Hot-Jupiter Inflation

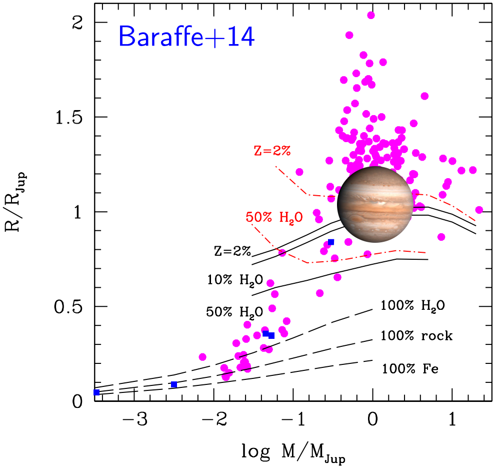
due to deep energy deposition

Sivan Ginzburg Re'em Sari

Racah Institute of Physics, The Hebrew University, Jerusalem, Israel

July 1, 2015

Inflated Hot Jupiters



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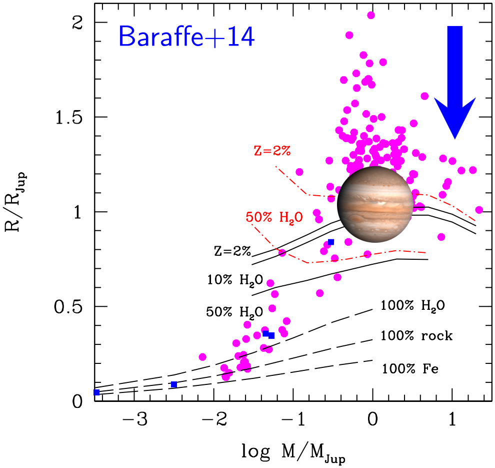
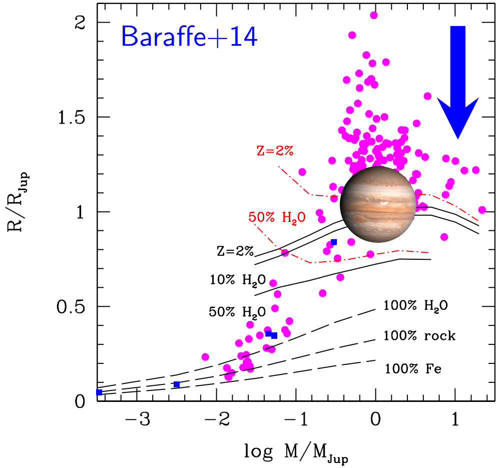


Stellar irradiation slows cooling

- Explains $\sim 1.3 R_J$
- Not enough $1.5 - 2.0 R_J$

Inflated Hot Jupiters



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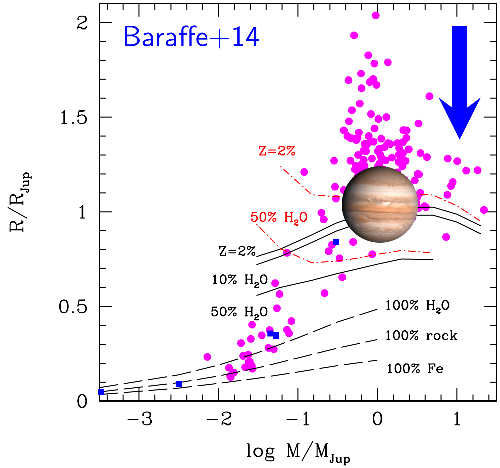
Gyr old planets

Inflated Hot Jupiters



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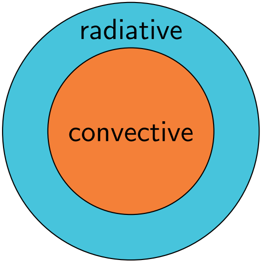
Extra power

Internal Luminosity of Irradiated Planets

τ-U Plane

- $U \equiv aT^4$
  radiation
- $\tau \equiv \int^R \kappa\rho\,\mathrm{d}r$
  optical depth



