FU Ori objects

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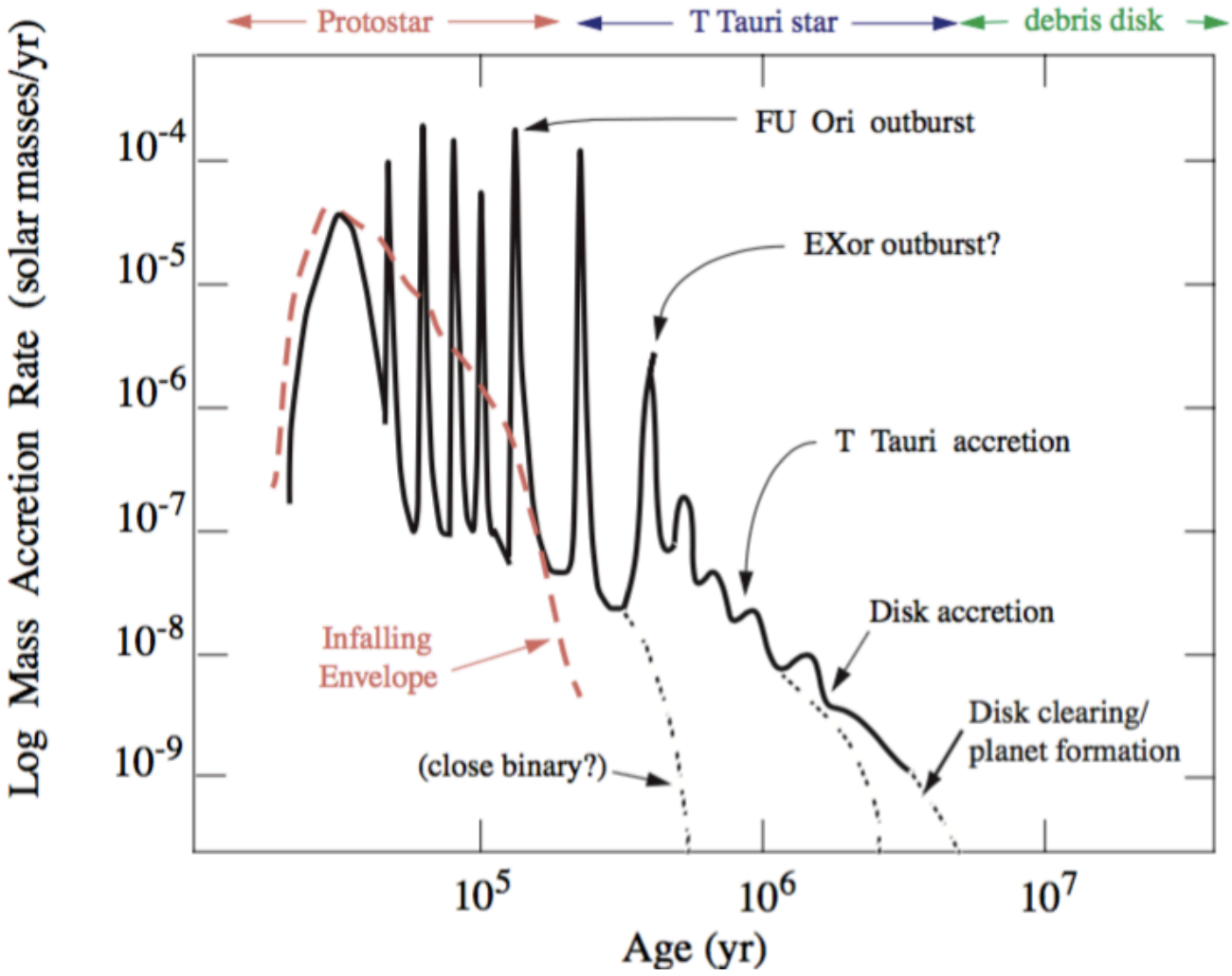


