Luminosities of young directly-detectable gas giants

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Overview

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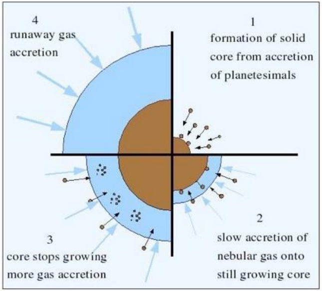
Gas giant formation scenarios

- Core accretion $\rightarrow M_p \lesssim 30\ M_J$, closer-in, higher [Fe/H]
- Gravitational instability $\rightarrow$ heavier, $\gtrsim$ 10–30 au



W. Benz

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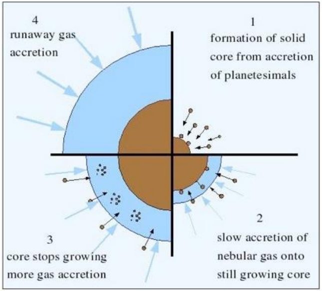

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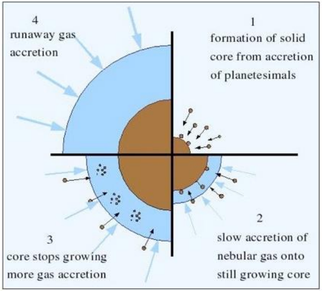

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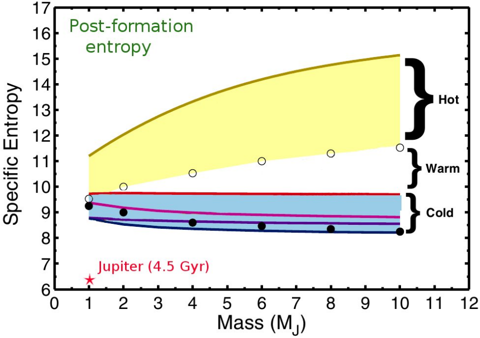

Spiegel & Burrows (2012)

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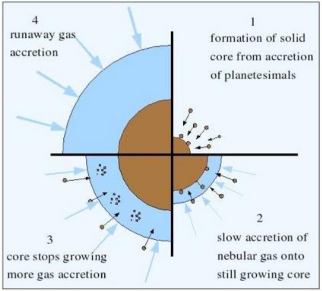

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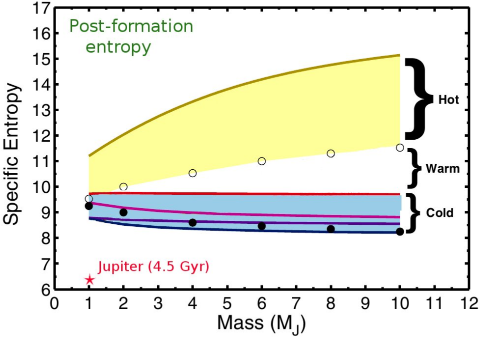

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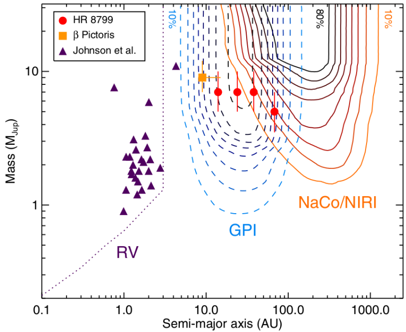
Given composition: $L = L(M, S)$

Direct imaging

- Probe far/closer in, CA–GI boundary, interaction with disc, . . .
- In particular: infant planets → remember birth process
- ! Caveat: Conversion from brightness to mass not trivial



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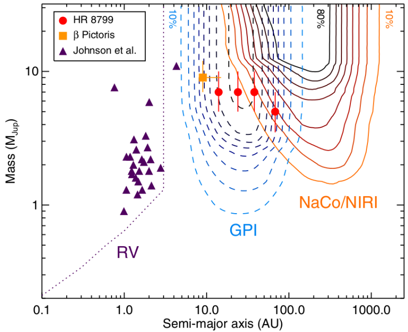

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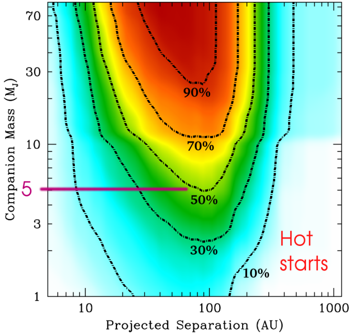

