Finding YSOs in GLIMPSE

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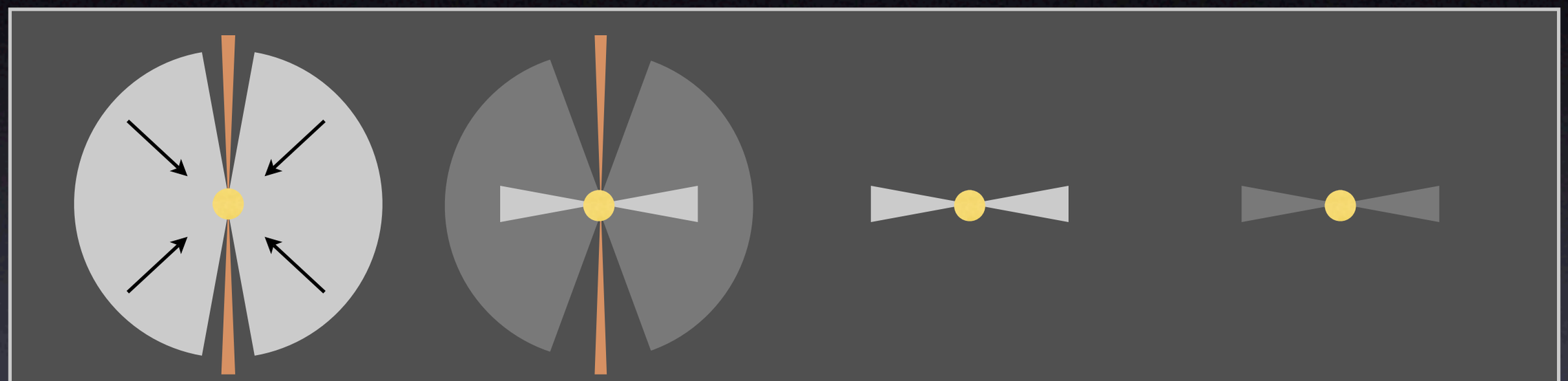
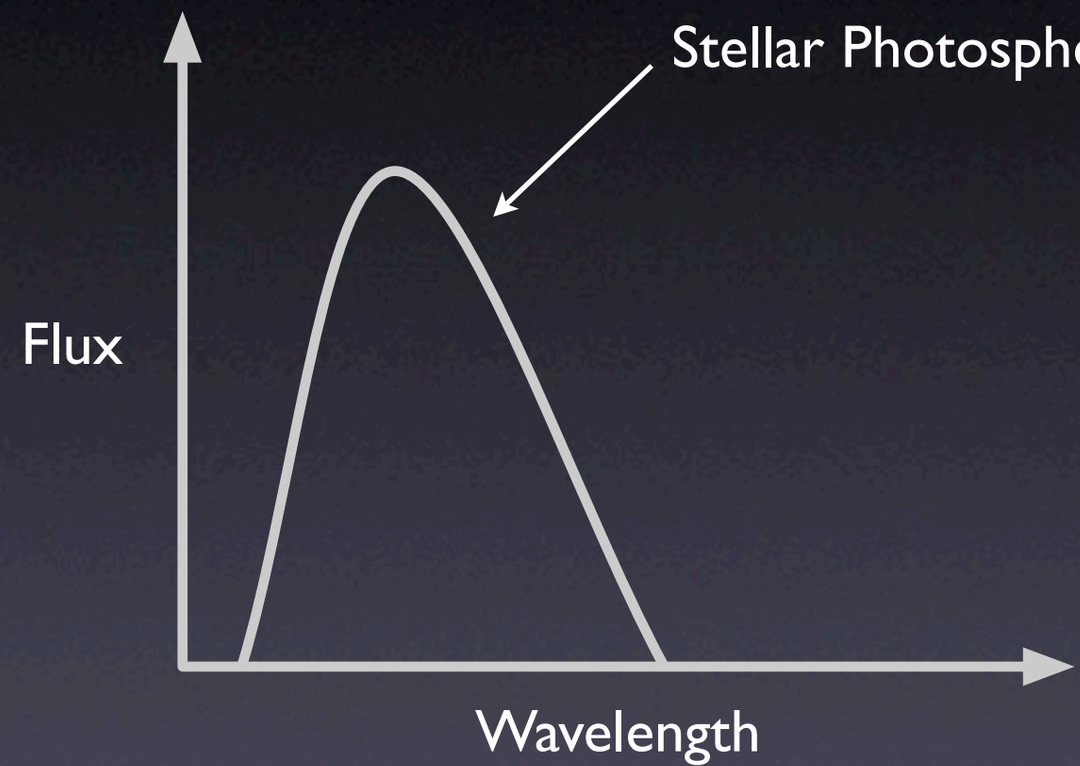
Low-mass star formation paradigm

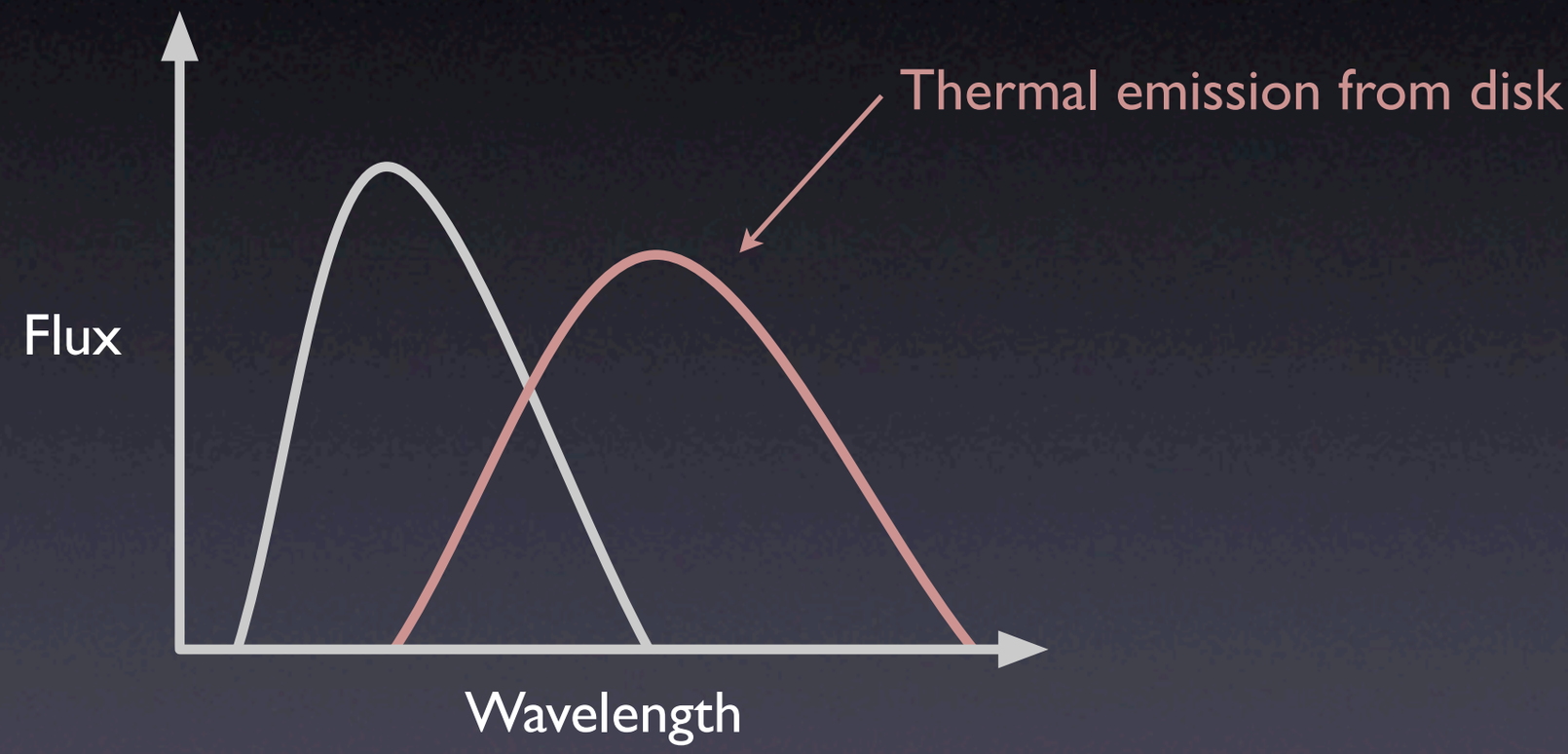


Class 0	Class I	Class II	Class III
$t \sim 10^4 \mathrm{yr}$	$t \sim 10^5 \mathrm{yr}$	$t \sim 10^6 \mathrm{yr}$	$t \sim 10^7 \mathrm{yr}$
$R_{\mathrm{env}} \sim 10^4 \mathrm{AU}$	$R_{\mathrm{env}} \sim 10^3 \mathrm{AU}$	$R_{\mathrm{disk}} \sim 100 \mathrm{AU}$	

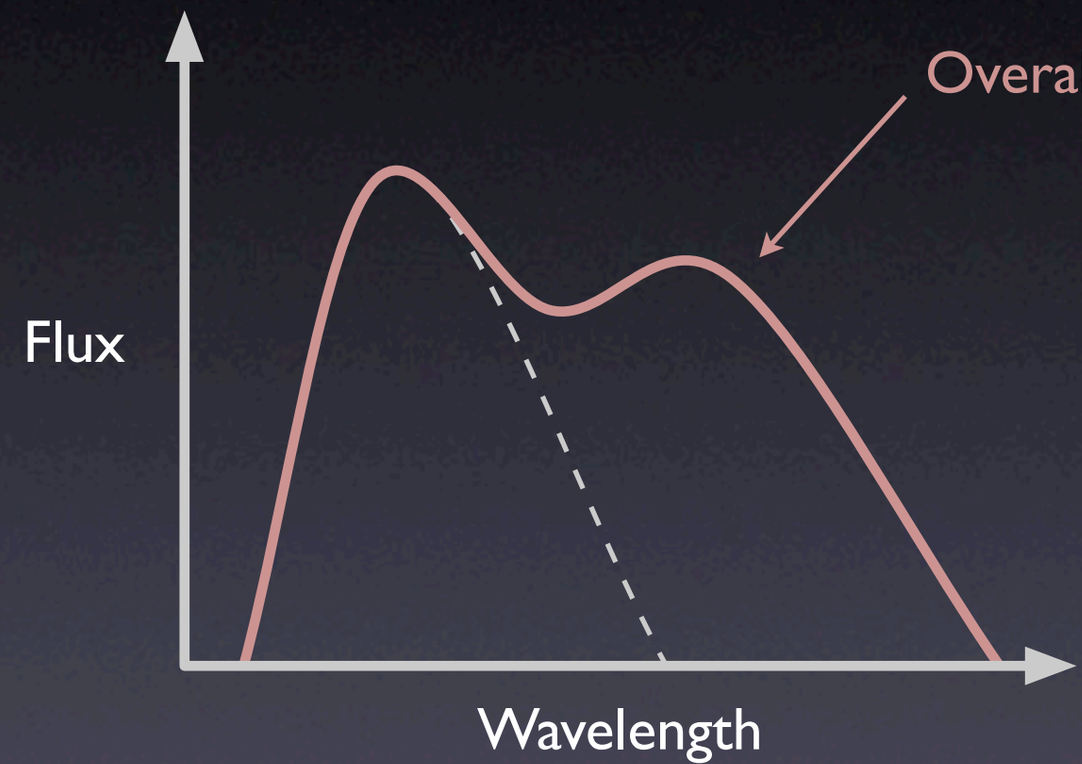
Example of a YSO SED



Example of a YSO SED



Example of a YSO SED



IRAC bands [4] (R), [2] (G), [3] (B)

