Diagnosing FU Ori-like Sources:

The Parameter Space of Viscously Heated Disks

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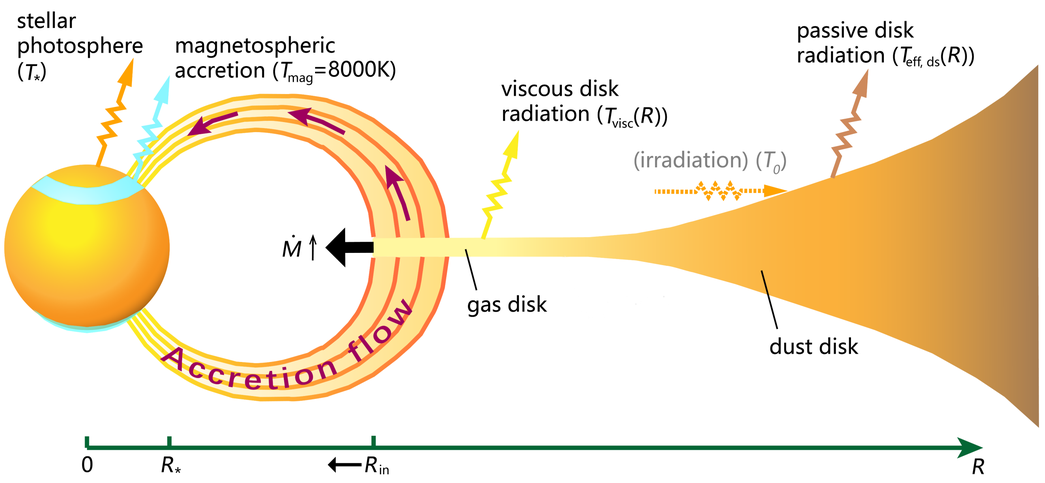
Abstract

FU Ori type objects (FUors) are decades-long outbursts of accretion onto young stars that are strong enough to viscously heat disks so that the disk outshines the central star. We construct models for FUor objects by calculating emission components from a steady-state viscous accretion disk, a passively-heated dusty disk, magnetospheric accretion columns, and the stellar photosphere. Mainly determined by the accretion rate $\dot{M}$ and the stellar mass M_*, the brightness ratio between the viscous disk and the stellar photosphere, η, provides an important guide for identifying viscous accretion disks, with $\eta = 1$ and $\eta = 5$ marking turning points in near-infrared diagnostics. These turning points indicate the emergence and complete development of FUor characteristics, including the location in color-magnitude diagrams as well as strong CO absorption, weak metallic absorption, and a triangular spectral continuum shape in the H-band.

1. FUors: viscously heated disks around young stars

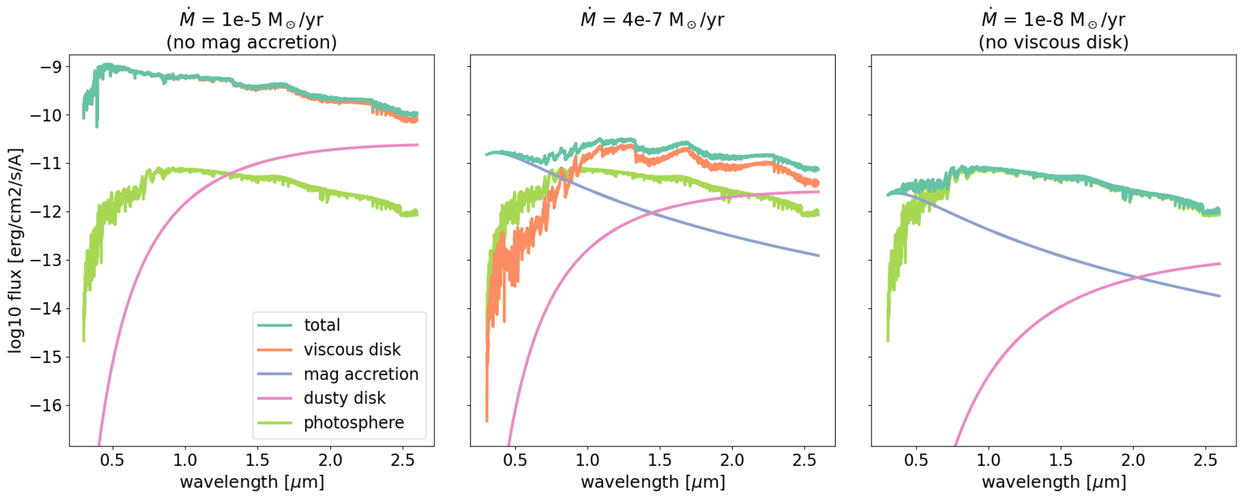
- FU Ori type objects (FUors) have very large accretion rates ($\dot{M}\sim10^{-5}$ to $10^{-4}\mathrm{M}_\odot/\mathrm{yr}$). Such outbursts might inform stellar mass assembly.
- Some objects with FUor-like spectroscopic features have modest luminosity.
- We consider multiple emission components that are likely important for low-luminosity FUors across a wide range of M_* and $\dot{M}$.



