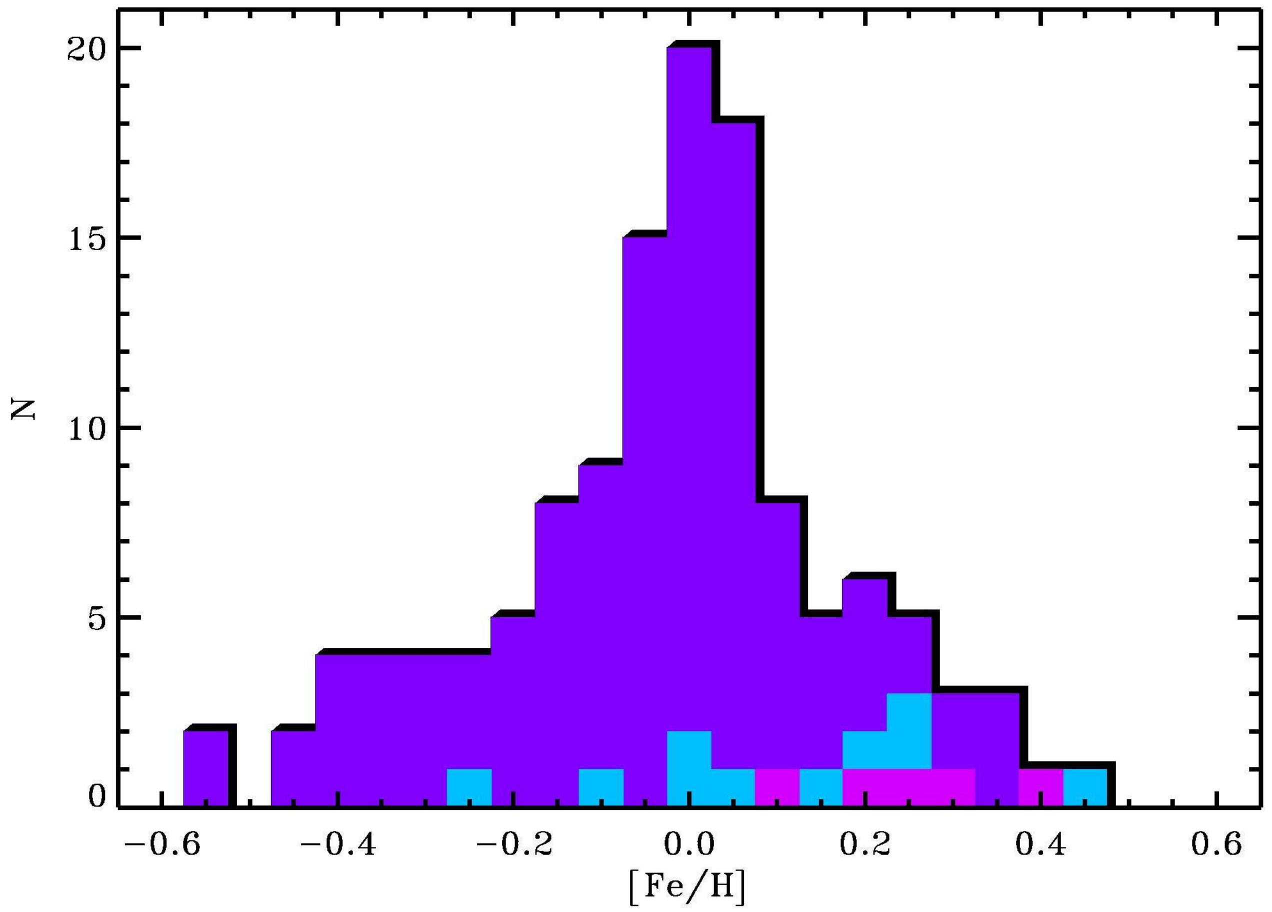
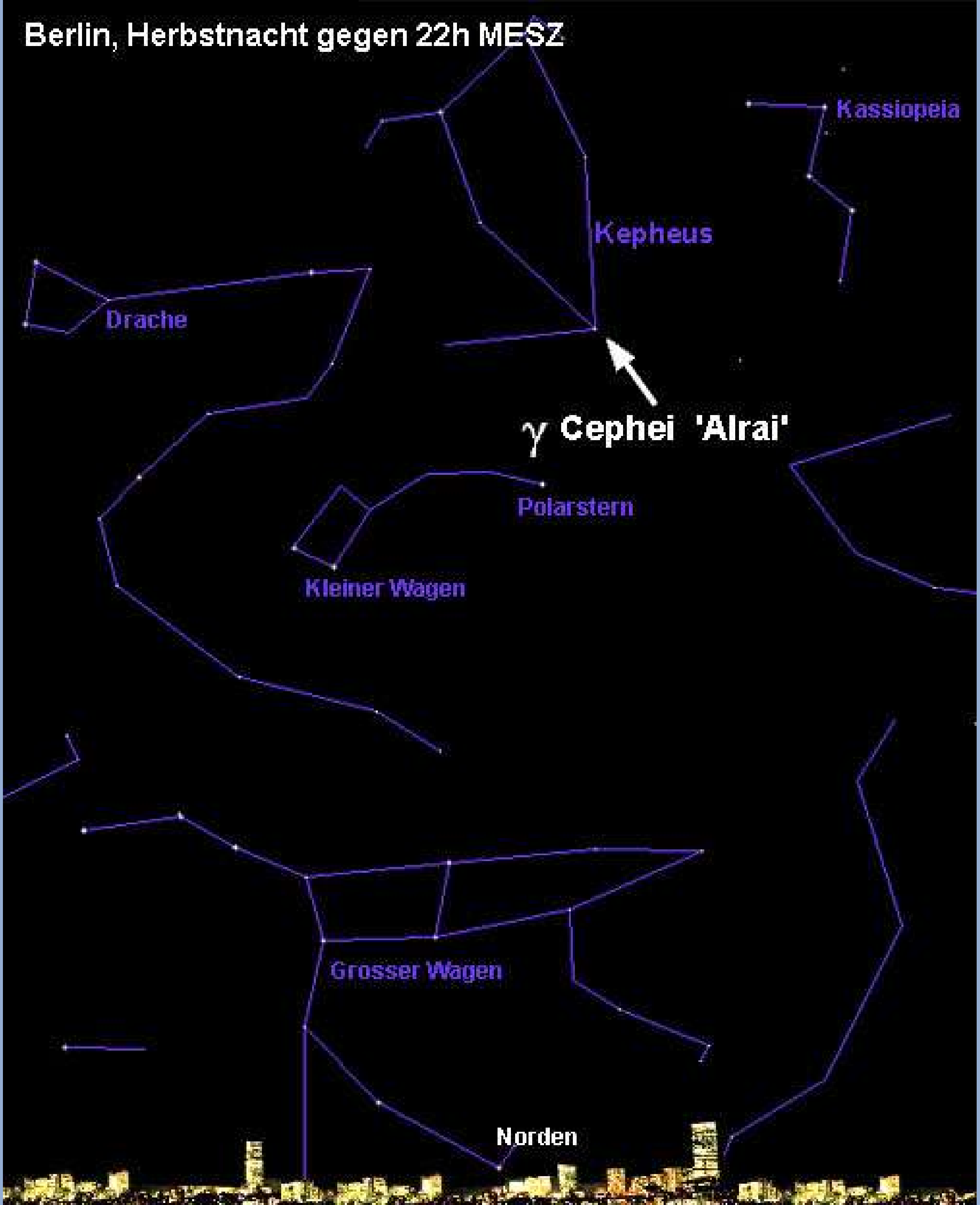
Metallicities of nearby thin disk stars

