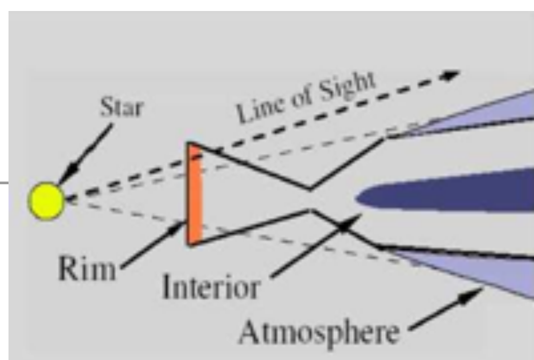
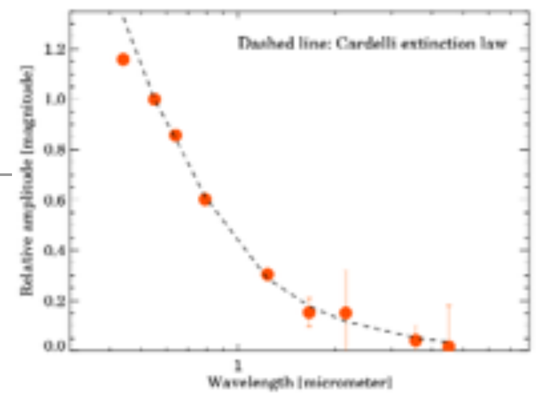
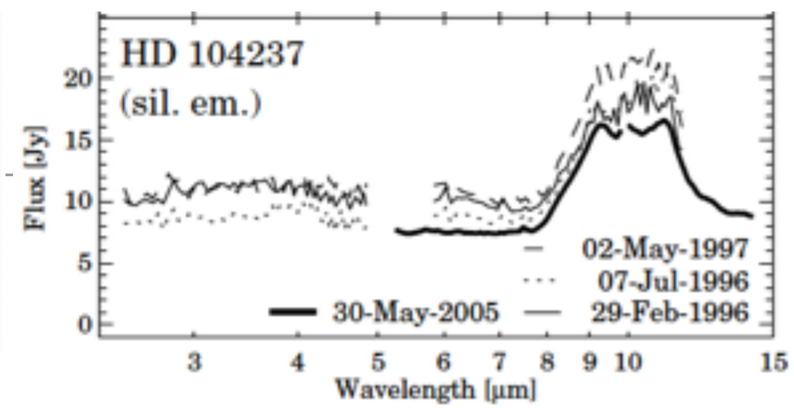
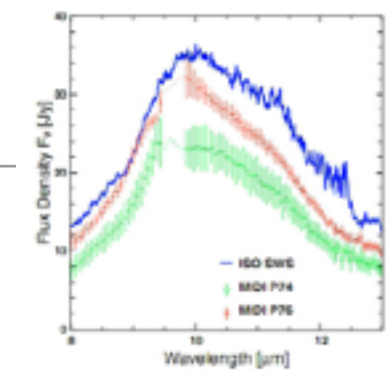
Time-variable phenomena in Herbig Ae/Be stars









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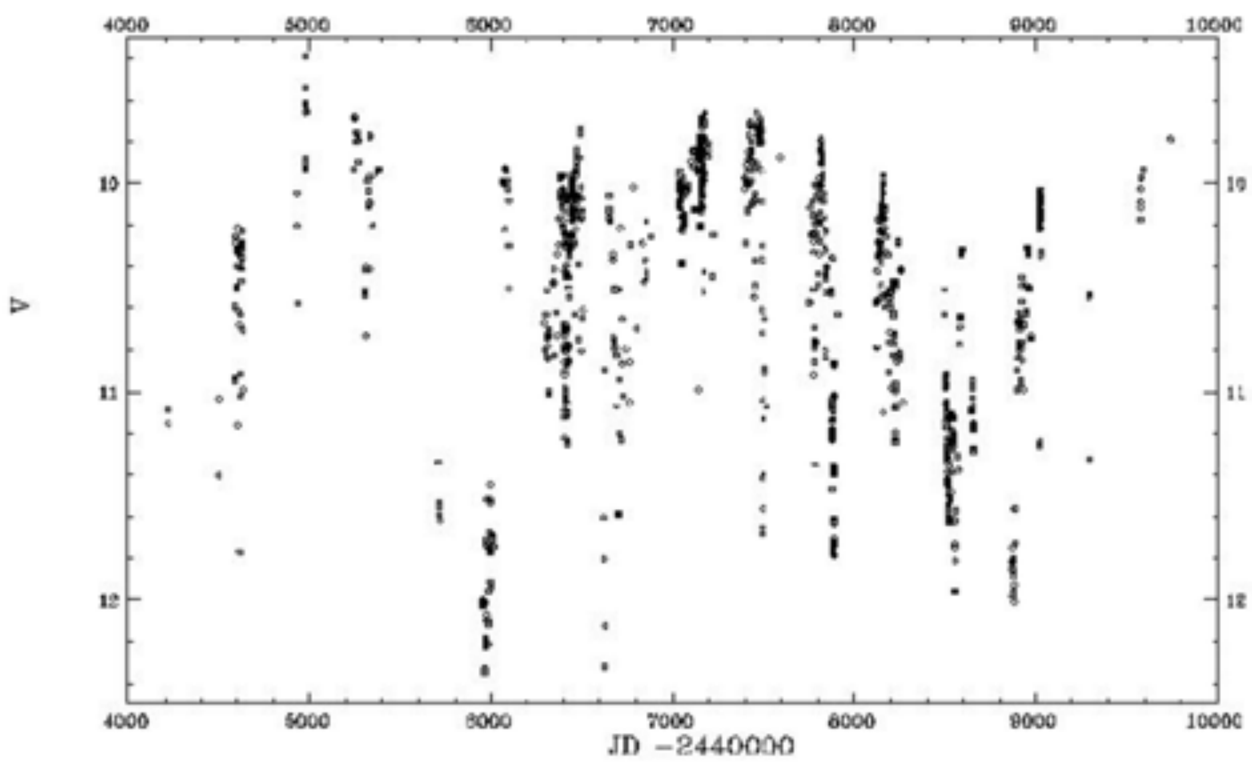
Santiago, 2014 April 7

Variability - and why it is interesting

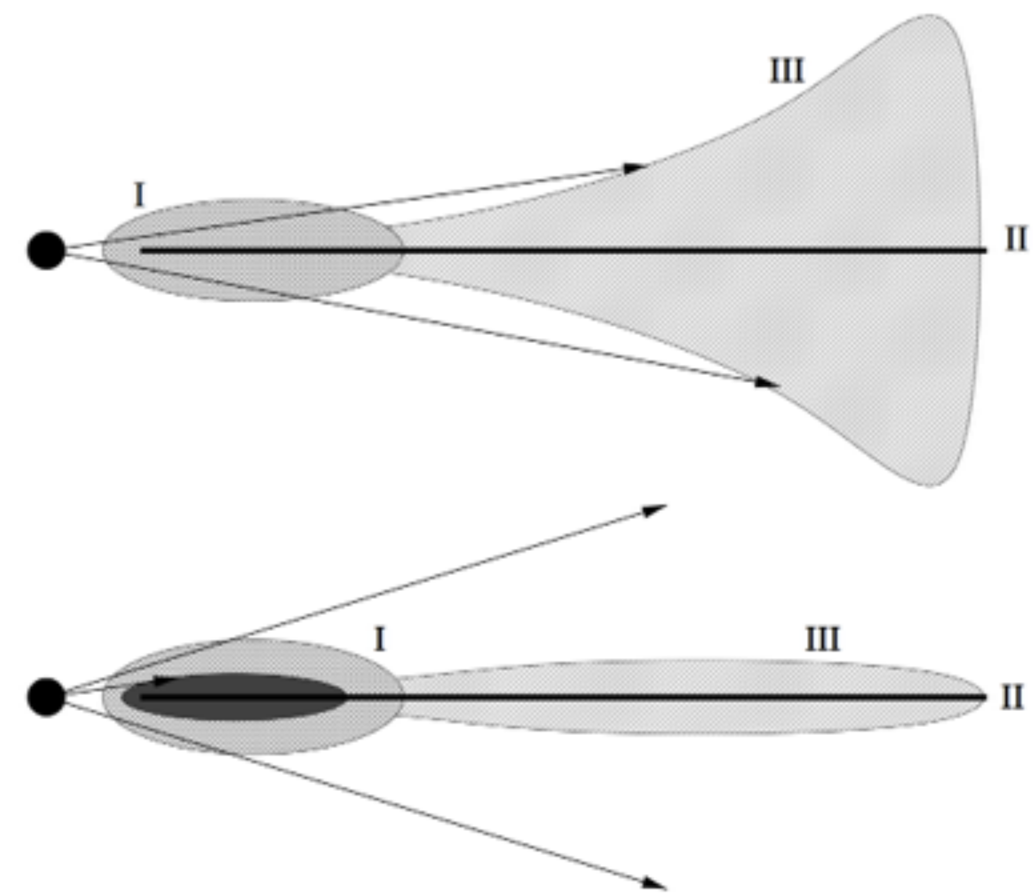
- Herbig Ae/Be stars often exhibit optical variability
- Most studied type is the *UXor phenomenon:* protocometary clouds or protocomets (Grady et al. 2000), hydrodynamic fluctuation in the disk surface (Bertout 2000), puffed-up inner rim (Dullemond et al. 2003)
- For long, fluxes in the thermal infrared (*disk emission*) were assumed to be constant, although IRAS variability flag showed definite changes in several cases (Prusti & Mitskevich 1994)



Light curve of UX Ori

Variability - and why it is interesting

- Both the UXor phenomenon and infrared variability deliver information about the disk structure.
- Two main avenues: (1) try to derive disk parameters from the measurements in a model-independent way: (2) test disk models for temporal perturbations, and compare with observations.
- Possibility to study dynamical phenomena via determining timescales
- How dangerous is it to compile non-contemporoeous SEDs or interferometric observations?



