Architecture of planetary systems: HR 8799 and ε Eridani

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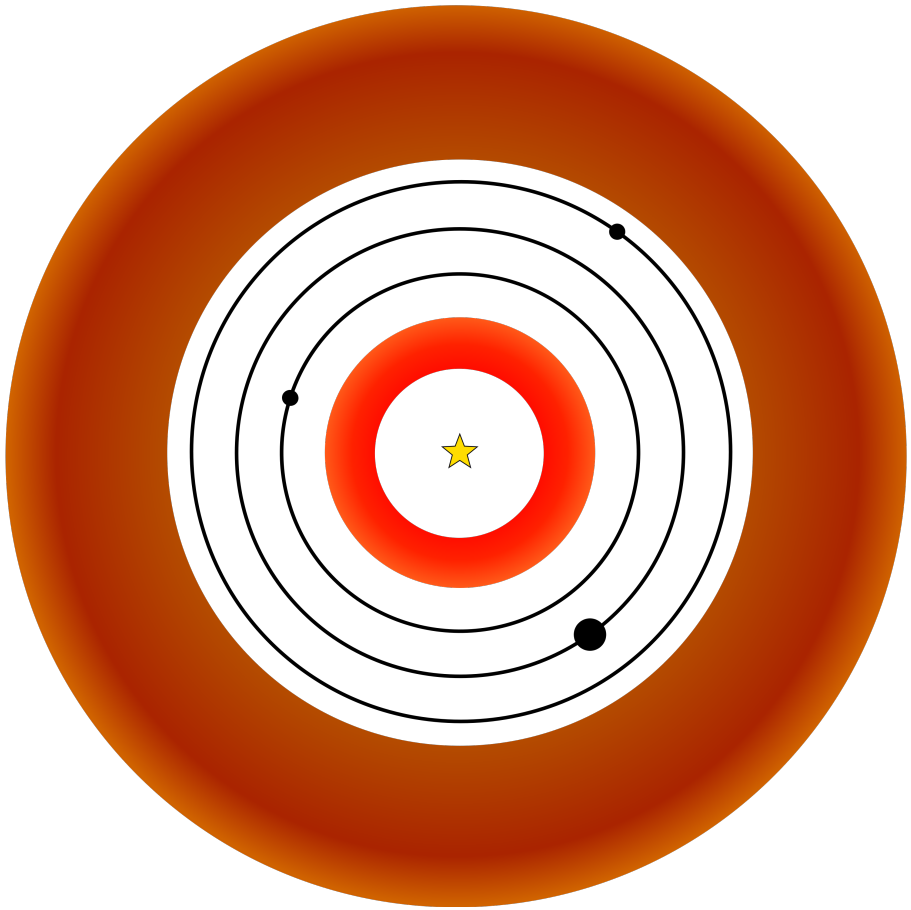
Content

Introduction

Definition

Architecture of planetary system:

- star
- planet(s)
- dust
- planetesimal belts (source of dust)



Introduction

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Architecture of planetary system:

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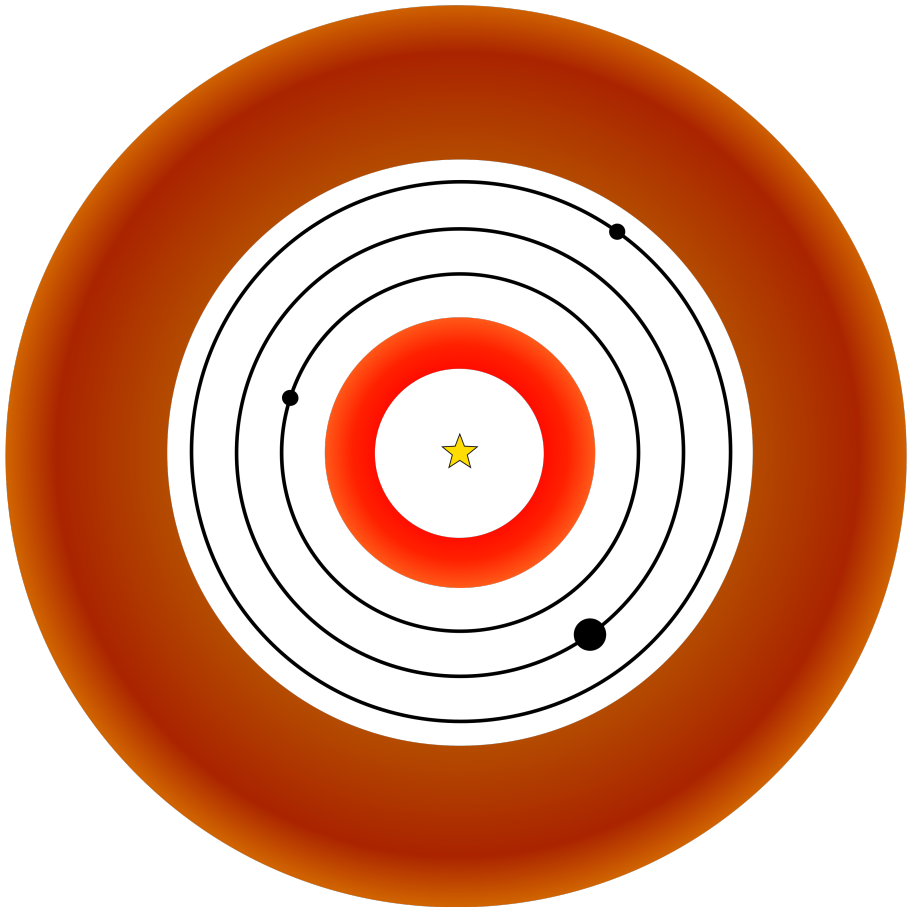
Motivation

