Photometric evolution of FU Orionis objects:

Discs, winds, envelopes and their interaction

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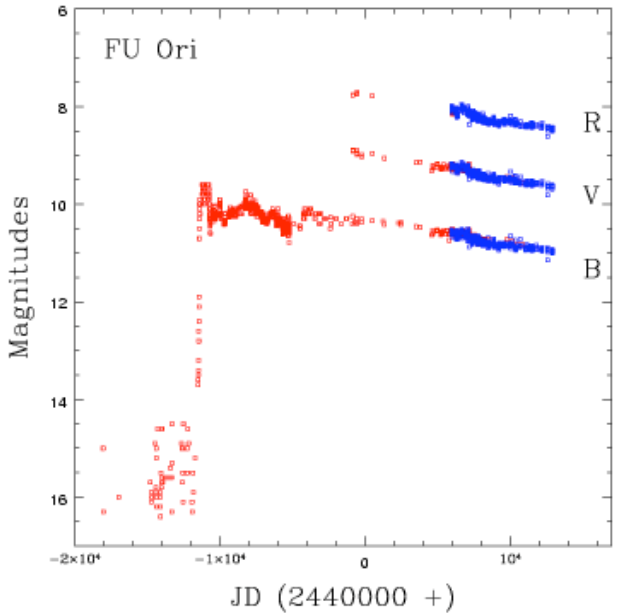
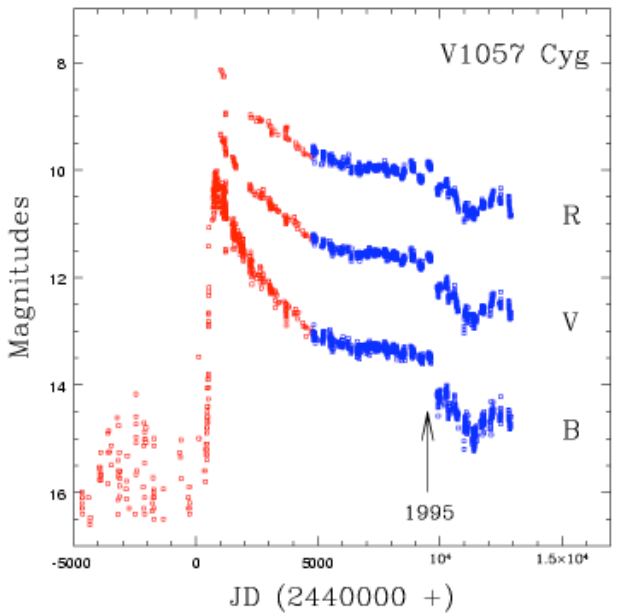
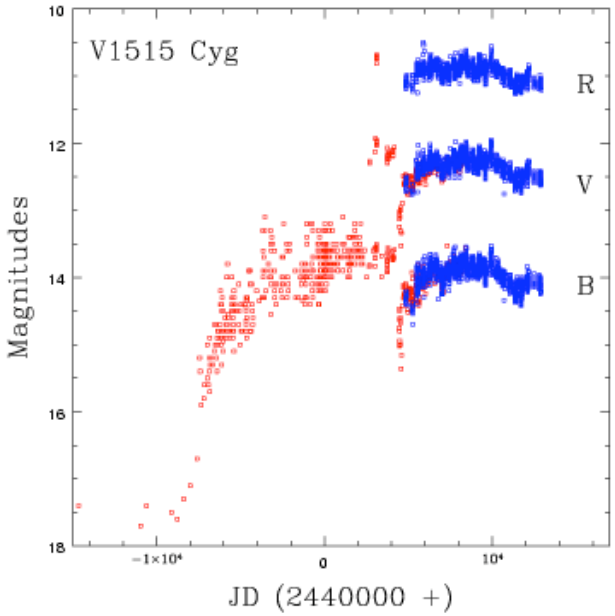
Light-curves