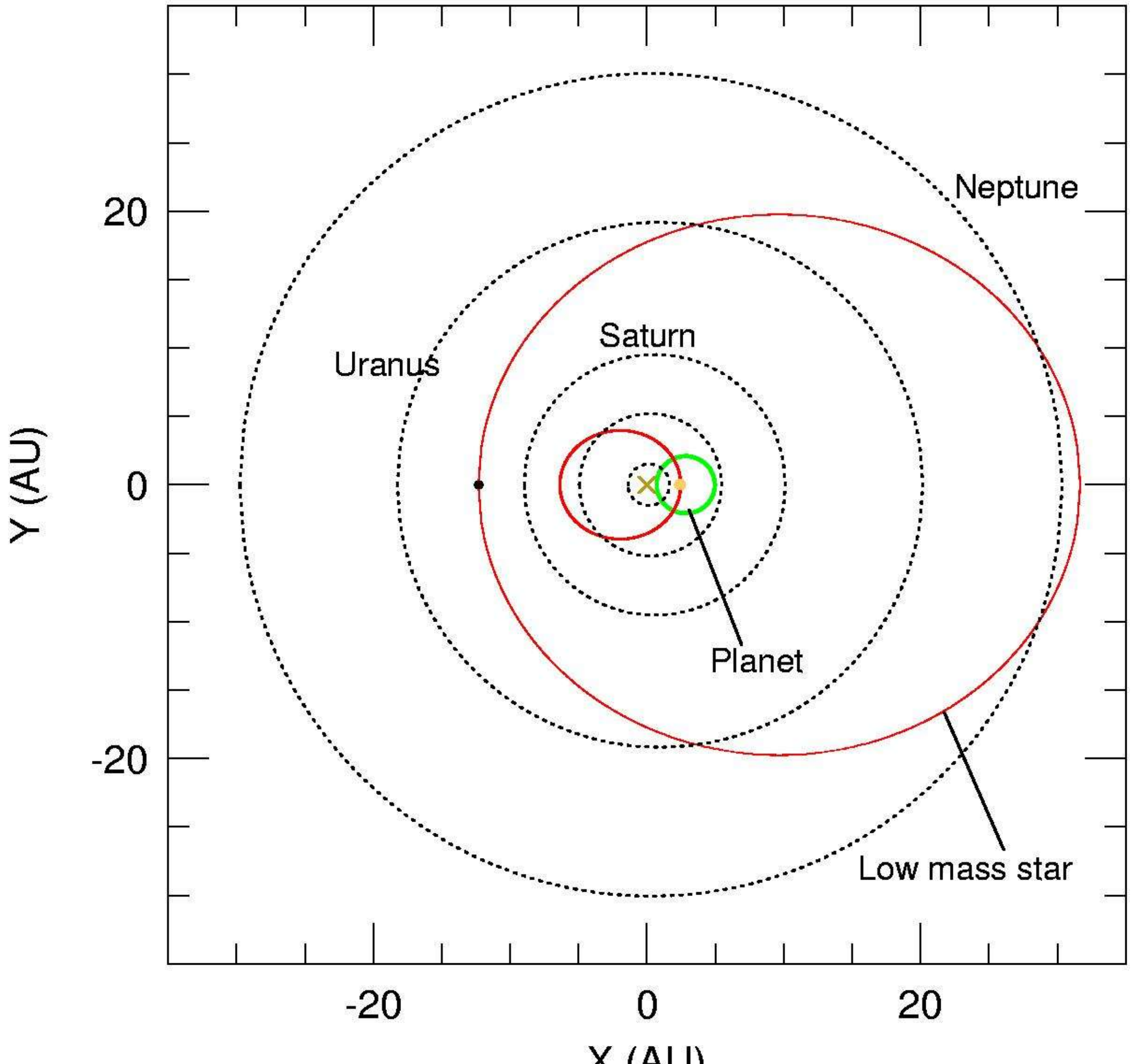


Klaus Fuhrmann, ... 2003, pre/re. and
properties of planet primaries at http://youngstars.mpe.mpg.de



Gamma Cep Finding Chart

Gamma Cep Orbits



... Hatzes ... 2003

FORMATION OF PEGASI-PLANETS

A VORTEX AT THE CRITICAL MASS?

Günther Wuchterl, MPE

PLANET FORMATION BY NUCLEATED INSTABILITY

Growing a condensible element core
to gravitationally catch nebula gas

The protoplanetary nebula

- theoretically and observationally uncertain,
- use solar system concept of minimum reconstitutive mass,
- vary nebula conditions to understand planet formation in general.

The core

- rigid body,
- particle-in-box planetesimal accretion-rate,
- feeding-zone with given initial mass.