- multiple interactions between dust, planetesimals and planets
- constrain planet masses, eccentricity, inclination
- planetesimals are remnants of planet formation

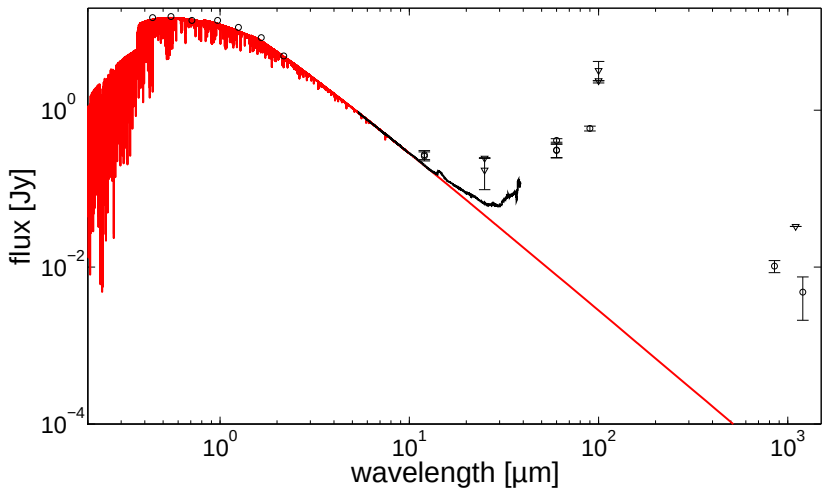


Content

HR 8799 – Introduction

Parameters

A5 V star with $d = 39.4$ pc
age of $\lesssim 50$ Myr Reidemeister et al. (2009)
(20 Myr up to 1 Gyr)
γ Doradus (variable star)
λ Bootis (metalpoor Pop. I)



Observations

- strong IR excess (IRAS, ISO)

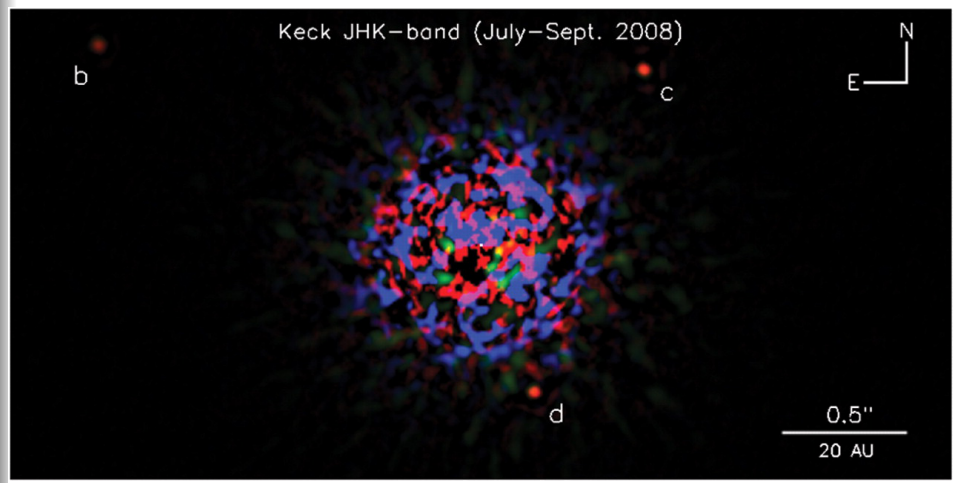
  Sadakane&Nishida (1986), Zuckerman&Song (2004),

  Moor et al. (2006), Rhee et al. (2007)