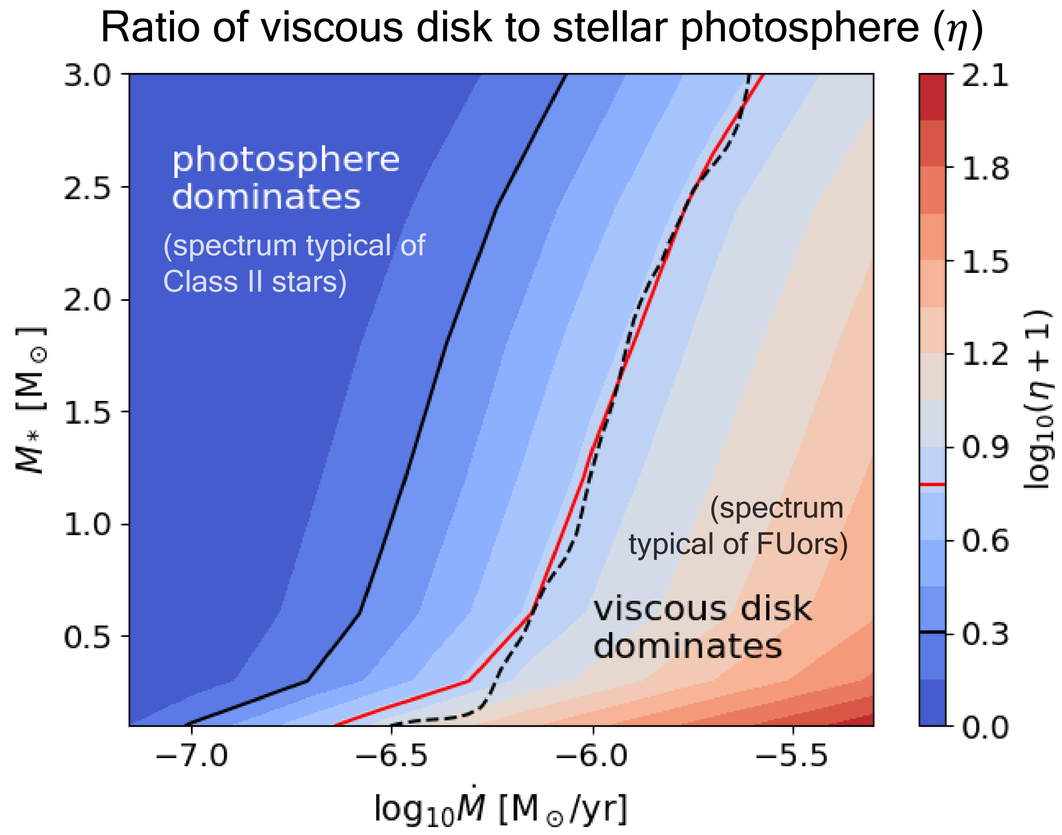
Cartoon of a star-disk system adapted from Hartmann et al. (2016). Four emission components are considered here: a steady-state viscous accretion disk, a passively-heated dusty disk, magnetospheric accretion columns, and the stellar photosphere. Large $\dot{M}$ tends to push the inner disk radius R_{in} inwards.

