IR characterization of atmospheres of directly resolved exoplanets, brown dwarfs, and very low-mass stars

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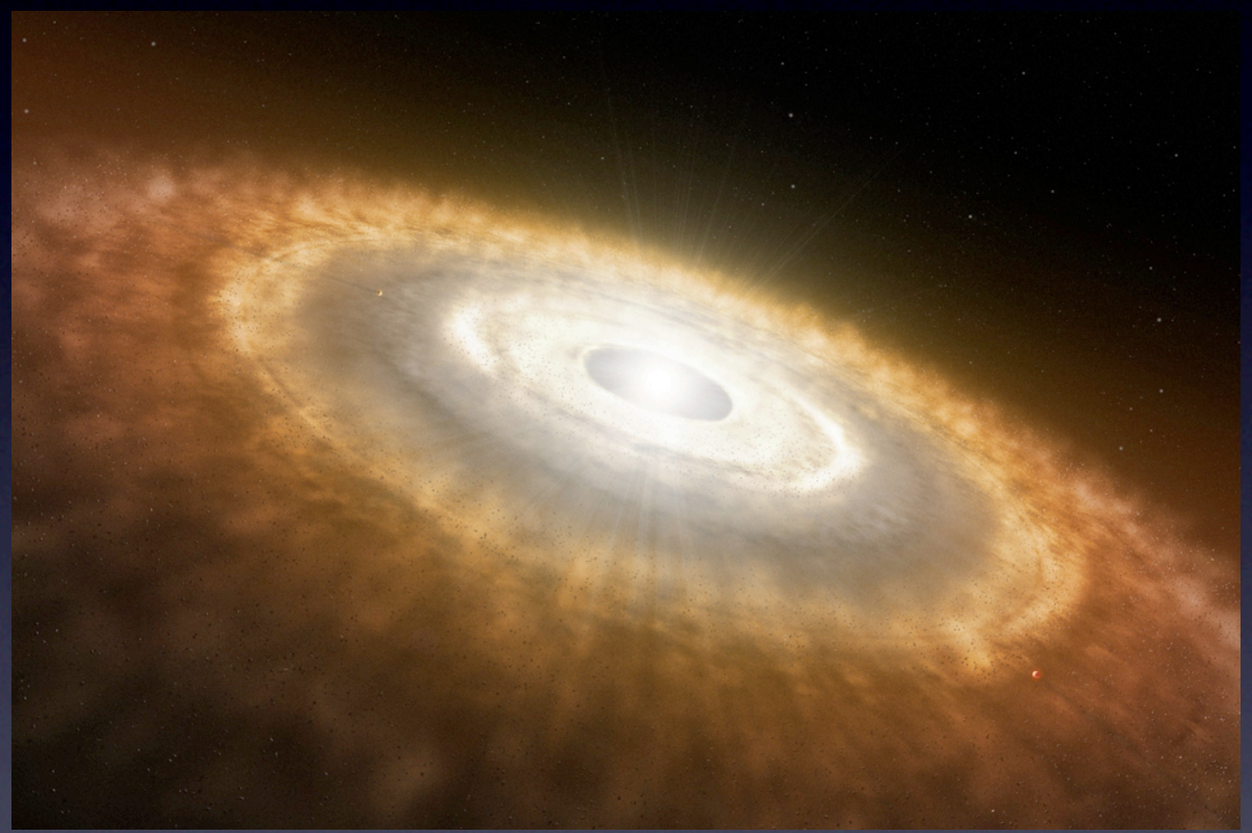
- Models vs. Observations
- SPHERE target list (AstroLux)
- HYADES binary survey
- ...

Photometry and High-Resolution of CHXR 20: Origin of the Variability



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Aurora Sicilia-Aguilar (UAM, Madrid)