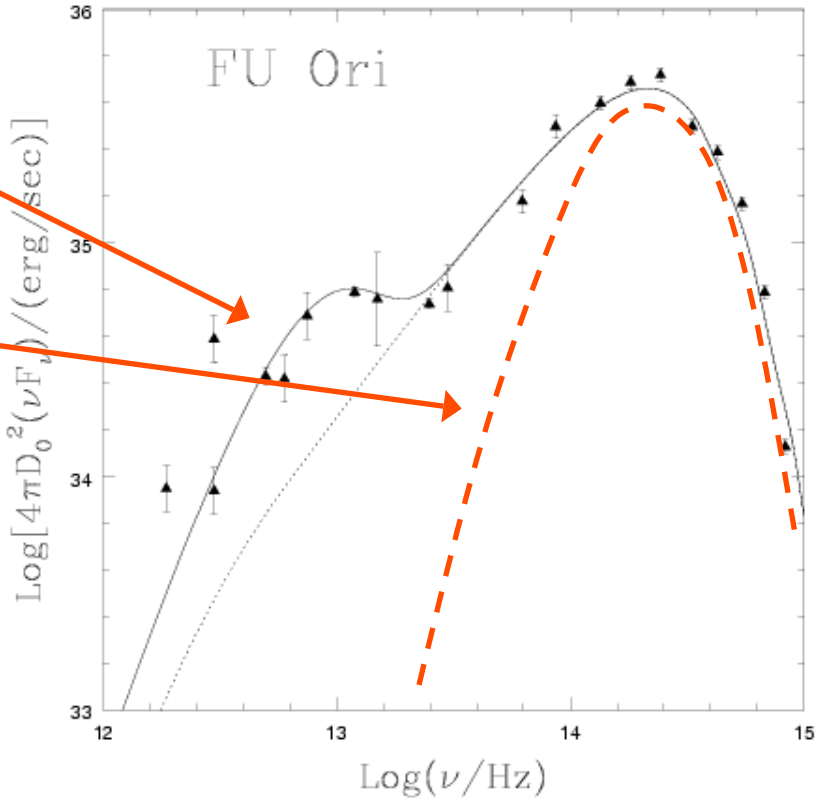
- Red: historical data
- Blue: new photometry (Melnikov, Ibrahimov: Maidanak Observatory): long monitoring campaign from 1981 to 2003.

Evidences for discs

- SEDs: NIR excess over stellar photosphere
  (Kenyon et al. 1998)

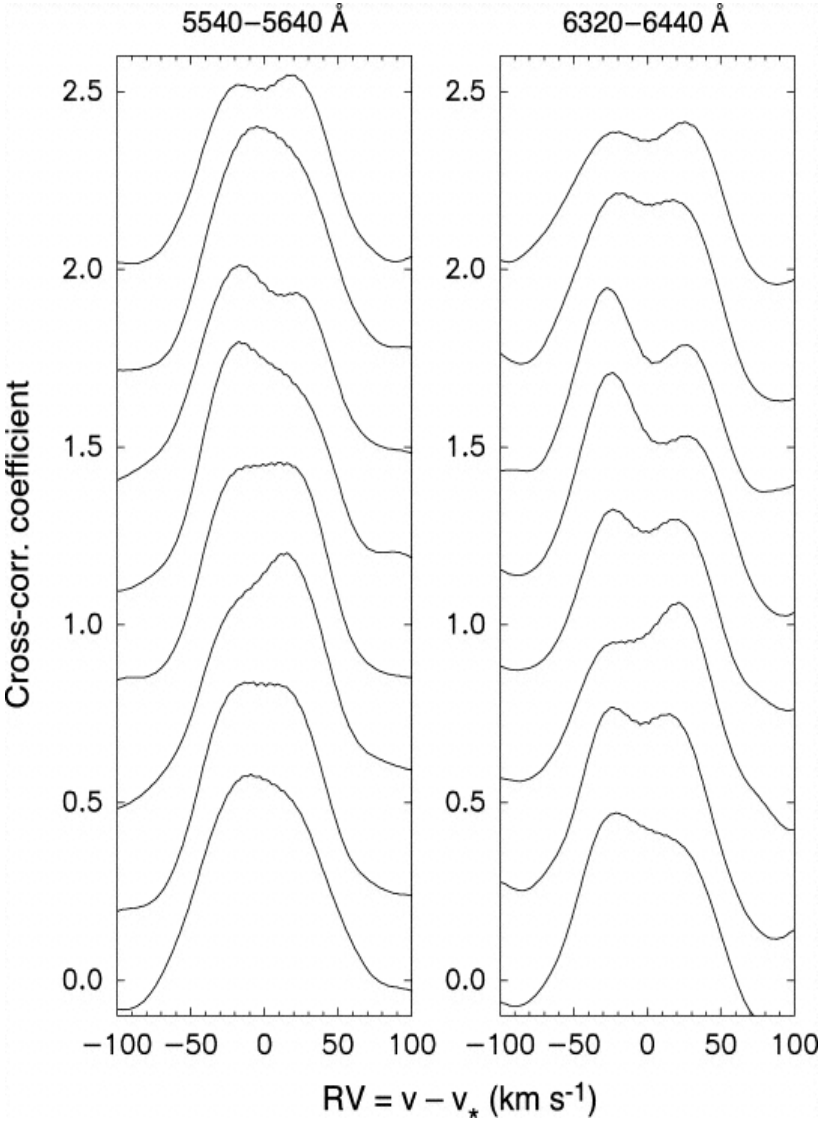
FIR excess: dusty envelope
(for V1057 Cyg: inner radius ≈ 10 AU)
Kenyon & Hartmann 1991