MIPS 24μ (R), IRAC bands [4] (G), [1] (B)

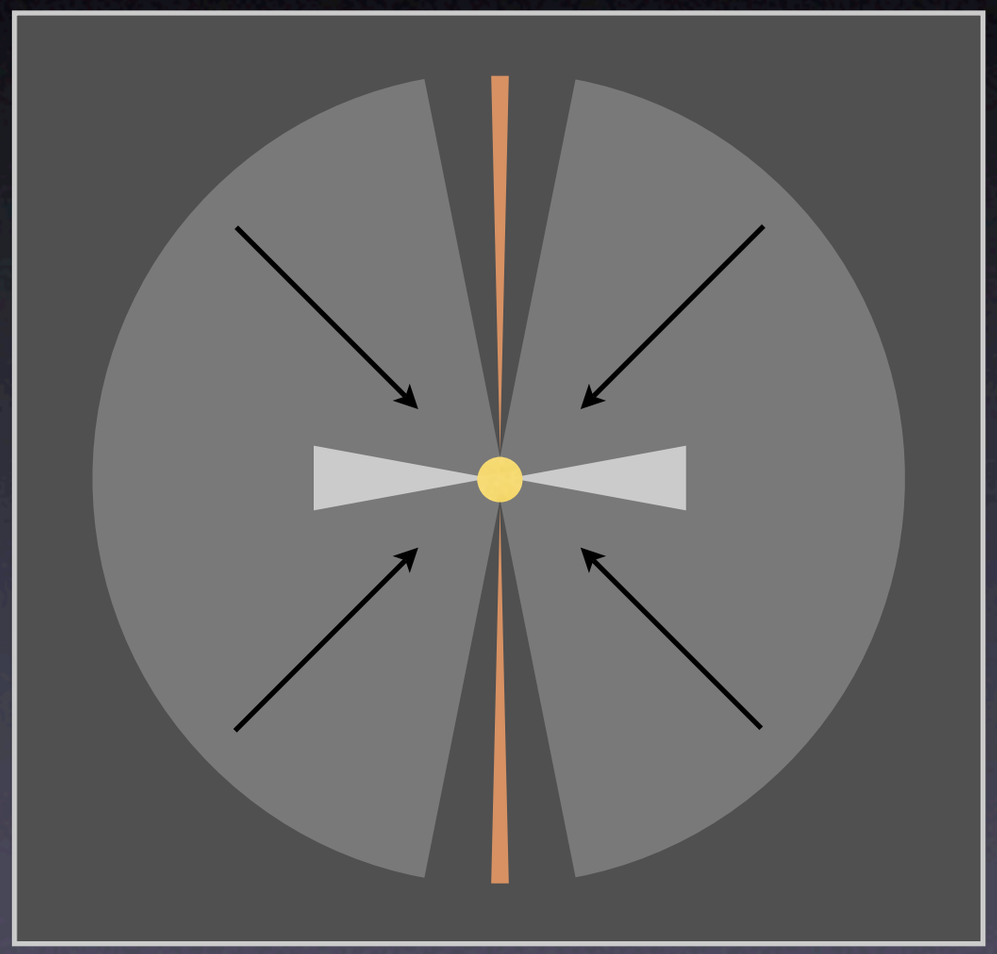
Predicting colors of YSOs

- Use radiation transfer models to predict how YSOs at various evolutionary stages should look.
- We have done this by producing synthetic SEDs for 20,000 different combinations of physical parameters and 10 inclinations
- These are available online

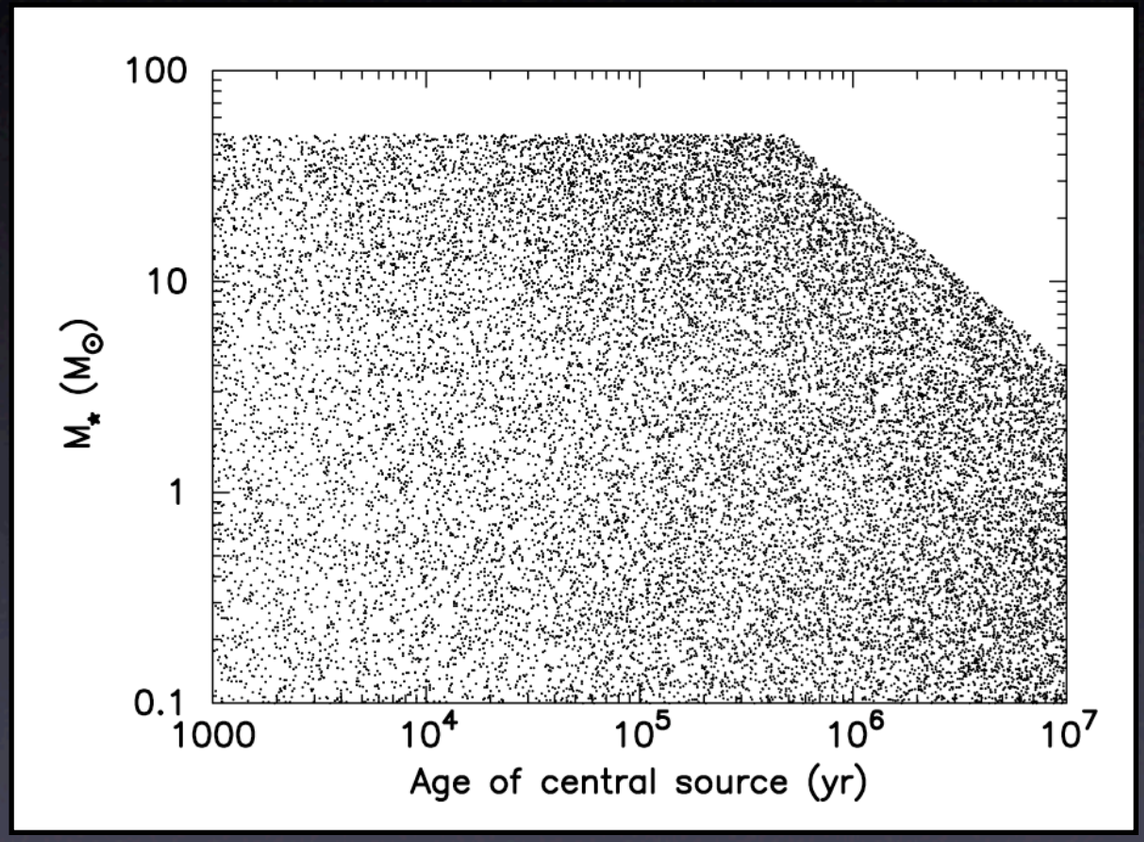
The new set of models

- Use Monte-Carlo radiation transfer models (Whitney et al.)
- Span a wide range of stellar masses & evolutionary states
- Allow for uncertainties in evolutionary stages by allowing ranges of parameters
- Sample randomly within these ranges