The gaseous envelope

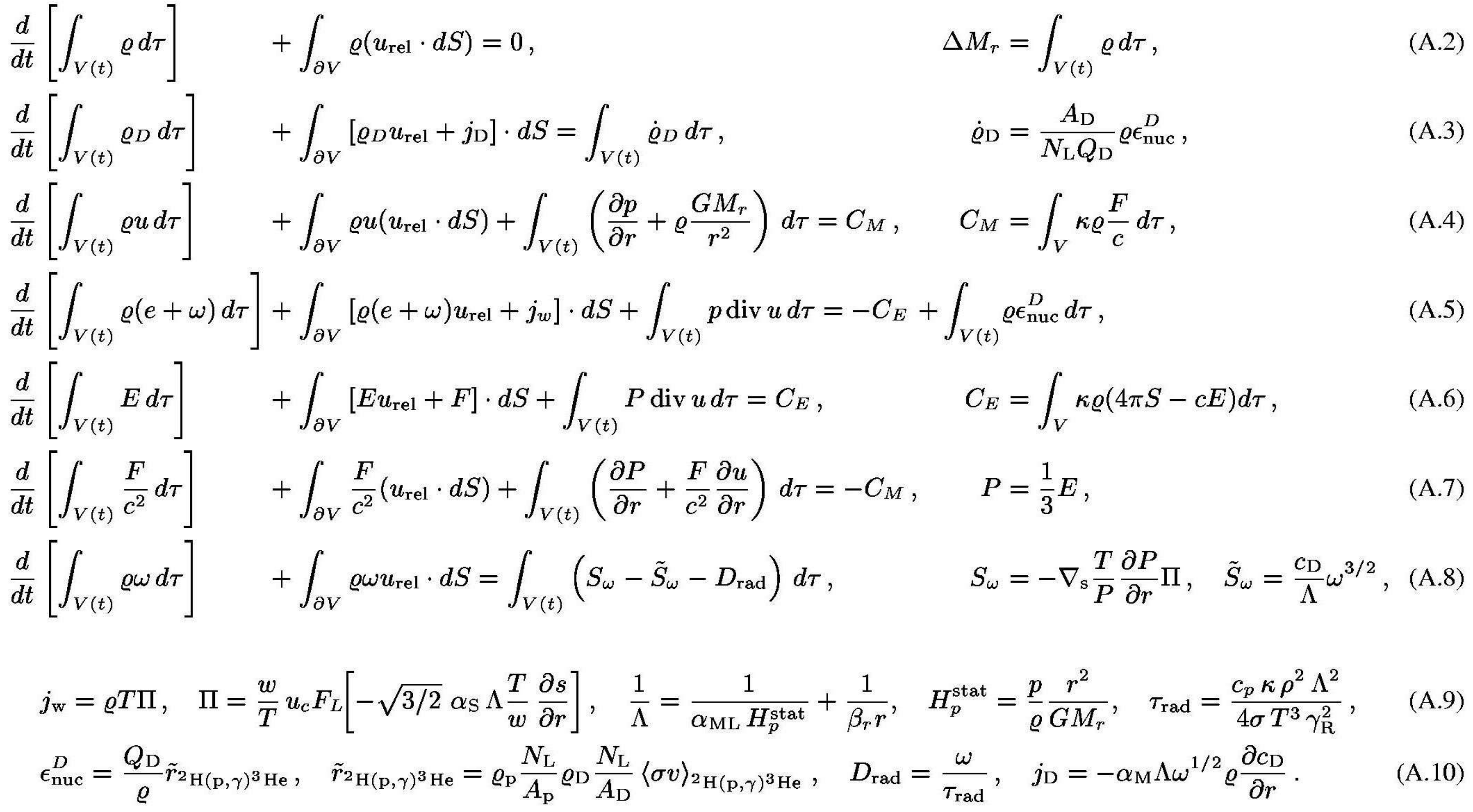
- from core surface to the unperturbed nebula (Hill-radius),
- dynamics of radiating fluids,
- time-dependent convection,
- spherical symmetry.

Equations: limiting cases

- static limit: stellar structure equations,
- convection@Sun: (1) fix mixing-length parameter; (2) test by zone-bottom passed (Wuchterl and Feuchtinger 1998),
- RR-Lyrae lightcurves are now correct (Feuchtinger 1999,…).

Equations for self-gravitating, convective, radiating fluids

G. Wuchterl and W.M. Tscharnuter: From clouds to stars Astron. Astrophys, **398**, 1081-1090, 2003



$$\frac{d}{dt}\left[\int_{V(t)} \varrho \, d\tau\right] + \int_{\partial V} \varrho(u_{\rm rel} \cdot dS) = 0\,, \qquad \Delta M_r = \int_{V(t)} \varrho \, d\tau\,, \tag{A.2}$$

$$\frac{d}{dt}\left[\int_{V(t)} \varrho_D \, d\tau\right] + \int_{\partial V} [\varrho_D u_{\rm rel} + j_{\rm D}] \cdot dS = \int_{V(t)} \dot{\varrho}_D \, d\tau\,, \qquad \dot{\varrho}_{\rm D} = \frac{A_{\rm D}}{N_{\rm L} Q_{\rm D}} \varrho \epsilon^D_{\rm nuc}\,, \tag{A.3}$$

$$\frac{d}{dt}\left[\int_{V(t)} \varrho u \, d\tau\right] + \int_{\partial V} \varrho u(u_{\rm rel} \cdot dS) + \int_{V(t)} \left(\frac{\partial p}{\partial r} + \varrho \frac{G M_r}{r^2}\right) d\tau = C_M\,, \qquad C_M = \int_V \kappa \varrho \frac{F}{c} \, d\tau\,, \tag{A.4}$$