- Spitzer/IRS spectrum

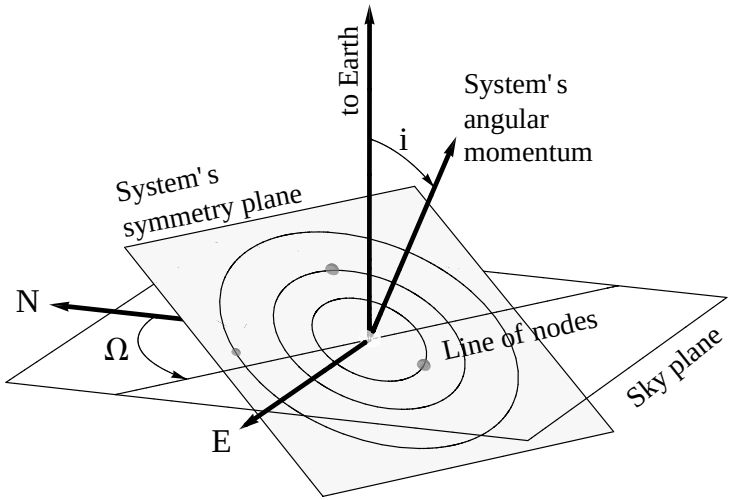
  Jura et al. (2004), Chen et al. (2006)

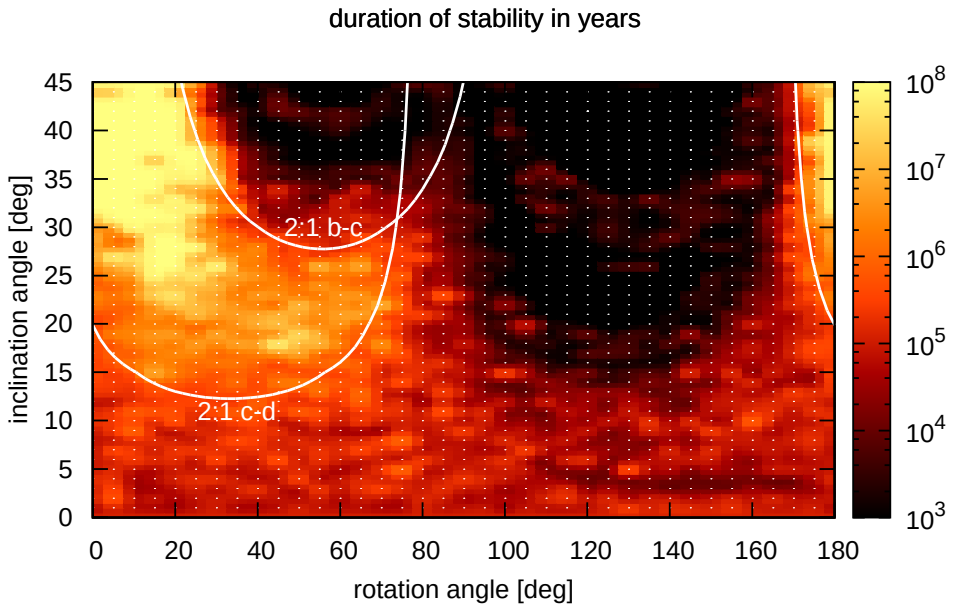
- 3 directly imaged planets
  at 68, 38 & 24 AU
  with $M_{\rm P} = 5$–$13 M_{\rm Jup}$



Marois et al. (2008)