Meeus et al. 2001

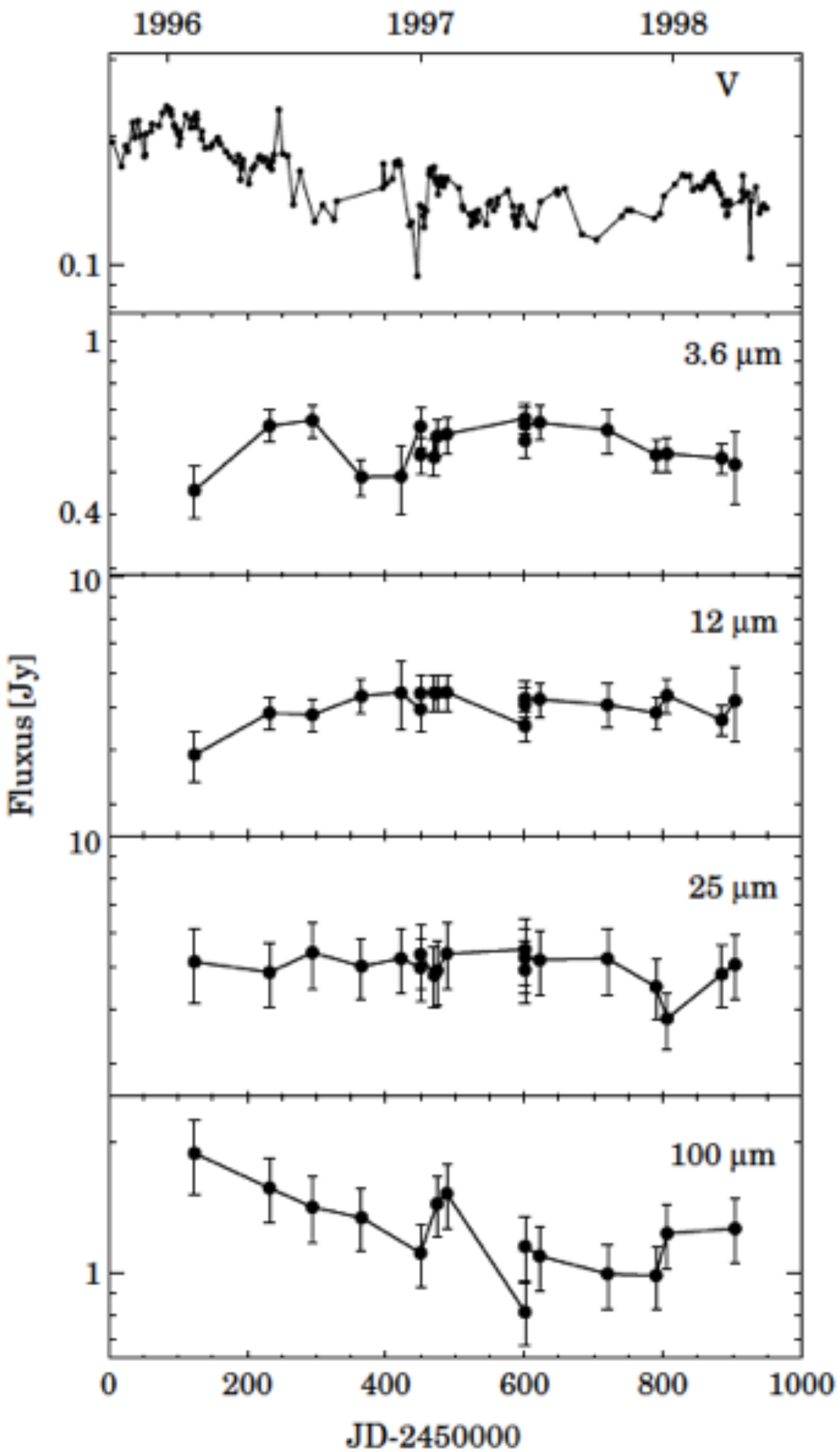
Available variability datasets

- IRAS variability flag (~half a year time difference)
- Infrared Space Observatory: monitoring of 5-6 UXors (e.g. SV Cep, Juhász et al. 2008)
- Ground based photometric or spectroscopic monitoring observations up to 10-20 micrometer (e.g. Sitko et al. 2008, Shenavrin et al. 2012)
- Spitzer Space Telescope (both cryogenic and post-He). Very accurate measurements.
- MIDI interferometric monitoring
- FIR: Herschel Space Observatory

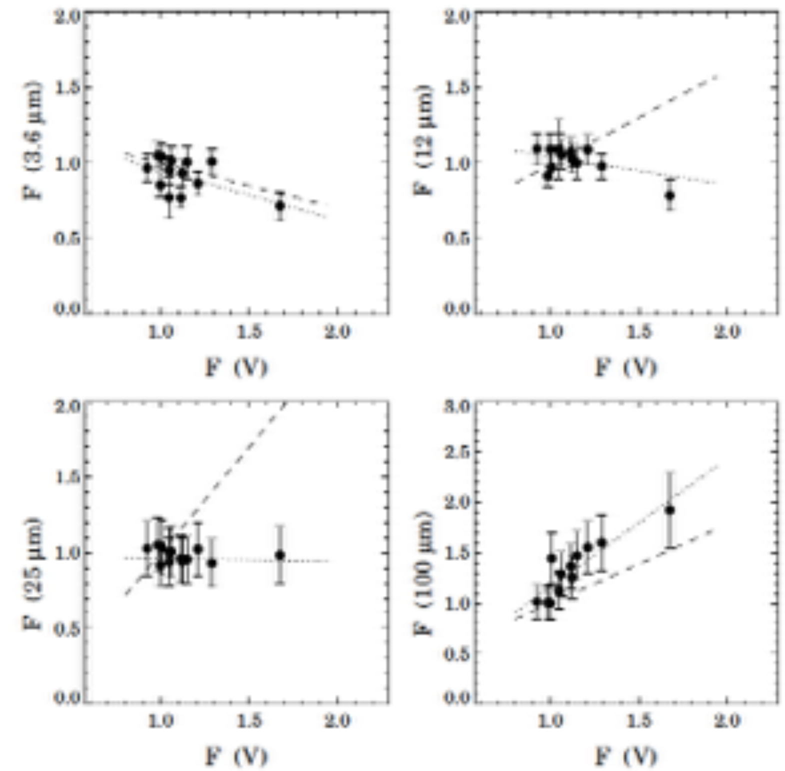

Credit: NASA/IPAC

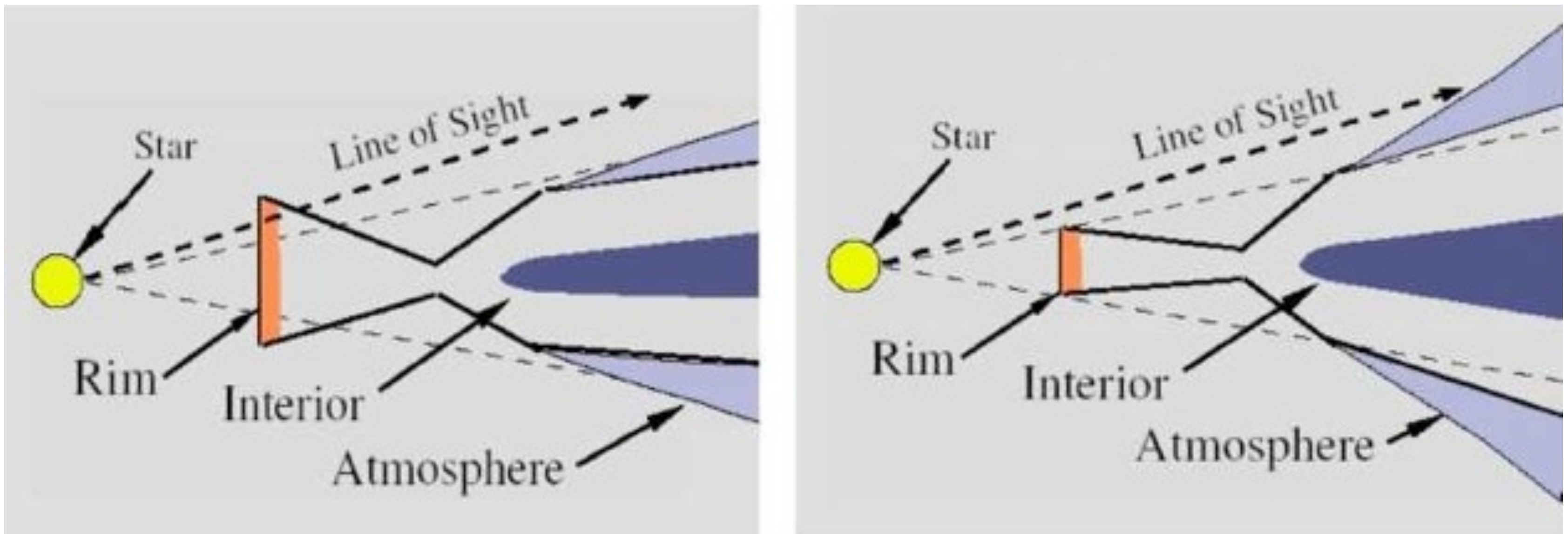
- Problem now: very limited possibilities to observe (especially monitor!) mid- and far-infrared. Use archive data, wait for new instruments…

Monitoring and modeling of SV Cep



- B9-A0-type star
- ISOPHOT data
- Long-term variability
- Optical-MIR anticorr.
- Optical-FIR corr.
- Optical change: Av
- RT modeling: changing inner rim