Image credit: AstroClock 2010

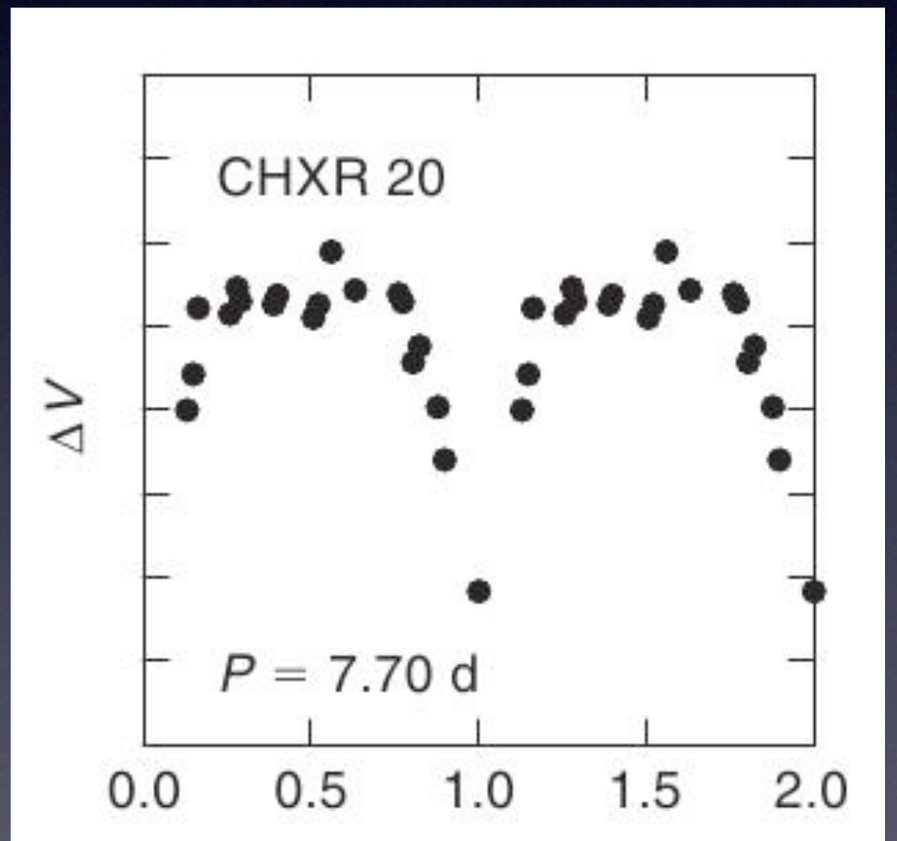
CHXR 20

- Chameleon I dark cloud member (160–170 pc, $A_V < 5$, age ~ 2 Myr)
- K6 spectral type, T = 4205 K, L = 1.1 $L_\odot$ (Luhman, 2004, 2007)
- 0.9 $M_\odot$ (based on models of Siess et al., 2000)
- SED II class (Luhman, 2008) –> ***circumstellar disk***

Photometric Variability of CHXR 20

- V-band variability (Lawson & Crause, 2009): $\Delta V = 1.7^m$, period of 7.7 or 15.4 days
  –> ***binary system?***

- Other bands: $\Delta B = 2.63^m$, $\Delta R = 1.75^m$, $\Delta I = 1.38^m$, $\Delta J = 2.40^m$, $\Delta H = 1.81^m$, $\Delta K_S = 1.83^m$ (DENIS, USNO-B1, 2MASS)



Lawson & Crause, 2009

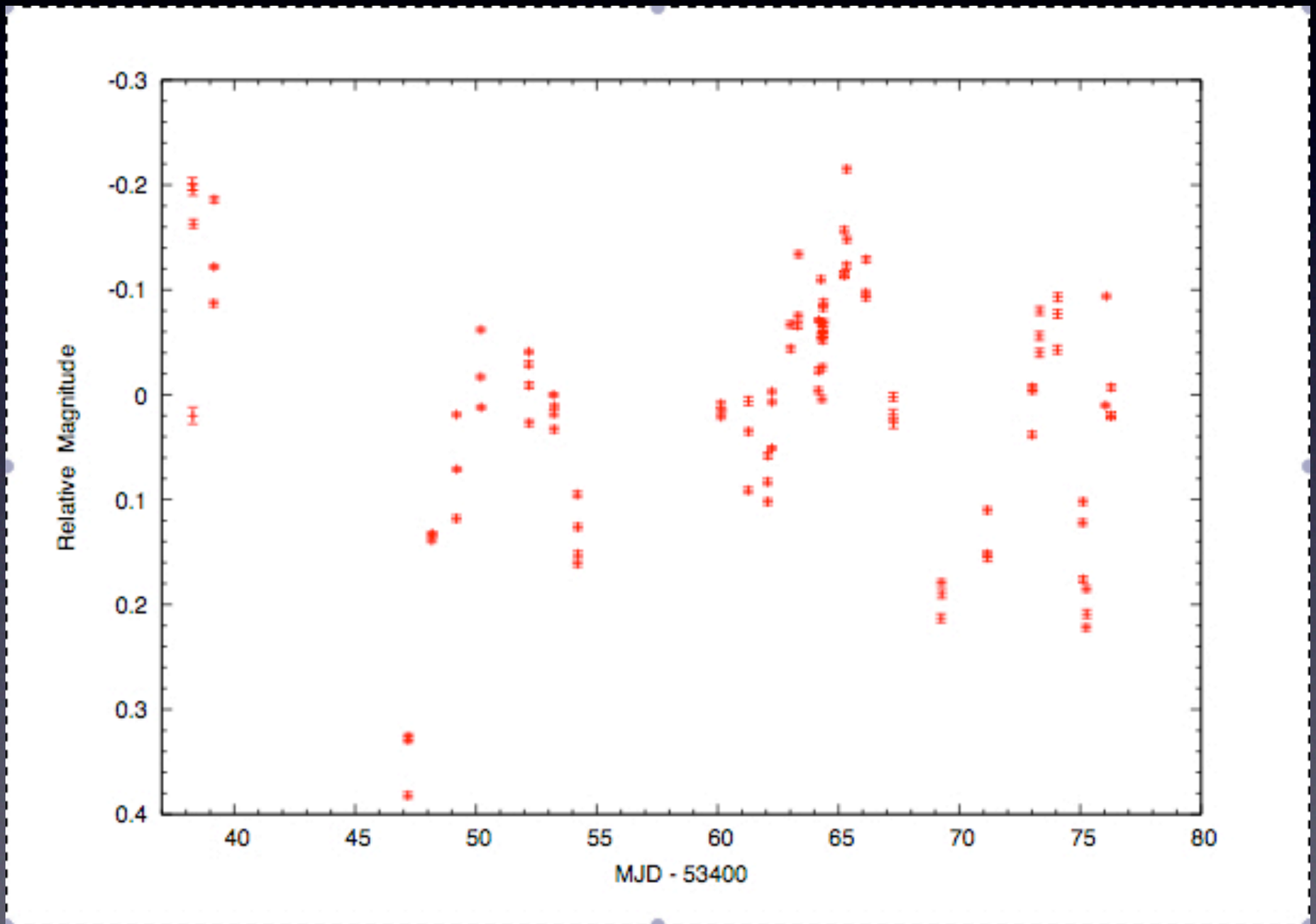
Origins of Variability

- Binary system
- Hot and cool spots
- Variable extinction
- Variable accretion

Study of CHXR 20 in this work

- WFI photometry (39 points, Mar–Apr 2005)
- FEROS spectroscopy (8 points, Jan–Apr 2009)
- Disk modeling (RADMC, Dullemond & Dominik, 2004)
- Analysis of 2MASS photometry