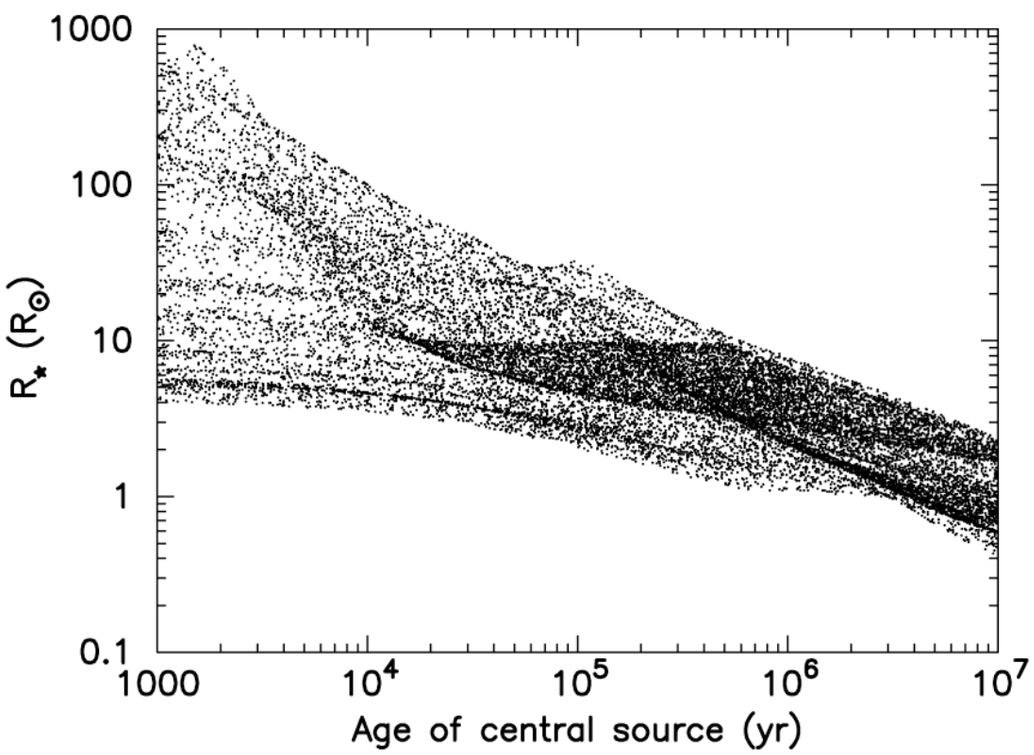
The general YSO model

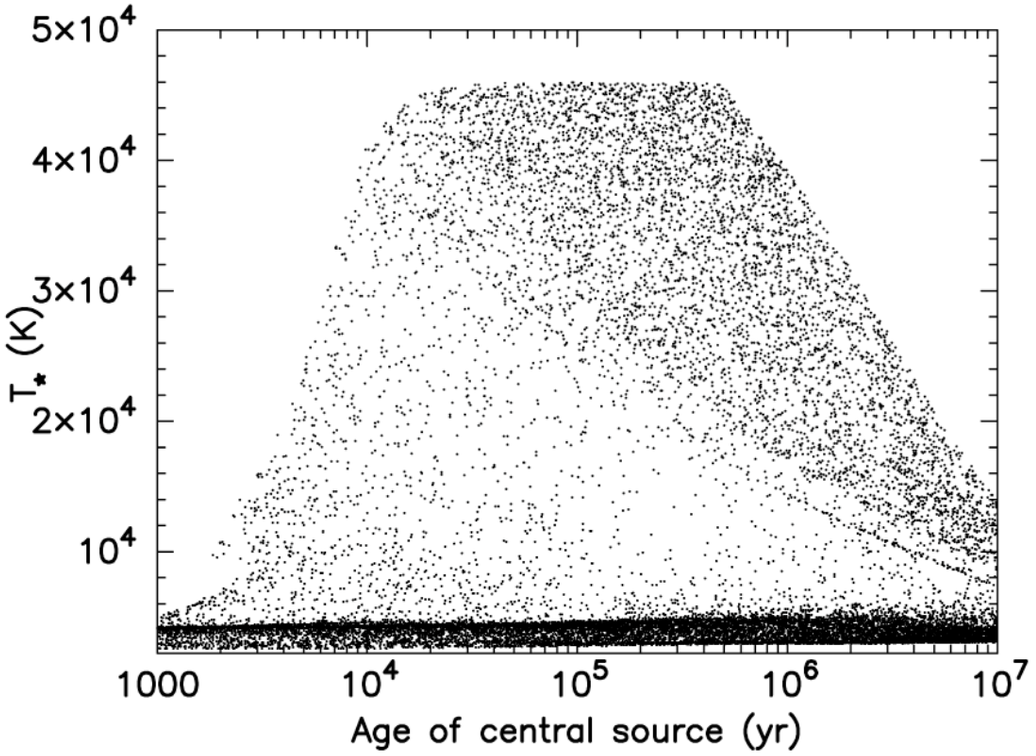


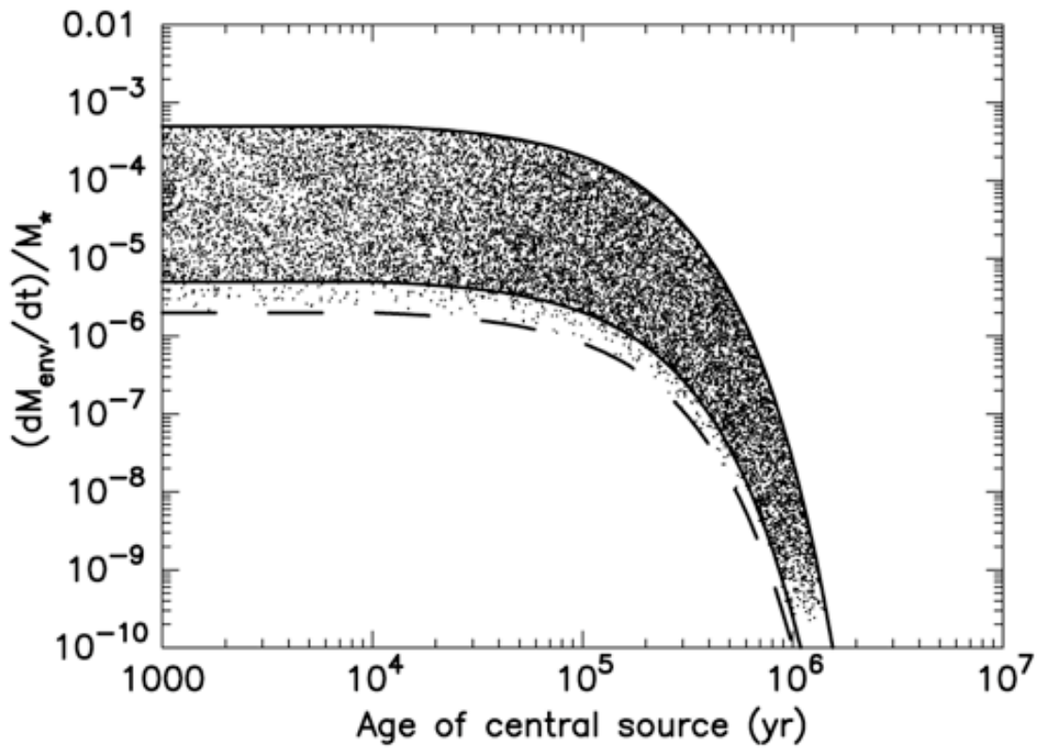
Sampling the model parameters...

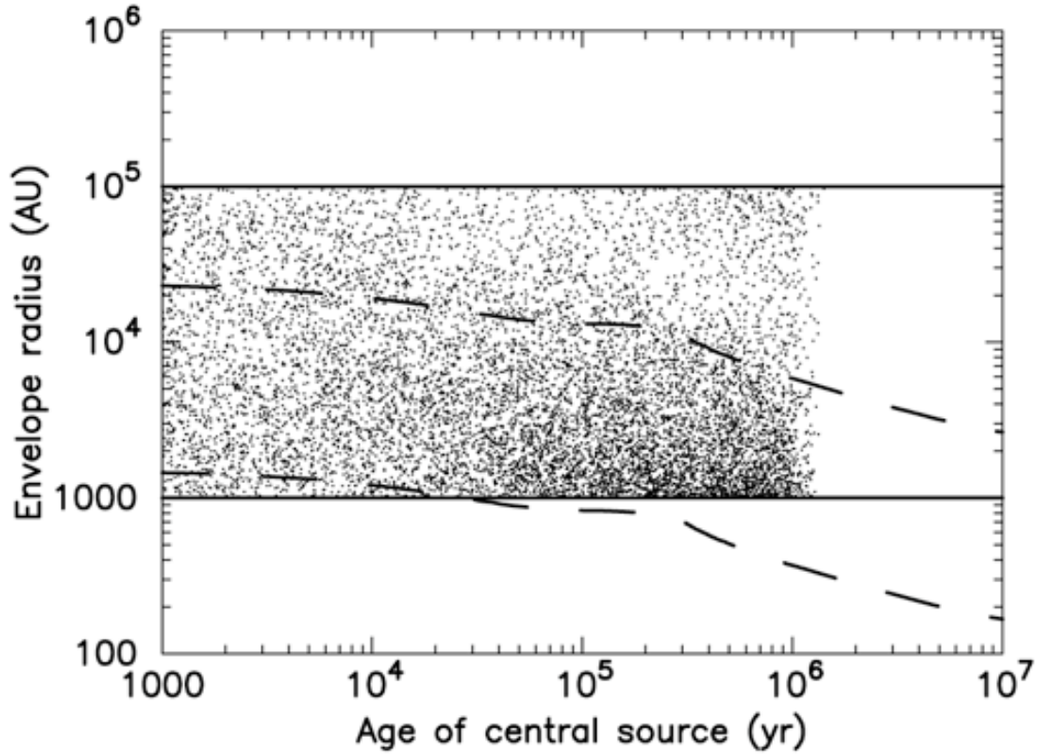


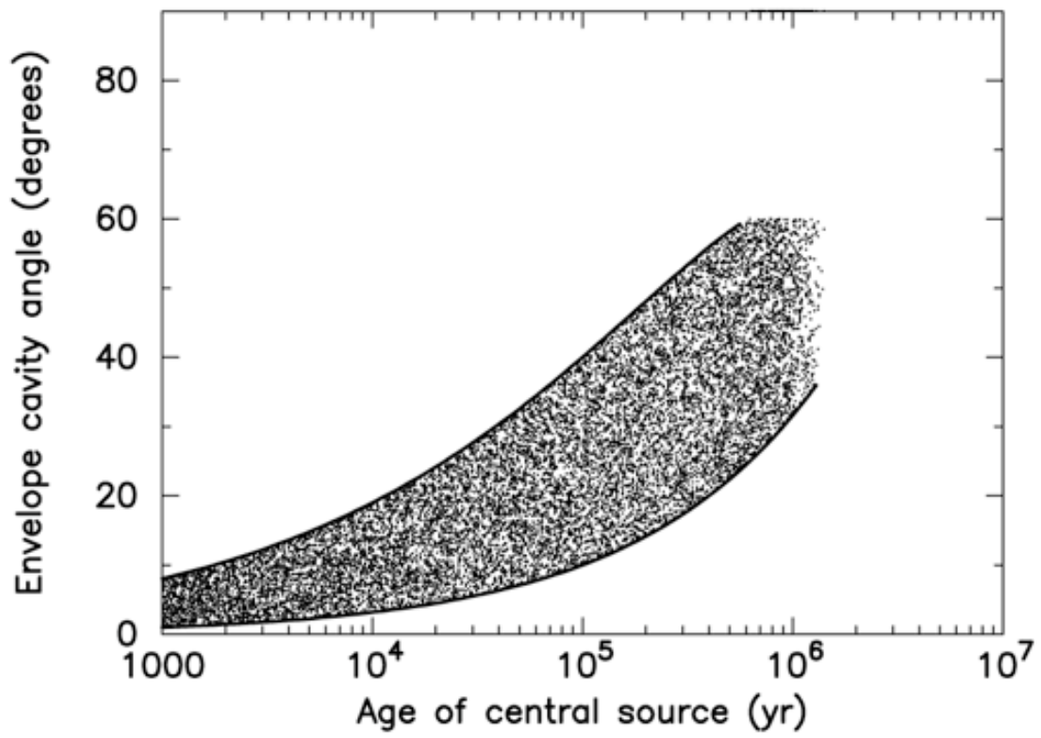
Sampling the model parameters...