HR 8799 – The planets

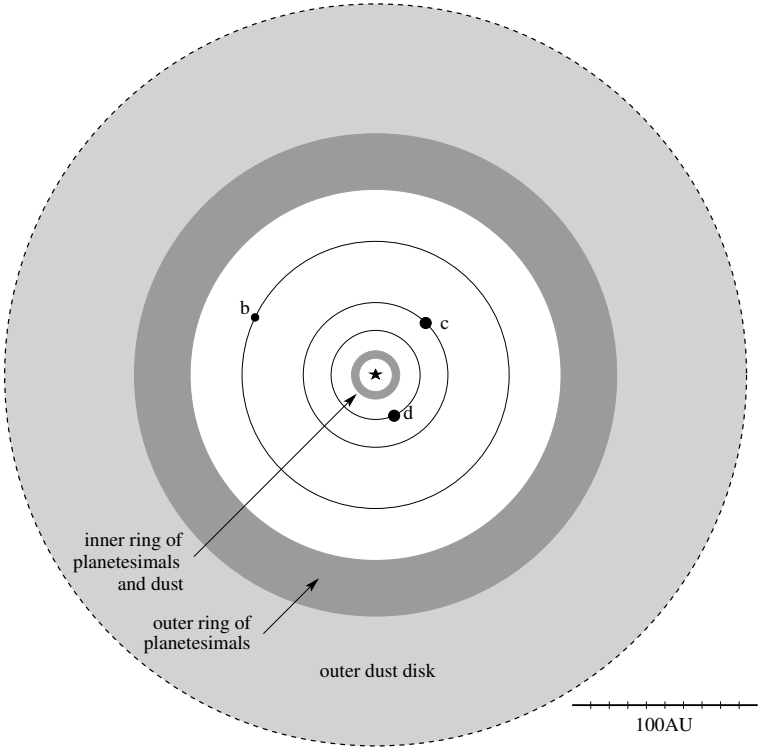




Results

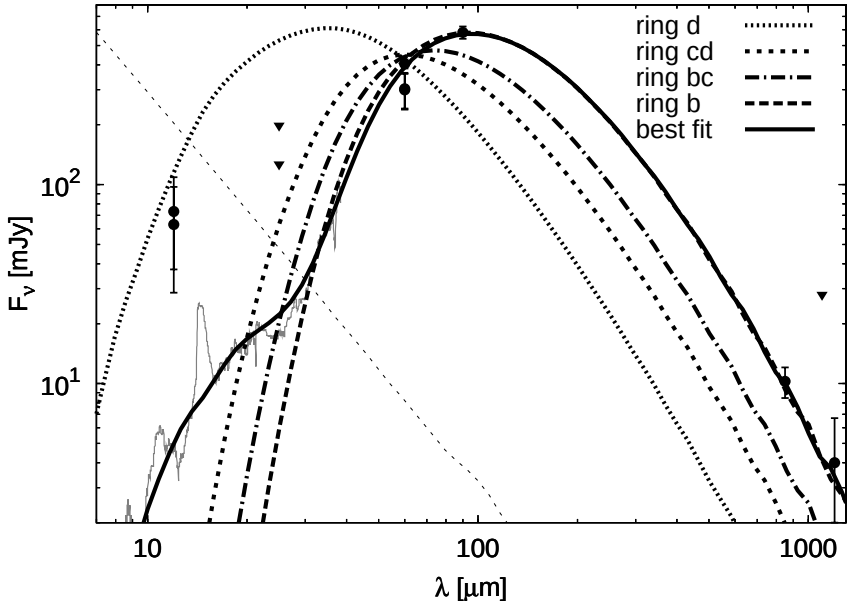
- inclination of 20–30° (rotational period: 13–30°)
- rotation angle of 0–50°
- slipping in 1:2:4 resonance