WFI Photometry



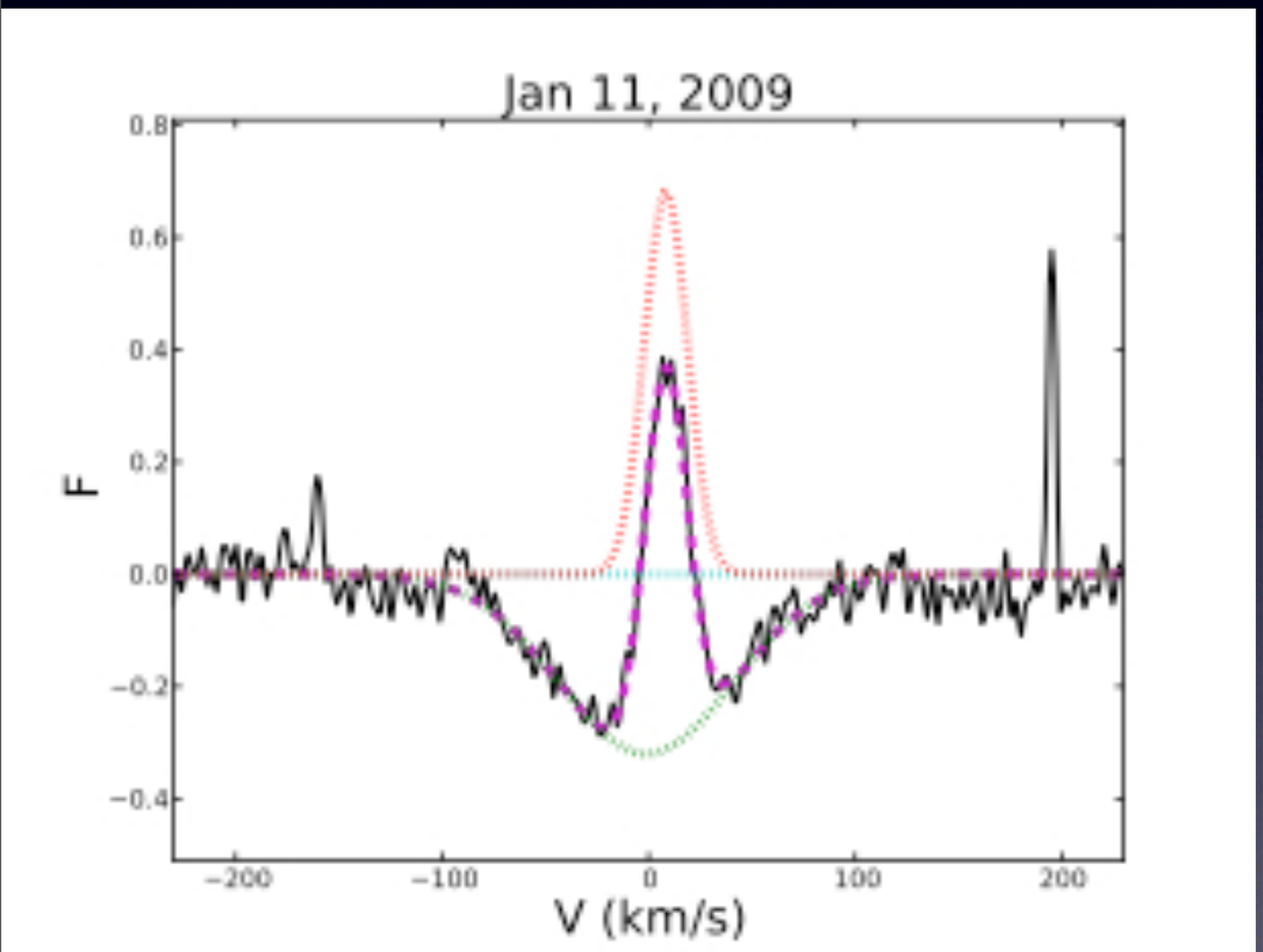
- ESO 845 filter (λ_{cent}=743.845 nm)
- Amplitude ~ 0.6^m
- Two detected periods: **0.87 and 6.96 days**

