Modeling the SED of LkCa 15

Is this a reliable method for characterizing unresolved disks?

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Astronomical Observational Techniques and Instrumentation

Outline

- Motivation
- Introduction to YSOs
- Target: LkCa 15
- Observations
- Robitaille et al. 2007 – SED model
- Analysis – SED modeling
- Discussion – validity of model
- Conclusions

Motivation

Motivation

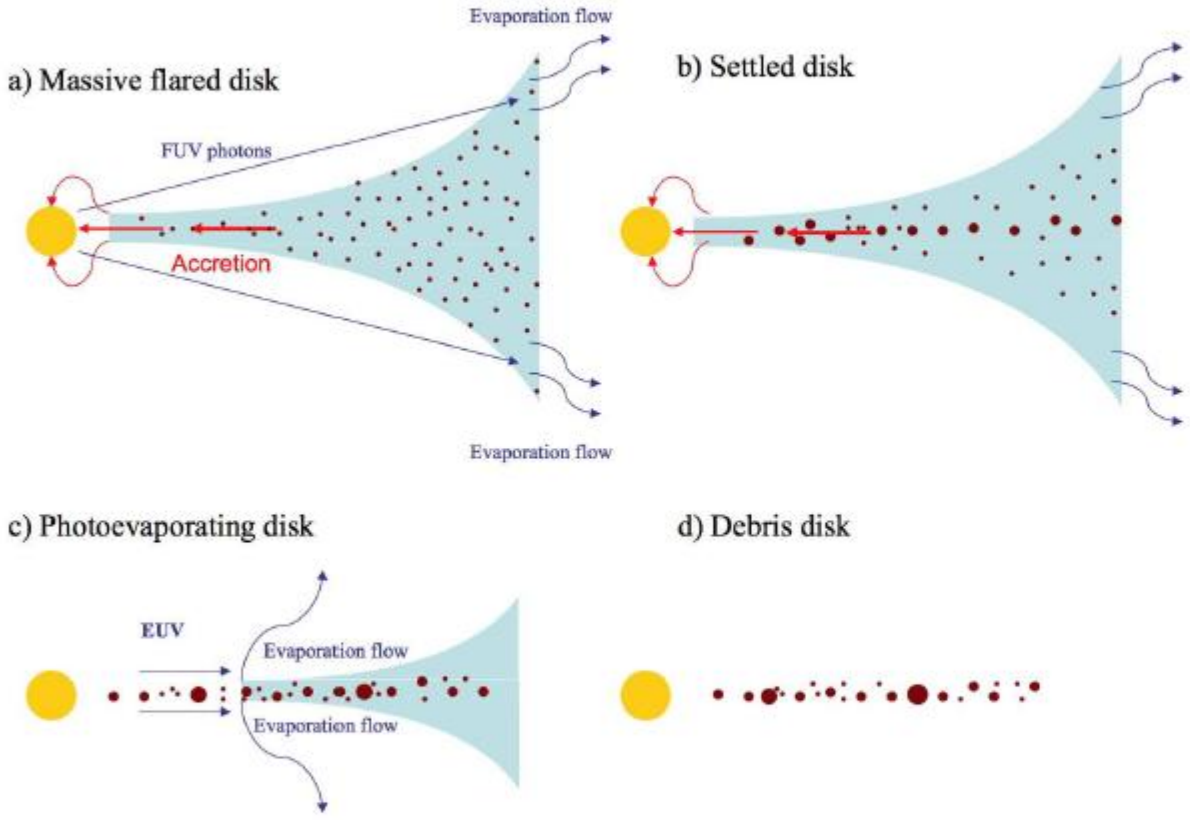
- What can we learn about YSOs from optical/IR observations?
- What can models of their SEDs tell us about the physical parameters of these systems?
- How reliable are these models and can they be used to determine properties of unresolved star/disk systems?