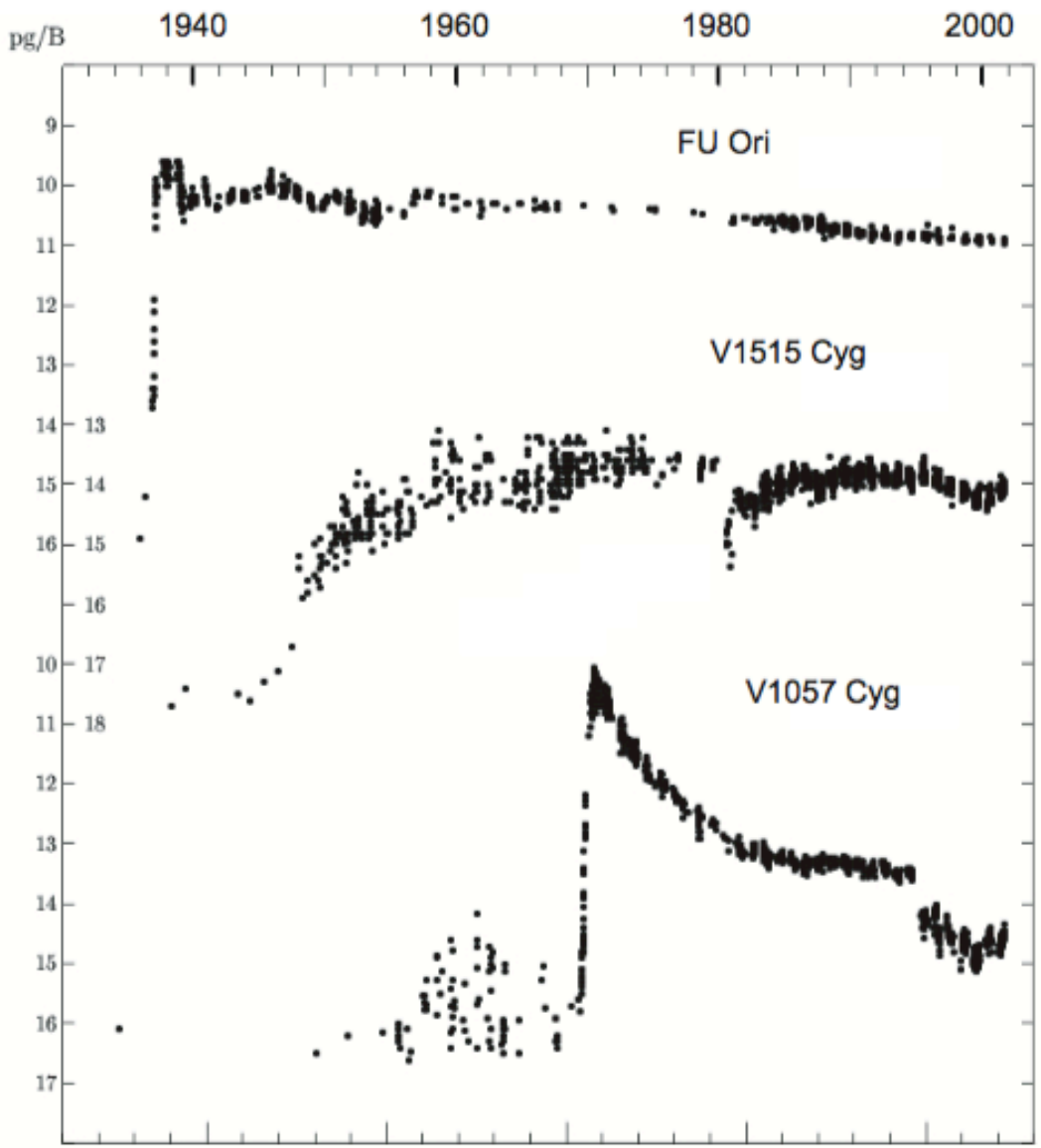
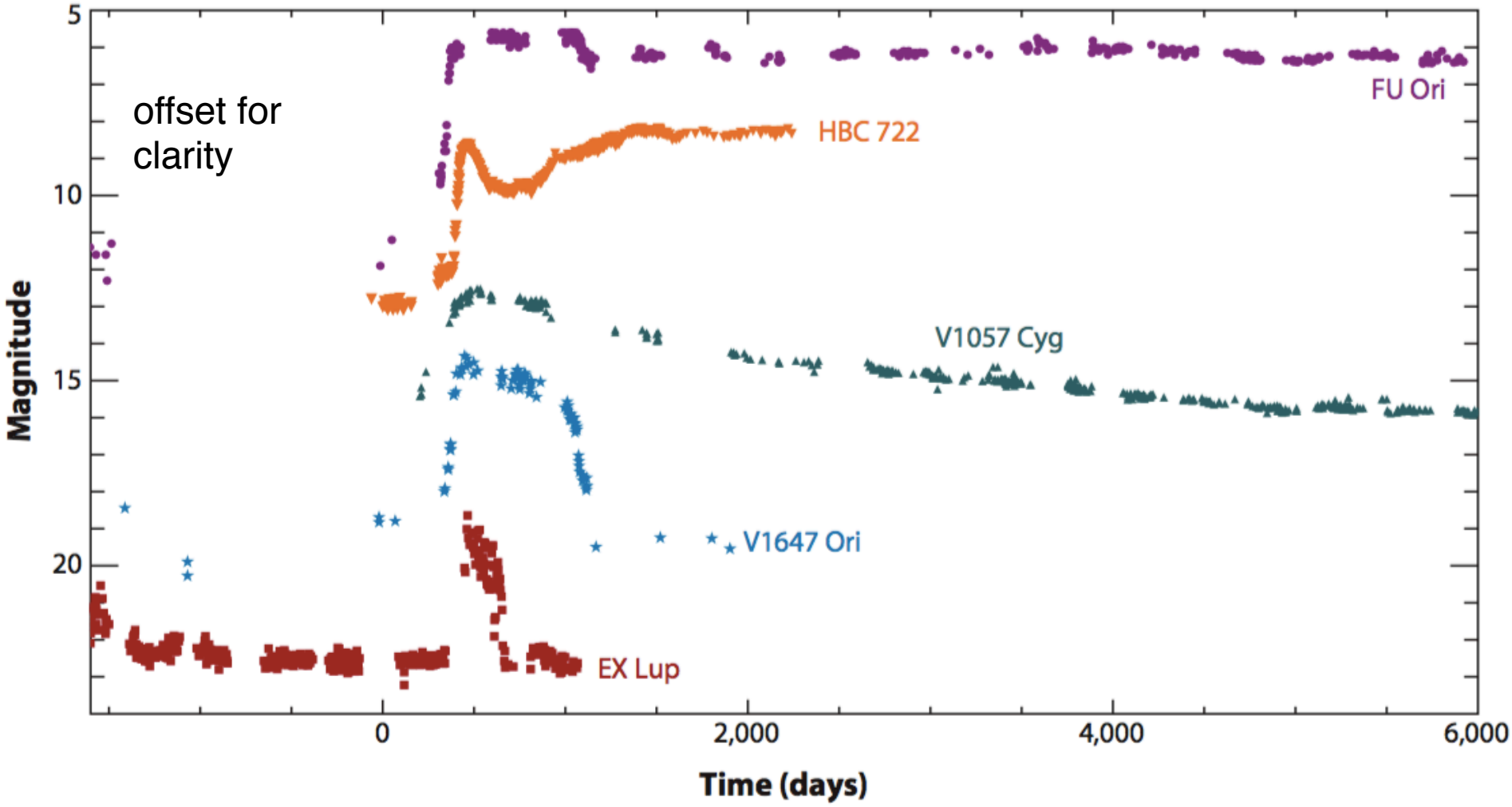


Fig. 9.1. Historical optical photometry of outbursts in three FU Ori objects. Modern photometry is in the B