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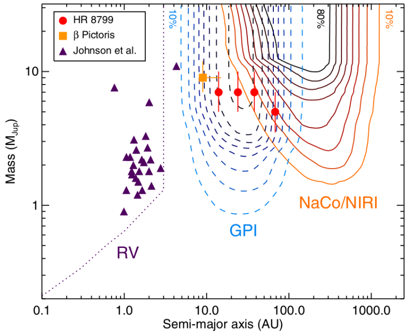

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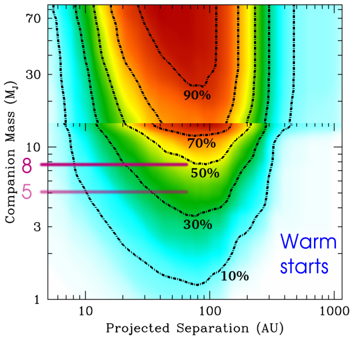

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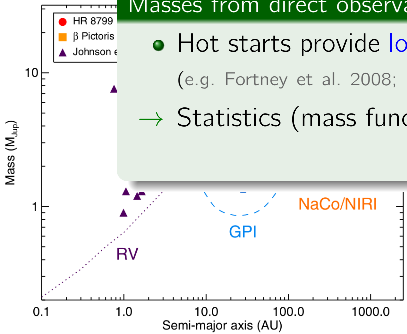


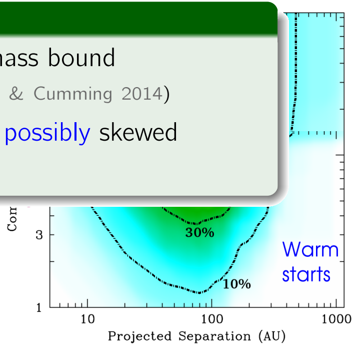
Vigan et al. (201

Masses from direct observations

- Hot starts provide lower mass bound

  (e.g. Fortney et al. 2008; Marleau & Cumming 2014)

→ Statistics (mass function) possibly skewed



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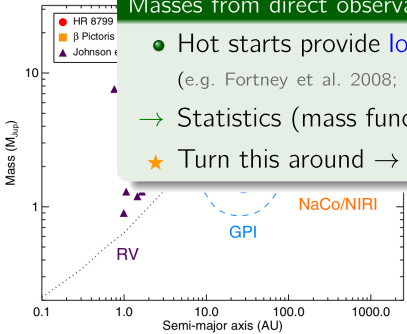

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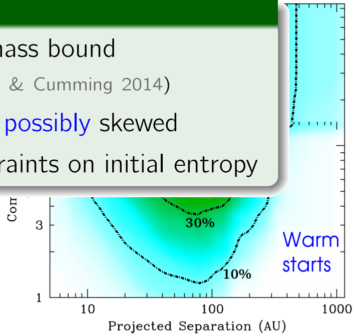
- → Statistics (mass function) possibly skewed
- ★ Turn this around → constraints on initial entropy



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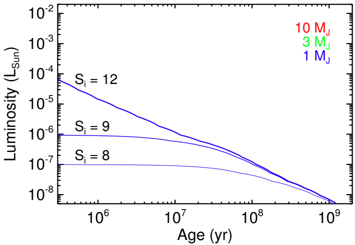
Overview

Standard cooling tracks for gas giant planets

! Low entropy → long cooling time t_{cool}

- $t < t_{\text{cool}}$: ≈ remember initial entropy
- $t > t_{\text{cool}}$: ≈ power law

(Burrows & Liebert 1993; Arras & Bildsten 2006)



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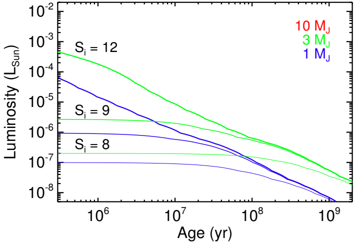

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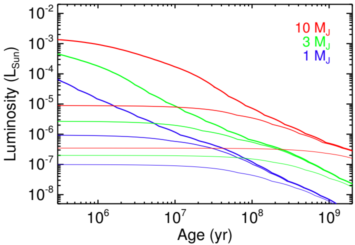