Introduction to YSOs

Classification of YSOs

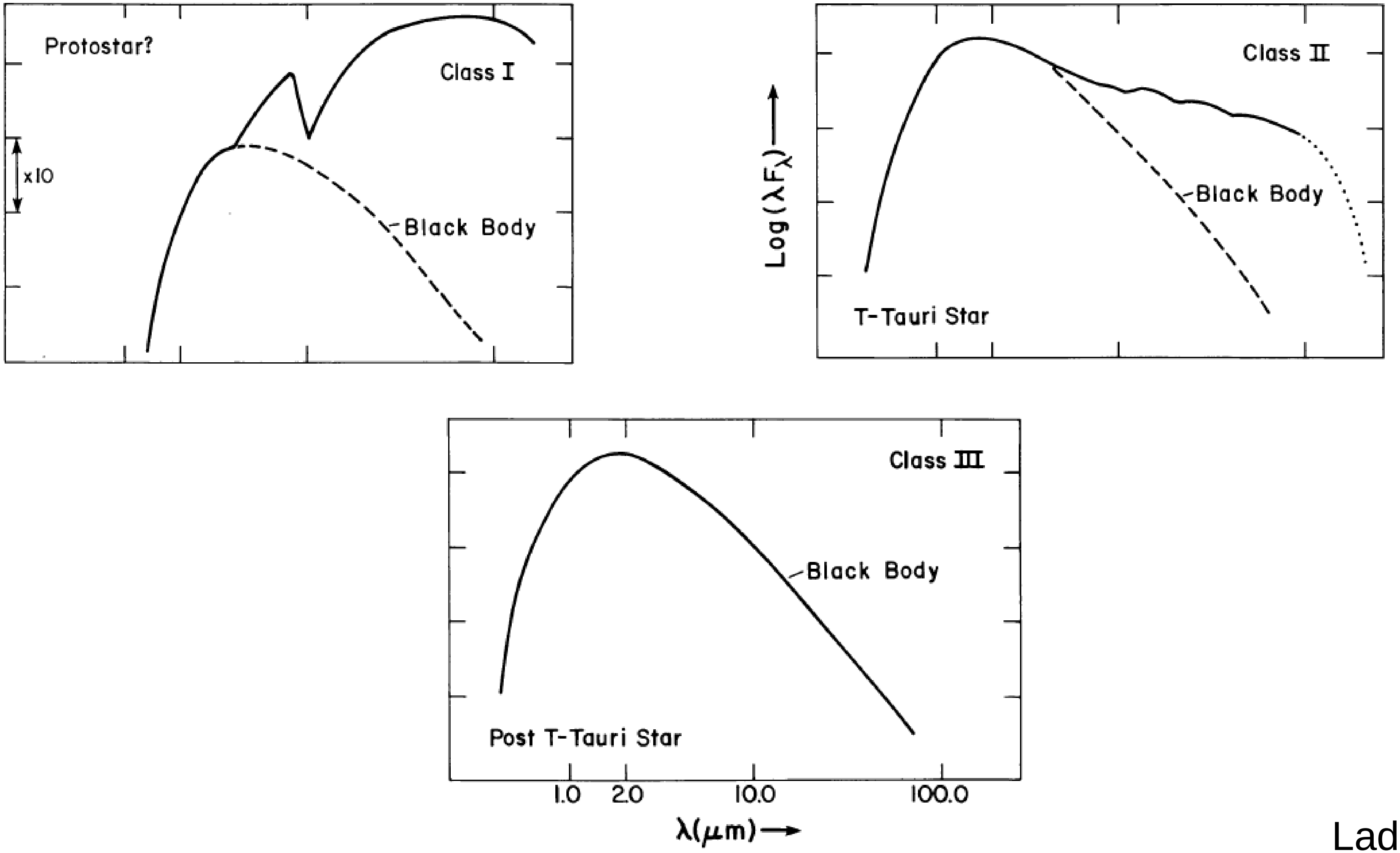
- Based on SED slope from 2-25 microns
- Class 0: collapse phase
- Class I: embedded phase
- Class II: optically visible transition disk
- Class III: optically thin or no disk
- Does not give unique description of amount, distribution of circumstellar material (degeneracy with inclination/extinction)
- Resolved images needed!