$$\frac{d}{dt}\left[\int_{V(t)} \varrho(e + \omega) \, d\tau\right] + \int_{\partial V} [\varrho(e + \omega) u_{\rm rel} + j_w] \cdot dS + \int_{V(t)} p \, {\rm div}\, u \, d\tau = -C_E + \int_{V(t)} \varrho \epsilon^D_{\rm nuc} \, d\tau\,, \tag{A.5}$$

$$\frac{d}{dt}\left[\int_{V(t)} E \, d\tau\right] + \int_{\partial V} [E u_{\rm rel} + F] \cdot dS + \int_{V(t)} P \, {\rm div}\, u \, d\tau = C_E\,, \qquad C_E = \int_V \kappa \varrho (4\pi S - cE) d\tau\,, \tag{A.6}$$

$$\frac{d}{dt}\left[\int_{V(t)} \frac{F}{c^2} \, d\tau\right] + \int_{\partial V} \frac{F}{c^2}(u_{\rm rel} \cdot dS) + \int_{V(t)} \left(\frac{\partial P}{\partial r} + \frac{F}{c^2}\frac{\partial u}{\partial r}\right) d\tau = -C_M\,, \qquad P = \frac{1}{3} E\,, \tag{A.7}$$

$$\frac{d}{dt}\left[\int_{V(t)} \varrho \omega \, d\tau\right] + \int_{\partial V} \varrho \omega u_{\rm rel} \cdot dS = \int_{V(t)} \left(S_\omega - \tilde{S}_\omega - D_{\rm rad}\right) d\tau\,, \qquad S_\omega = -\nabla_{\rm s} \frac{T}{P} \frac{\partial P}{\partial r} \Pi\,, \quad \tilde{S}_\omega = \frac{c_{\rm D}}{\Lambda} \omega^{3/2}\,, \tag{A.8}$$

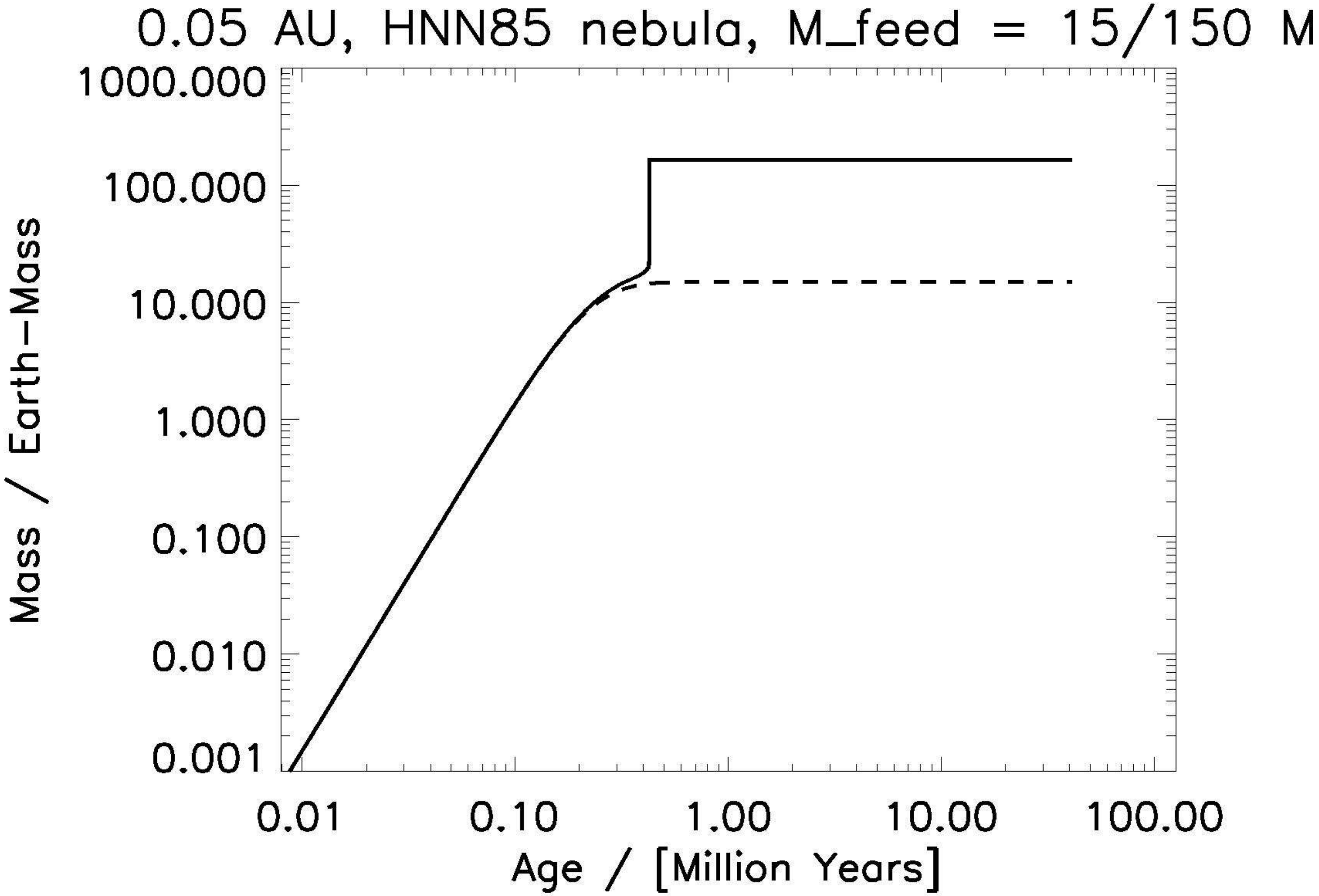
$$j_{\rm w} = \varrho T \Pi\,, \quad \Pi = \frac{w}{T} u_c F_L \left[-\sqrt{3/2}\, \alpha_{\rm S} \Lambda \frac{T}{w} \frac{\partial s}{\partial r}\right], \quad \frac{1}{\Lambda} = \frac{1}{\alpha_{\rm ML} H_p^{\rm stat}} + \frac{1}{\beta_r r}, \quad H_p^{\rm stat} = \frac{p}{\varrho} \frac{r^2}{G M_r}, \quad \tau_{\rm rad} = \frac{c_p \kappa \rho^2 \Lambda^2}{4 \sigma T^3 \gamma_{\rm R}^2}\,, \tag{A.9}$$