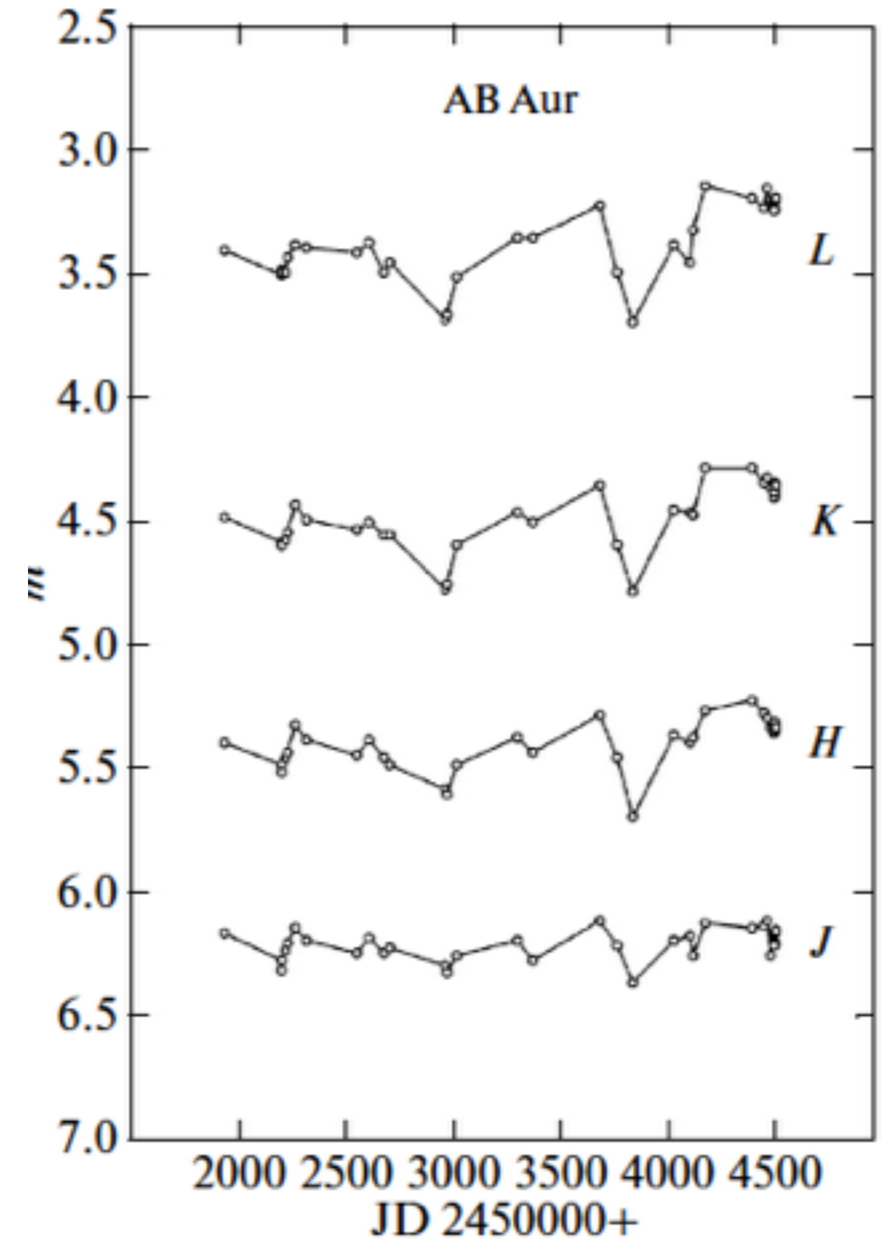


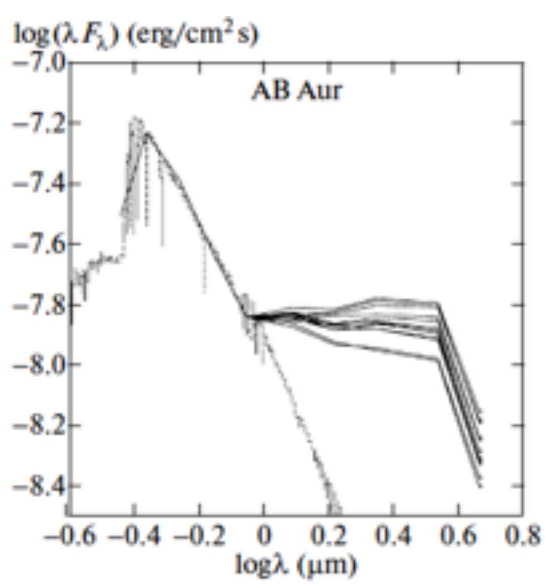


(Juhász, Prusti, Ábrahám, Dullemond 2008)

Disk variability with no luminosity change

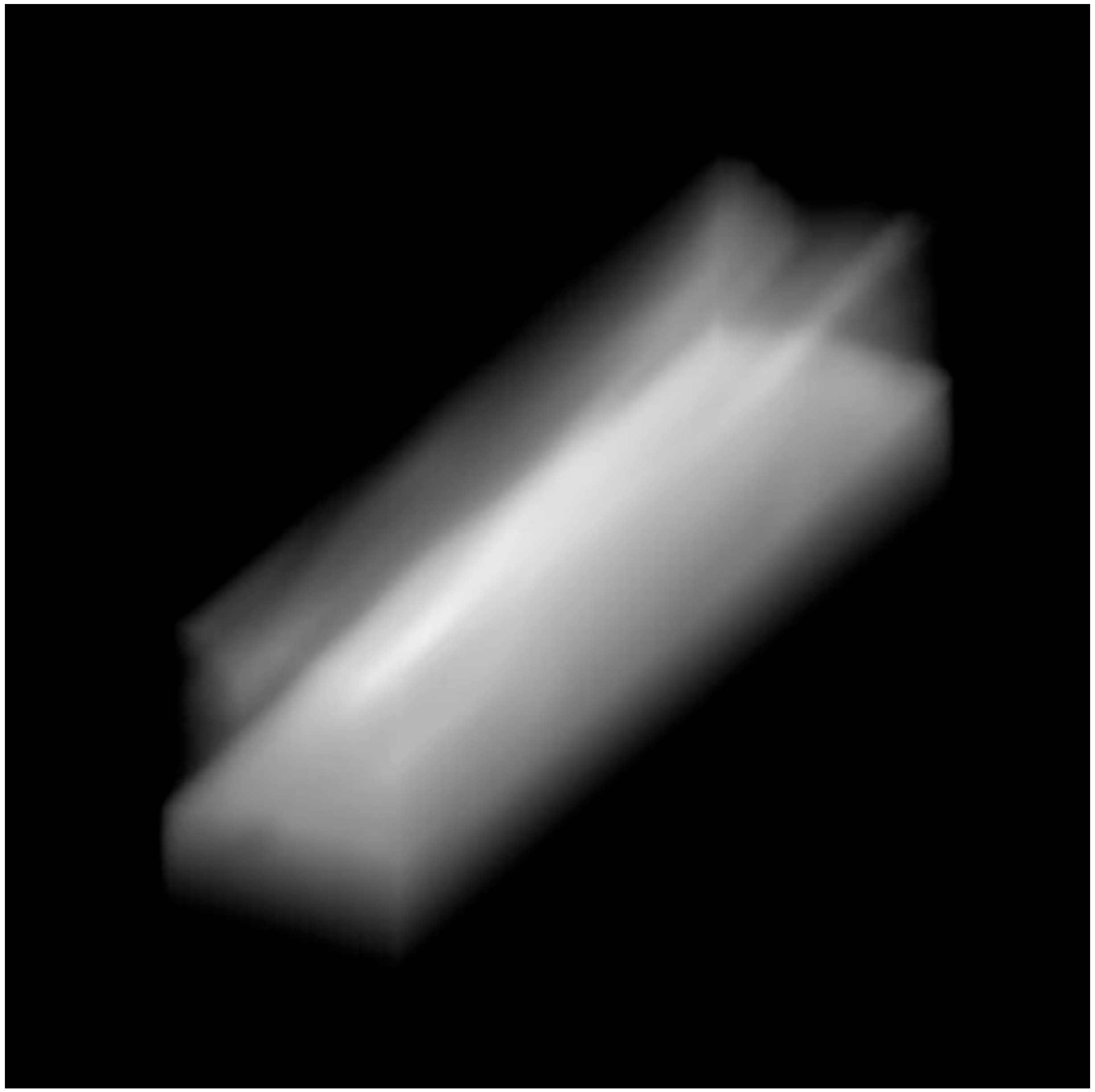
- SV Cep indicated that infrared variability can occur even if the luminosity of the star is constant!
- Prediction: there might be many other Herbig stars, stars which are constant in the optical but variable in the infrared. AB Aur!
- It is the disk structure which changes, and we are not sure about the physical mechanisms. Inner disk instability? Planets?





Shenavrin et al. 2012

Observable disk changes



Turbulent motions lift up dust clouds in the disk atmosphere (Turner et al. 2010)

In a simple view, Herbig disks can:

- react on changing stellar illumination, e.g due to varying accretion - tomographic techniques?
- re-arrange their structure
- orbiting parts of the disk eclipse the central region (UXors)

In reality, these effects probably work in parallel.