Stellar photosphere



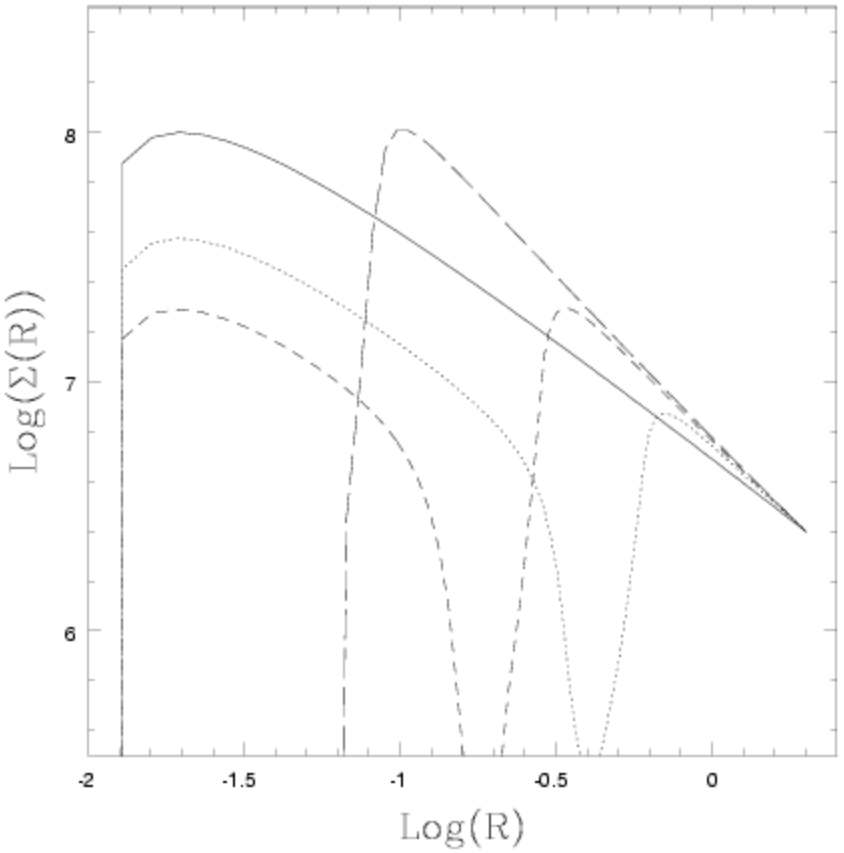
Evidences for discs

- Double peaked line profiles (Kenyon et al. 1998)
- However, periodic modulation (Herbig et al 2003, Errico et al. 2003) not predicted by simple models
- Possible explanation: accretion onto embedded massive planet (Clarke & Armitage 2003)