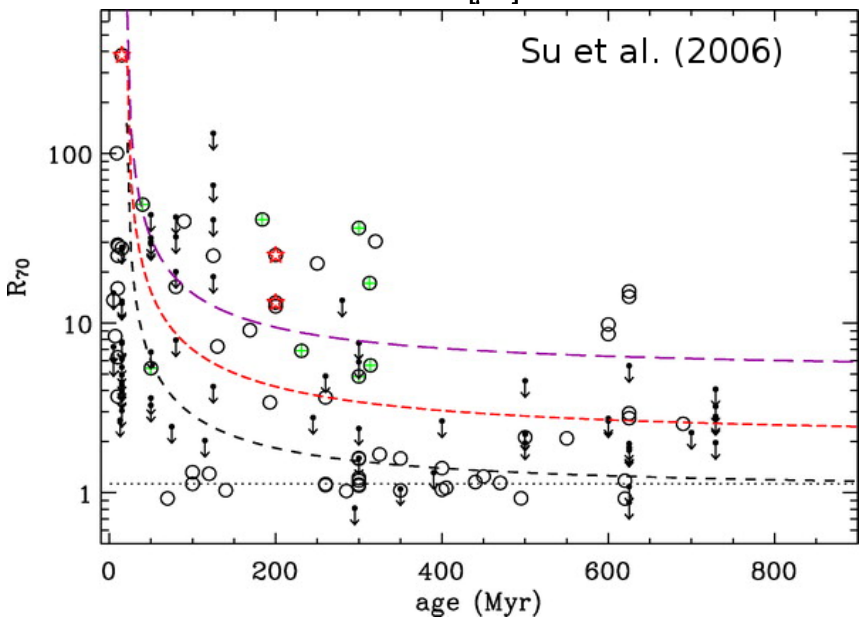
HR 8799 – The dust



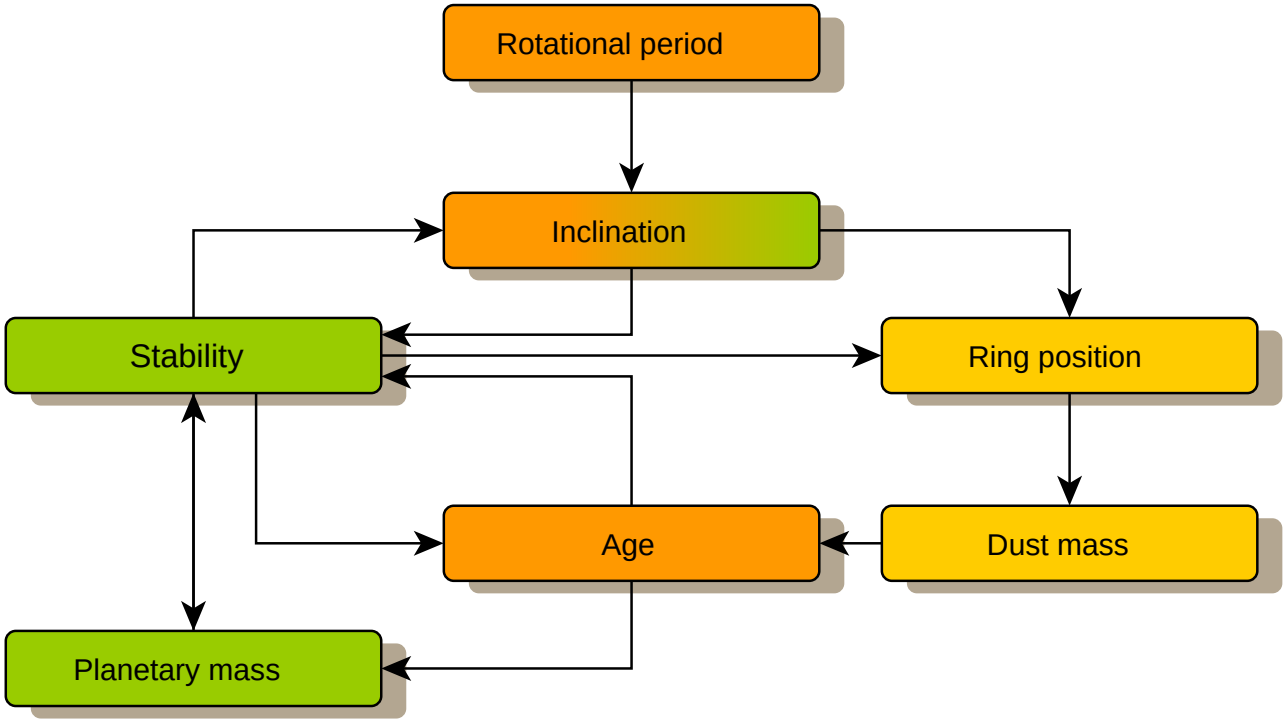
dust rings

- outer ring $\gtrsim$ 100 AU
  $M_{\mathrm{dust}} \approx 4 \times 10^{-2} M_{\oplus}$
- inner ring 2–10 AU
  $M_{\mathrm{dust}} \approx 10^{-5} M_{\oplus}$