Evolution of a Typical Disk



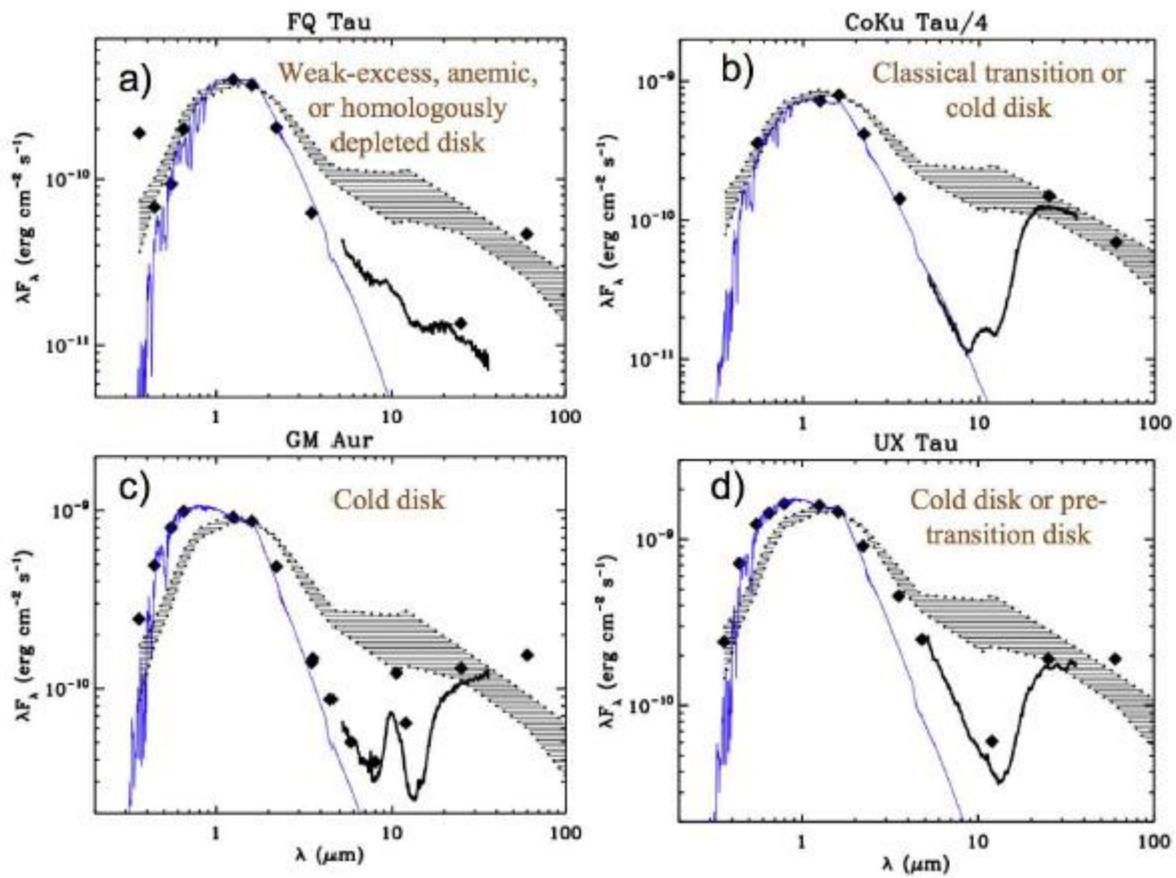
Williams & Cieza 2011

SED Examples



Lada 1987

Transition Disk SEDS



Williams & Cieza 2011

Target: LkCa 15

LkCa 15

- 2-5 Myr old
- K5 star
  - 0.74 $L_\odot$
  - 1.0 $M_\odot$
- Taurus-star forming region
  - D ~ 140 pc
- Transition disk