Planet-disc interaction

- Fast rising light curves only in triggered thermal instability
- Massive planet ($10M_J$), gap opening, migration rate slower than Type II banking up of disc material (Lodato & Clarke 2004)



Disc model for V1057 Cyg

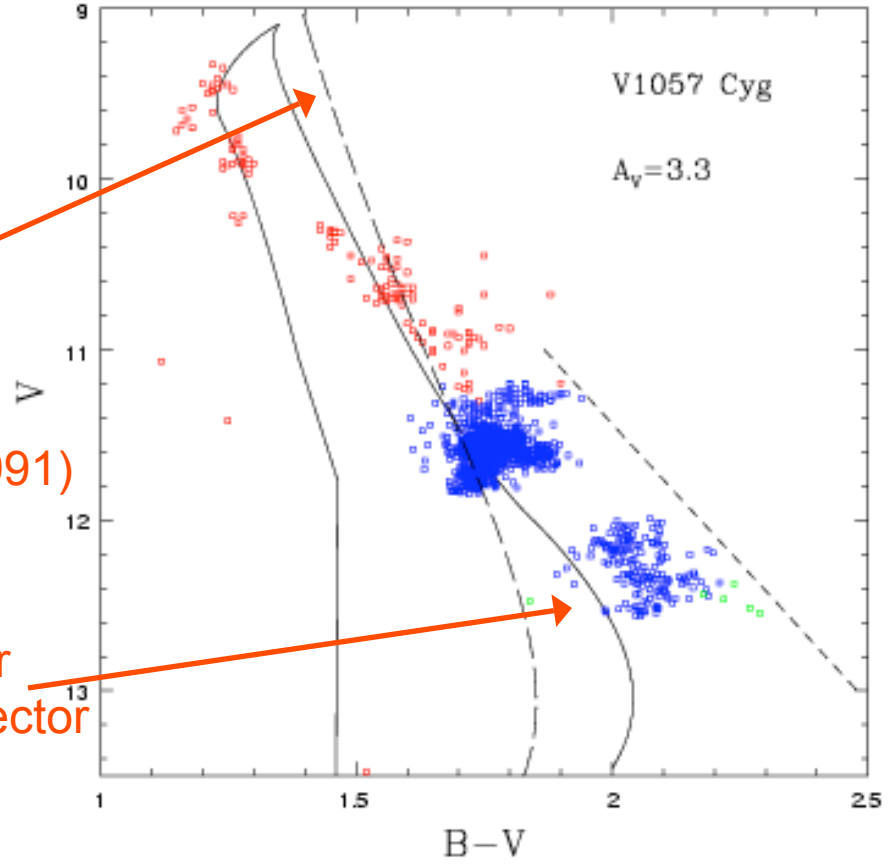
- Triggered thermal instability:
  - $M_* = 0.5 M_o$, $M_{planet} = 10 M_J$
- Triggering radius: ≈ 12 R_o
- Peak luminosity: ≈ 750 L_o
- Peak mass accretion rate:

  ≈5 $10^{-4} M_o$/yr

Sequence of steady state models too red at peak (Kenyon & Hartmann 1991)

Recent dimming: too fast and too red for disc evolution. Consistent with reddening vector