band, to correspond as nearly as possible with archival photographic photometry. Courtesy of Mansur Ibrahimov.

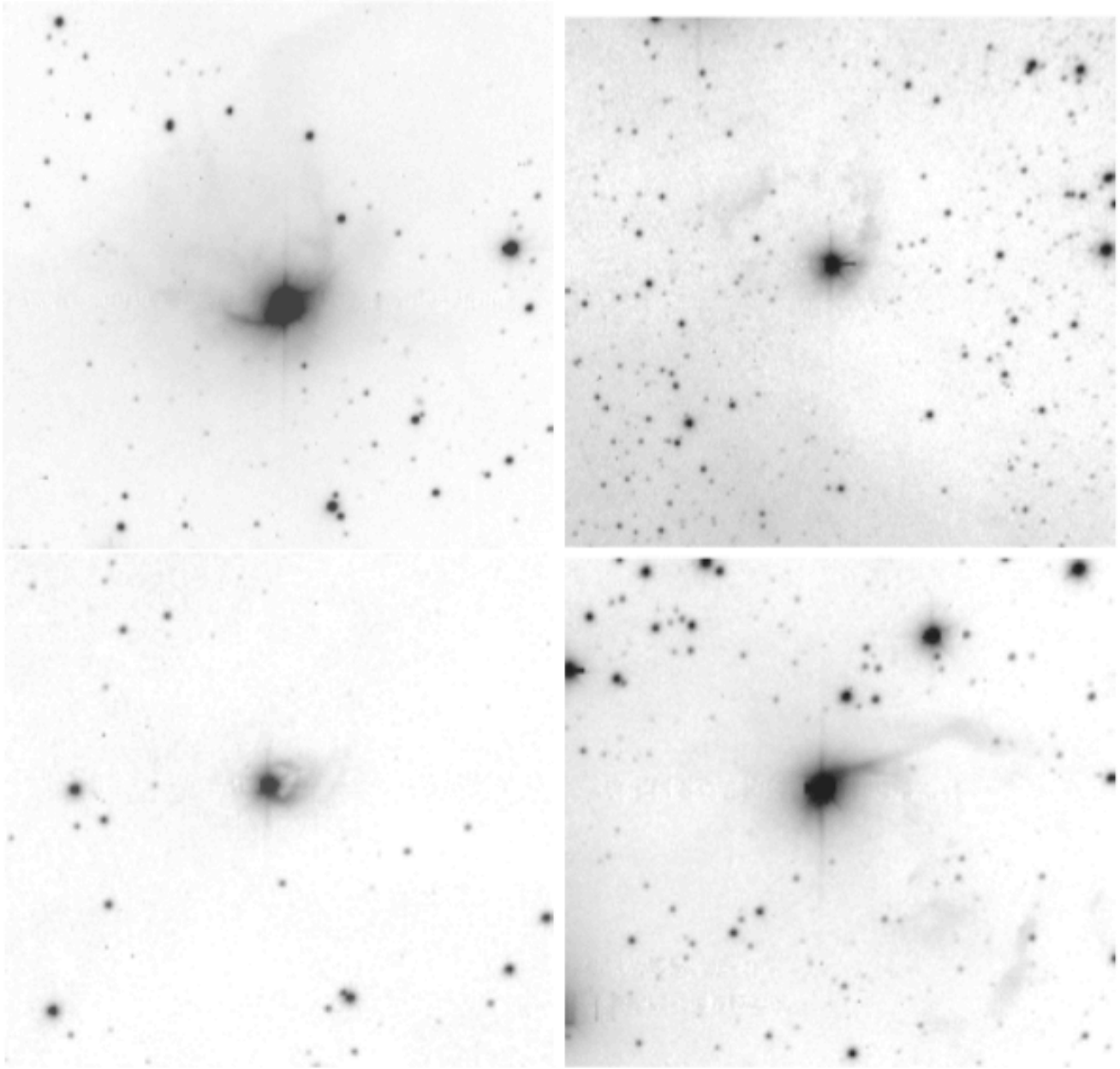
both inside-out and outside-in (?)