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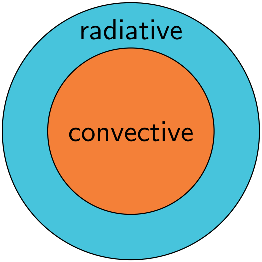

Convective Interior

$$\frac{U}{U_c} = \left(\frac{\tau}{\tau_c}\right)^\beta$$

Radiative Envelope

$$U = U_{\mathrm{eq}} + \frac{3}{c}\frac{\boldsymbol{L_{\mathrm{int}}}}{4\pi R^2}\tau$$

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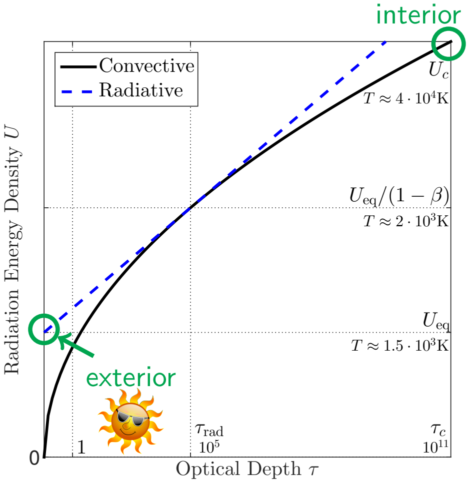

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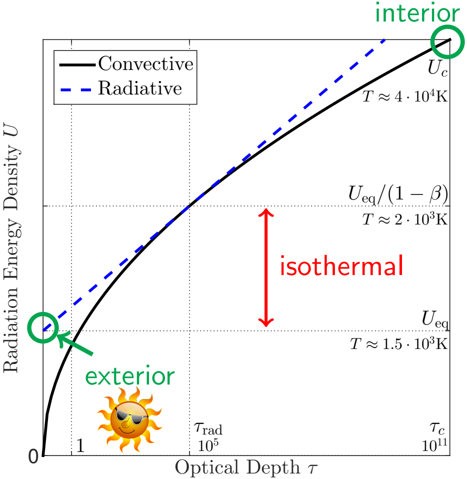


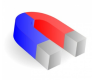
irradition → deep radiative zone → lower luminosity

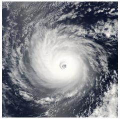
Additional Power Deposition

Cooling too Fast

Baraffe+03,Liu+08, Burrows+07

Additional Power Source[1]





[1] Bodenheimer+01,Guillot&Showman02,Ibgui&Burrows09,Batygin&Stevenson10,Leconte+10,Perna+10

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- Depth τ_{dep}

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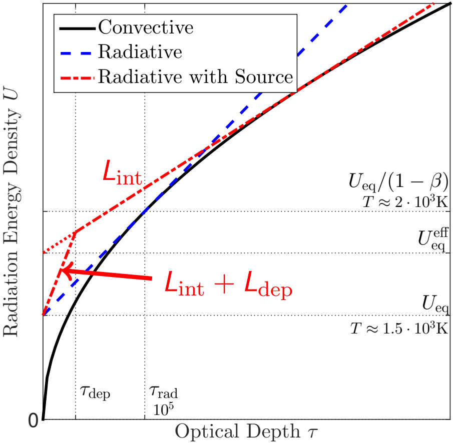

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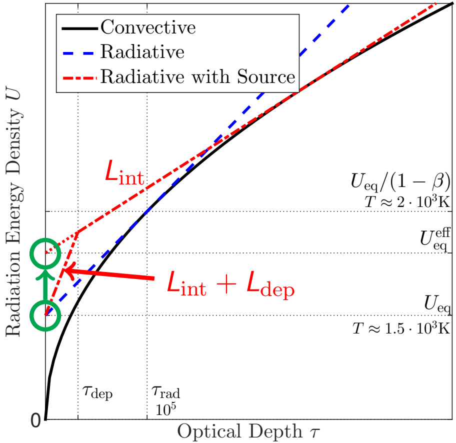
Effectively Stronger Irradiation