Our programs on infrared variability

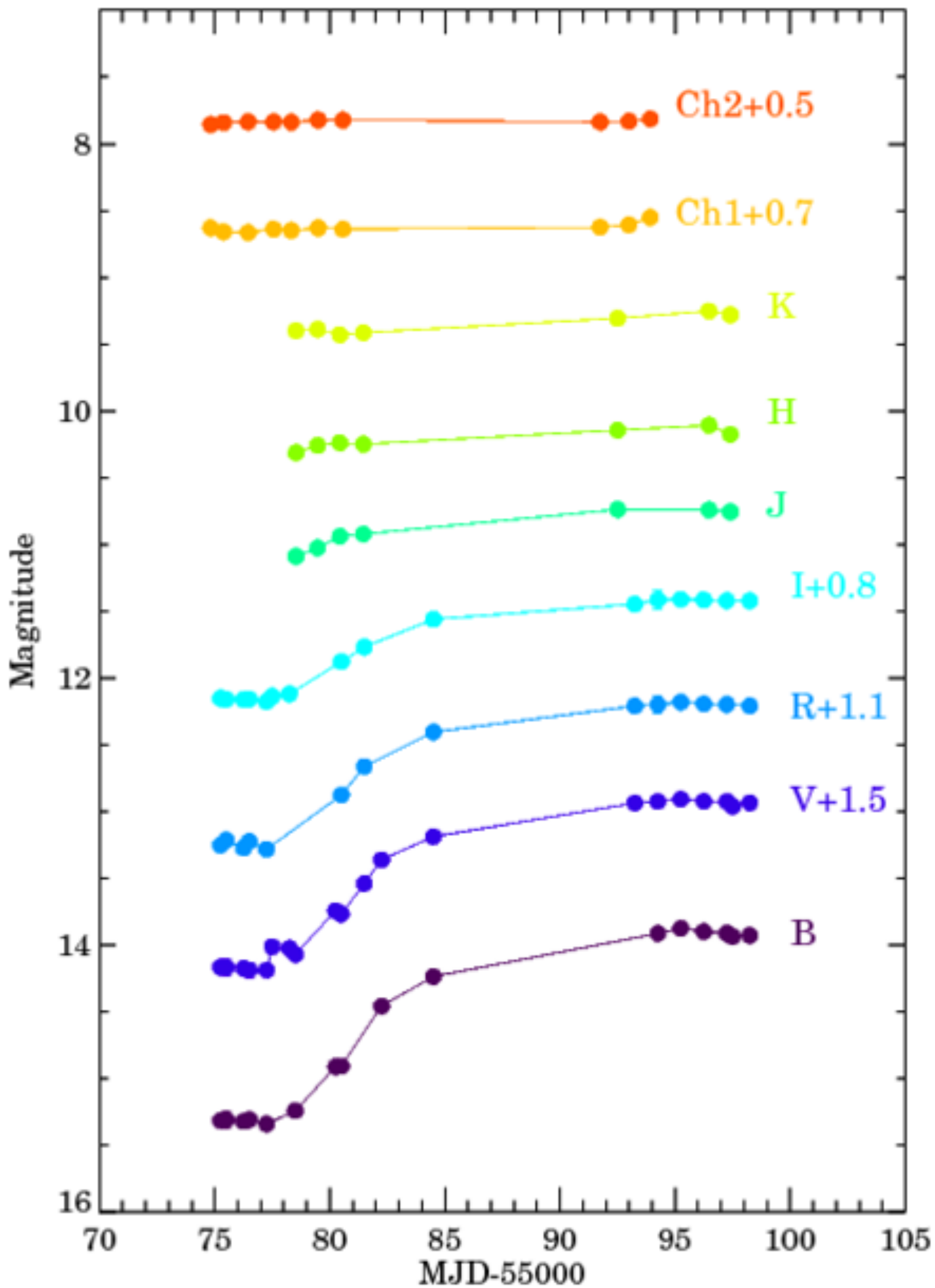
Konkolyvar: a Spitzer warm-phase GO-6 program (in prep.)

- UXor sample: VX Cas, V517 Cyg, SV Cep, BM And, VV Ser, WW Vul, UX Ori, BF Ori, RR Tau
- Spitzer IRAC 3.6 & 4.5 micrometer data, simultaneous ground-based BVRIJHK observations
- 14 days monitoring, daily cadence
- search for variability on daily/weekly timescale

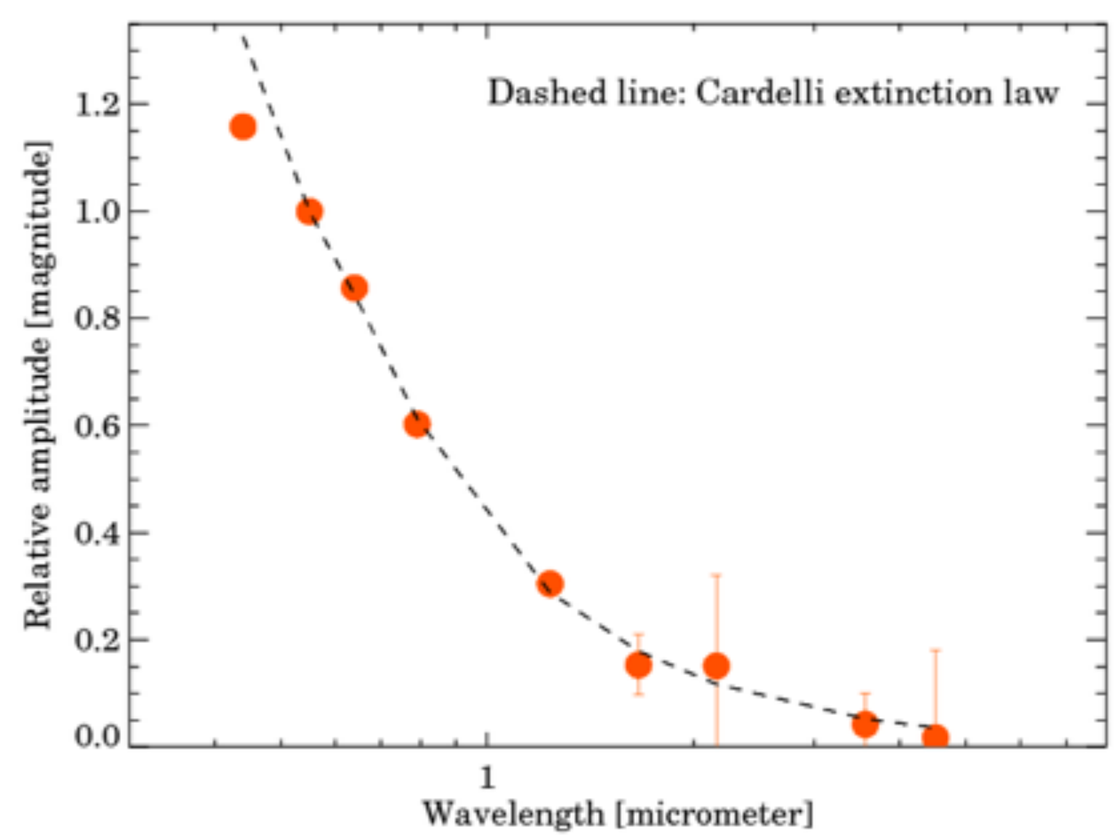
Mid-infrared spectral variability atlas (Kóspál, Ábrahám et al. 2012)

- search for variability on annual/decadal timescales
- comparison of 5.8-11.7 micrometer ISOPHOT-S low resolution spectra with 5.2-14.5 micrometer Spitzer IRS low resolution measurements
- 33 intermediate-mass stars, in 18 cases we could study variability

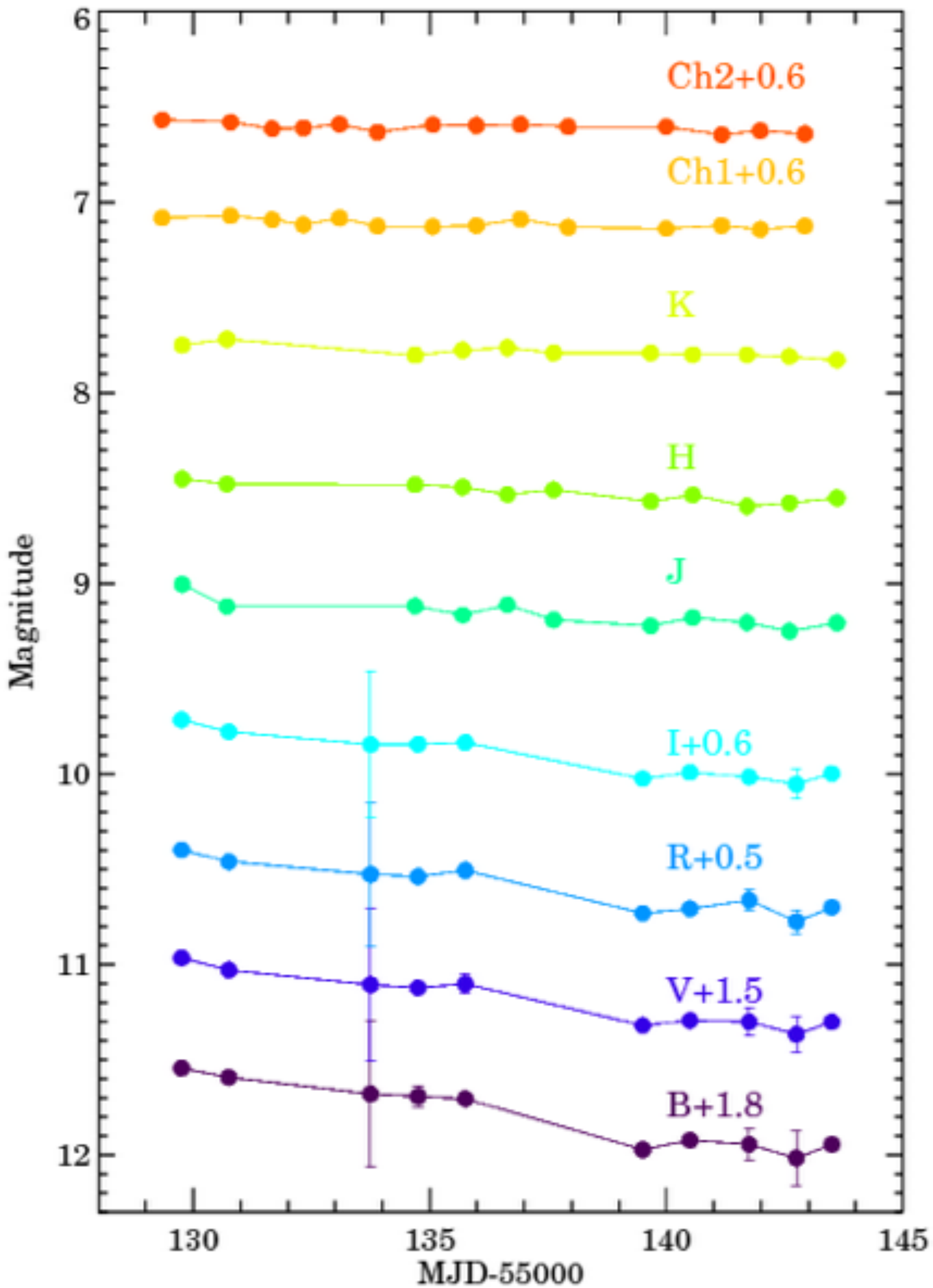
Konkolyvar: V517 Cyg - a UXor eclipse?