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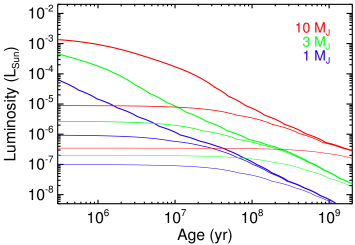
Analytical approximation

⇒ Cooling curve with arbitrary L_{init}:

$$\frac{1}{L(t)} = \frac{1}{L_{\text{init}}} + \frac{1}{L_{\text{hot start}}(t)}$$



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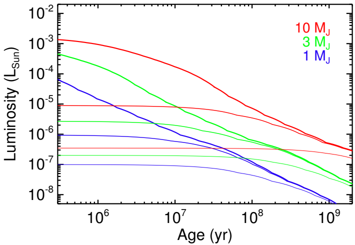
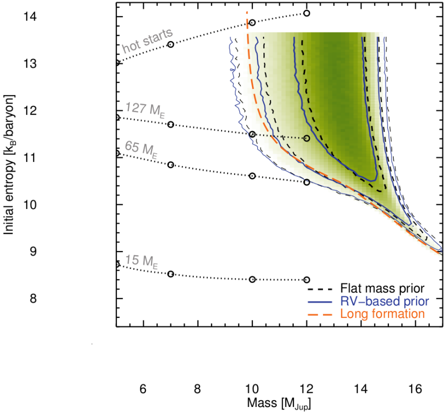


→ Map $(t, L)_{\text{obs}}$ point to $M_p(L_{\text{init}})$ curve (Marleau & Cumming 2014)

- General principle—valid for all sets of cooling curves

  (vary atmospheric grids, semi-convection, etc.)

β Pictoris b



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- MCMC for 21 ± 4 Myr and $\log L = -3.90 \pm 0.07$
- Use RV constraints (here, small effect)

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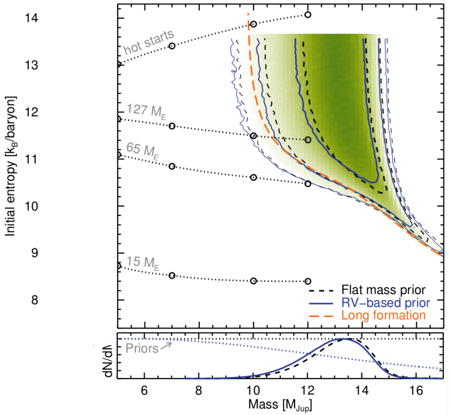

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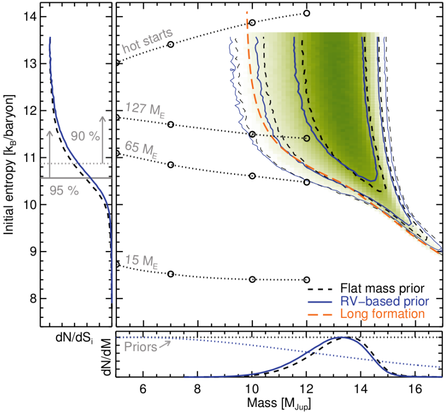

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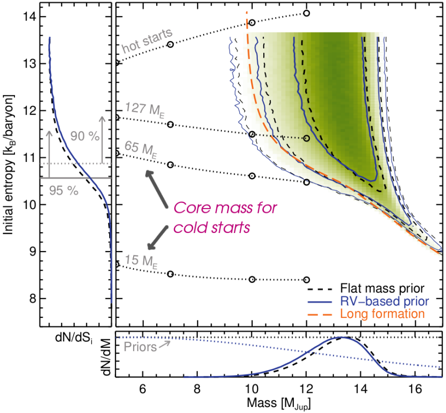

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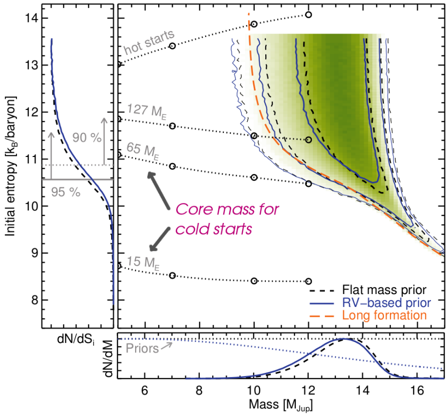