FEROS Spectroscopy

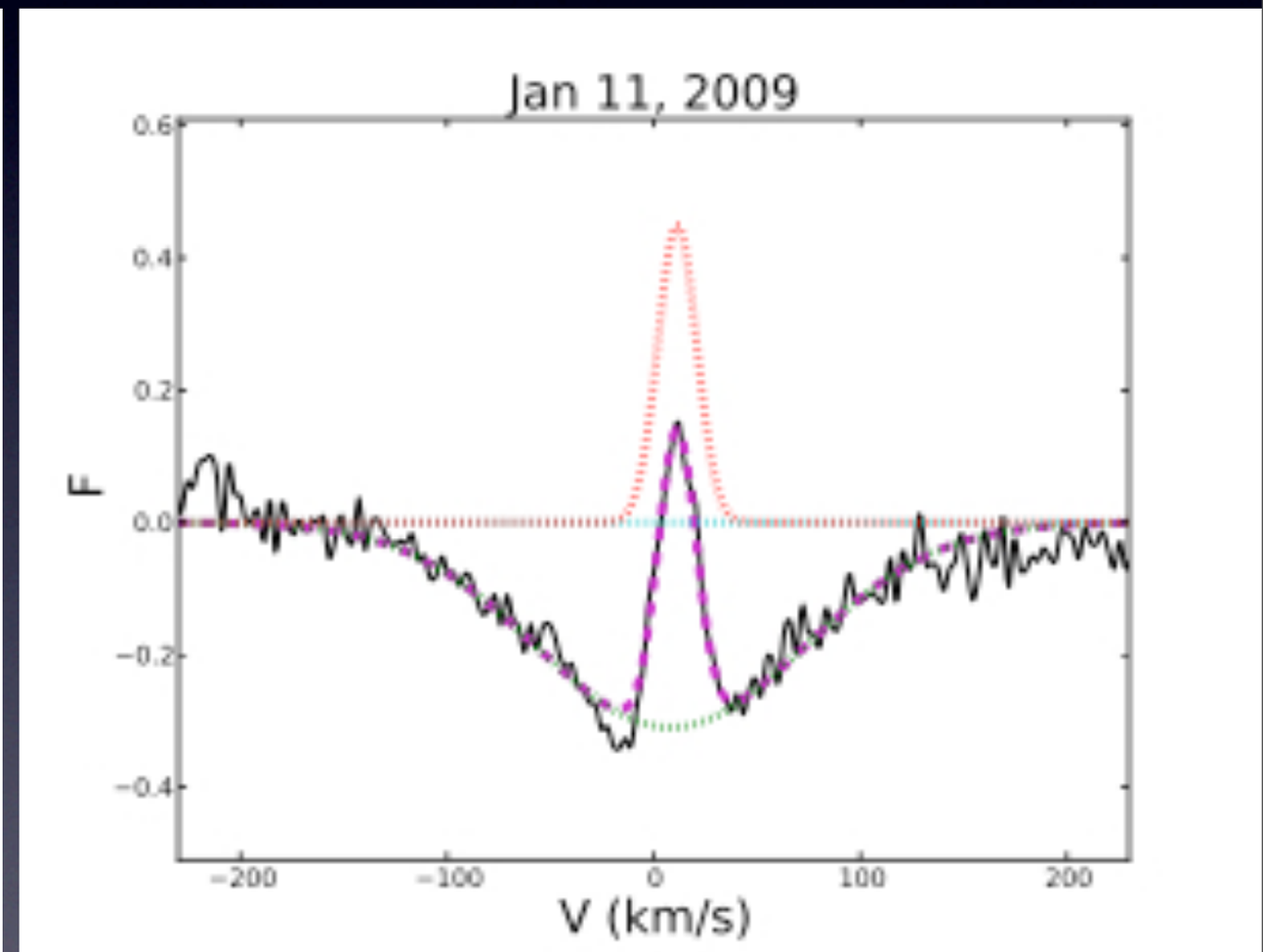
- RV variations: 3.4 km s^{-1} peak-to-peak
  –> ***activity or a very low-mass companion?***
- Line broadening ~ 11 km s^{-1}
- Line shape analysis
  - Ca II IR, absorption with an emission core: ***accretion (?) and chromospheric activity***
  - Hα complex shape: ***winds or moving gas clumps, accretion, and stream to a hypothetical companion?***