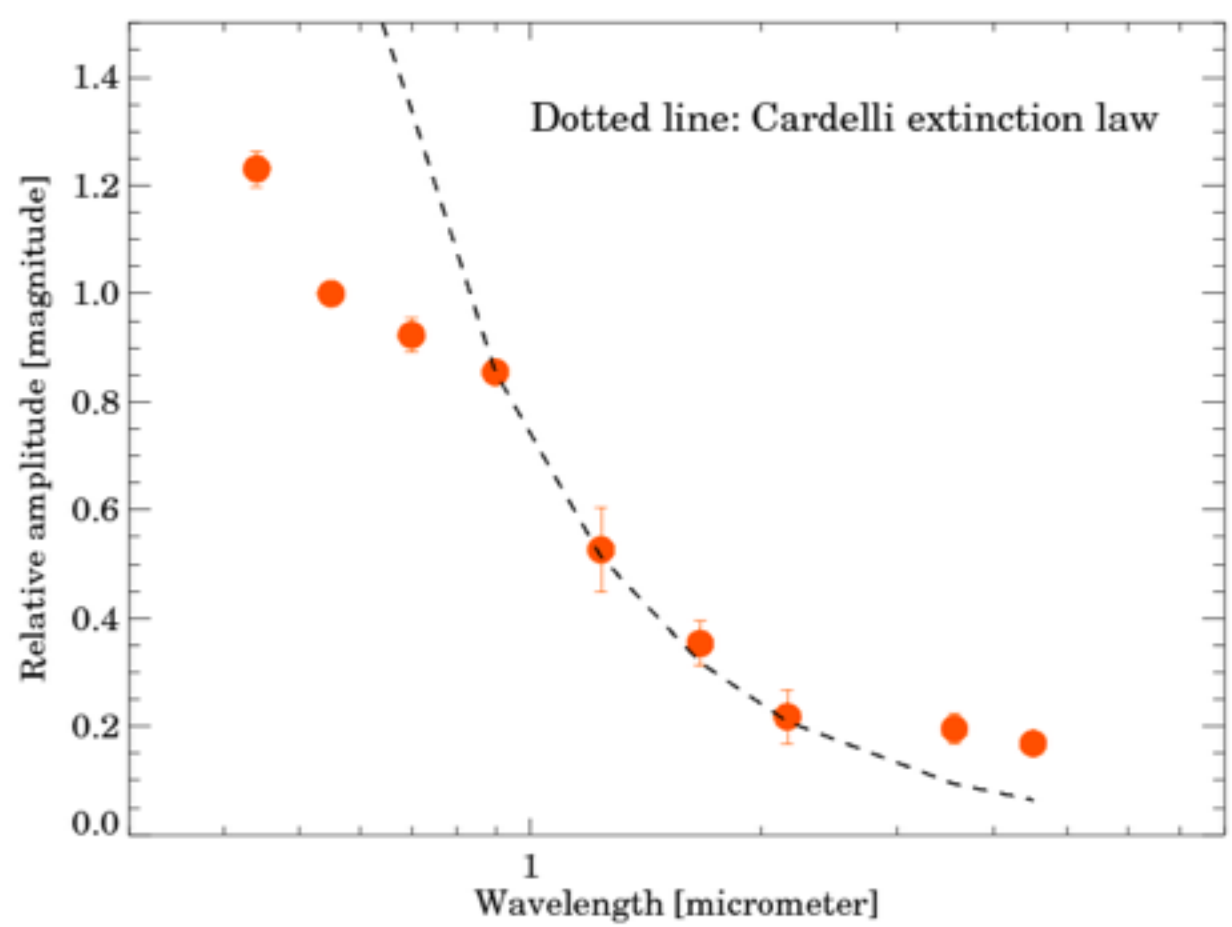
- Luckily, we measured a short brightening period - an UXor dip?
- Wavelength-dependence: follows the extinction law
- Confirmation that UXor-theory continues working also in the infrared
- What fraction of the inner disk is covered? Size of the dust cloud?



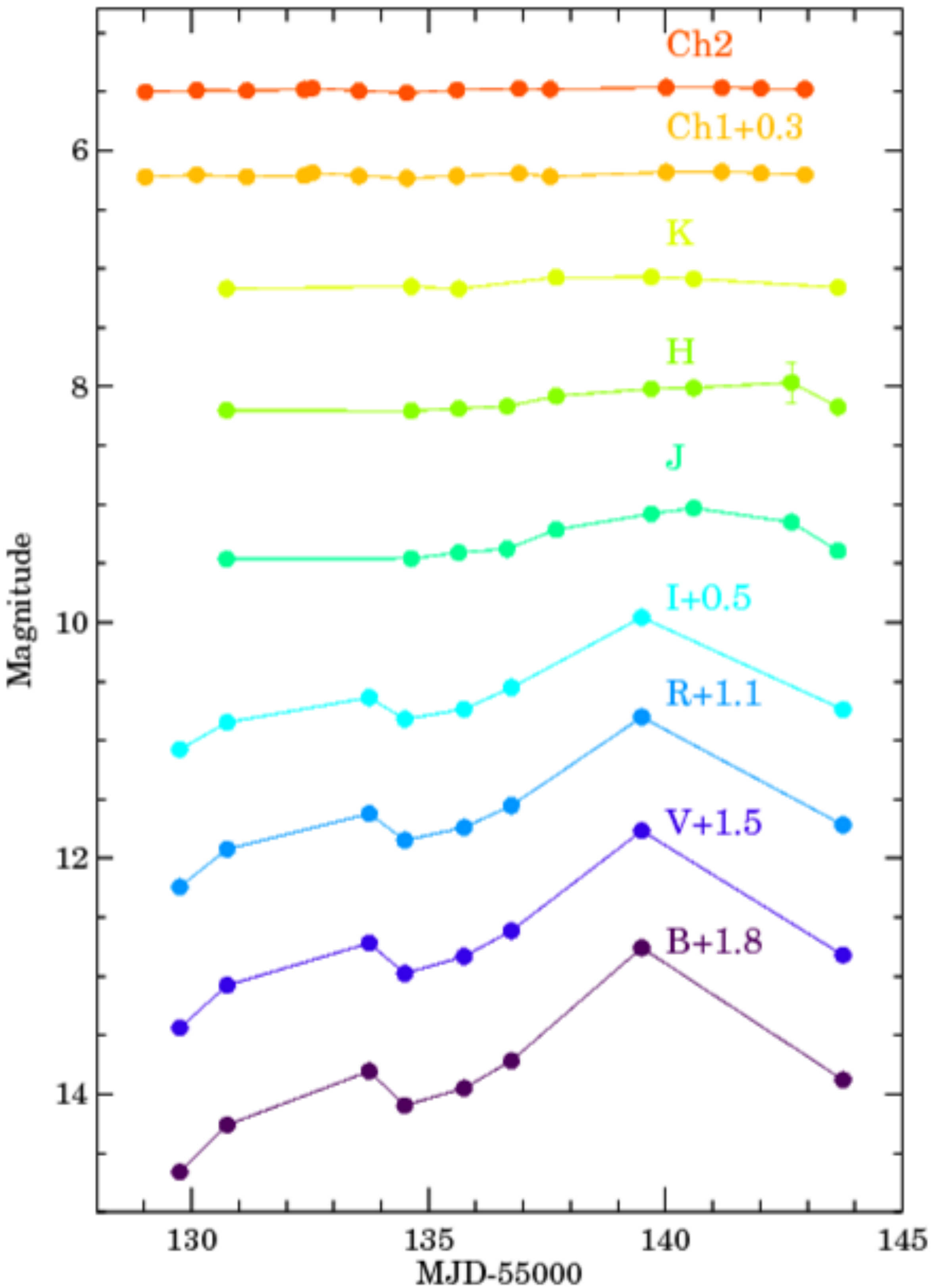
Monotonic fading of BF Ori



- Changes on weekly timescale
- Correlation among the light curves
- Precision measurements
- Deviations from extinction curve