$$\epsilon^D_{\rm nuc} = \frac{Q_{\rm D}}{\varrho} \tilde{r}_{^2{\rm H(p,\gamma)^3He}}\,, \quad \tilde{r}_{^2{\rm H(p,\gamma)^3He}} = \varrho_{\rm p} \frac{N_{\rm L}}{A_{\rm p}} \varrho_{\rm D} \frac{N_{\rm L}}{A_{\rm D}} \langle \sigma v \rangle_{^2{\rm H(p,\gamma)^3He}}\,, \quad D_{\rm rad} = \frac{\omega}{\tau_{\rm rad}}\,, \quad j_{\rm D} = -\alpha_{\rm M} \Lambda \omega^{1/2} \varrho \frac{\partial c_{\rm D}}{\partial r}\,. \tag{A.10}$$

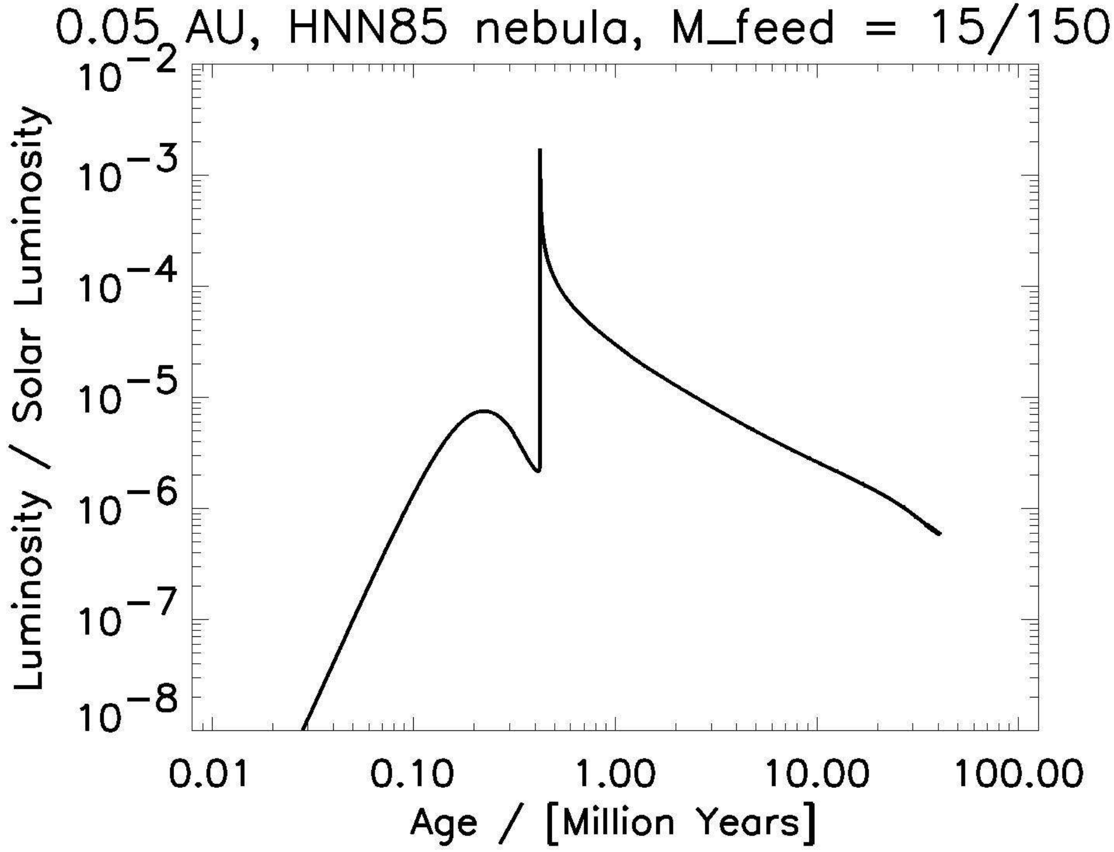
A Pegasi-Planet

- 0.05 AU from a solar-mass star,
- in minimum reconstitutive mass nebula,
- 15 earth-masses solids,
- feeding-zone 150 earth-masses gas.