HR 8799

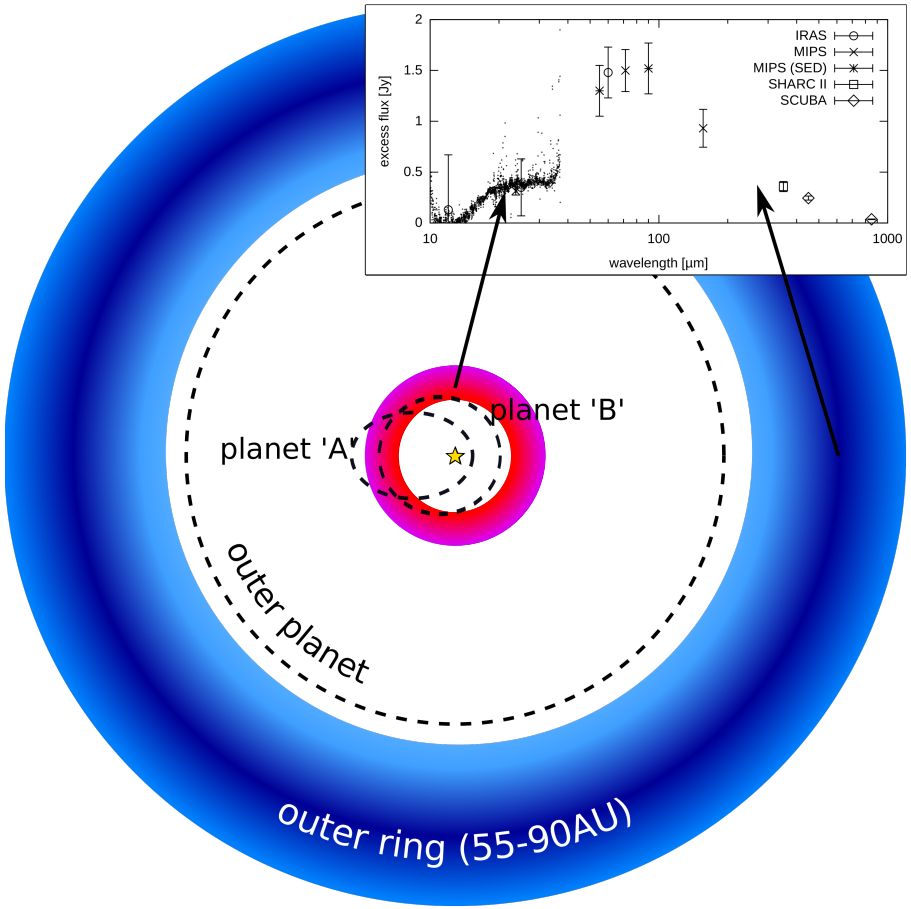

Rotational period
Inclination
Stability
Ring position
Age
Dust mass
Planetary mass

Content

ε Eridani

Parameter

- K2 V star at $d = 3.2\,\mathrm{pc}$
  age $\lesssim 1\,\mathrm{Gyr}$ DiFolco et al. (2004)
  SW: $30\dot{M}_{\odot}$ Wood et al. (2002)
- "Kuiper belt" analog in sub-mm around 65 AU Greaves et al. (1998, 2005)
- assumed outer planet
- RV planet at 3.4 AU Hatzes et al. (2000)
  A: $e = 0.70$ Benedict et al. (2006)
  B: $e = 0.25$ Butler et al. (2006)
- Spitzer/IRS spectrum indicates warm dust at a few AU Backman et al. (2009)