FUors typically have very large outbursts – EX Lup type smaller, shorter, could be disk-magnetosphere effects

flickering of ~ 3-5%, few day timescales

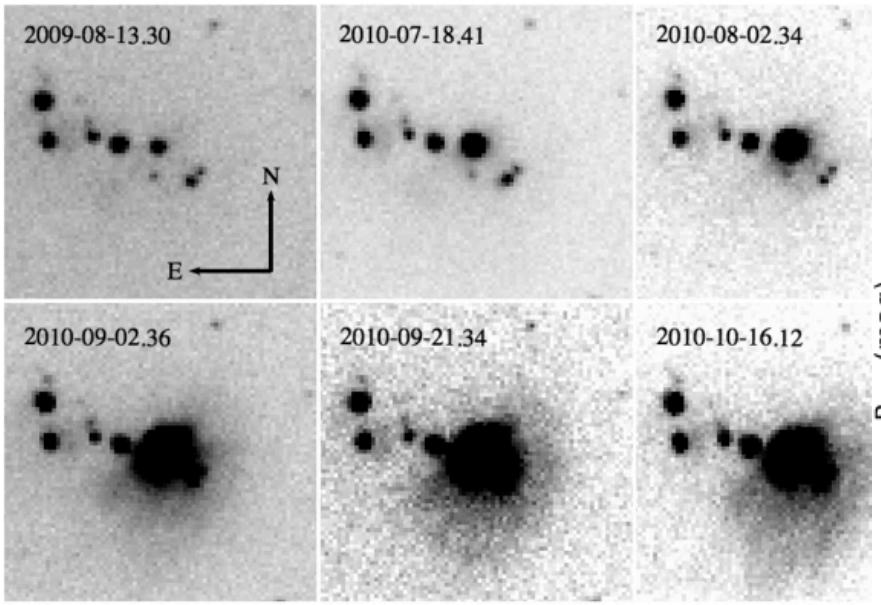
Hartmann, Herczeg, Calvet, 2016 ARAA

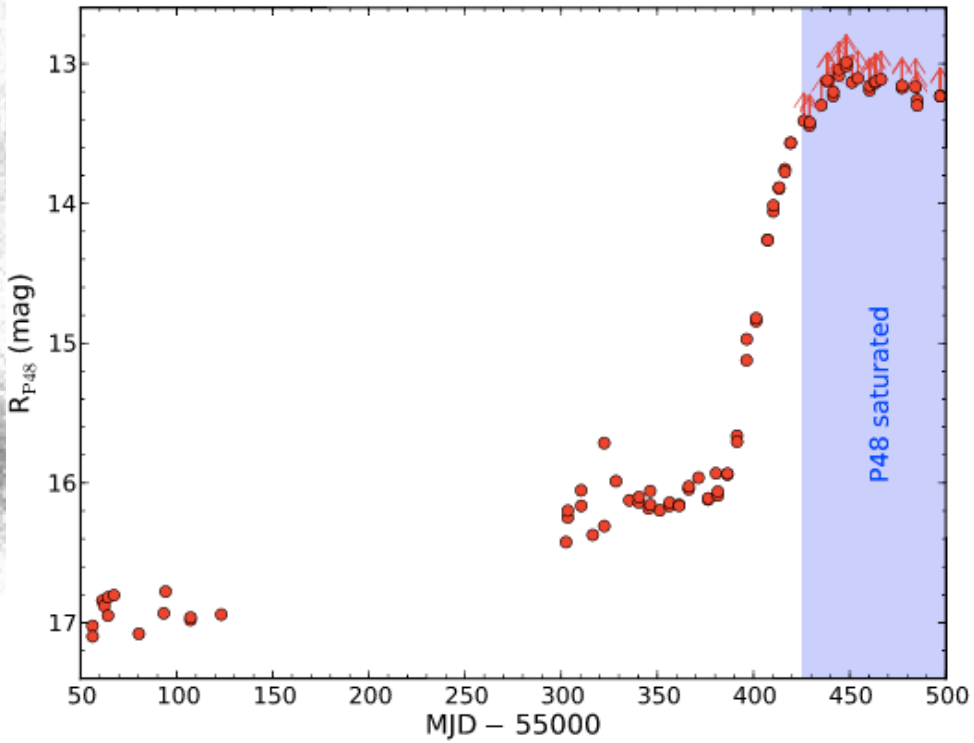


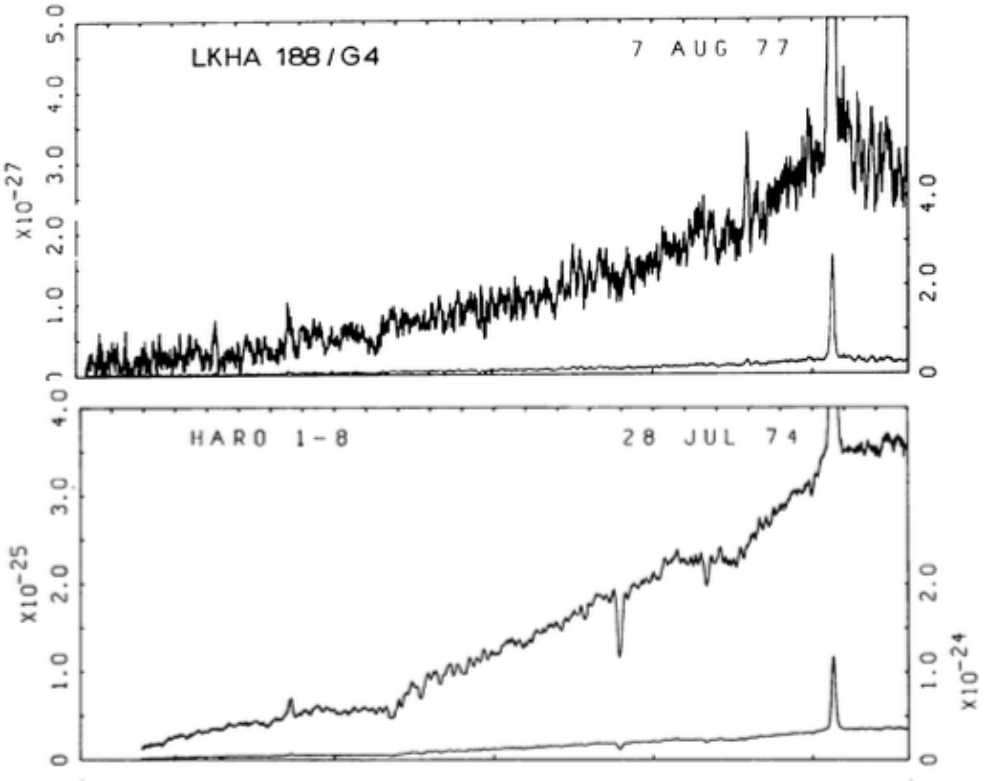
generally (always?) have dusty envelopes – infall probably

some objects are seen only because we look down outflow hole

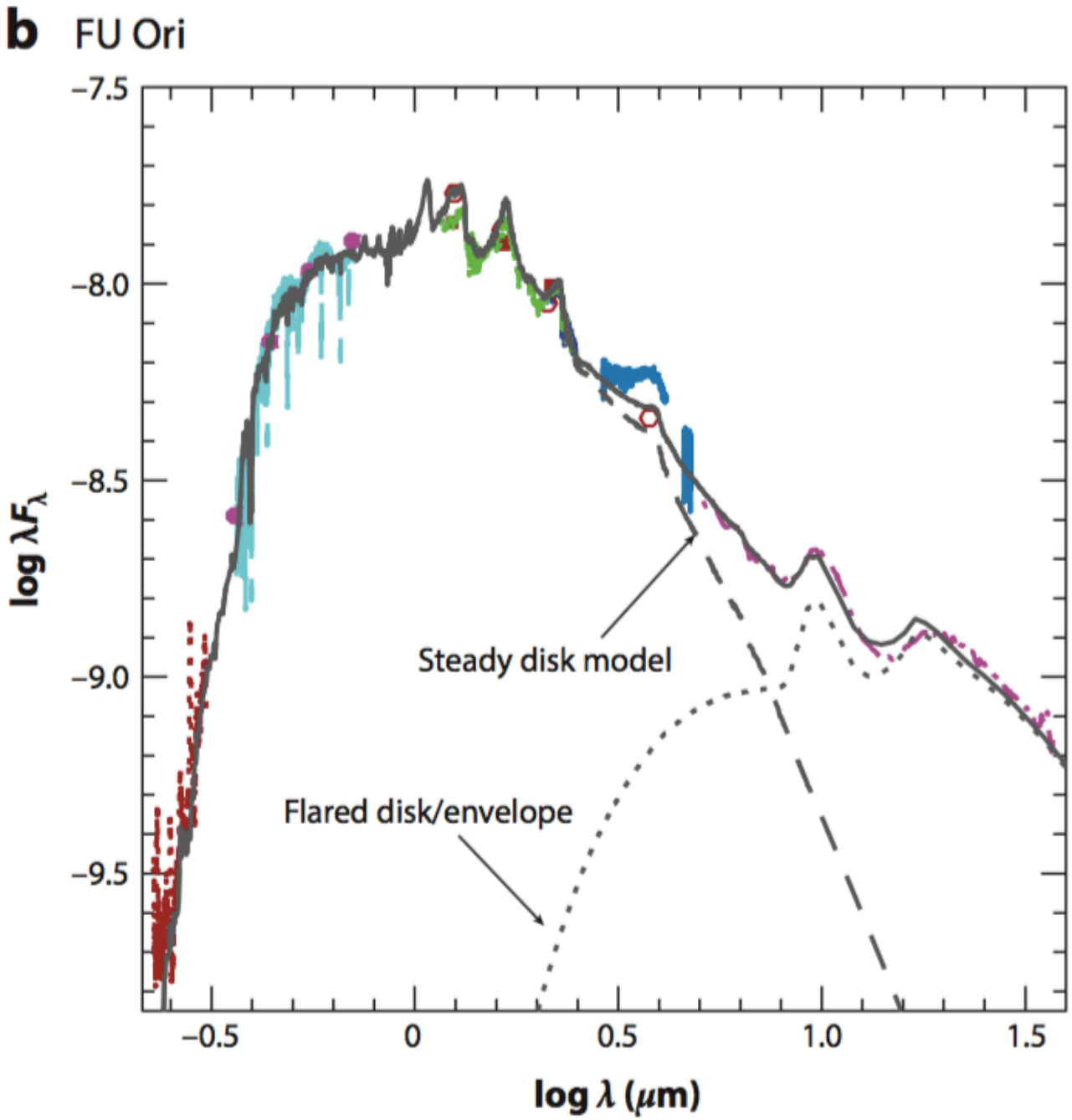
Fig. 9.2. FU Ori (upper left) and V1057 Cyg (upper right); V1515 Cyg (lower left) and Z CMa (lower right) in optical images. Courtesy C. Briceño.