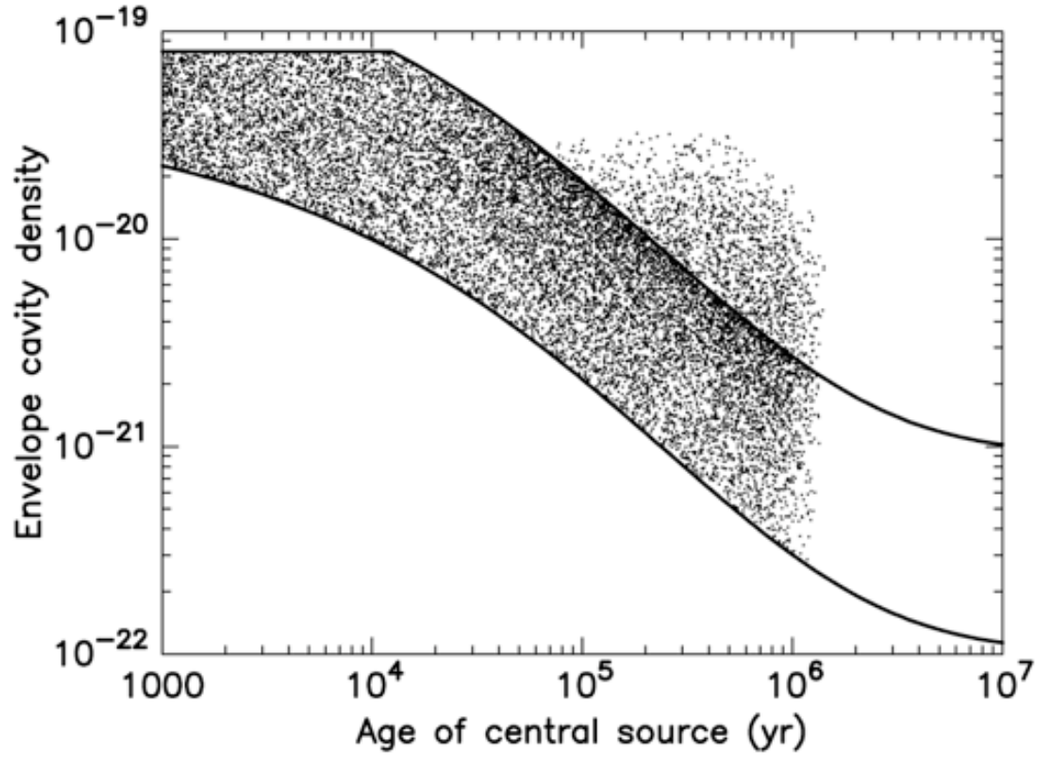


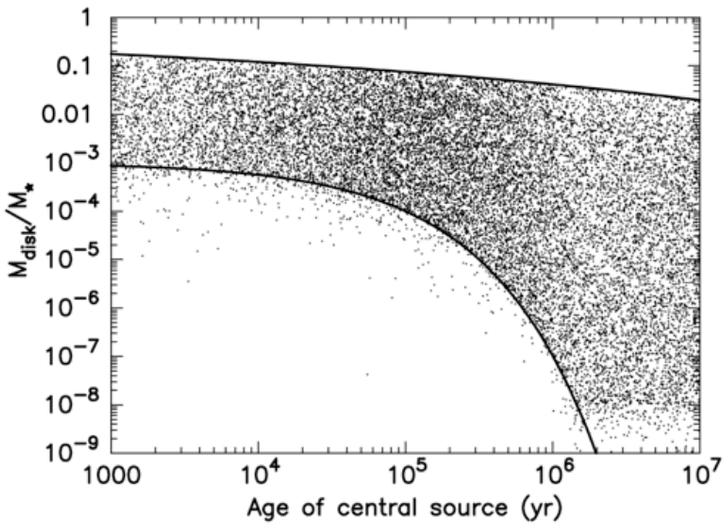


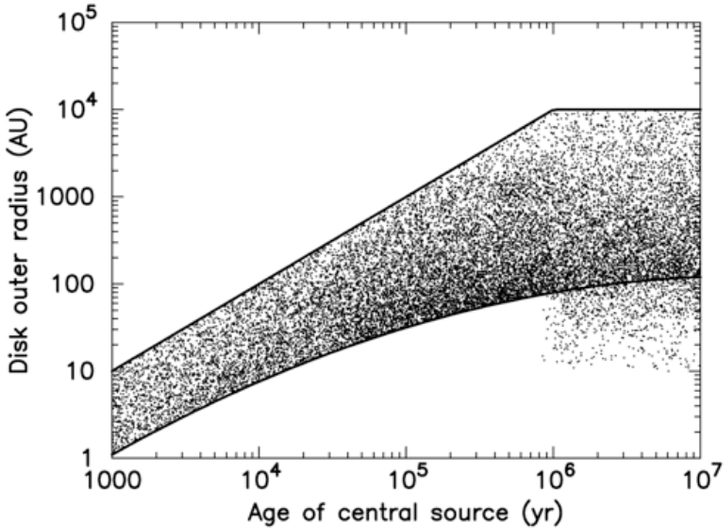

0.01
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
$(dM_{env}/dt)/M_*$
1000
10^4
10^5
10^6
10^7
Age of central source (yr)

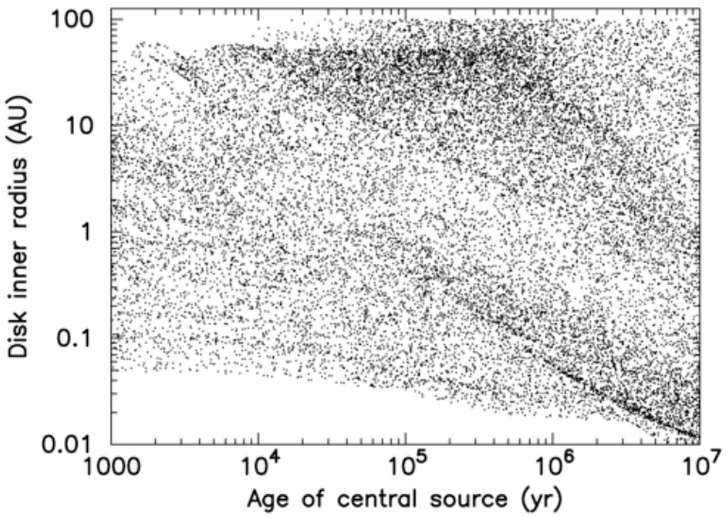

10^6
10^5
10^4
1000
100
Envelope radius (AU)
1000
10^4
10^5
10^6
10^7
Age of central source (yr)

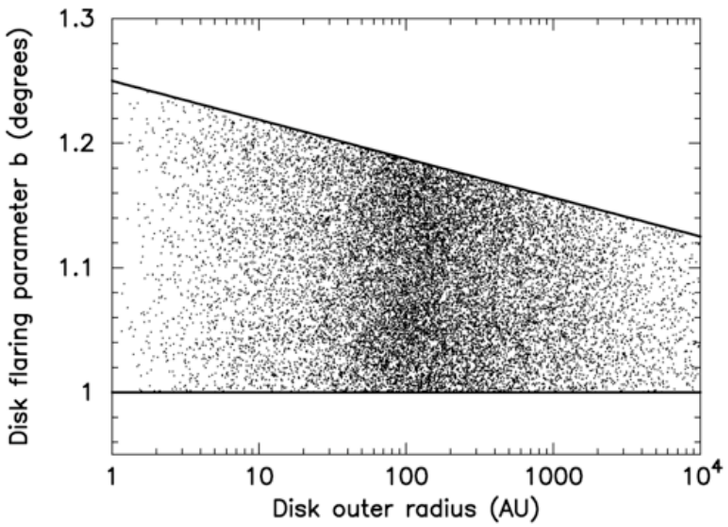

80
60
40
20
0
Envelope cavity angle (degrees)
1000
10^4
10^5
10^6
10^7
Age of central source (yr)

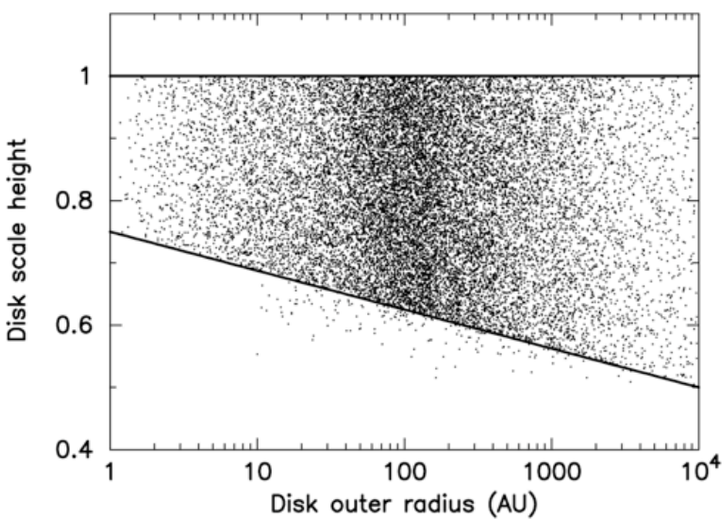

10^{-19}
10^{-20}
10^{-21}
10^{-22}
Envelope cavity density
1000
10^4
10^5
10^6
10^7
Age of central source (yr)

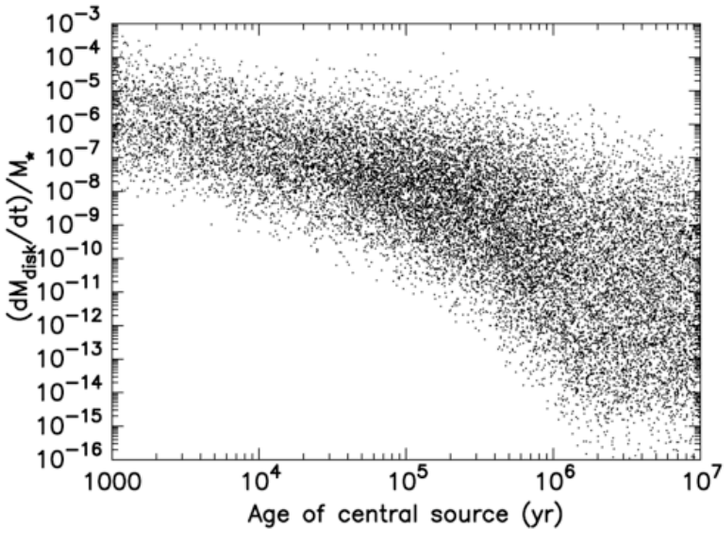

M_{disk}/M_*
1
0.1
0.01
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
1000
10^4
10^5
10^6
10^7
Age of central source (yr)


Disk outer radius (AU)
10^5
10^4
1000
100
10
1
1000
10^4
10^5
10^6
10^7
Age of central source (yr)