Brightness fluctuations of RR Tau



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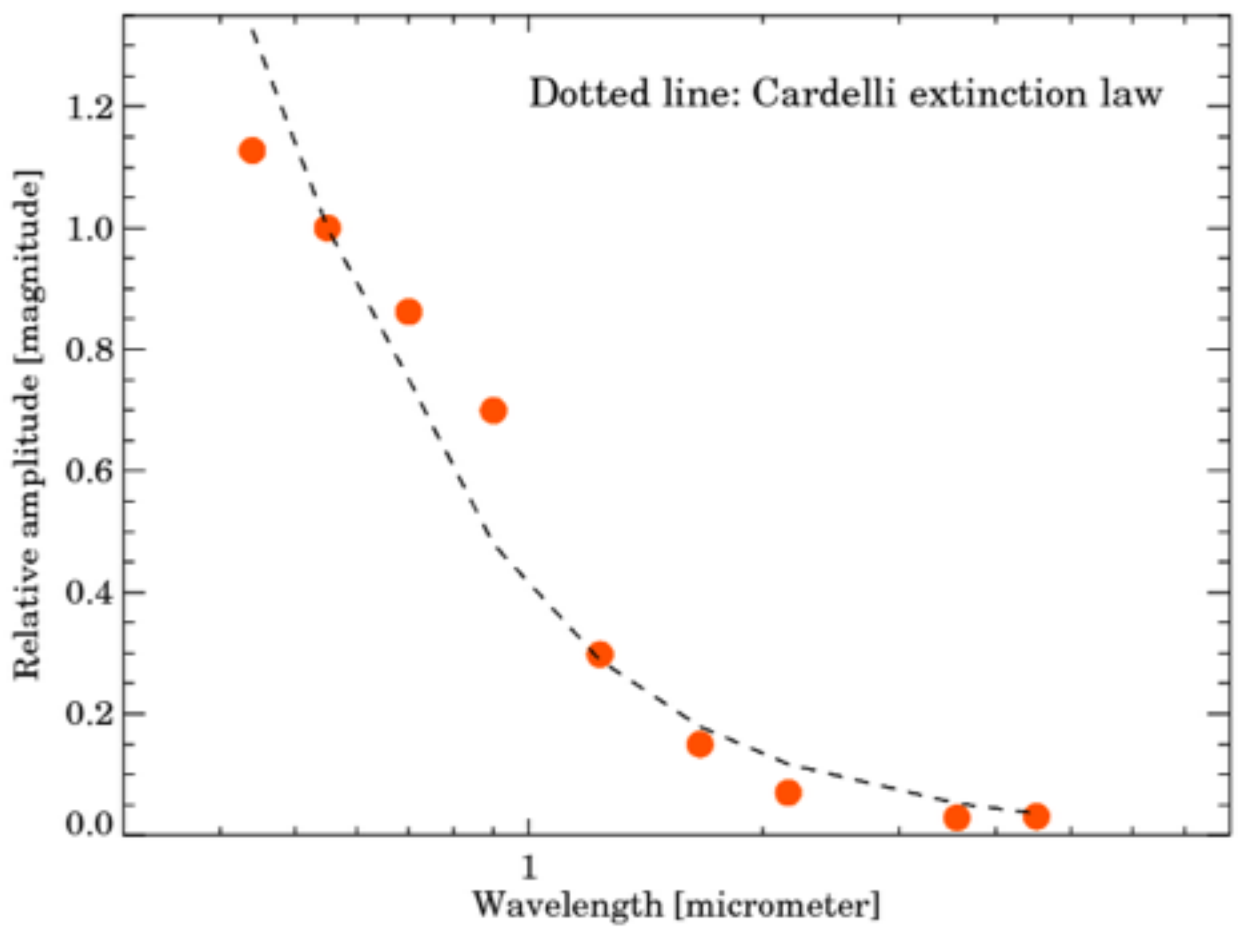
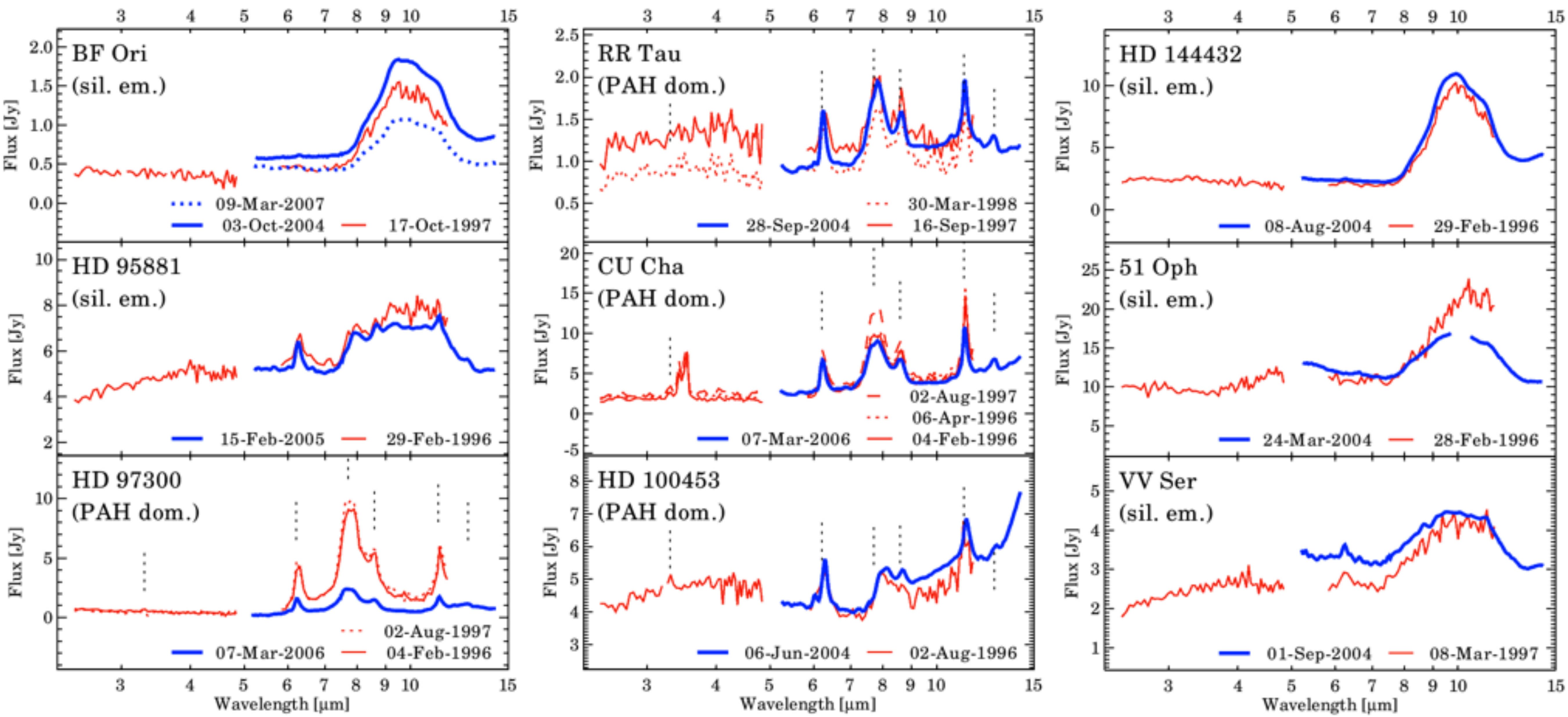


Mid-infrared spectral variability atlas



Kóspál et al. 2012

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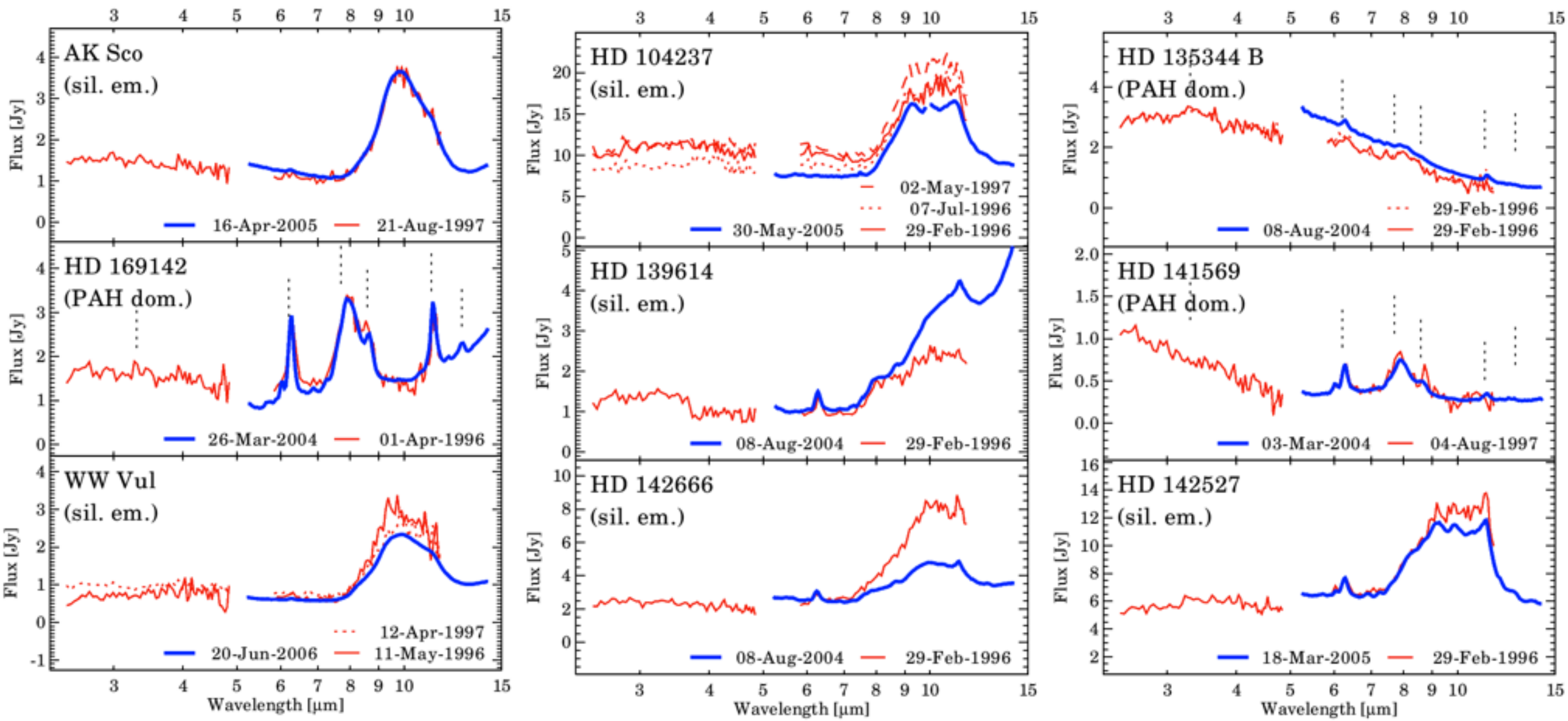