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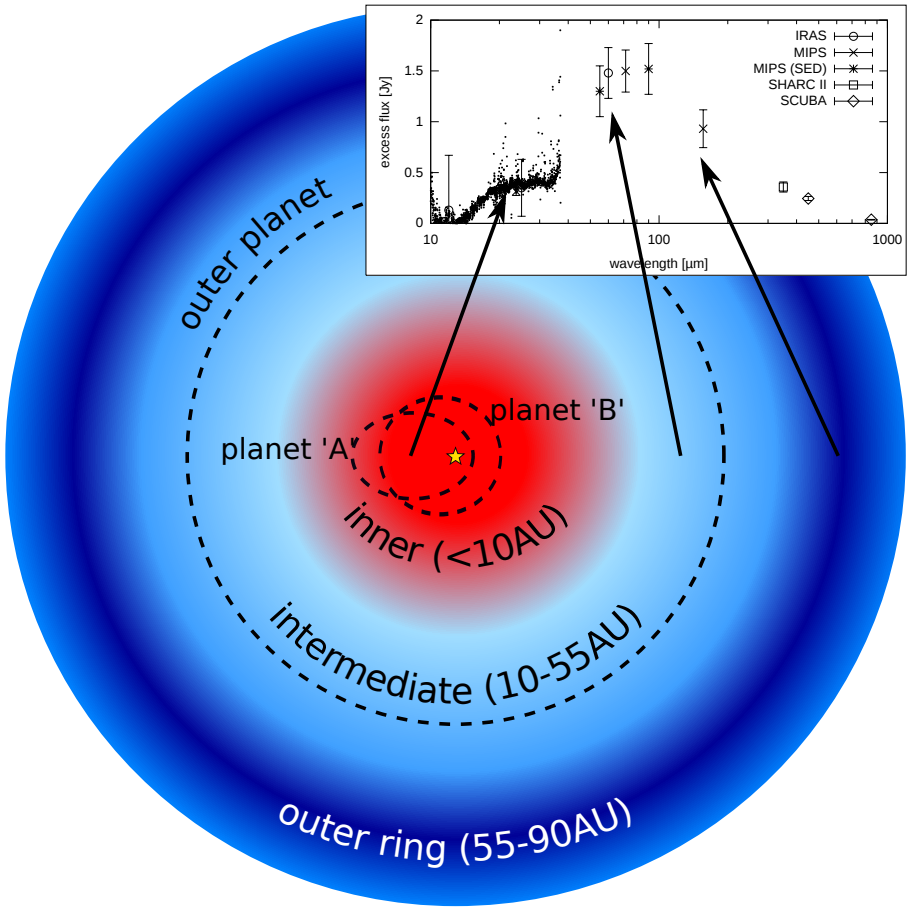
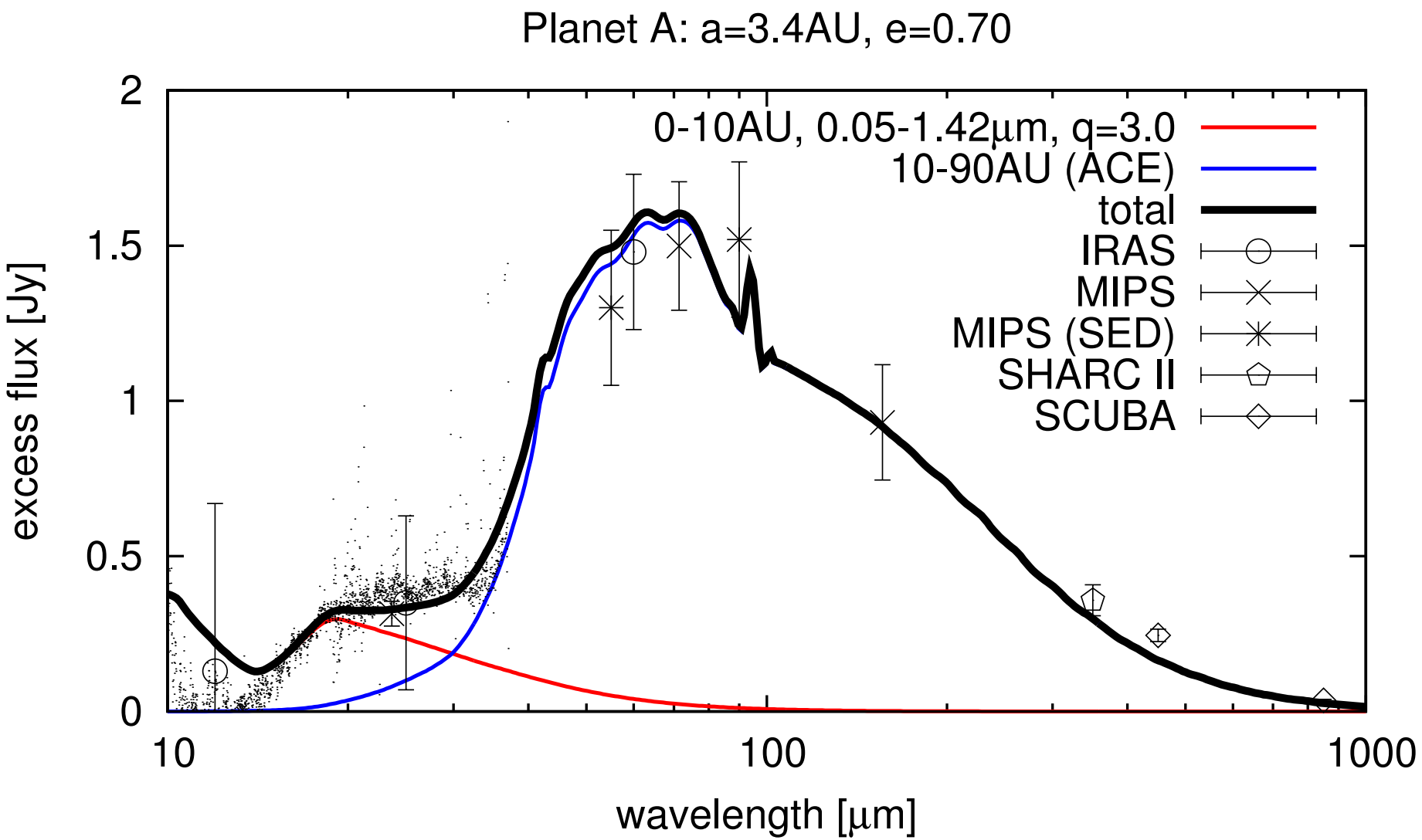


"The cold origin of the warm dust"