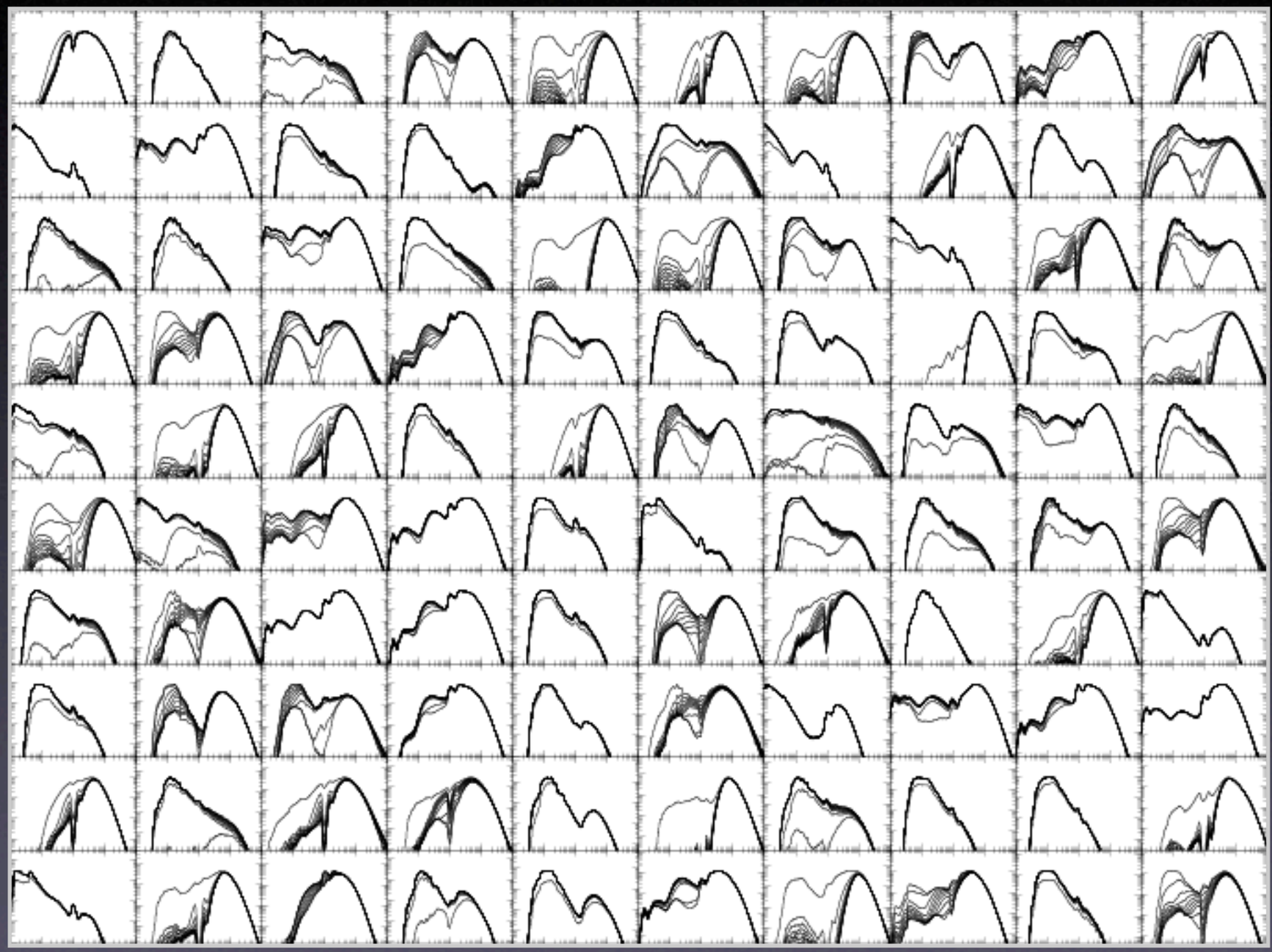

Disk inner radius (AU)
100
10
1
0.1
0.01
1000
10^4
10^5
10^6
10^7
Age of central source (yr)


Disk flaring parameter b (degrees)
1.3
1.2
1.1
1
1
10
100
1000
10^4
Disk outer radius (AU)


Disk scale height
1
0.8
0.6
0.4
1
10
100
1000
10^4
Disk outer radius (AU)

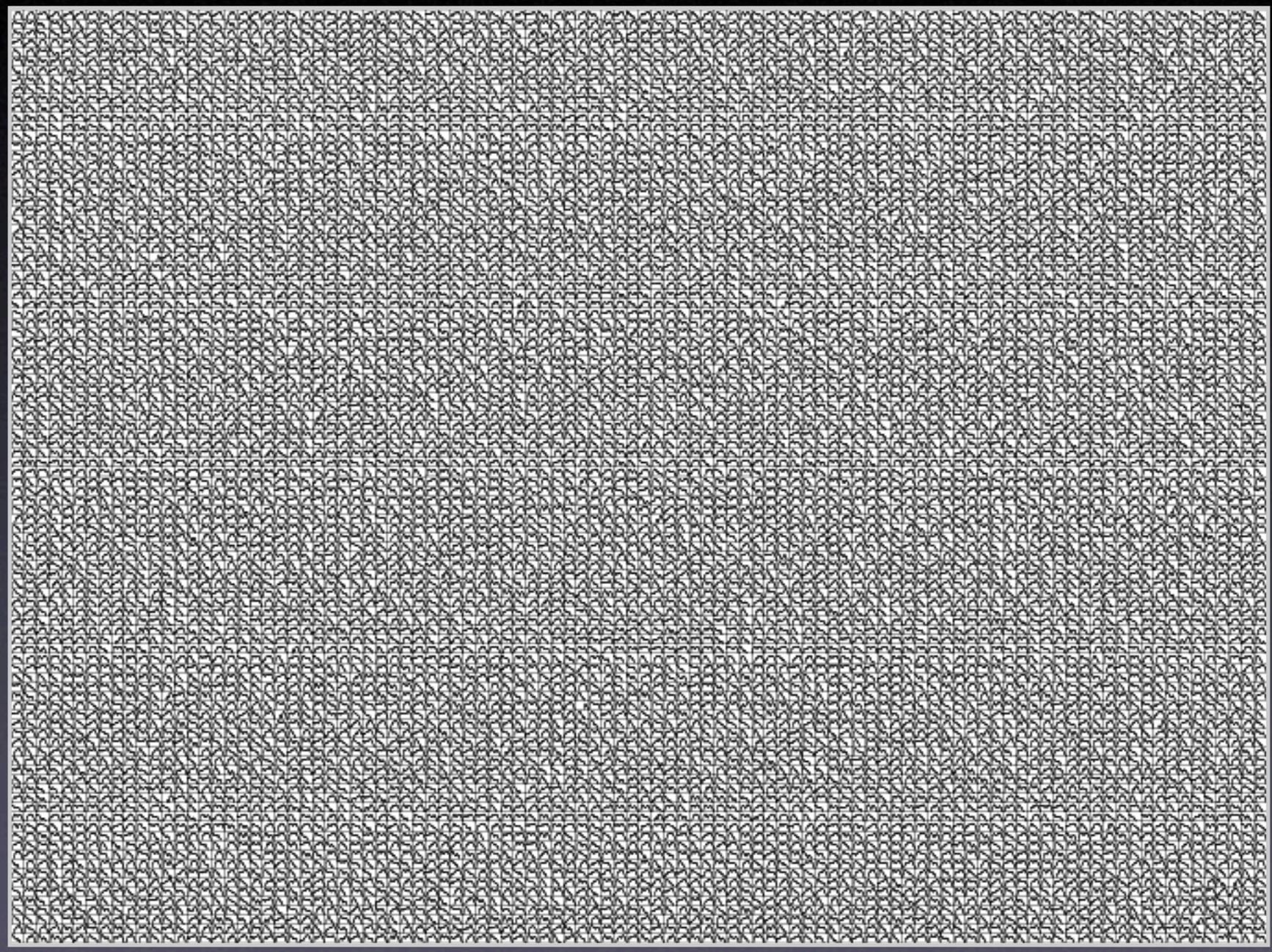

$(dM_{disk}/dt)/M_*$
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
1000
10^4
10^5
10^6
10^7
Age of central source (yr)

200,000 models at a glance...



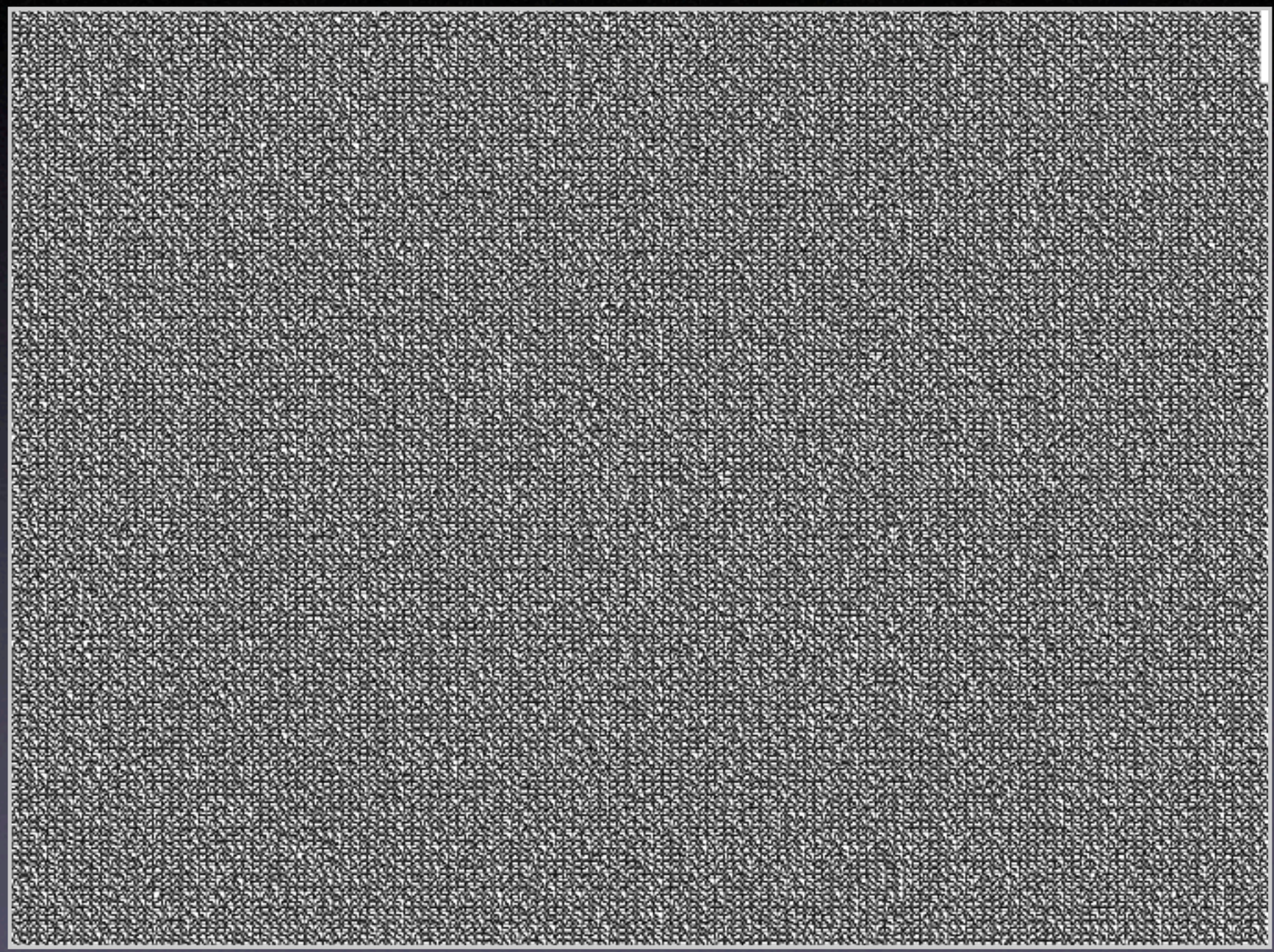
1000 SEDs

200,000 models at a glance...