Obscuration by intervening dust

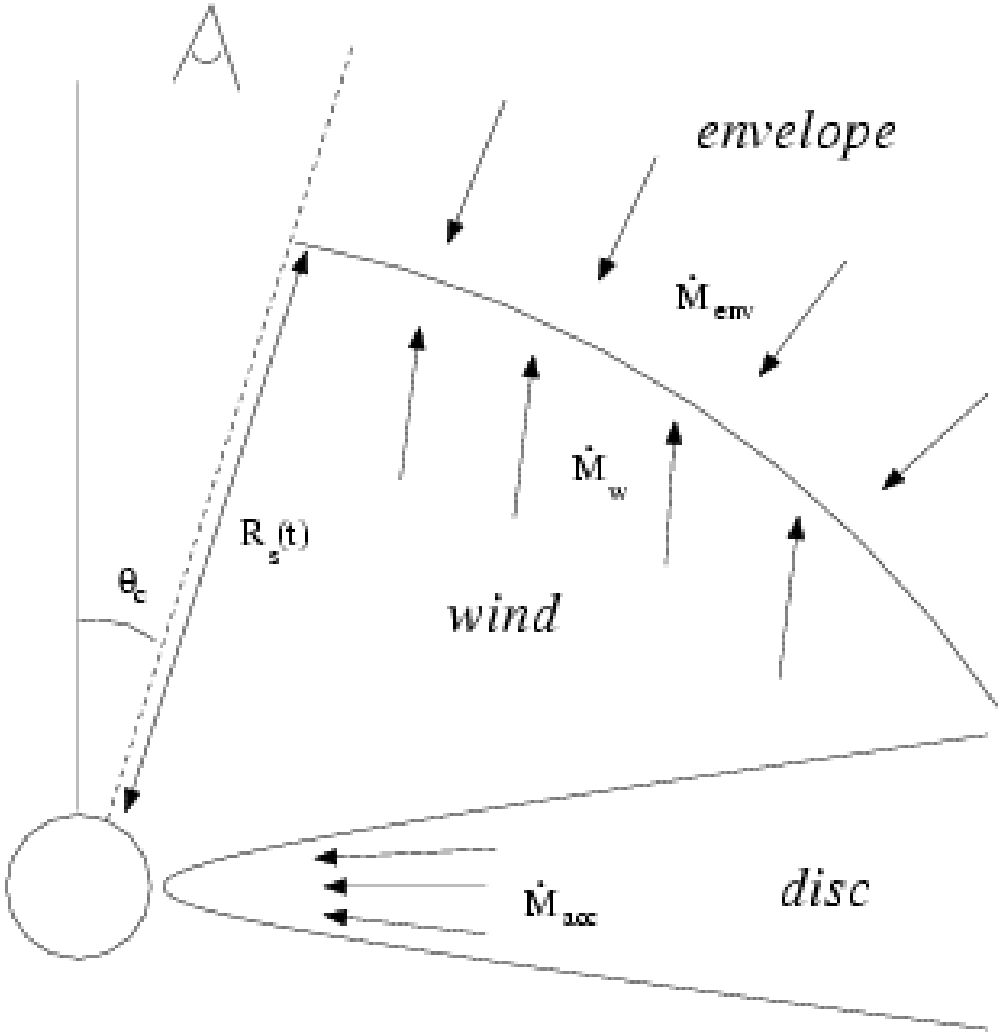


Wind-envelope interaction

- V1515 Cyg: photometric variability early in the evolution (close to peak luminosity ≈ 100 L_o)
- V1057 Cyg: obscuration only after luminosiy has decreased to ≈ 100 L_o
- FU Ori: no obscuration
- New model wind-envelope interaction (Clarke, Lodato, Melnikov & Ibrahimov, 2005)

Wind-envelope interaction

- 1D spherical model
- $\dot{M}_{wind} \propto \dot{M}_{acc}$ (at peak: $\approx 7\ 10^{-6}\ M_o/yr$)
- Wind velocity: 300km/sec
- Envelope initially in equilibrium (Kenyon & Hartmann 1991), with $\dot{M}_{env} \approx 10^{-5}\ M_o/yr$