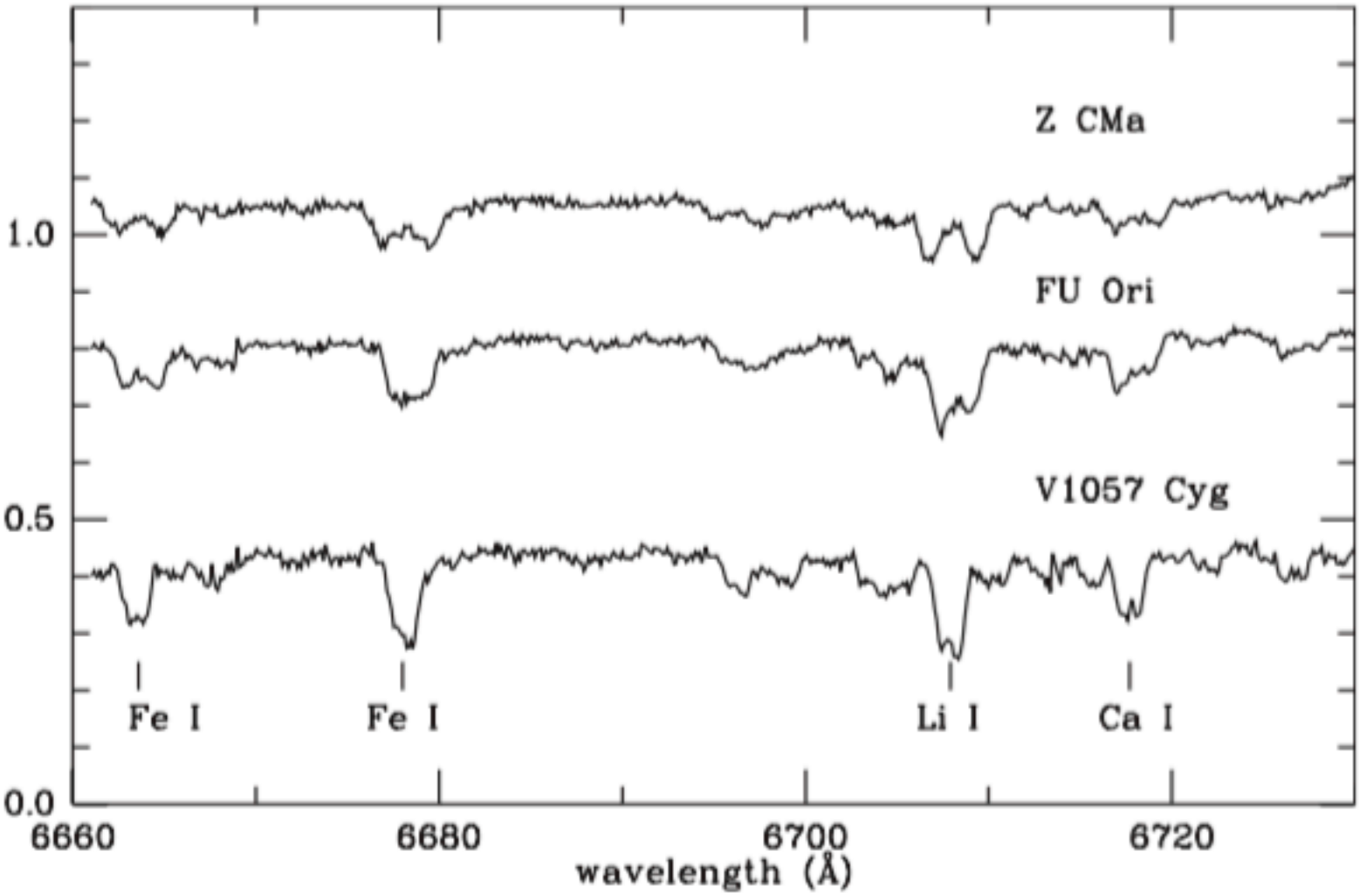
HBC 722: pre-outburst spectrum that of a typical low-mass T Tauri star



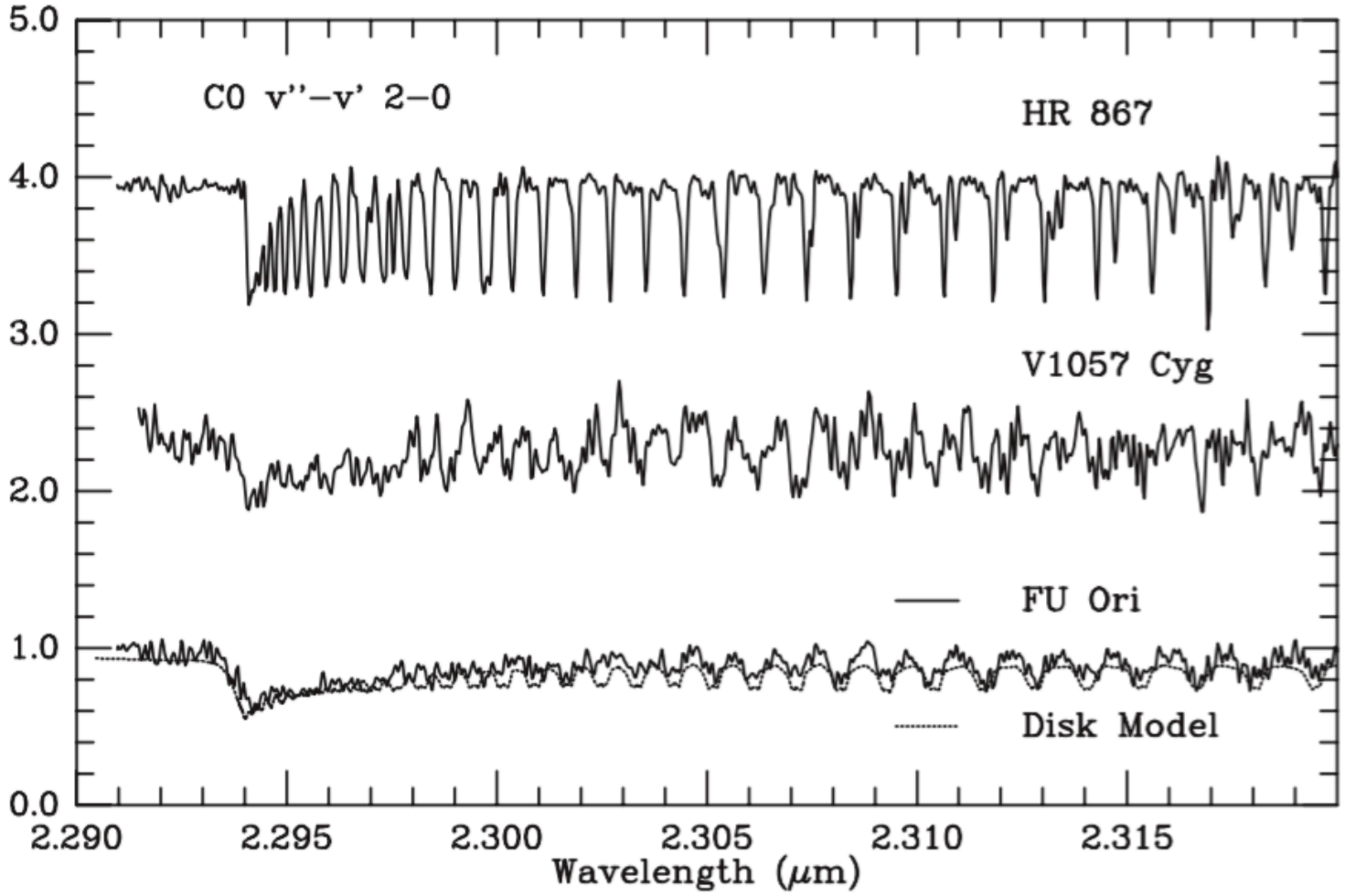
inner disk: absorption features (centrally heated)

long-wavelength: silicate emission (heated from outside)