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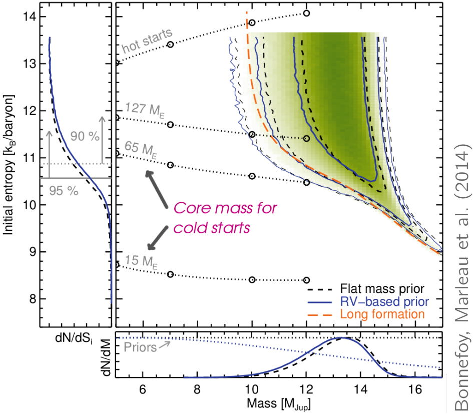

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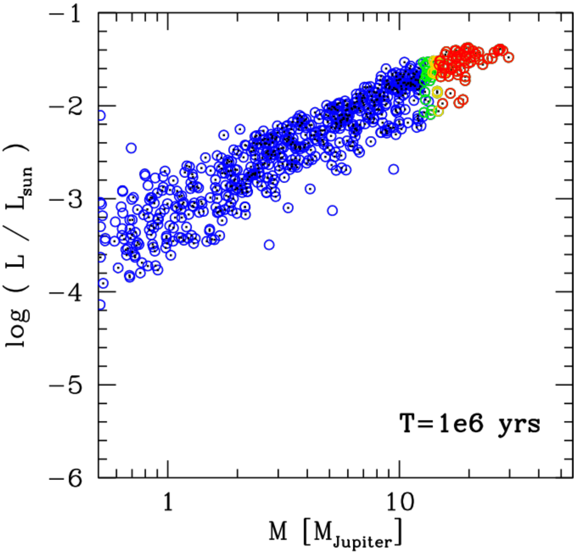

Mordasini et al., in prep.

D-burning

$L_D \geq 5\% \, L_{int}$

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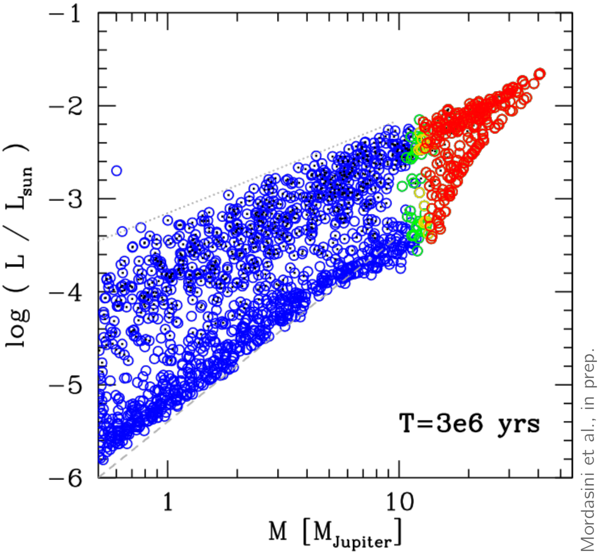
- Big L spread ($\sim$ 1.5 dex)
- ! All have same opacity. . .



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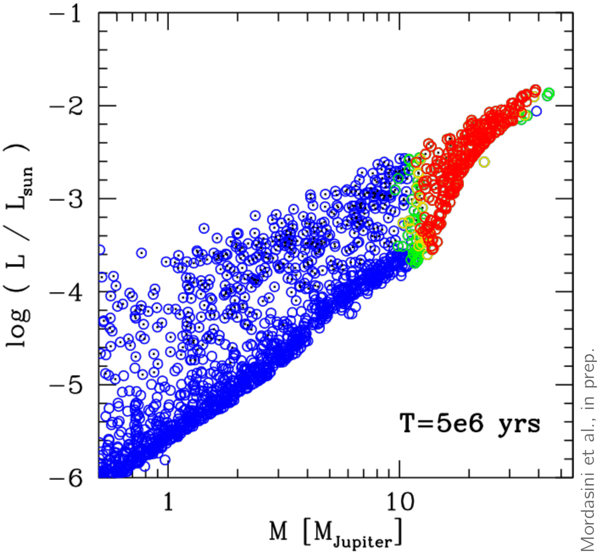