Accretion and Chromospheric Activity

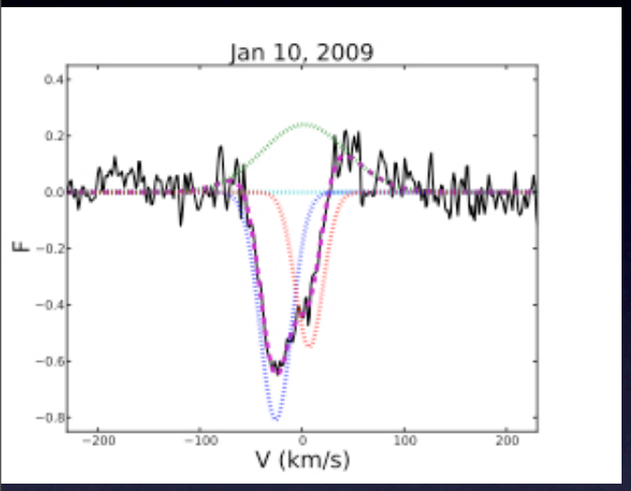
Ca II 8498

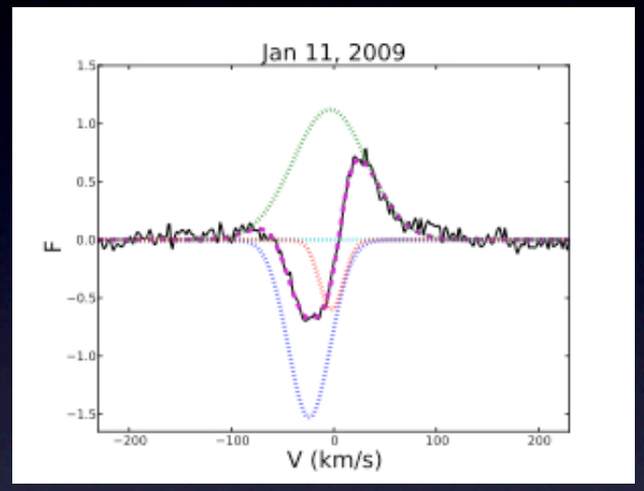


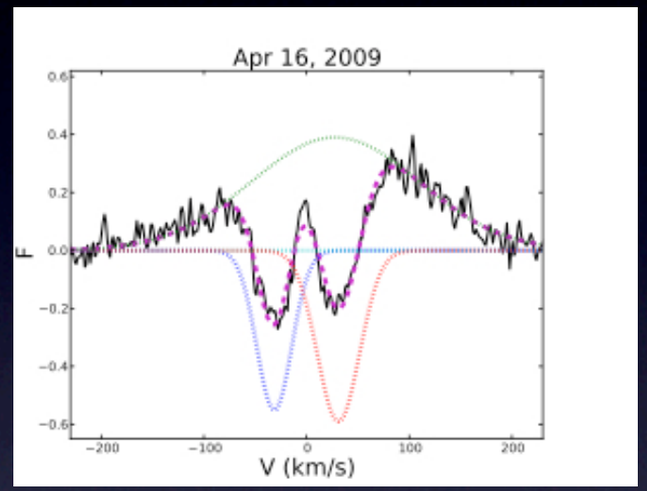
Ca II 8662

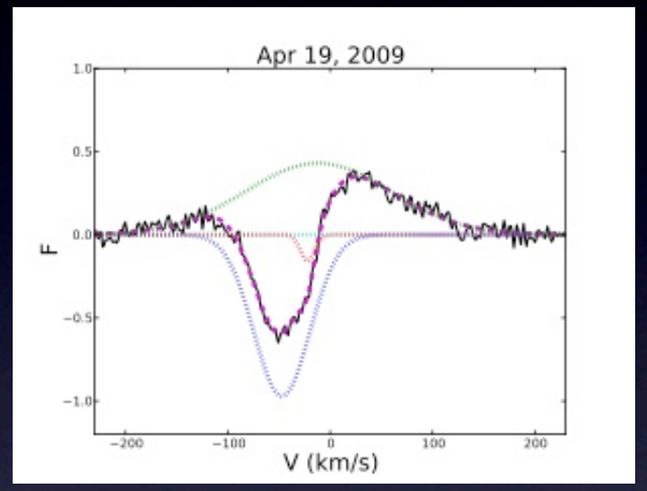


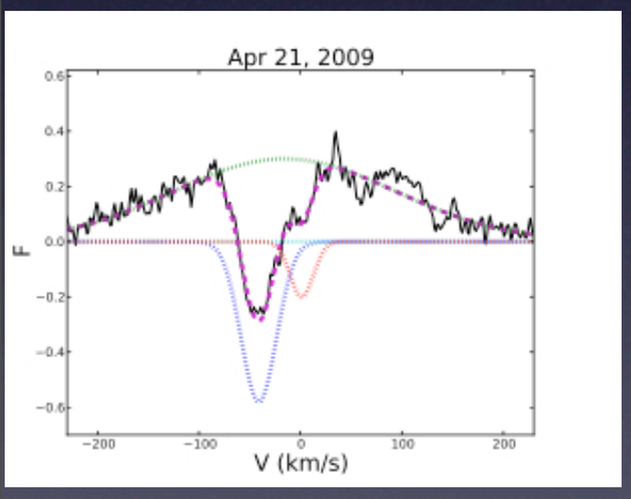
Hα: winds or gas clumps, accretion, stream to a companion (KH 15D case?)