Kóspál et al. 2012

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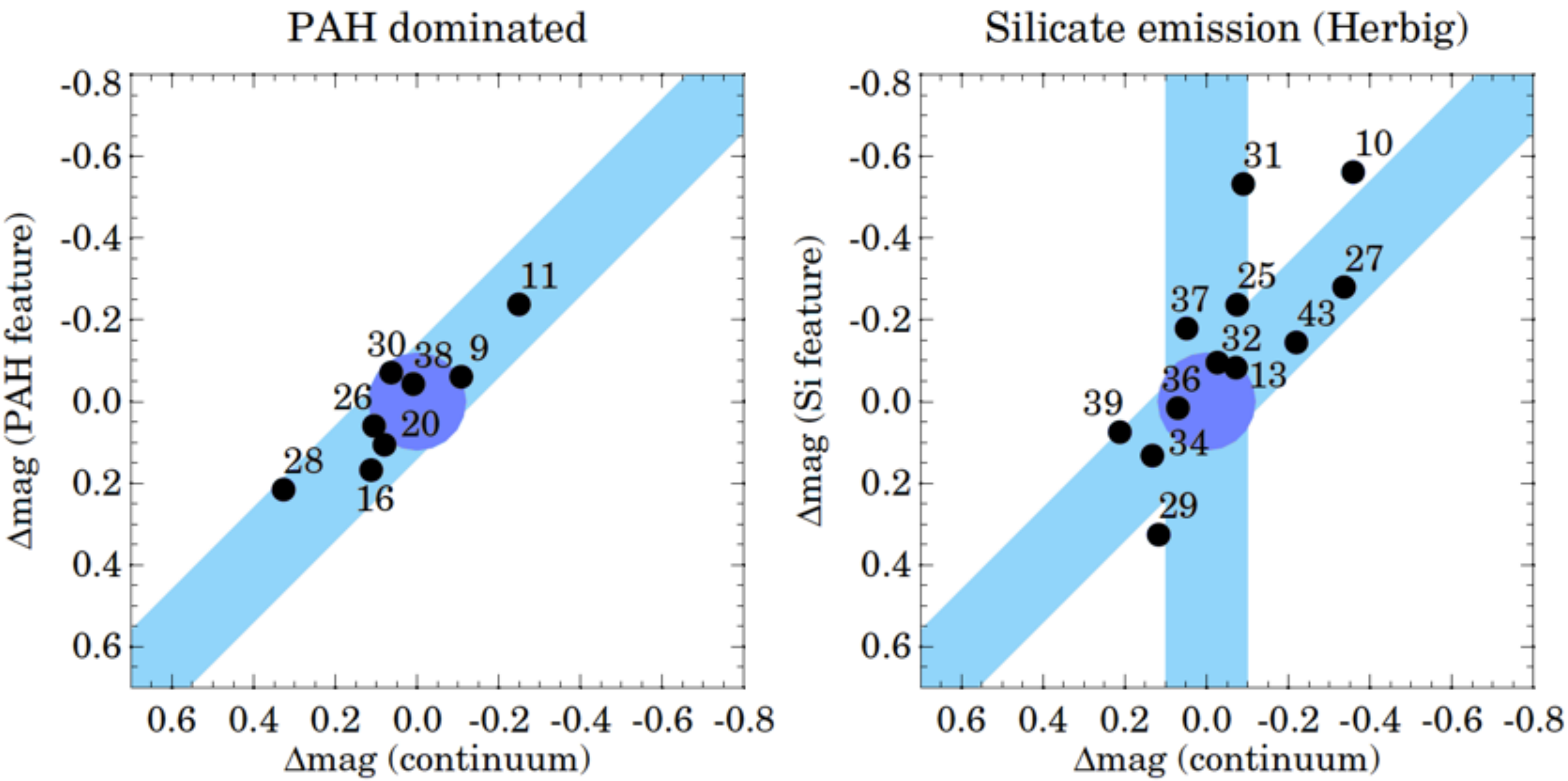
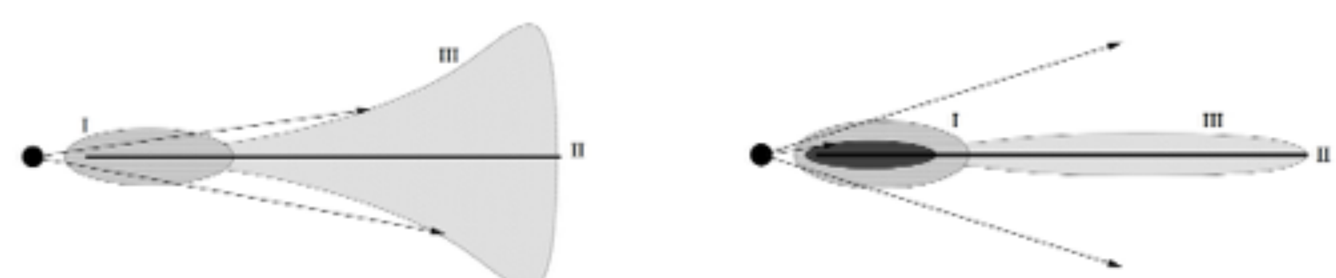
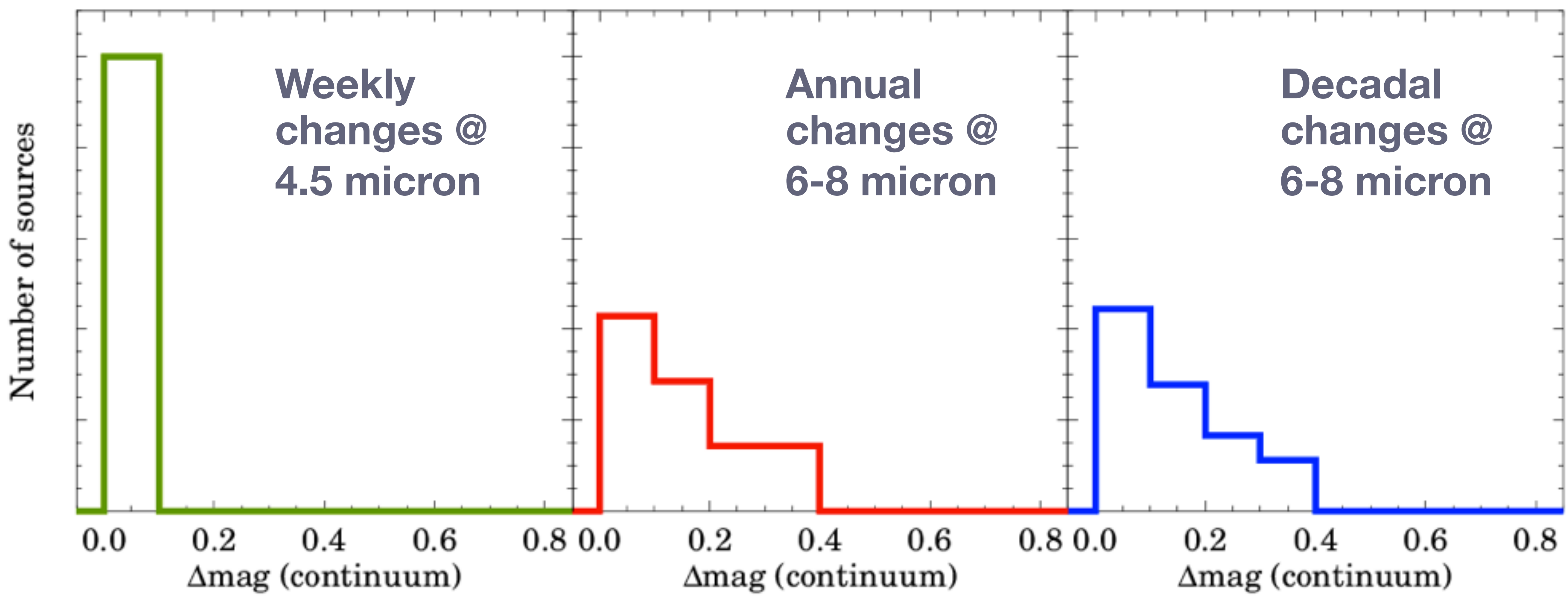




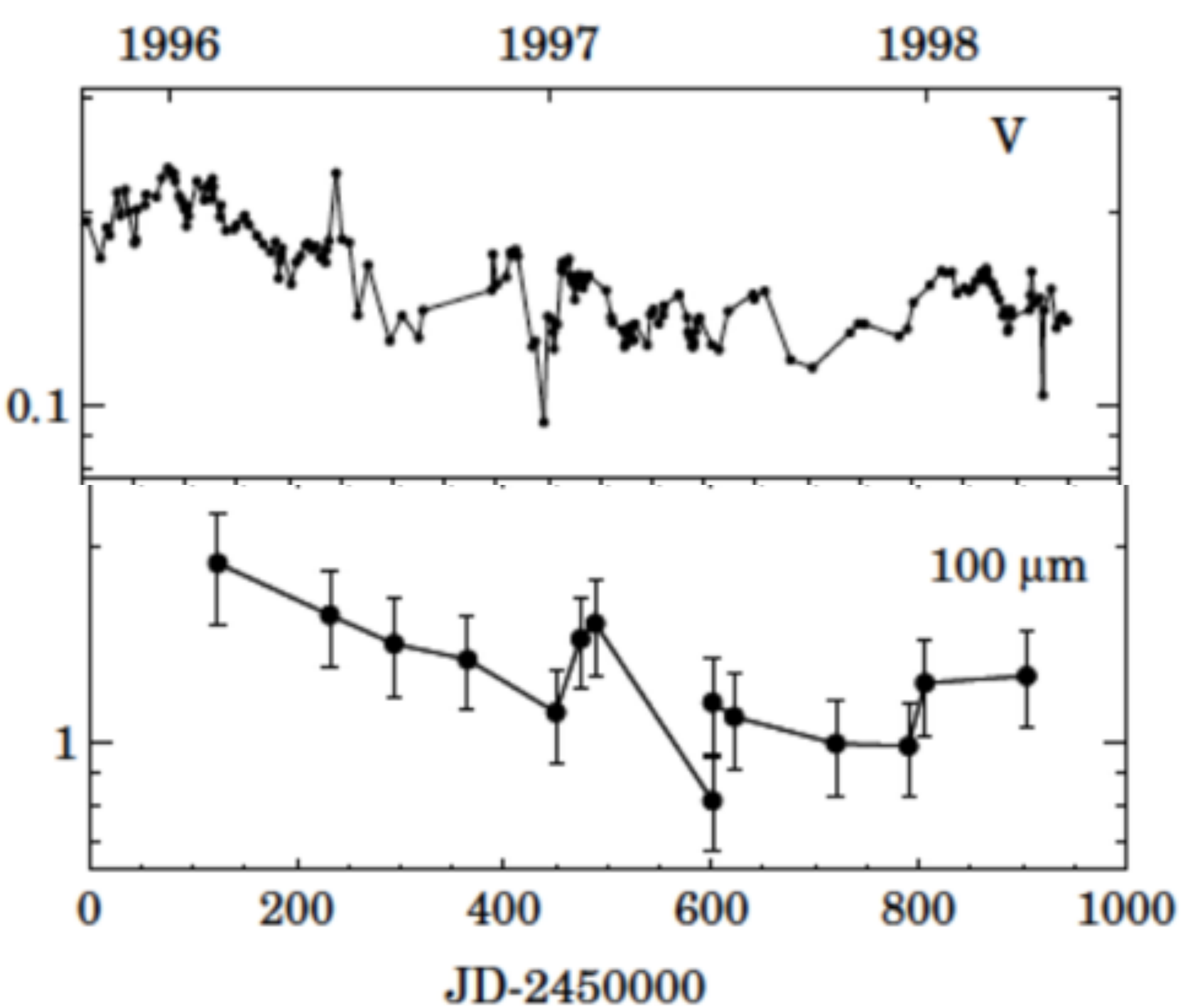
Kóspál et al. 2012

Weekly/annual/decadal variability timescales

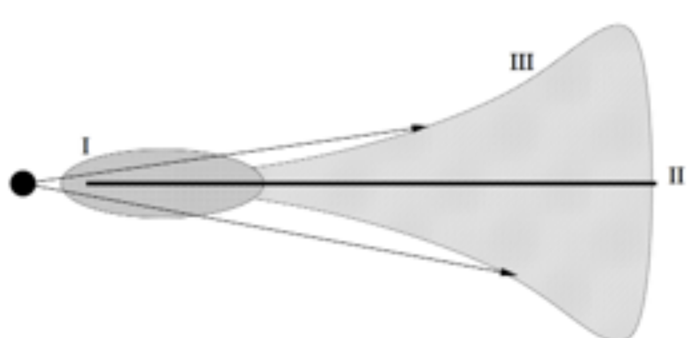


Tipical MIR variability timescales in Herbig stars: week < t < year.
Typical dynamical timescale of the inner disk.