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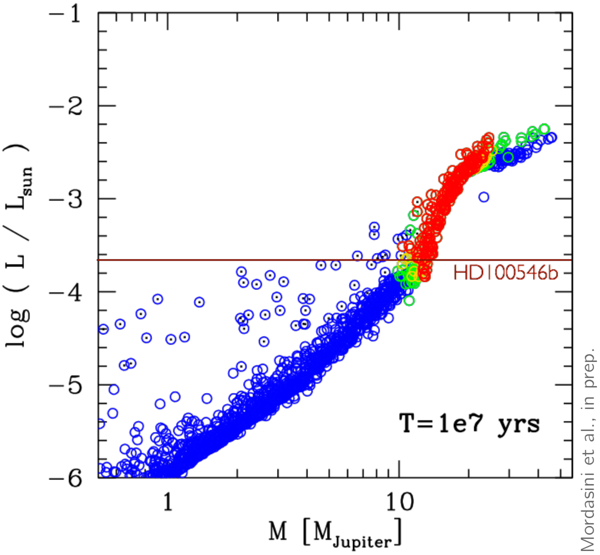

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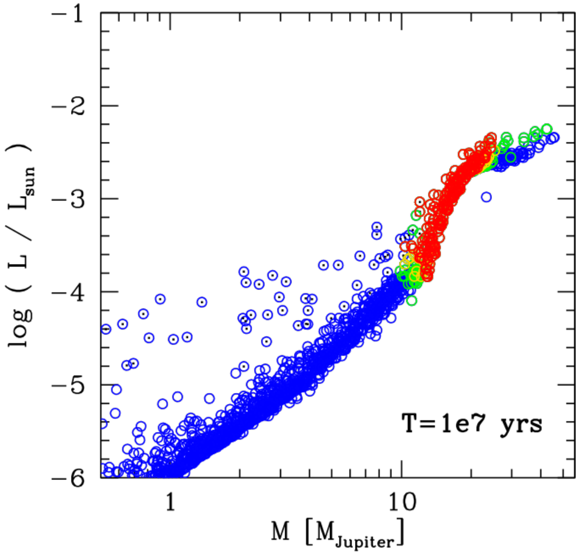

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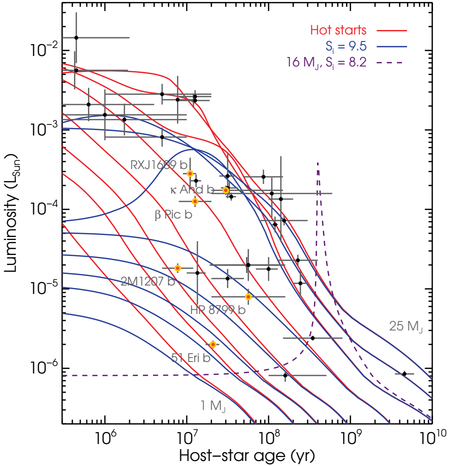

Hot-start mass $\lesssim 25\ M_J$

(Neuhäuser & Schmidt 2012, updated)

Cooling curves for 1–25 M_J

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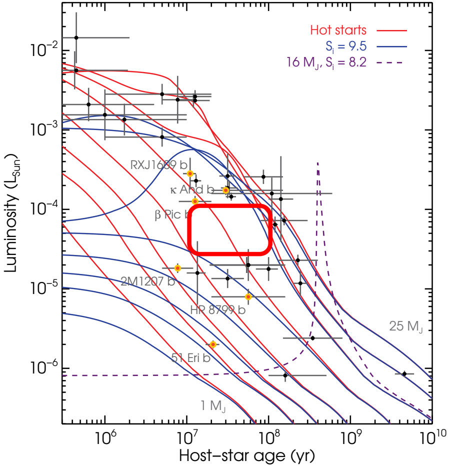

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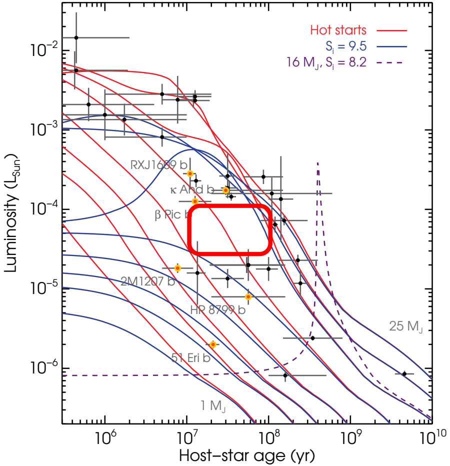

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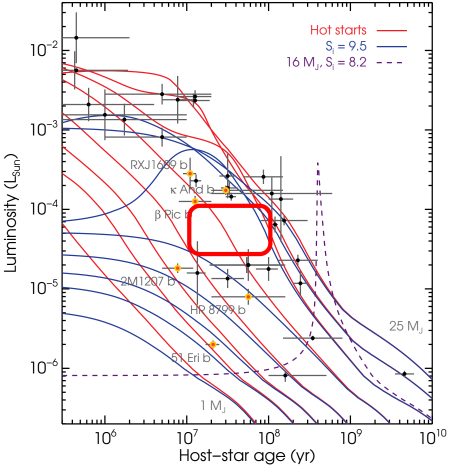

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- Speculative

→ See what surveys say!