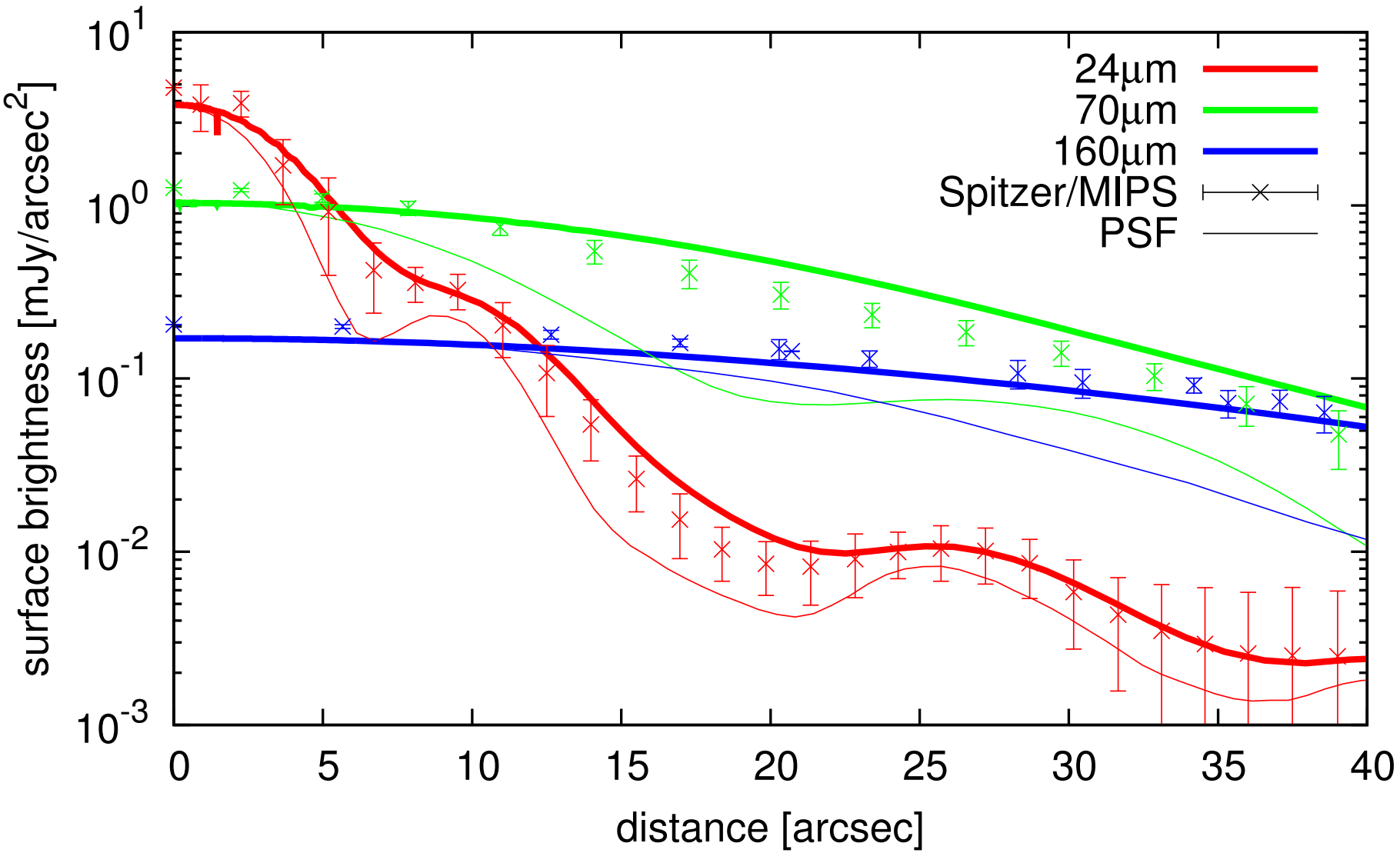
ε Eridani – Results

Spectral energy distribution



ε Eridani – Results

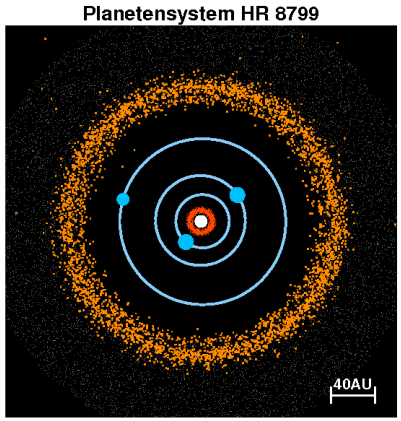
Surface brightness profile

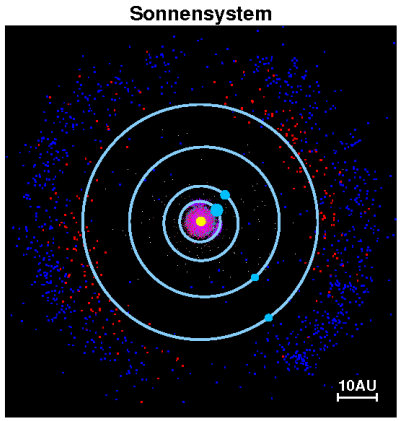


Summary

HR 8799

- young system ($\lesssim 50$ Myr)
  - planets with lower mass
  - high dust mass
- solar system like architecture:
  two dust rings
  gas giants in between





ε Eridani

- gap in the sub-mm indicates an outer planet
- inner planetesimal belt unstable
- massive dust disk ($10^{-3} M_{\oplus}$) but transport dominated
- dust can stem from outer ring and supply the inner system