100,000 SEDs

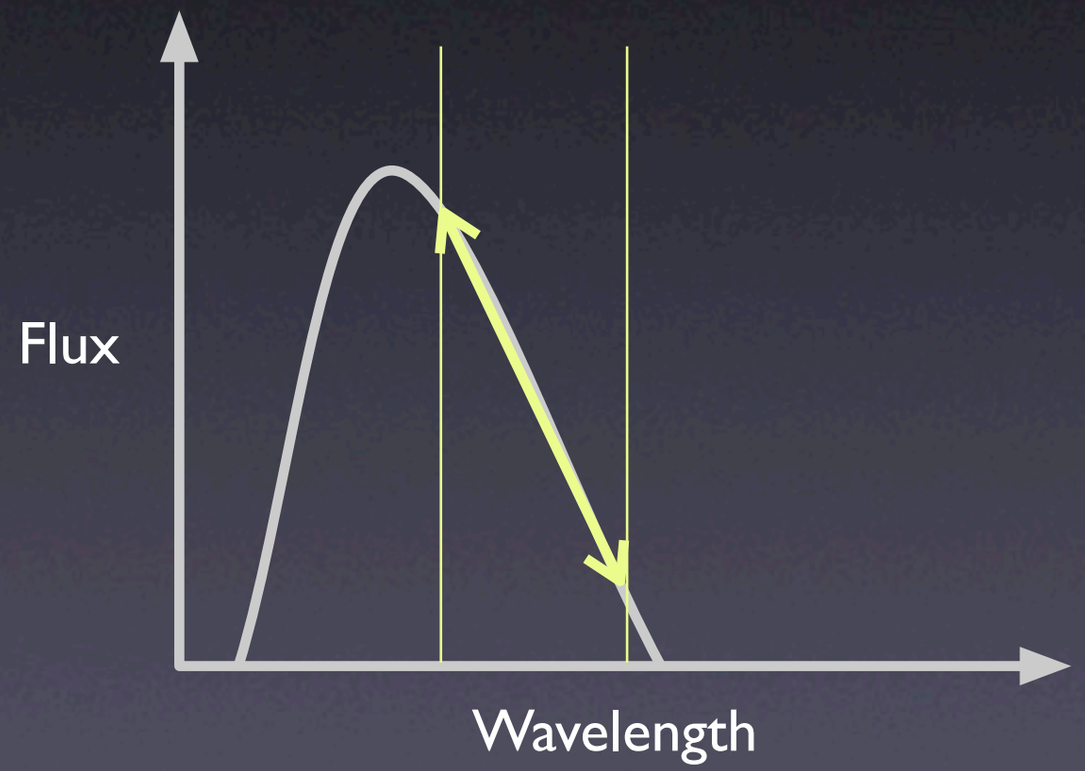
200,000 models at a glance...

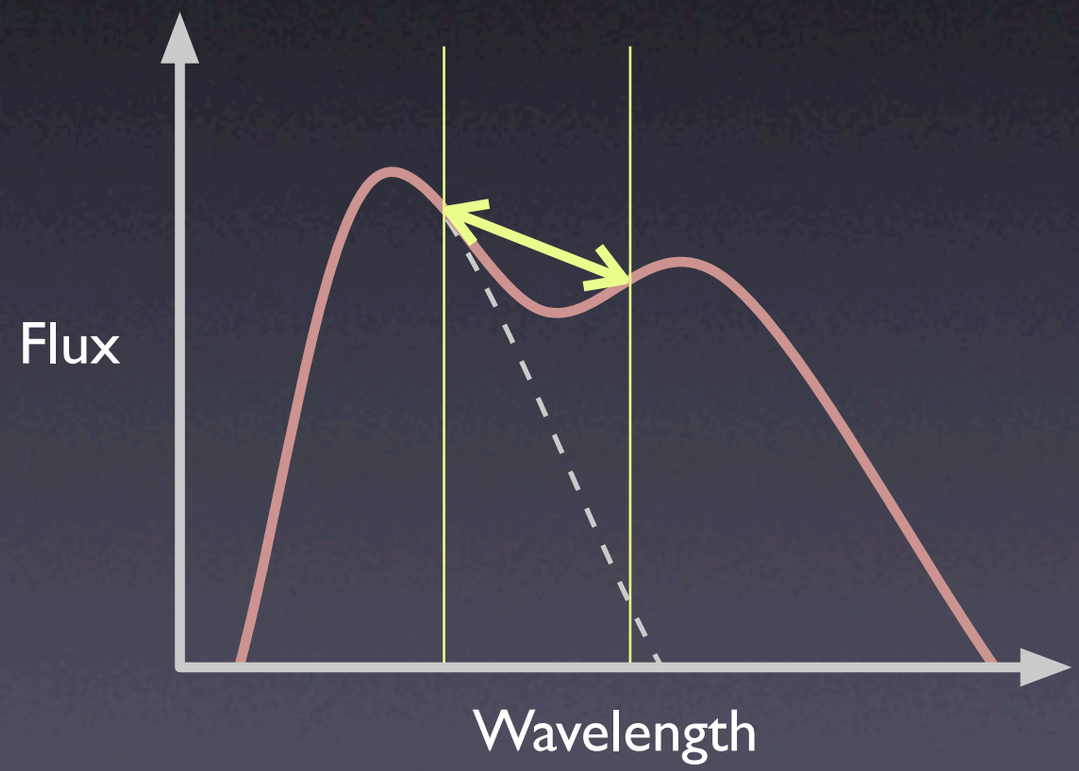


200,000 SEDs

Spectral indices

- Easiest way to quantify observations of a YSO: define a *spectral index* between two wavelengths





Spectral indices

- Defined as $\alpha = \dfrac{d \log \lambda F_\lambda}{d \log \lambda}$
- Traditionally three ‘Classes’ of objects:

$$\alpha > 0 \longrightarrow \text{Class I}$$

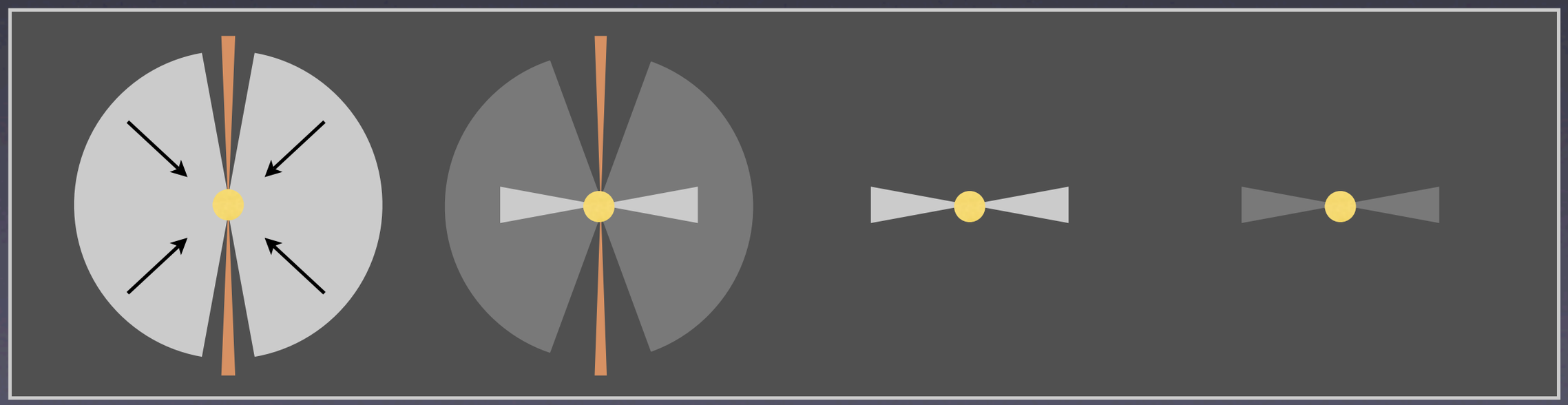
$$-2 < \alpha < 0 \longrightarrow \text{Class II}$$

$$-3 < \alpha < -2 \longrightarrow \text{Class III}$$

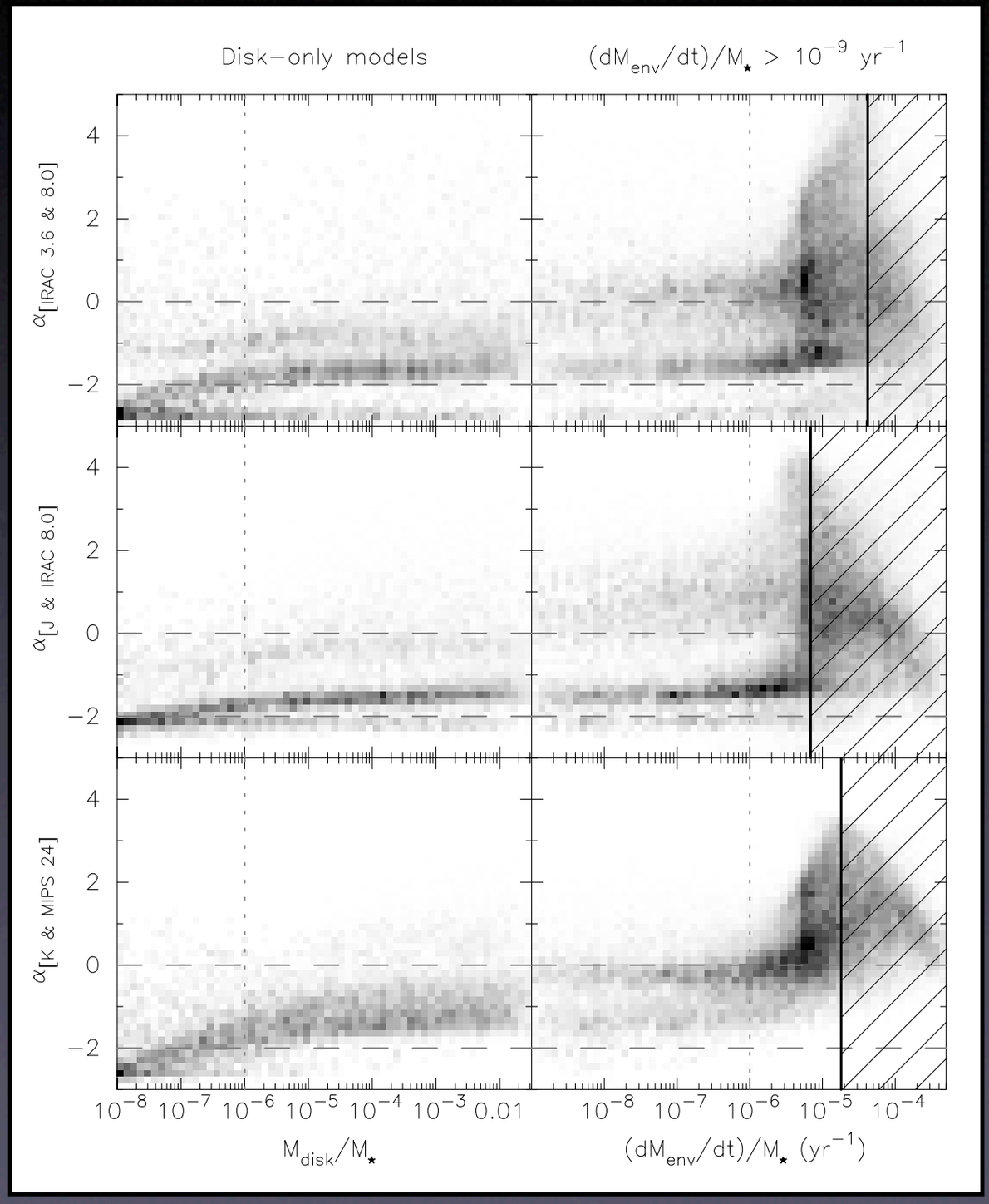
Spectral index vs YSO evolution?

$$\alpha = \frac{d \log \lambda F_\lambda}{d \log \lambda}$$

?