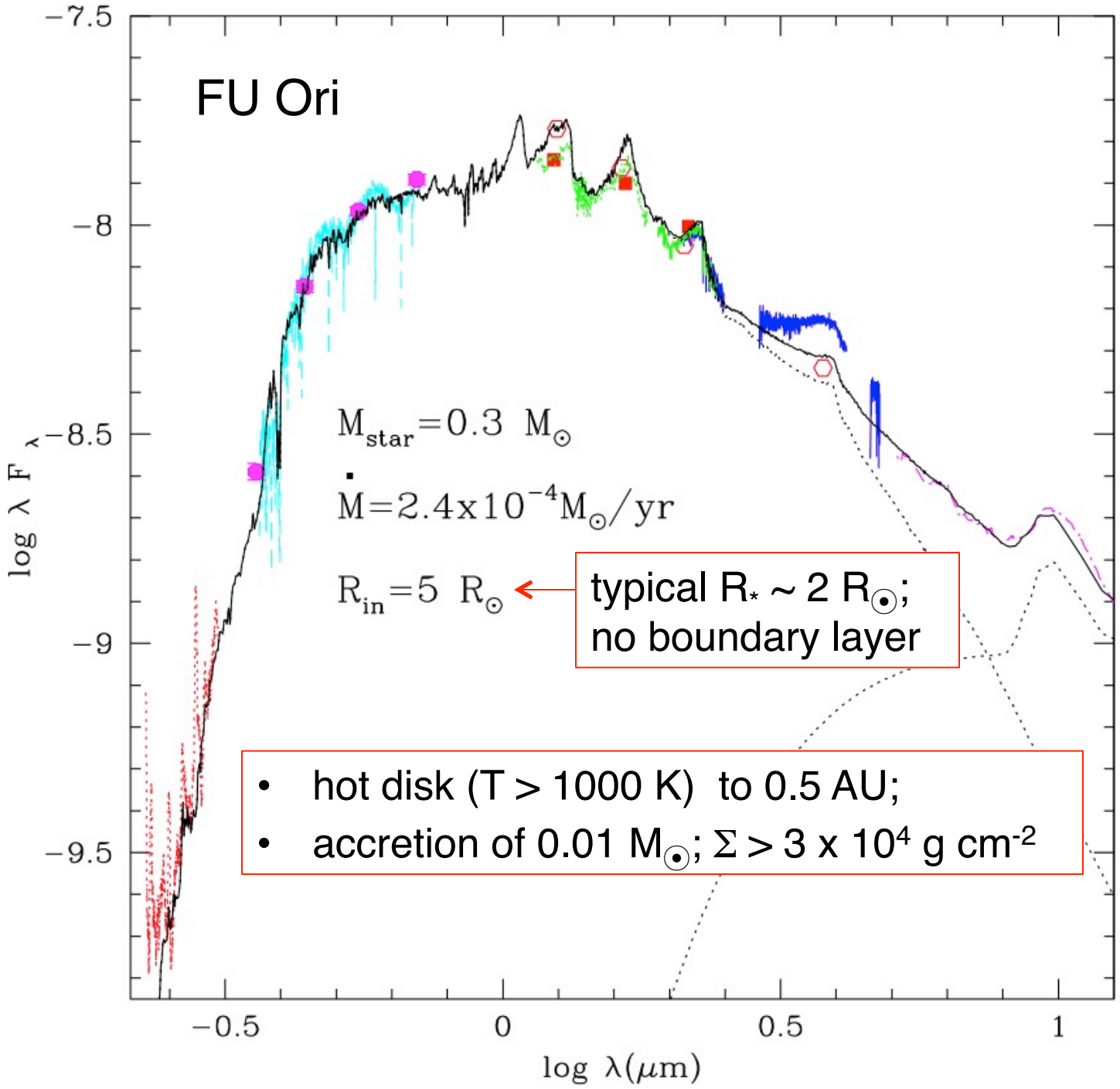
Hartmann, Herczeg, Calvet, 2016 ARAA

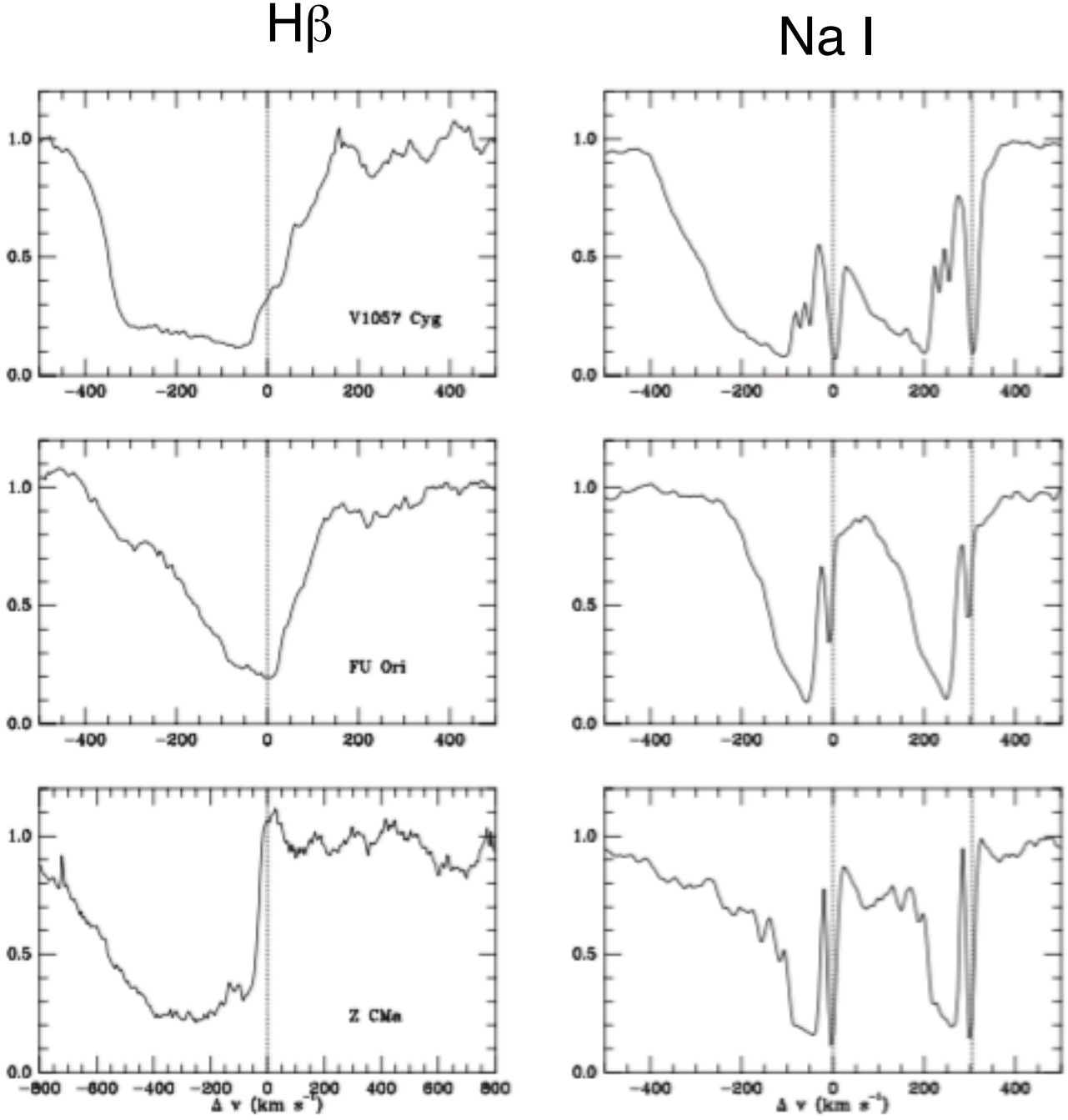


disk (doubled) line profiles; some turbulence, wind



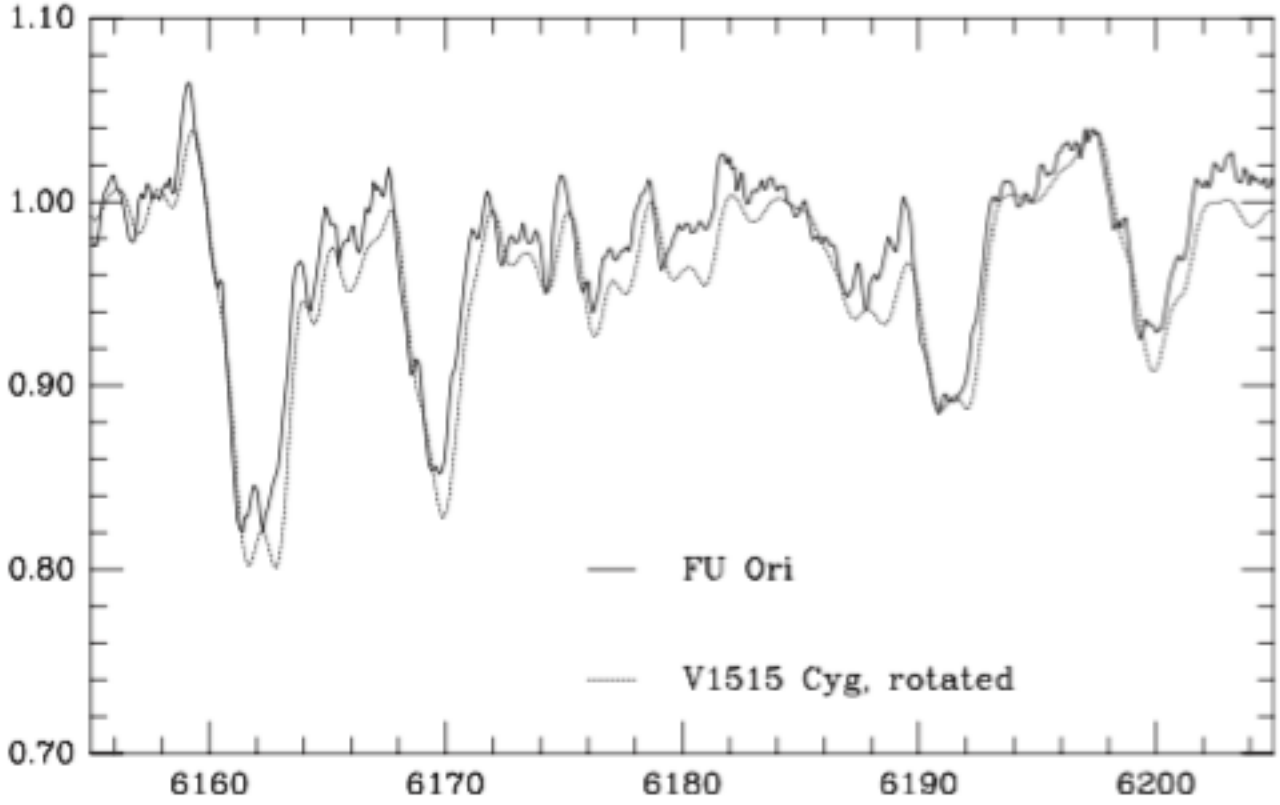
differential rotation with wavelength 0.6 – 5 microns (65, 36, 22 km/s – consistent with Keplerian


FU Ori
$M_{star}=0.3\ M_\odot$
$\dot{M}=2.4x10^{-4}M_\odot/yr$
$R_{in}=5\ R_\odot$
typical $R_* \sim 2\ R_\odot$;
no boundary layer
• hot disk (T > 1000 K) to 0.5 AU;
• accretion of 0.01 $M_\odot$; $\Sigma > 3 \times 10^4$ g cm^{-2}
log λ F λ
log λ(μm)
−7.5
−8
−8.5
−9
−9.5
−0.5
0
0.5
1