stronger "irradiation" → slower cooling

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Additional Power Source

- Power L_{dep}
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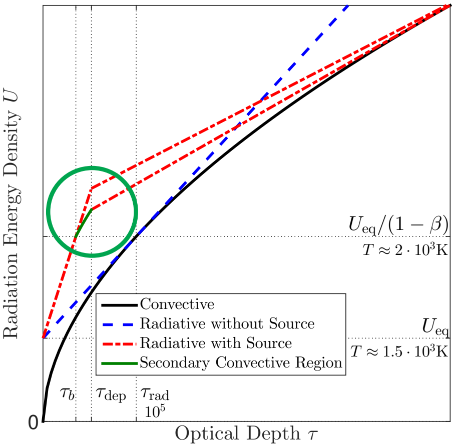
Effectively Stronger Irradiation

$$\frac{U_{\text{eq}}^{\text{eff}}}{U_{\text{eq}}} \sim \left(1 + \frac{L_{\text{dep}}\tau_{\text{dep}}}{L_{\text{eq}}}\right)^{\beta}$$



stronger "irradiation" → slower cooling

Comparison with Numerical Results

Radius Evolution

- $L_{\text{int}}(T_c) \propto \frac{dT_c(t)}{dt}$
- $\Delta R(t) \propto T_c(t)$

Equilibrium Inflation

Chabrier+04
Burrows+07, Liu+08

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Spiegel&Burrows13

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- Still contracting

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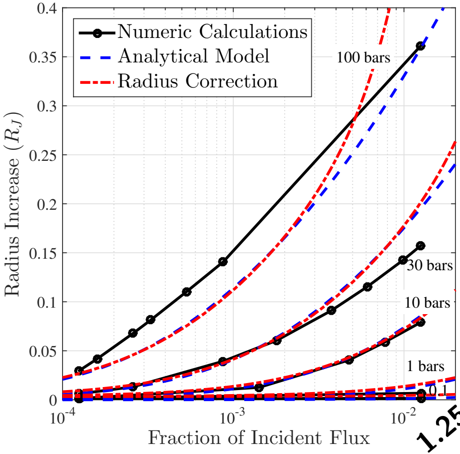

$1.25 R_J$

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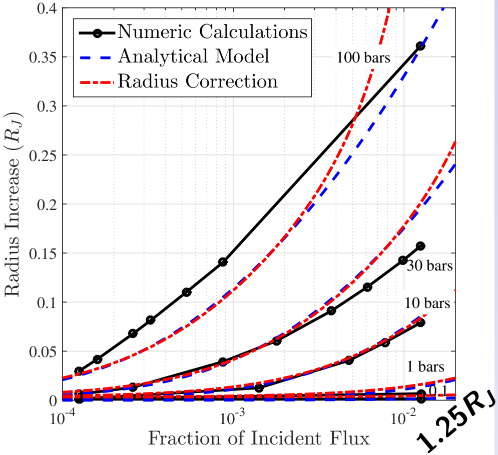
Fit $\eta \sim 1$



$$\Delta R_{\rm dep} = \Delta R_0 \left[\left(1+\eta\frac{L_{\rm dep}\tau_{\rm dep}}{L_{\rm eq}}\right)^{\delta} - 1\right]$$

Summary

Over Inflated Hot Jupiters

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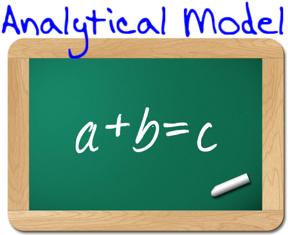
Irradiated Planets

- Reproduce previous results (Guillot+96,Arras&Bildsten06,Youdin&Mitchell10)



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Analytical Model

- $\frac{L_{\rm dep}\tau_{\rm dep}}{L_{\rm eq}} \gtrsim 1 \qquad L_{\rm dep} \gtrsim L^0_{\rm int}$
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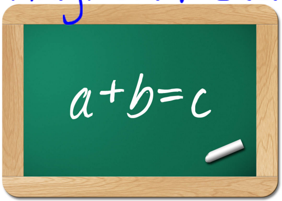

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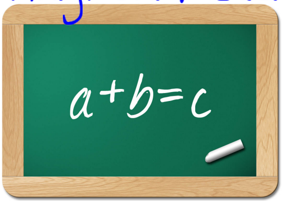

Applications

- Observational correlations (Laughlin+11, Schneider+11)

Thank you!