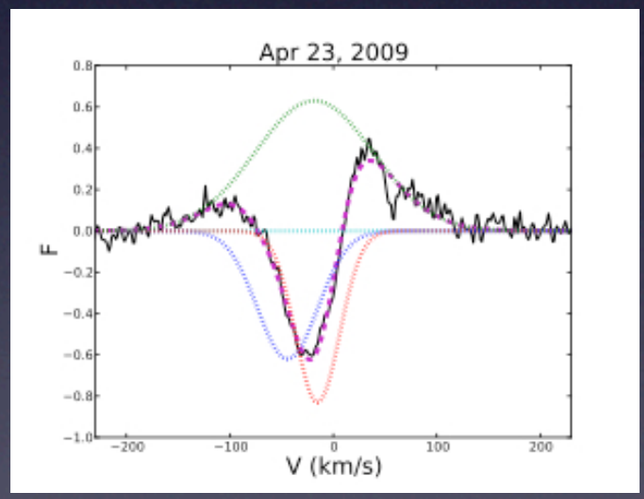


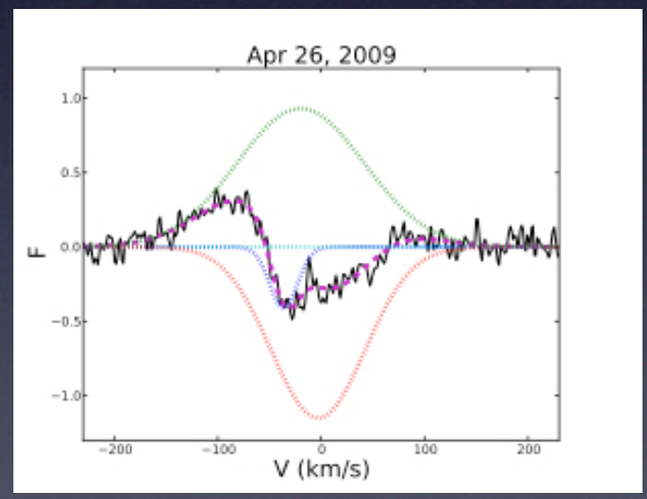


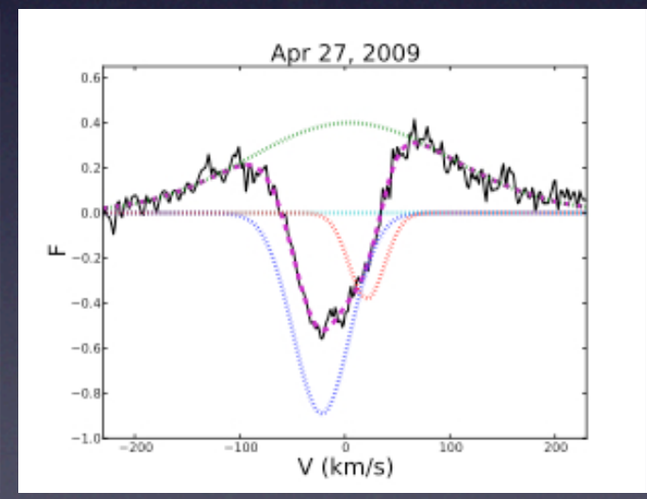






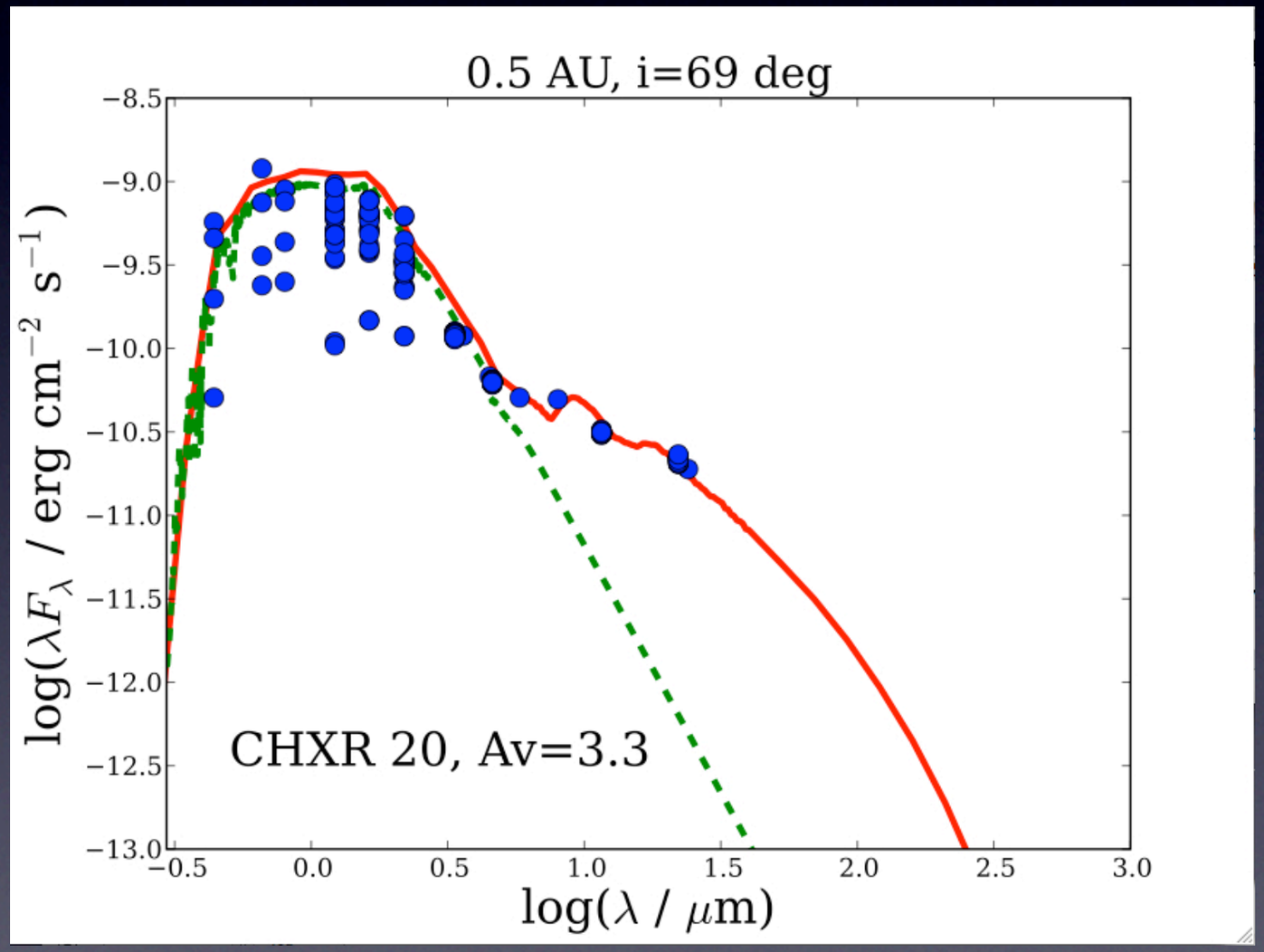






Disk modeling

- RADMC radiative transfere code (Dullemond & Dominik, 2004)
- i = 69°–85°
- Disk-to-star ratio 10^{-5}, 10^{-5}
- Models with ***an inner hole*** in the disk fit the SED better