2. Optical and near-IR spectra of multiple components

- Rapid accretion ($10^{-5}\mathrm{M}_\odot/\mathrm{yr}$): dominated by viscous disk emission
- Moderate accretion ($4\times10^{-7}\mathrm{M}_\odot/\mathrm{yr}$): mainly the viscous disk and the stellar photosphere
- Slow accretion ($10^{-8}\mathrm{M}_\odot/\mathrm{yr}$): dominated by stellar photosphere



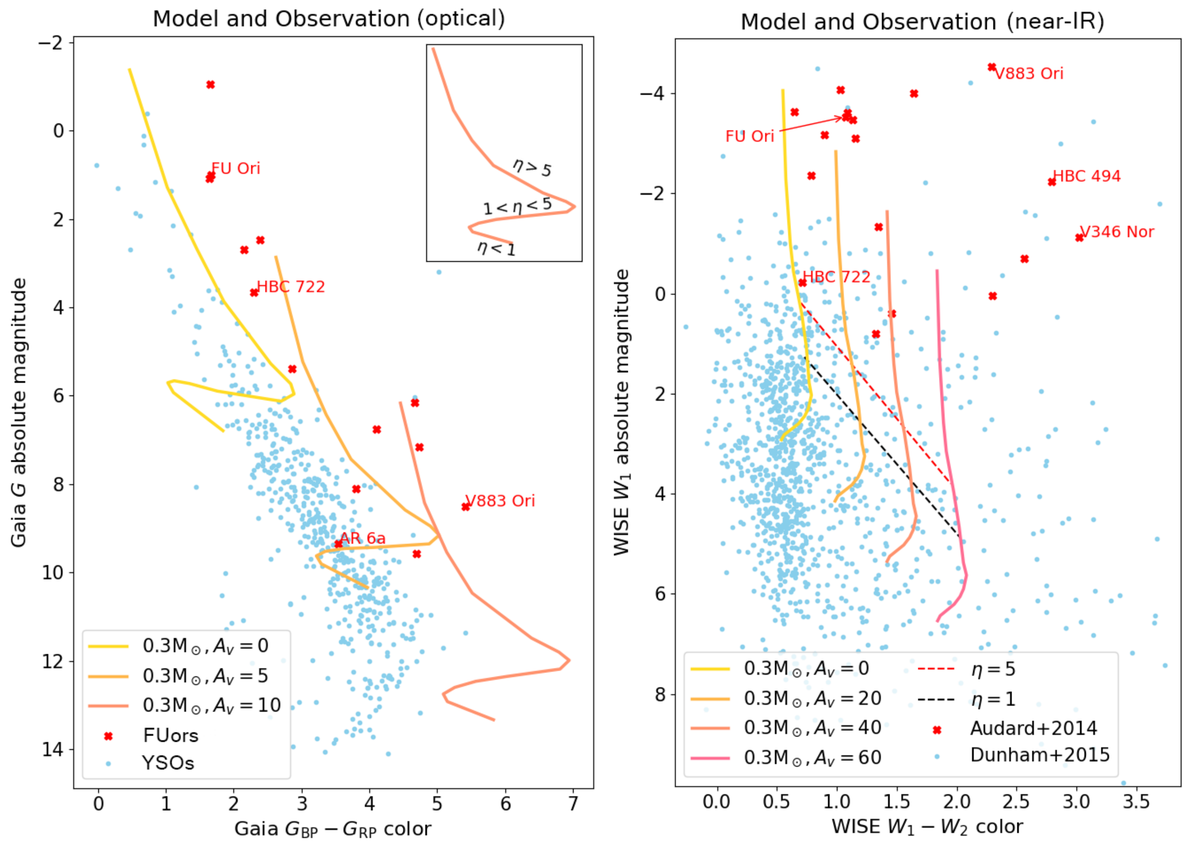
3. Viscous disk vs photosphere: what young stars become FUors?



η: near-IR brightness ratio of the viscous disk to the stellar photosphere. η depends on both $\dot{M}$ and M_*. Black solid line: $\eta = 1$. Red solid line: $\eta = 5$, which coincides with where the disk inner radius reaches the star (black dashed line).

4. FUors in color-magnitude diagrams

- Model: three- (two-) fold curve in the optical (near-IR) as $\dot{M}$ increases
- Observation: red crosses are known FUors (Audard et al, 2014), blue dots are more general young stellar objects (YSOs, Dunham et al., 2015)
- Most FUors agree with the highest model curve segment, while YSOs typically have $\eta \lesssim 1$
- Guidance for searching for FUors: look at where $\eta \gtrsim 1$
- Other FUor characteristics: CO and metallic absorption lines, triangular SED shape in the H-band (handout)



Take-home message:

- Viscously heated disk & stellar photosphere can be important for FUors of various M_* and $\dot{M}$
- Relative contribution of the two (η) determines spectral characteristics of FUors
- η provides guidance for searches for FUors

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