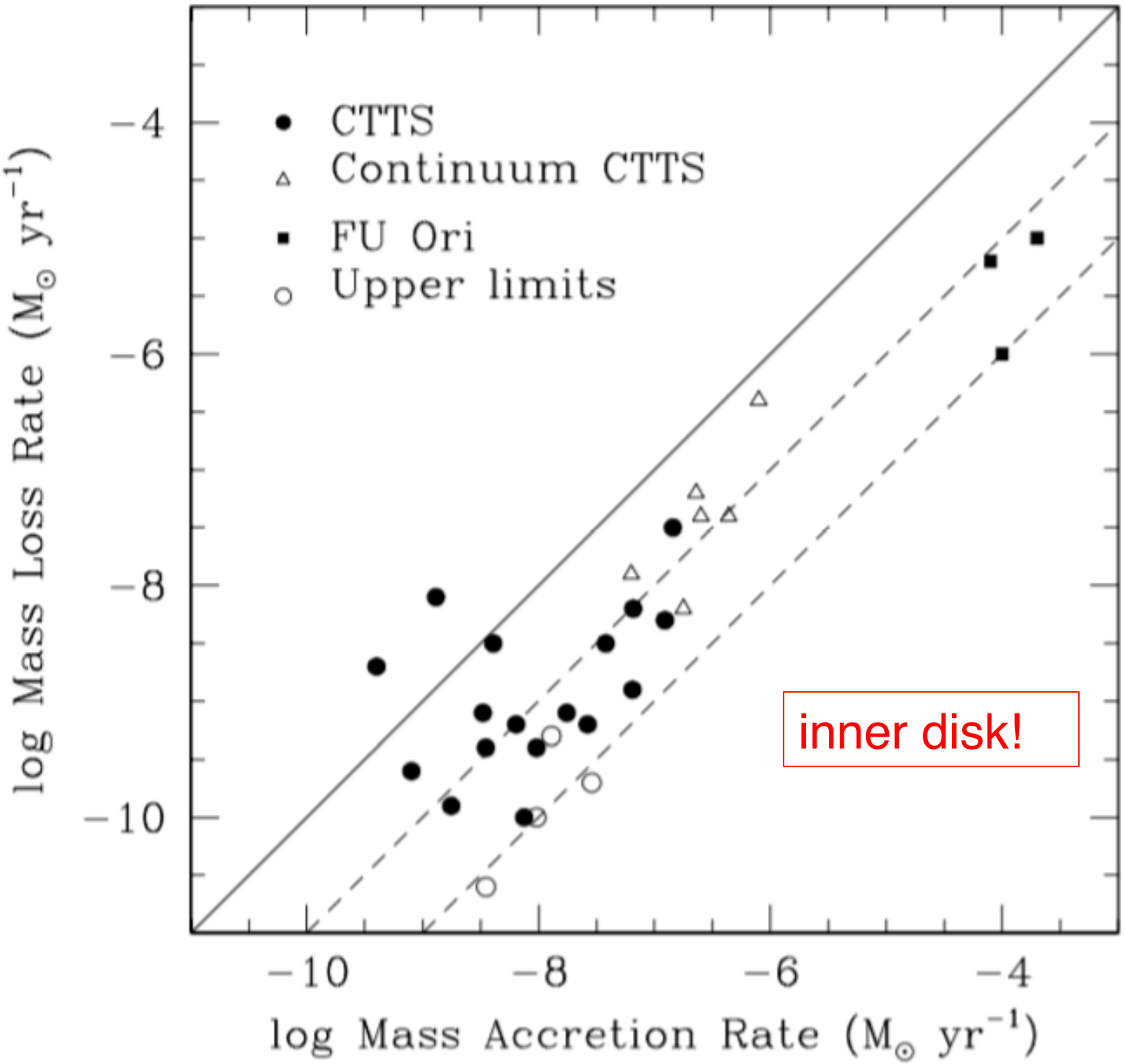


strong, low-temperature winds

clearly time-variable with bursts/shells

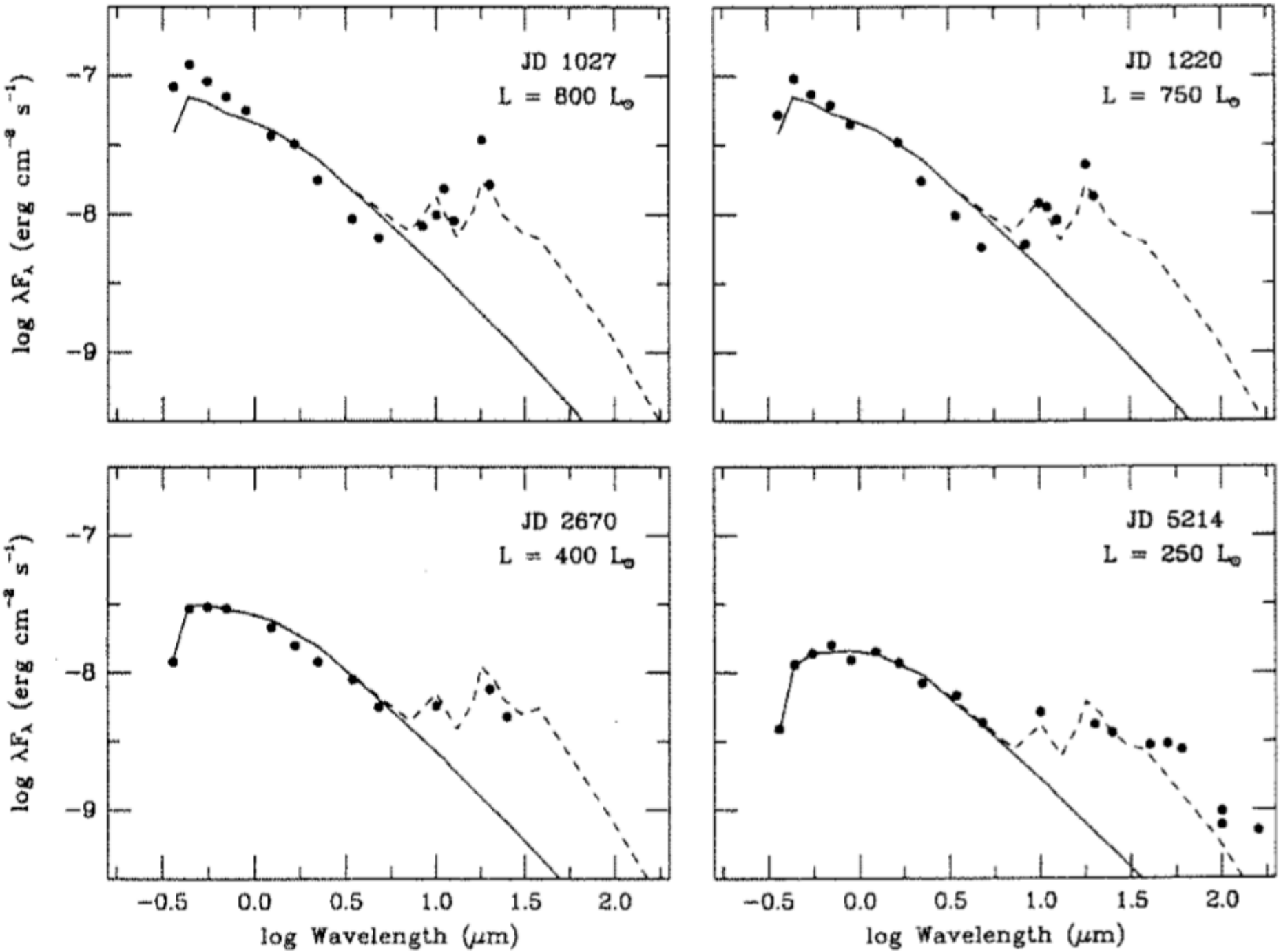


FU Ori: strong photospheric lines are blueshifted- trace wind coming off the disk


CTTS
Continuum CTTS
FU Ori
Upper limits
inner disk!
log Mass Loss Rate ($M_\odot$ yr^{-1})
log Mass Accretion Rate ($M_\odot$ yr^{-1})
−4
−6
−8
−10
−10
−8
−6
−4

FU Ori objects

- $dM/dt \sim 10^{-4} - 10^{-5}\ M_{\odot}/yr$
- decay timescales ~ decades to centuries
- $T_{max} \sim 6000$ K
- hot region ($T_{eff} > 800$ K) extends out to ~ 0.5 AU or more
- wind $dM/dt \sim 10^{-1}\ dM/dt$ (acc)
- repetitive? probably; taking the dozen or so known objects and comparing to average star formation rates suggests $\gtrsim$ 10x/star
- feature of very early evolution (likely continuing infall to disk)
- probably missing many in heavily extincted phases


JD 1027
L = 800 L⊙
JD 1220
L = 750 L⊙
JD 2670
L = 400 L⊙
JD 5214
L = 250 L⊙
log λF_λ (erg cm^-2 s^-1)
log Wavelength (μm)
-7
-8
-9
-0.5
0.0
0.5
1.0
1.5
2.0