Spectral indices (predictions)

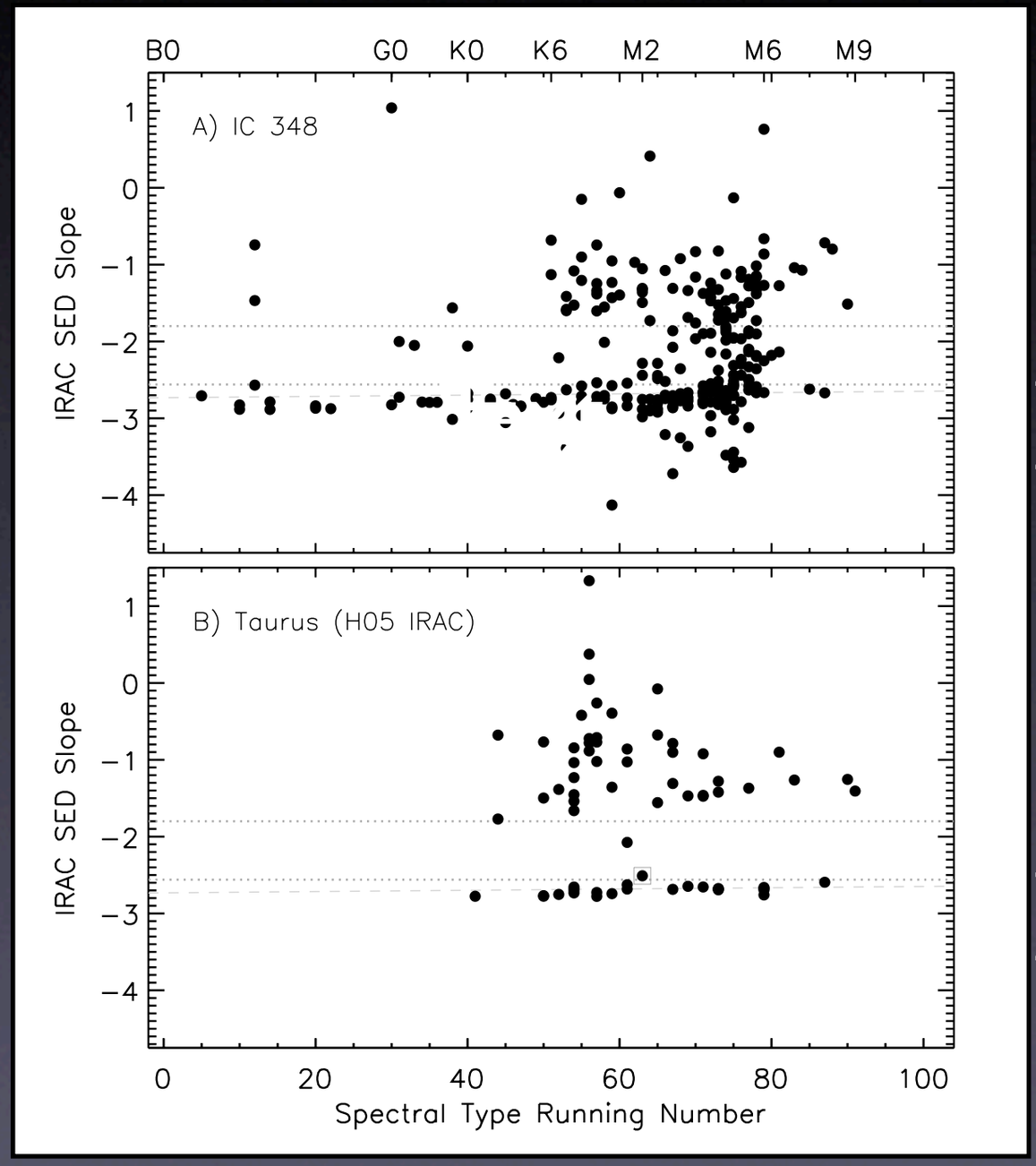


IRAC 3.6 to 8.0μm

J to IRAC 8.0μm

K to MIPS 24μm

Spectral indices (observations)

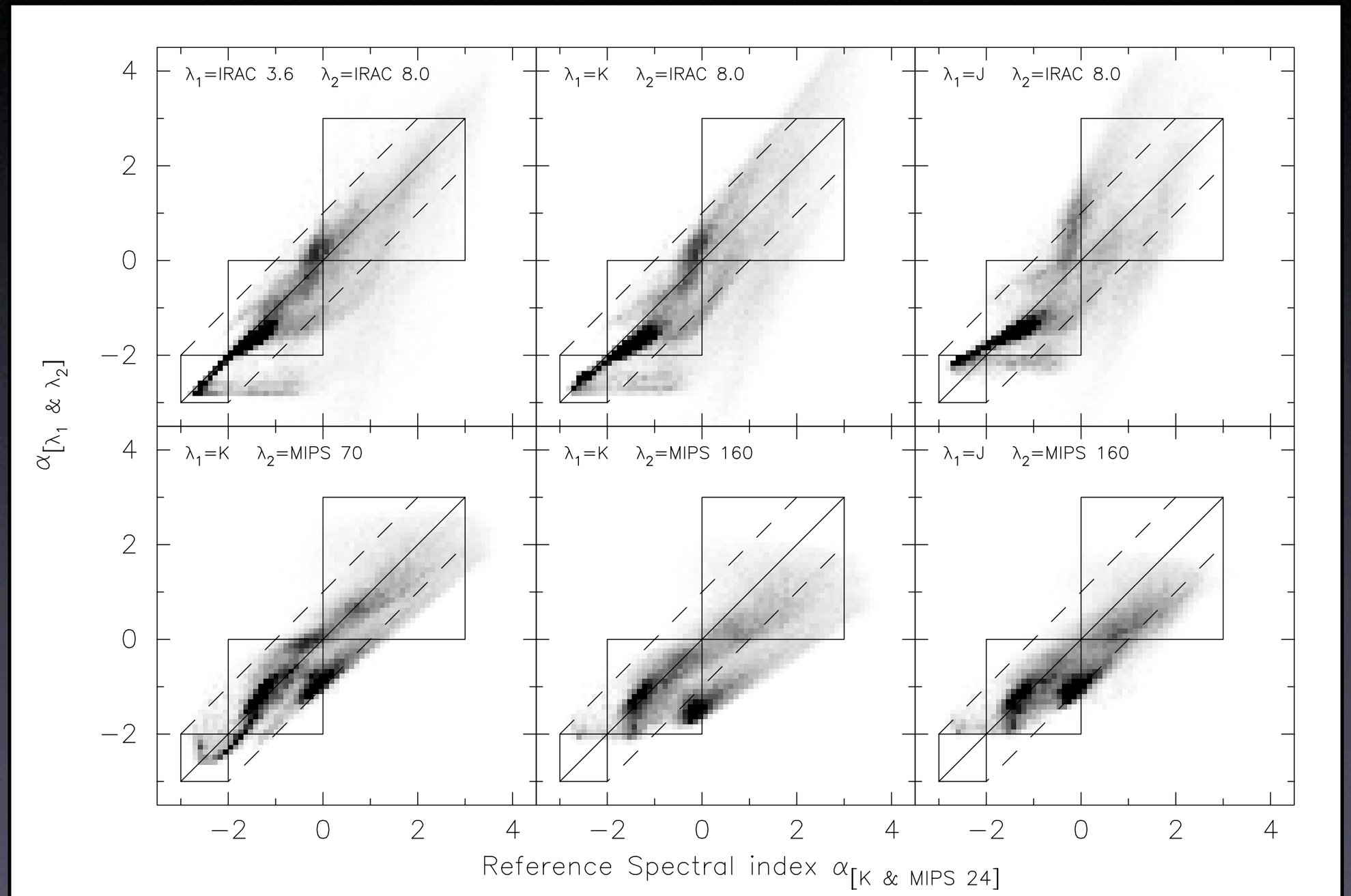


Lada et al. (2006)

Spectral index vs YSO evolution?

- 2-25μm spectral index is a decent (although not perfect) indicator of evolutionary stage.
- However, due to the small wavelength range, IRAC does not always correlate with evolutionary stage.