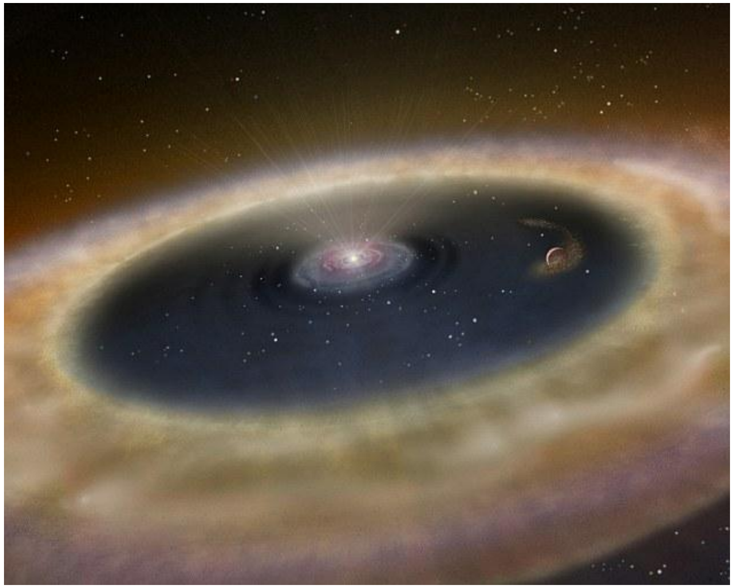


Image: Karen L. Teramura, UH IfA

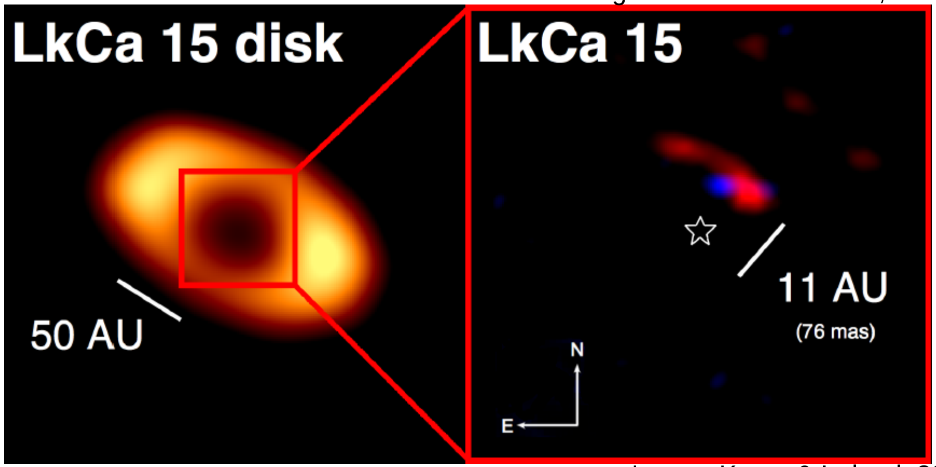


Image: Kraus & Ireland, 2011

LkCa 15

- Keplerian rotation out to ~900 AU
  - Gas to ~900 AU
  - Dust to ~120 AU
- Accretion rate = 3 x 10^{-9} $M_{\odot}$/year
- Very active chemistry (stellar radiation)
- Transition disk:
  - Partially dust-depleted inner region to ~50 AU
  - 6 M_J proto-planet in cavity at 16 AU?
  - Cavity shaped by?
    - dynamical interactions with giant planets
    - other clearing mechanisms (grain growth, protoevaporation)

Observations

Data

- UBVRI – Kenyon & Hartmann, 1995
- JHK – 2MASS Point Source Catalog
- IRAC 3.6, 4.5, 5.8, 8 micron – Rebull et al., 2010
- WISE 3.4, 4.6, 12, 22 micron – Rebull et al., 2011
- IRAS 12, 25, 60, 100 micron – Kenyon & Hartmann, 1995
- MIPS 24, 70, 160 micron – Rebull et al., 2010
- SHARC II 350 micron – Andrews & Williams, 2005
- SCUBA 850 micron – Andrews & Williams, 2005

- Adopted uncertainties:
  - 25%: IRAS, sub-mm
  - 10%: remaining data

Robitaille et al. 2007

Interpreting Spectral Energy Distributions from Young Stellar Objects.
II. Fitting observed SEDs using a large grid of pre-computed models

Robitaille et al. 2007

- Method to analyze SEDs of YSOs
- Fit data with pre-computed 2-D radiation transfer models
- Spans a large region of parameter space
- Obtain 14 physical parameters, evolutionary stage
- Optical to sub-mm observations
- Code is publically available

Robitaille et al. 2007

- 200,000 YSO model SEDs
  - 20,000 sets of physical parameters
  - 10 viewing angles
  - Covers a wide range of parameter space
- Pre-MS stars with combos of:
  - Axisymmetric circumstellar disks
  - Infalling flattened envelopes
  - Outflow cavities
- Assumes that stars of all masses form via accretion through a disk and envelope