Far-infrared variability: screen effect?

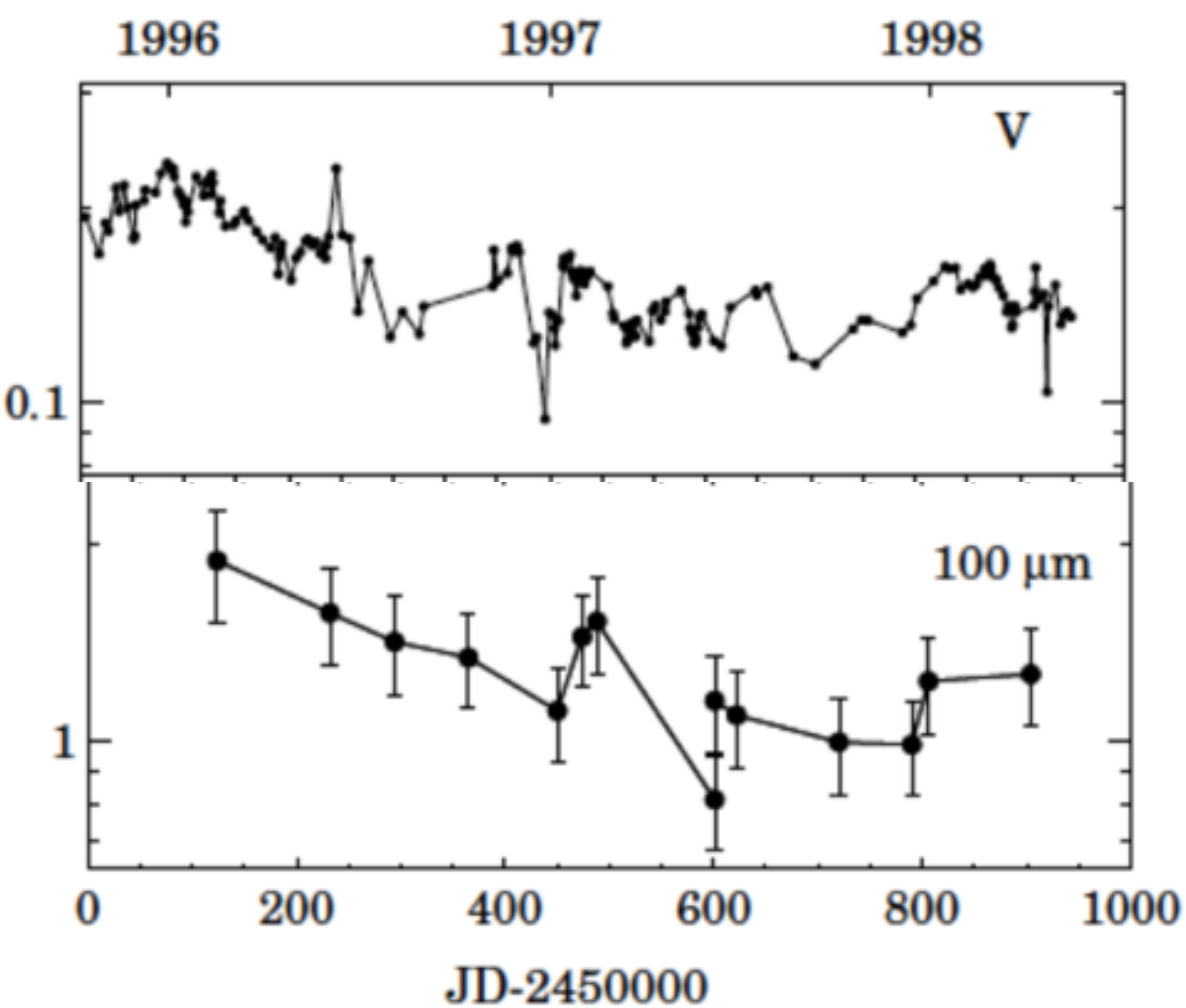


- **SV Cep**: correlation between optical and FIR fluxes
- The outer disk responds to the changing radiation from the central source
- It is the optically thin component, and it must be well visible from the centre (flared disk geometry)



FIR variability can be used to study processes in the inner disk

Far-infrared variability: screen effect?



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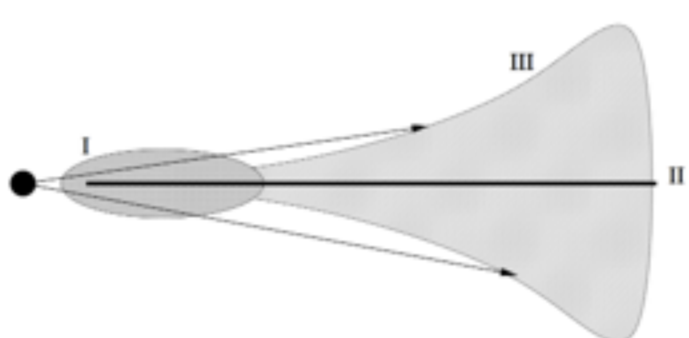


FIR variability can be used to study processes in the inner disk

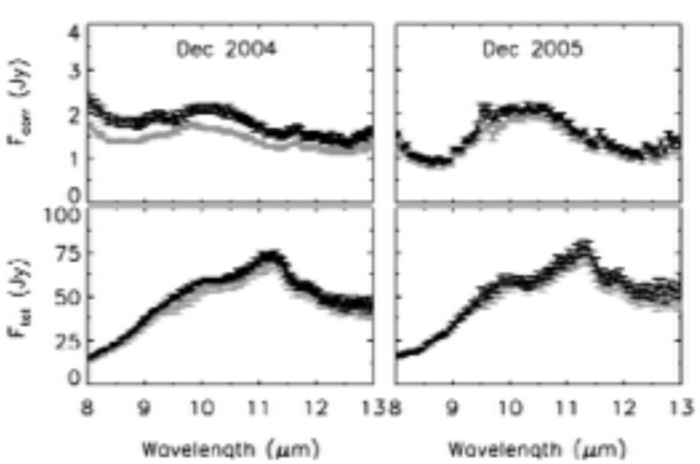
Radiative transfer modeling

- Disk structure is usually modeled using time-independent radiative transfer codes
- In the case of changing central illumination, different parts of the disk may adapt to the new irradiation conditions with different pace
- At short wavelengths the disk responses immediately
- At longer wavelengths part of the disk emission is originating from below the optical photosphere, due to lower IR opacity
- Inclusion of this effect into RT codes might help to interpret situations of rapidly changing illumination (e.g. outbursts)

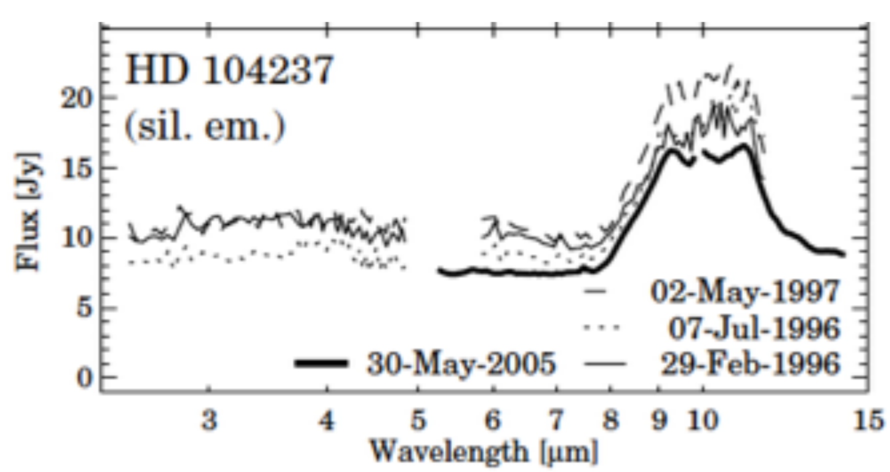
A systematic interferometric variability program

- ESO proposal (Grellmann et al, Ábrahám et al.): monitoring VLTI/MIDI + UVES/H-alpha observations (~10 per target)
- Accepted targets: **HD 100546** (reported MIDI variability, Panic et al.); **HD 163296** (infrared variability with a pivot point, Sitko et al.); **HR 5999, HD 104237** (Kóspál et al., 2012, significant mid-IR spectral variability around 10 μm).
- Proposed targets: **AB Aur, HD 50138**

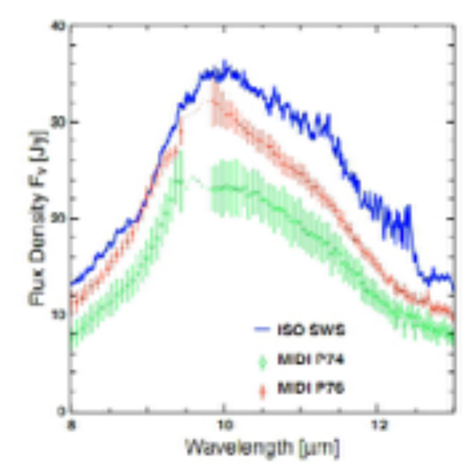
Goal: study re-arrangements in the inner regions; check if image reconstruction with Matisse could be performed



Panic et al. 2014



Kóspál et al. 2012



Di Folco et al. 2009

Summary

- The thermal emission of circumstellar disks around Herbig Ae/Be stars seems to be less constant than thought before
- Although variability at 4.5 micron is small, on longer (~annual) timescale it increases
- the timescale and the color of the flux changes carry information on the physical (dynamical) processes
- knowledge on timescales is important to construct SEDs and plan Matisse observations

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Thank you!