(Marleau & Cumming 2014)

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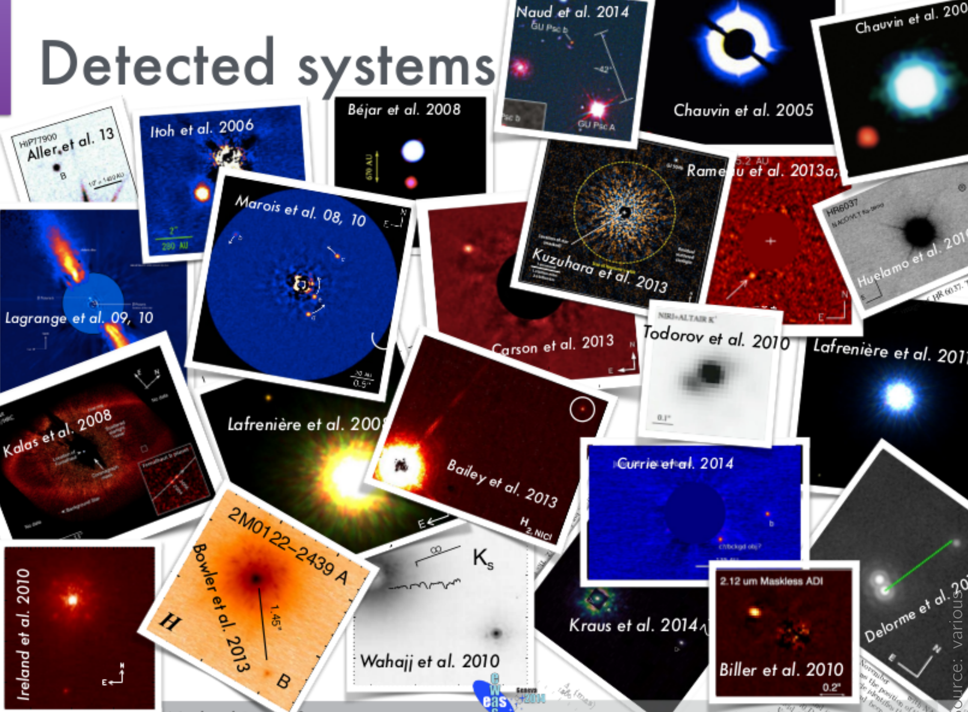
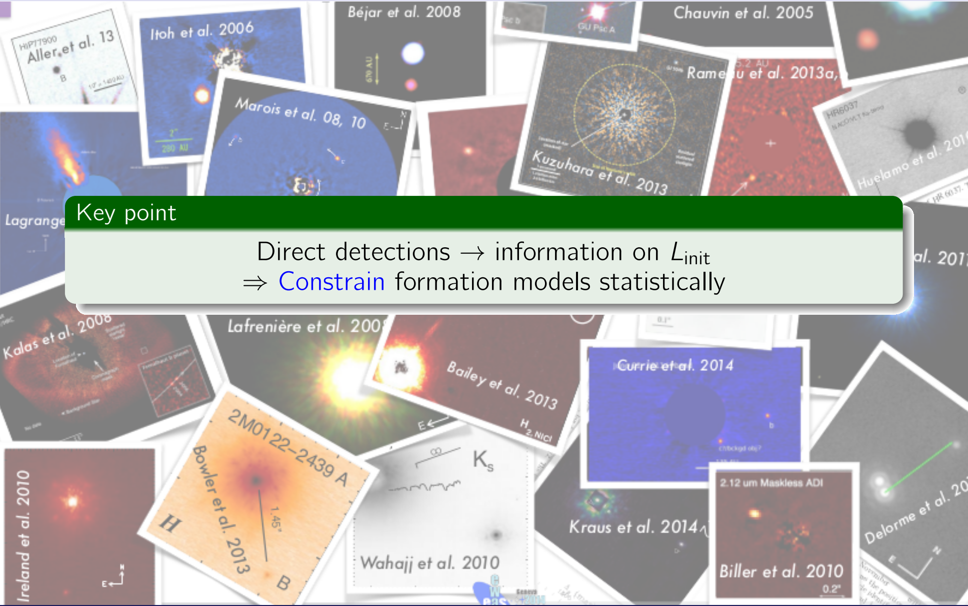
Detected systems