SED Modeling

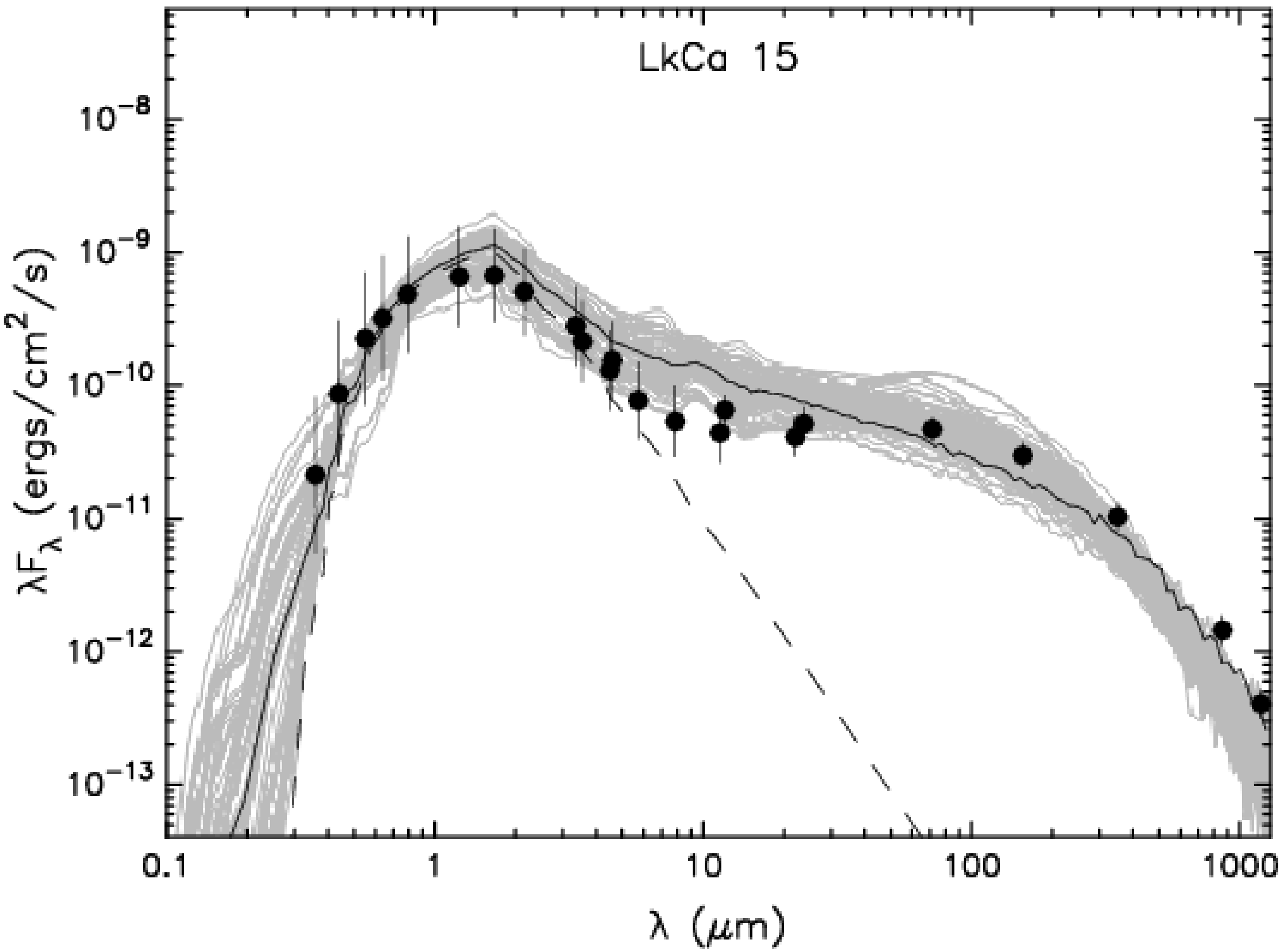
- Parameter Space:
  - Central Source
    - Stellar mass, radius, temperature
  - Infalling Envelope
    - Envelope accretion rate, outer radius, inner radius, cavity opening angle, cavity density
  - Disk Parameters
    - Disk mass (gas + dust), accretion rate, outer radius, inner radius, flaring power, scale height

SED Modeling

- Mass sampled from: 0.1 – 50 $M_{\odot}$
- Ages sampled from: 10^3 – 10^7 years
- Radii, temperatures:
  - Determined by mass, age using evolutionary tracks
- Disk, envelope parameters sampled randomly, depend on age of source
- Dust grain models:
  - Dense regions: 50micron-1mm exponential decay
  - Size in less dense regions > particles of diffuse ISM

Results

Spectral Energy Distribution



Parameter Comparison

	Literature	Model
Age (Myr)	2-5	1.52
Stellar Mass ($M_{\odot}$)	1.00	1.06
Stellar Temperature (K)	4350	4314
Stellar Radius ($R_{\odot}$)	1.7	2.27
Inclination Angle (Degrees)	~50	31.79
(Dust) Disk Inner Radius (AU)	~42	0.0923
(Dust) Disk Outer Radius (AU)	~120	97.8
Disk Accretion Rate ($M_{\odot}$/yr)	3×10^{-9}	2.75×10^{-8}
Luminosity ($L_{\odot}$)	0.74	1.94
Disk Mass ($M_{\odot}$)	0.05-0.1	0.0347
Class	II	II

Discussion

Discussion

- Age underestimated
- IR fluxes not well fit (mid-IR)
- Degeneracy!
  - Evolutionary stage, inclination
  - Class I vs Class II
- Size of dust depleted cavity not consistent
- Resolved disks not well-fit (sometimes!)
- Beware!

Discussion

- SEDs alone cannot provide a complete picture
- Need high resolution mm-wave observations
- Not all parameters may have an effect on SED at all wavelengths, any value may provide a good fit
- Adding fluxes at various wavelengths help constrain different parameters

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