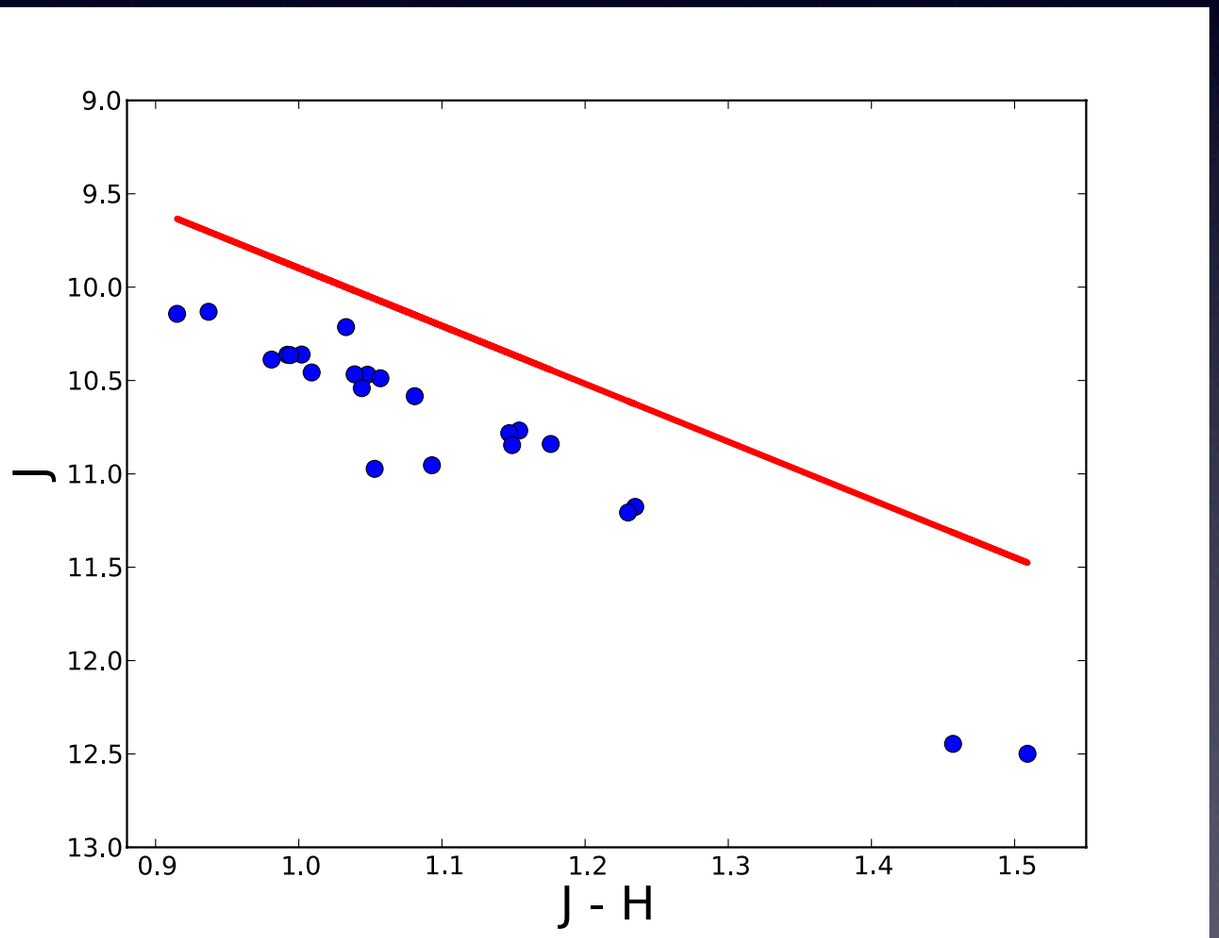


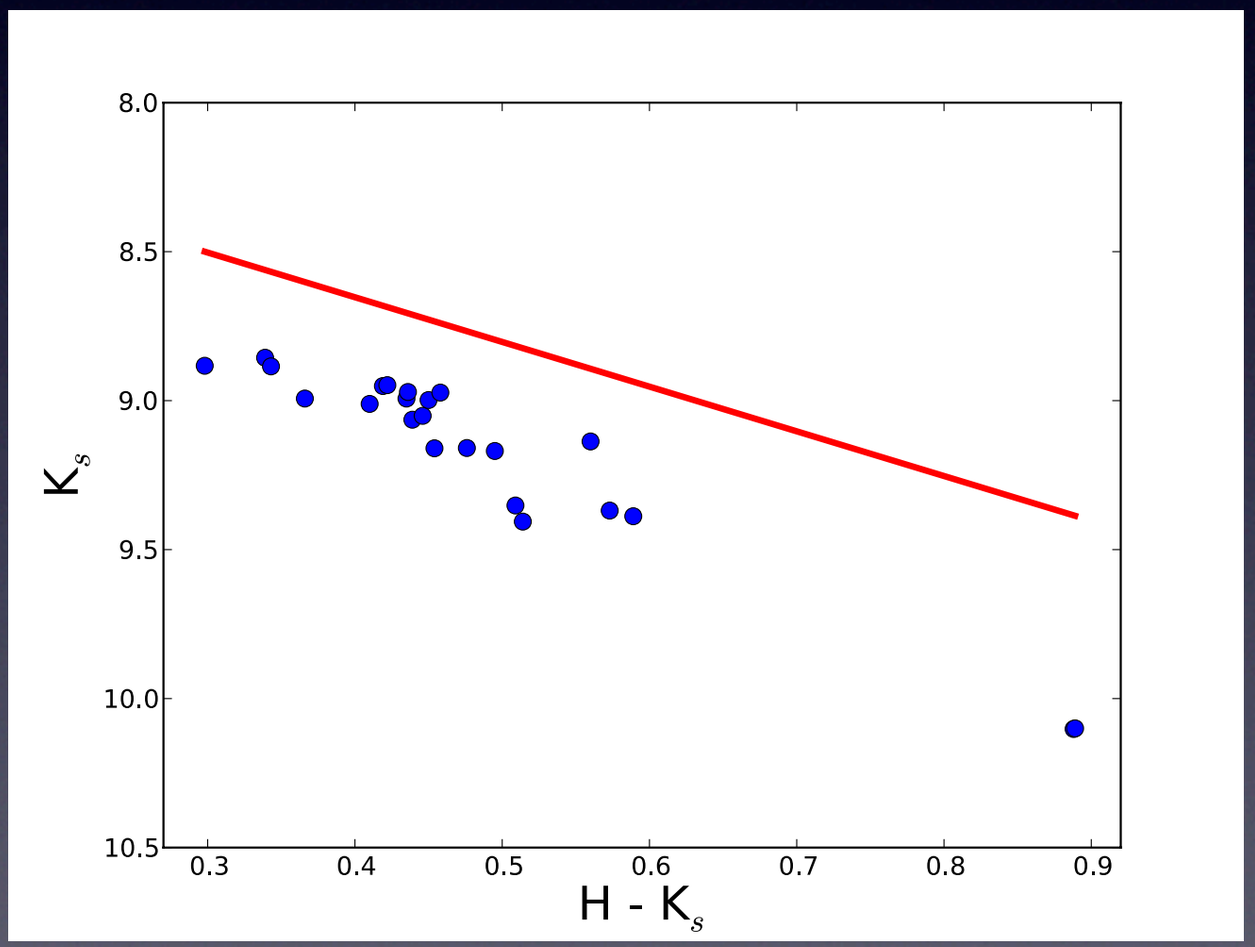
Binary Companion

- RV variations: 3.4 km s^{-1}
- Two detected periods: 0.87 and 6.96 days
- *m* sin*i*: 7.5 and 15 M_J, respectively
  –> **very low-mass companion**
  –> **cannot cause strong photometric variations**
- Semi-major axis: 0.02 and 0.07 AU
- **RV variations** can be also caused by **stellar activity**

