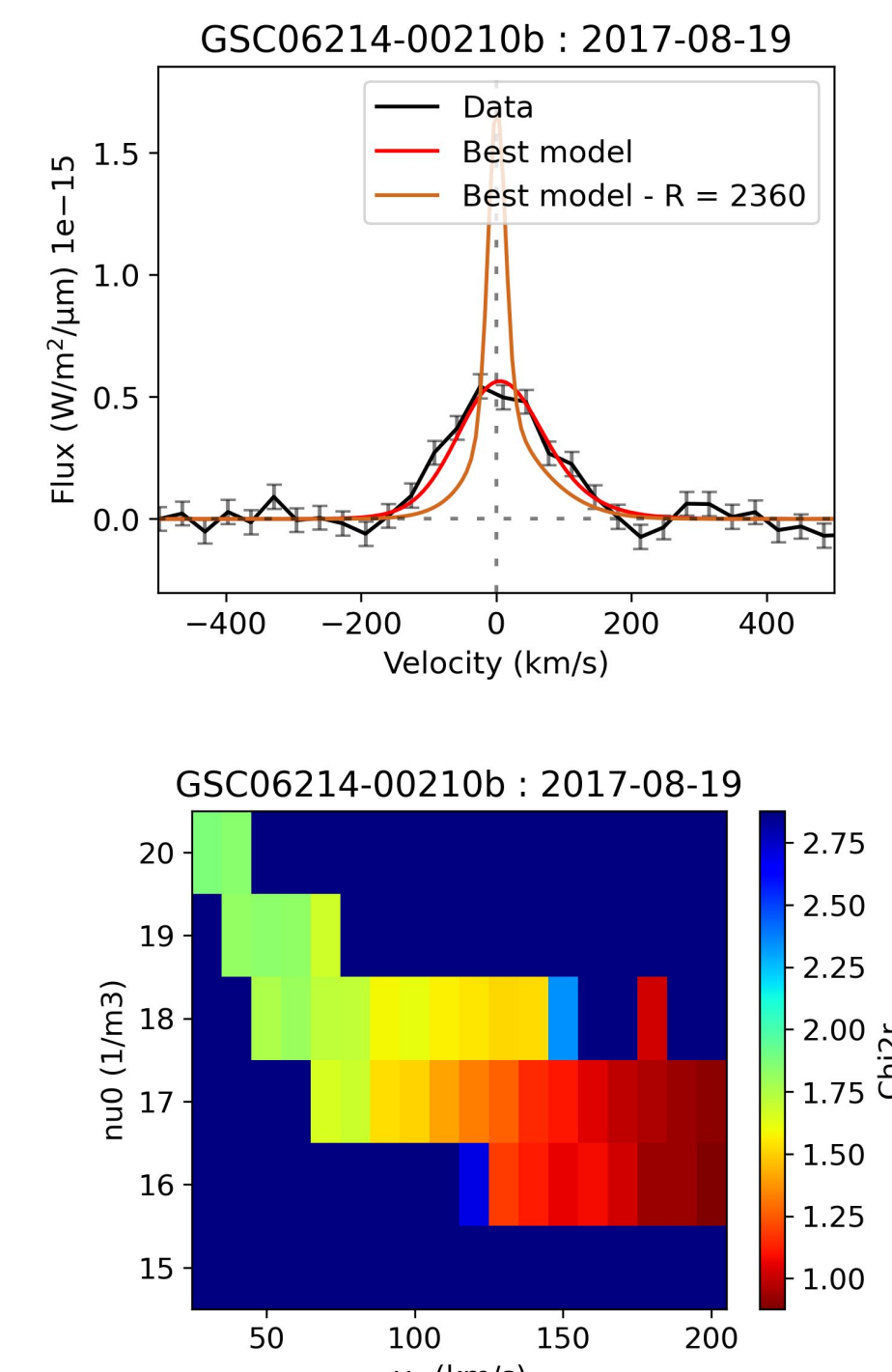
### Magnetospheric accretion models

Thanathibodee et al. 2019



### Models of embedded protoplanets

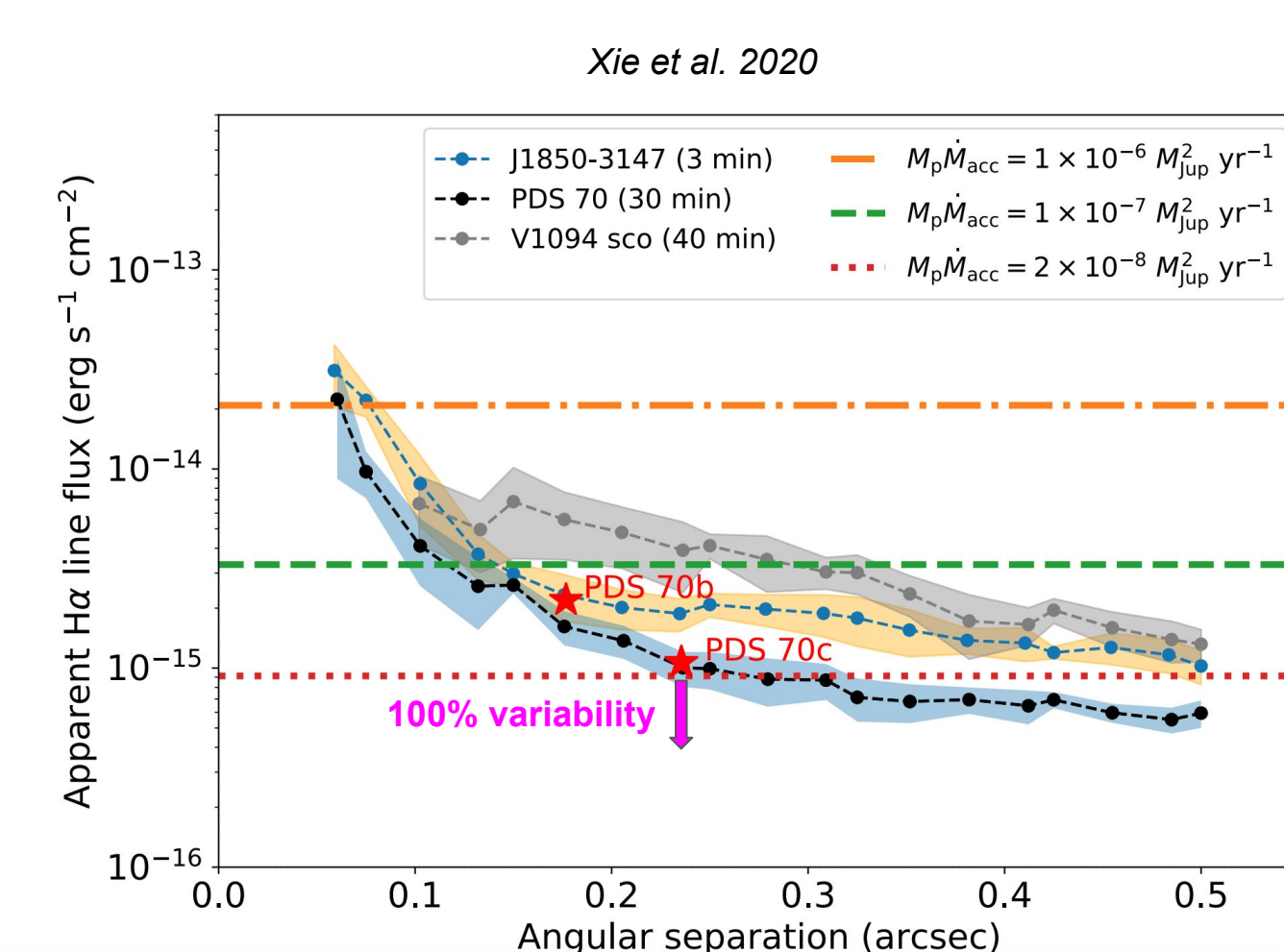
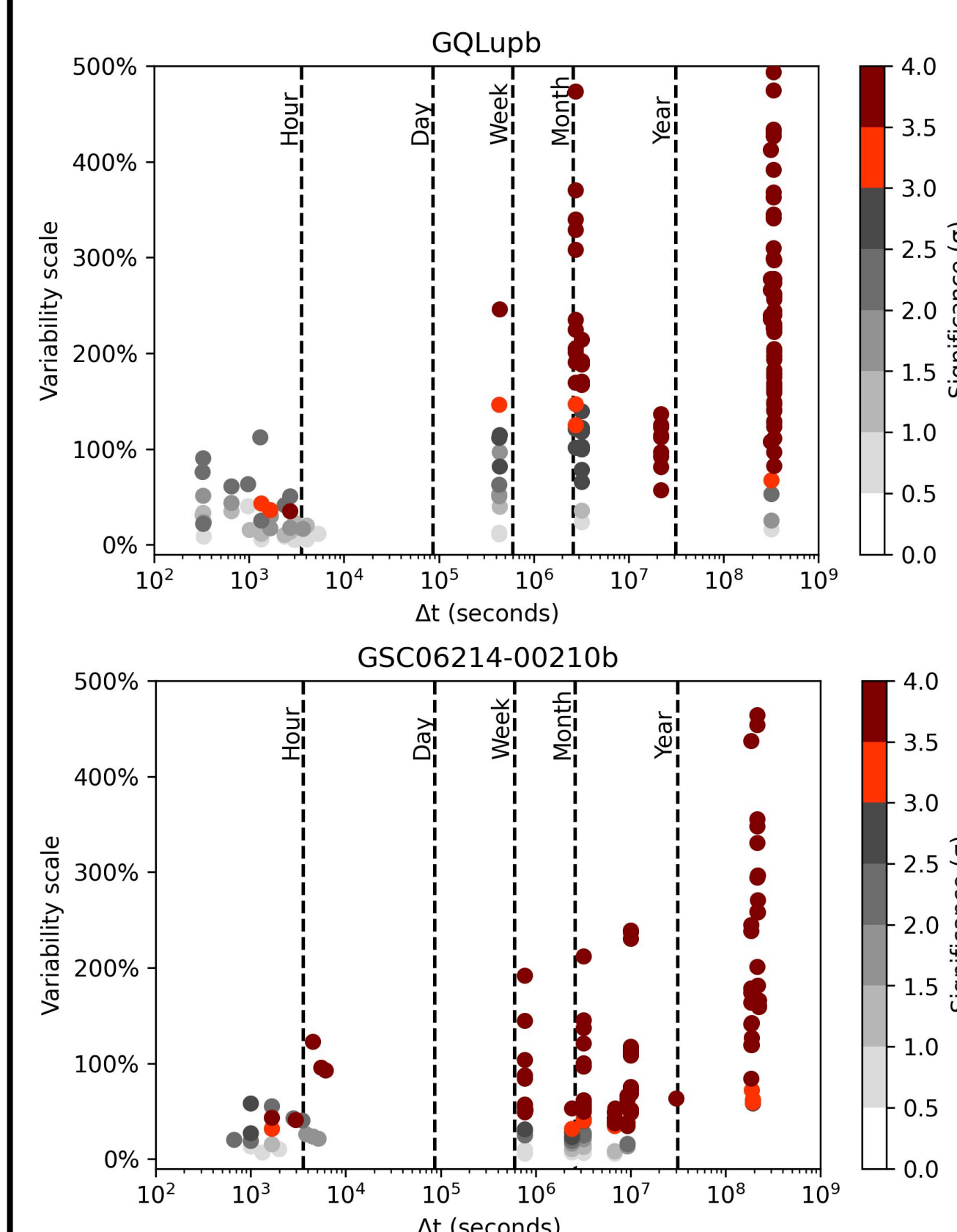
Aoyama et al. 2018



- **Magnetospheric models** succeed at reproducing the **blue-shifted line** of GQ Lup b, but do not reproduce the line width of GSC 06214b
- **Embedded protoplanets models** do not reproduce the **blue-shifted line** of GQ Lup b, but are better at reproducing the line width of GSC 06214b

## 5. Variability: implications for detection of protoplanets

- **Variability** is observed from **hours to years** timescale
- **~50%** line flux variability over **hours** timescales
- **100% and more** at **weeks** and longer timescales



Multi-epoch strategy to avoid missing protoplanets (VLT/MUSE) !

## 6. Conclusions

### I - GQ Lup b and GSC 06214-00210b exhibit CTTS-like behaviours

- Similar line profiles, variability timescales...
- Needs confirmation with **higher spectral resolution** and **monitoring at the rotational period**

### II - Line variability observed at hours to years timescales.

- **Multi-epoch strategy** for robust detection of accreting super-Jupiters