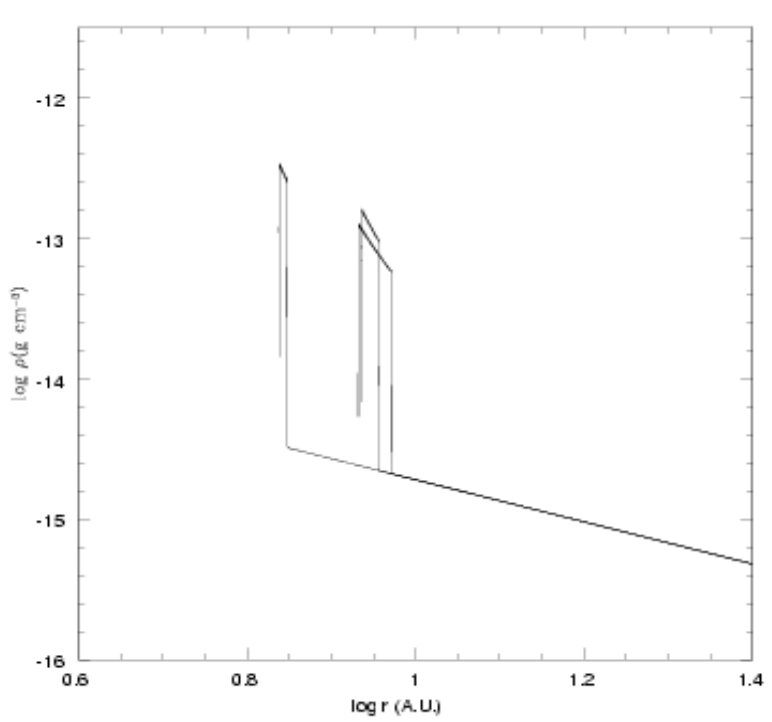


Wind-envelope interaction

Simulations

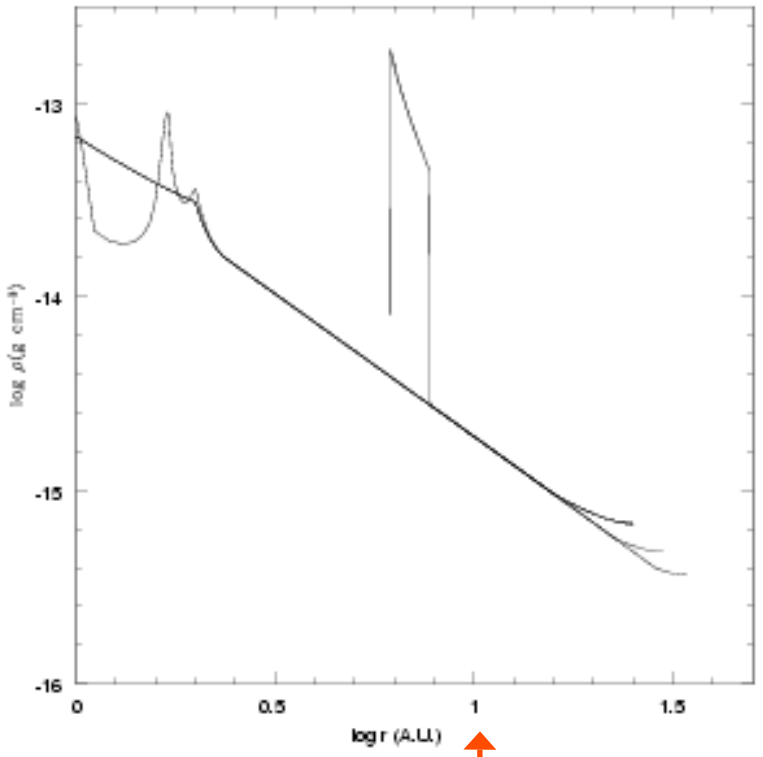
Density in the envelope after:

4, 8, 12 years



R=10AU

16, 20, 24 years



R=10AU

Conclusions

- New UBVR photometry of FU Ori, V1057 Cyg, and V1515 Cyg (Maidanak Obs.)
- Time-dependent disc thermal instability models reproduce well the colour evolution of V1057 Cyg (and V1515 Cyg)
- Planet-disc interaction required for fast rise
- Recent dimming in V1057 Cyg better explained as dust obscuration
- New model for wind-envelope interaction describes well the different evolution of the three objects
- Predicted inner cavity size consistent with long-wavelength SED