Variable Extinction

- A_V =3.3 (A_J=1.08, R_V =5.0, Luhmnan 2004, 2007)
- Redenning law from Cardelli et al., 1989





Surface Spots

- Simple spot model based e.g. on Carpenter et al. (2001)
  $\Delta m(\lambda) = -2.5 \log(1 - f\,[1.0 - B_\lambda(T_{spot})/B_\lambda(T_{eff})])$
  B_λ - the Planck function
  f - fraction of the surface covered by spots
- **Cool spots:** not larger than $\Delta V = 0.8^m$ and $\Delta I = 1.38^m$ in cool stars (Herbst et al., 1994)
- **Hot spots:** can cause variability in the optical (9000–10000K, 20-30%), but not in the near-IR (amplitudes are too large)
- **0.87 day cannot be a rotational period:**
  would need to have $v_r \sin i = 128$ km s^{-1}
  break-up velocity for CHXR 20: 294 km s^{-1}

Variable Accretion

- Line profile shape can point to an **accretion column**
- **He I emission** lines are formed in shock during accretion: **not observed** for CHXR 20
- *W* (Hα): 0.5–3.1 Å –> **not strong accretion**
- **Bluer when fainter** during accretion: **not the case** for CHXR 20
- **Variability** due to **accretion** is **highly unstable**
  Most likely accretion could not cause strong variability

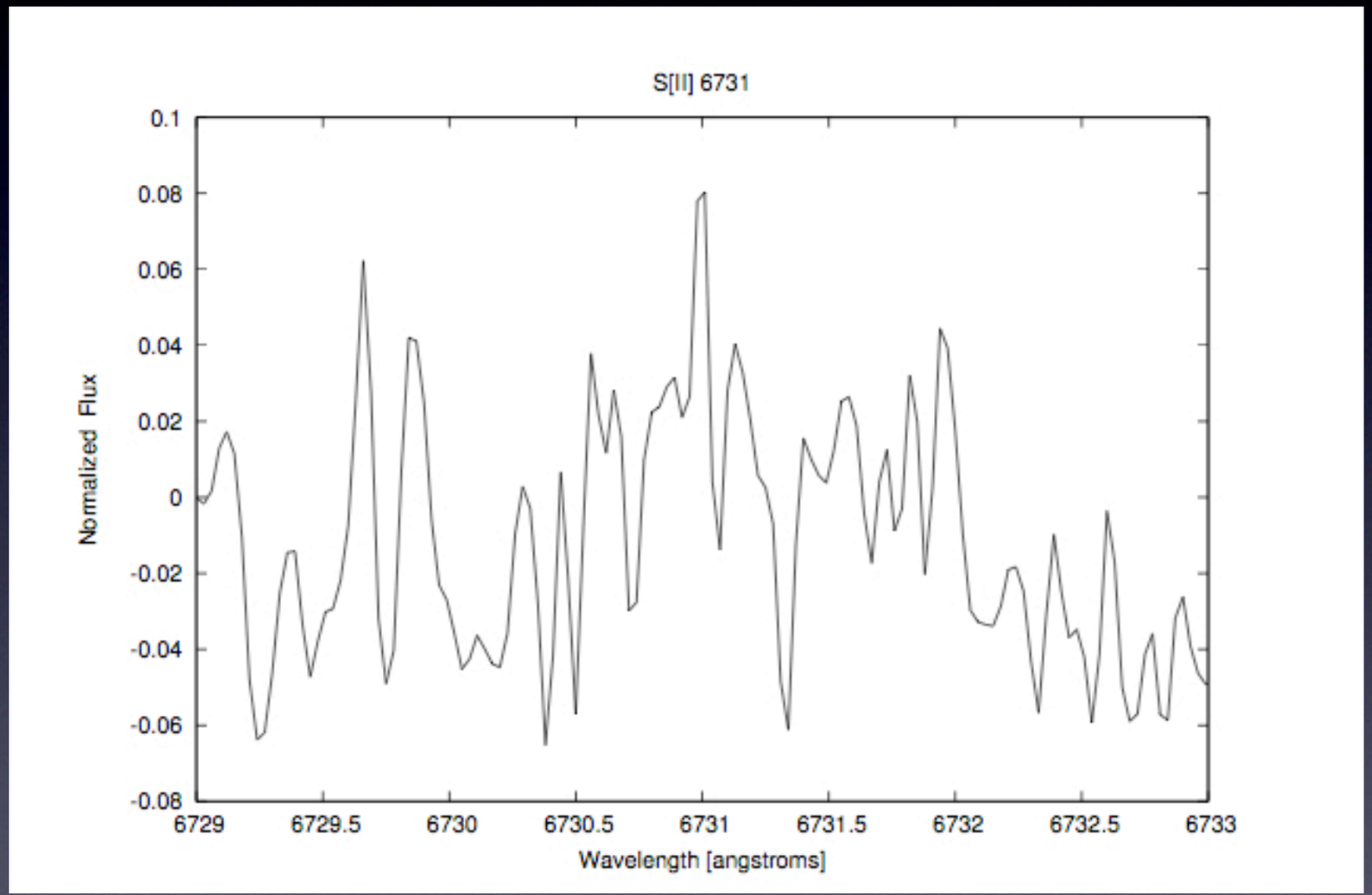
Who is guilty in the variability of CHXR 20?

- Variable extinction can explain the near-IR variability
- Rotational modulations due to hot spots could cause the optical variability
- Variable disk accretion most likely could not contribute to the variability
- The presence of a companion, which could clear-out a gap in the disk, is plausible BUT cannot explain the variability

Future

- None of the scenarios can explain the variability of CHXR 20 alone
- Not clear if the RV variations caused by a companion or activity
- More observations!
  - Spectroscopy: RV + line shape analysis
  - Photometry: correlations in different bands, colors, etc.
    –> more constraints to the model of CHXR 20

Discussion: [S II] line



Discussion: periodograms