Summary and outlook



Key point

Direct detections → information on L_{init}

⇒ Constrain formation models statistically

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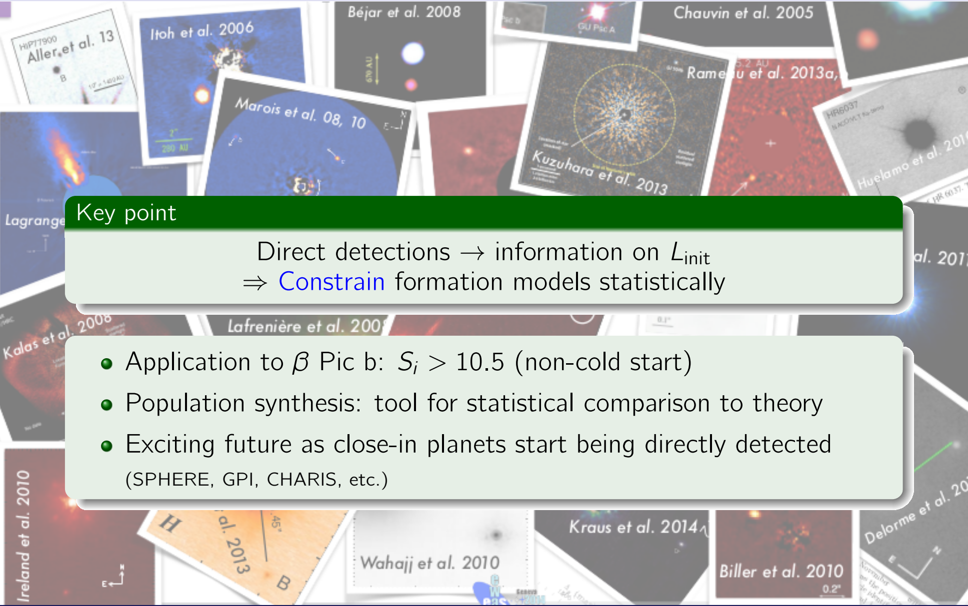

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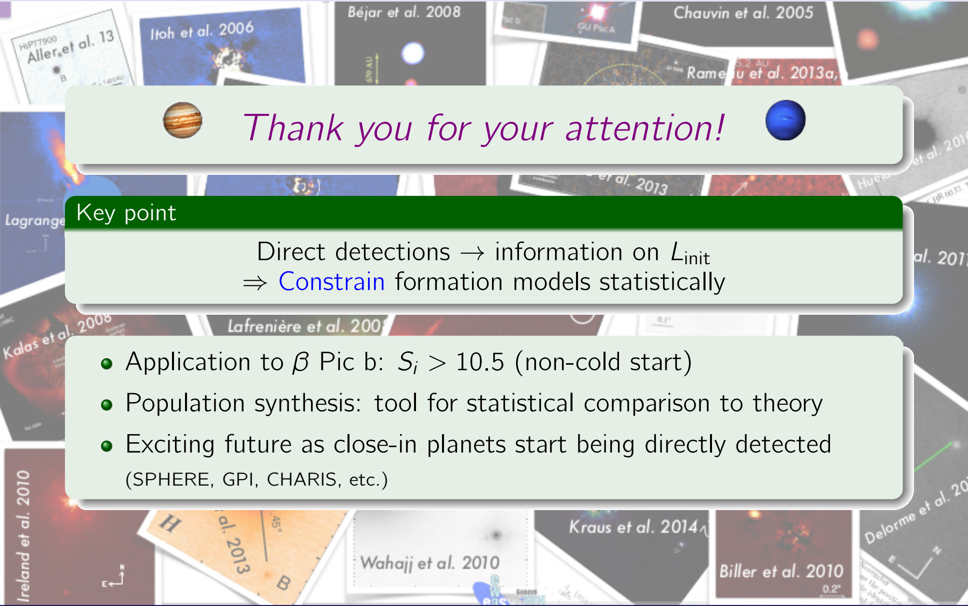

Thank you for your attention!

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