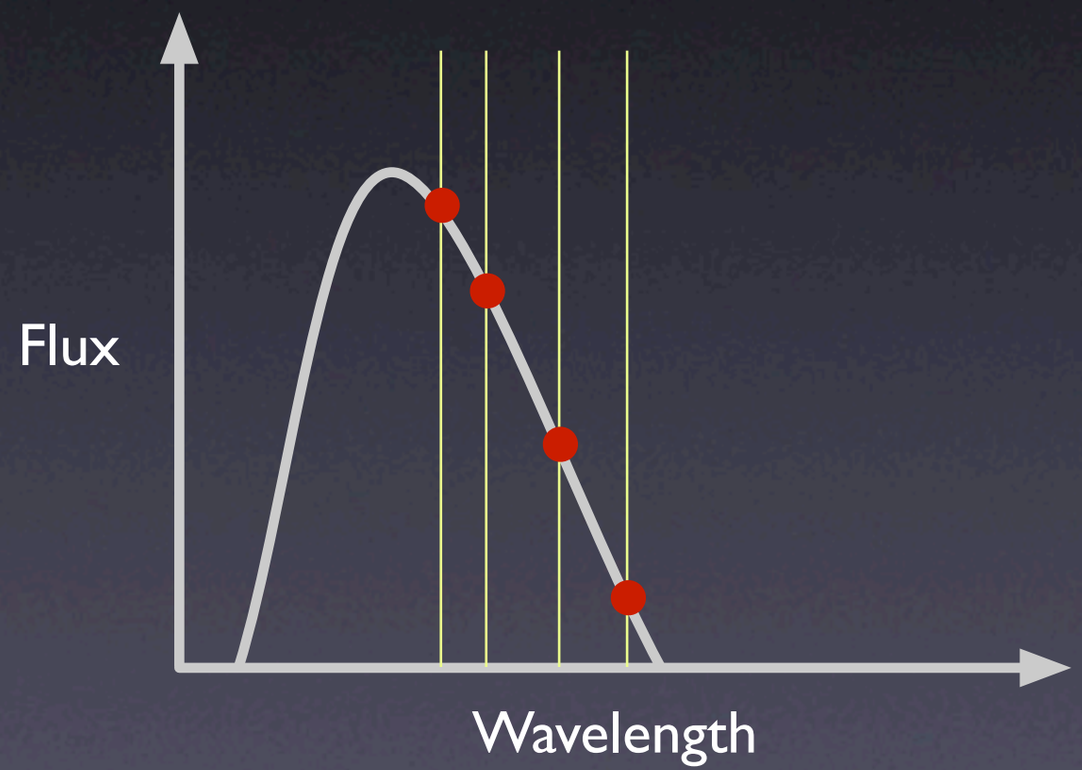
IRAC vs 2-25μm

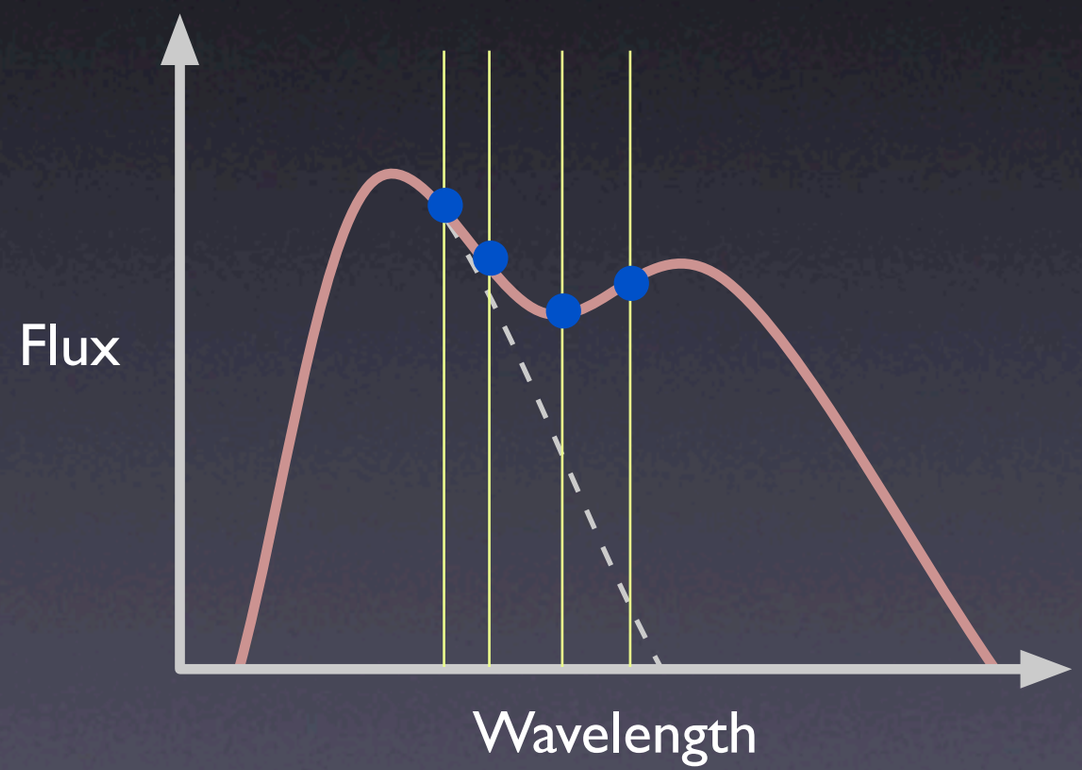


Robitaille et al. (2006) [accepted!]

Color-color plots

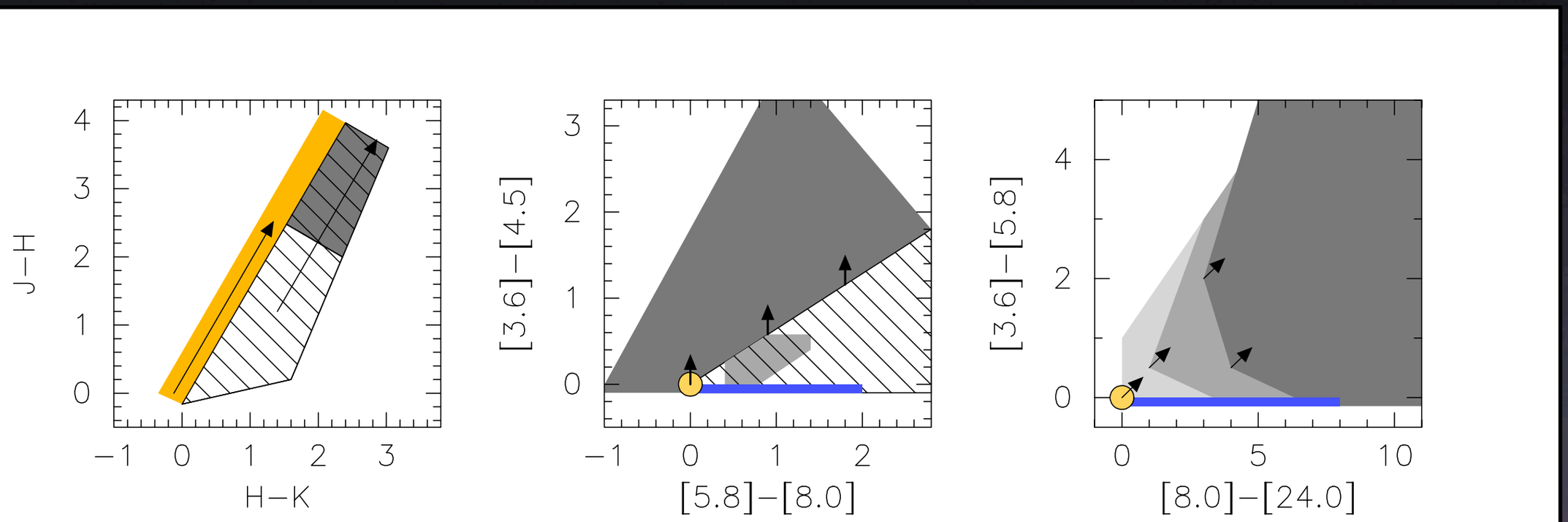
- Use three or four datapoints to define *colors*





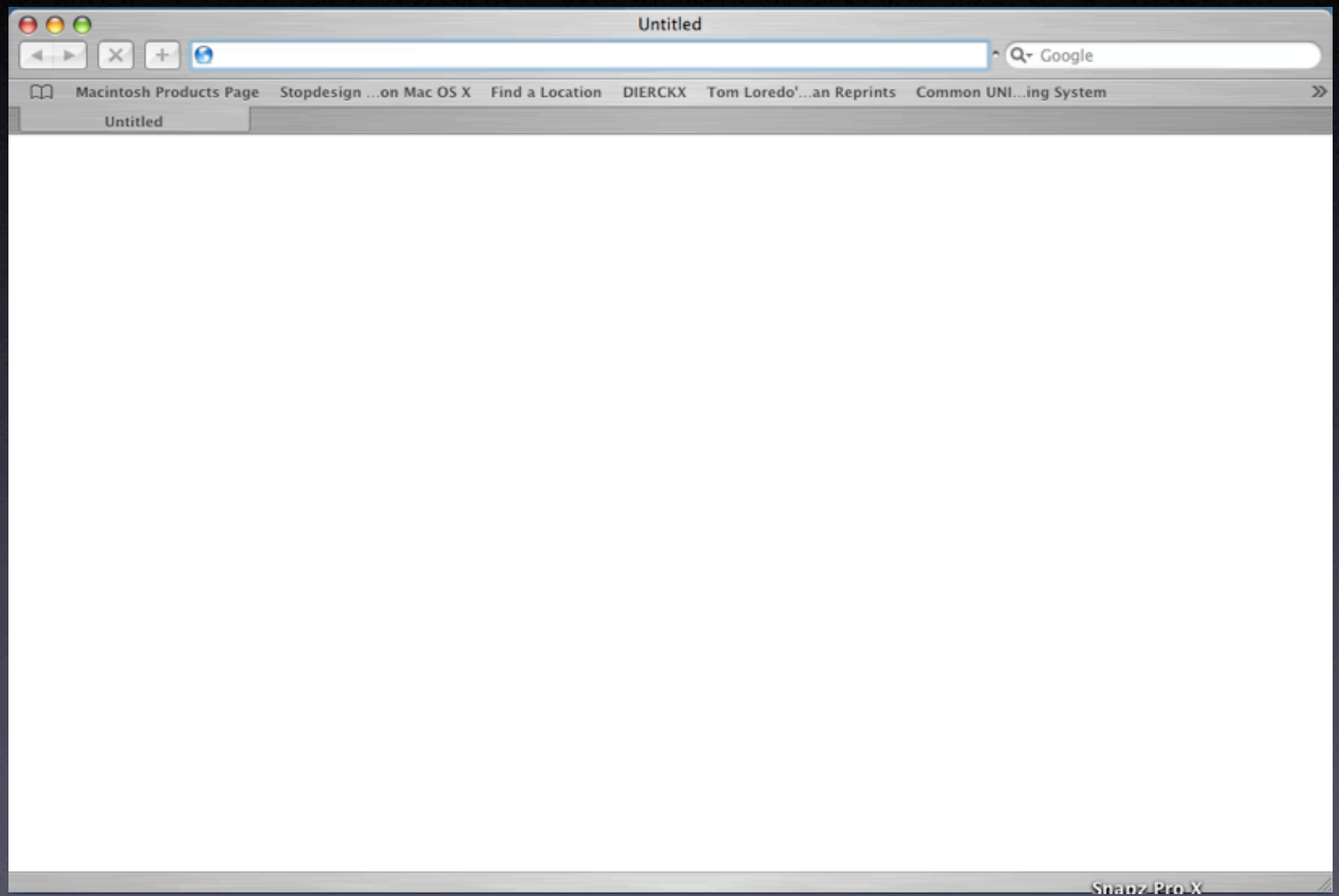
- Find magnitude at each of these points

YSOs in IRAC+MIPS color-color plots



Robitaille et al. (2006)

Available YSO model SEDs



Summary

- Can use spectral indices or color-color diagrams to find YSOs in GLIMPSE.
- MIPS 24μm is useful (even upper limits on fluxes).
- Synthetic SEDs for a large range of physical parameters are available online:

http://www.astro.wisc.edu/protostars