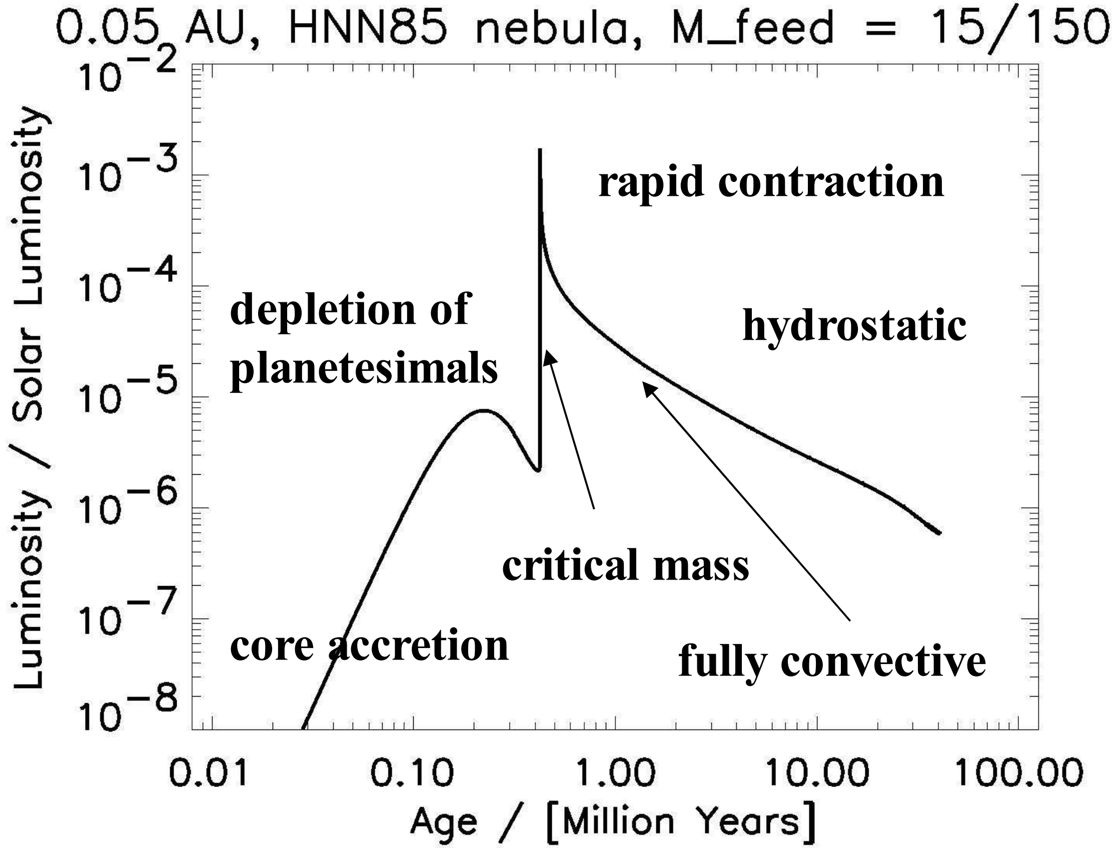
Pegasi-planet: mass-accretion



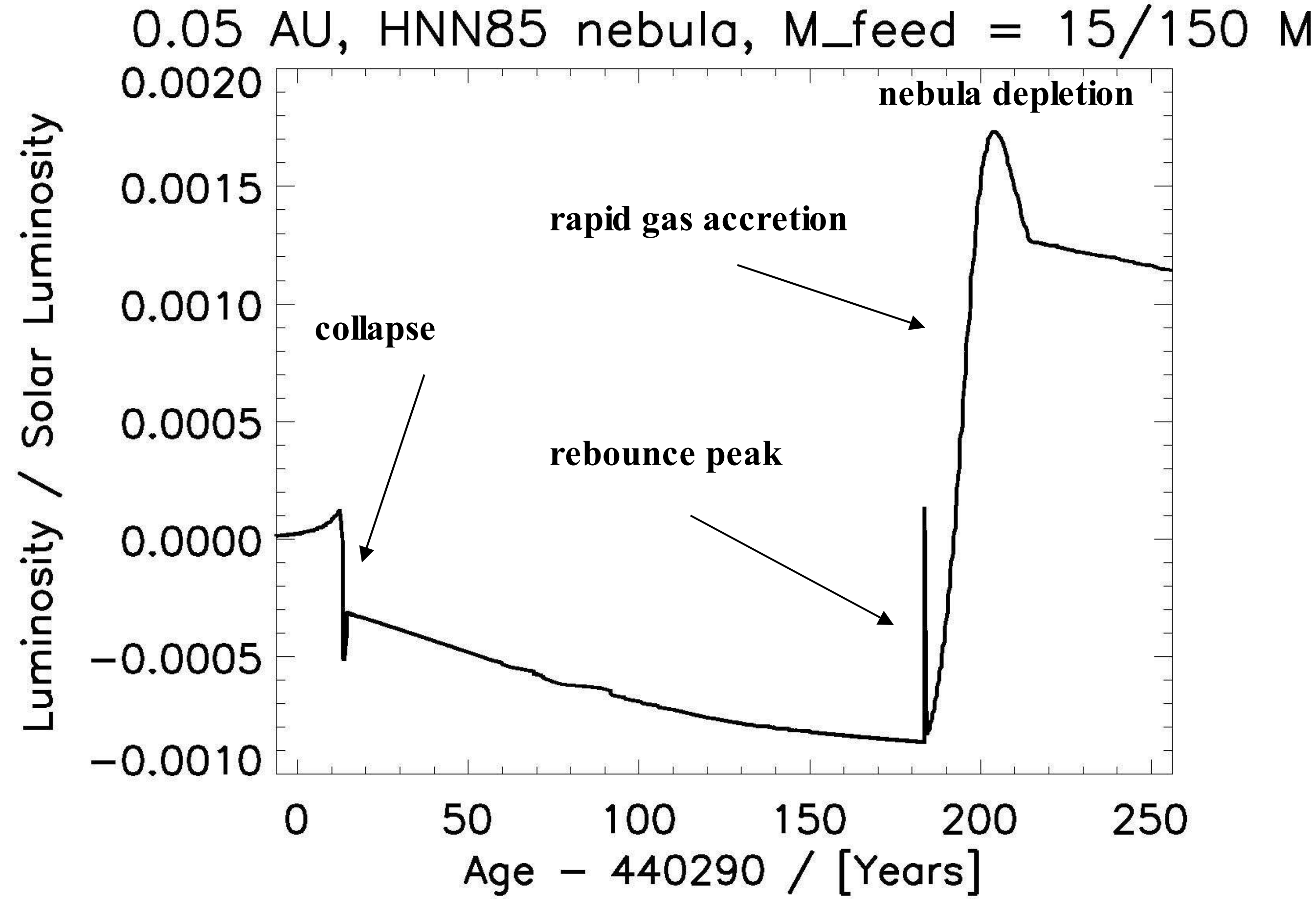
PEGASI-PLANET LUMINOSITY



PEGASI-PLANET LUMINOSITY II



Evolution around Maximum Luminosity



nebula depletion

rapid gas accretion

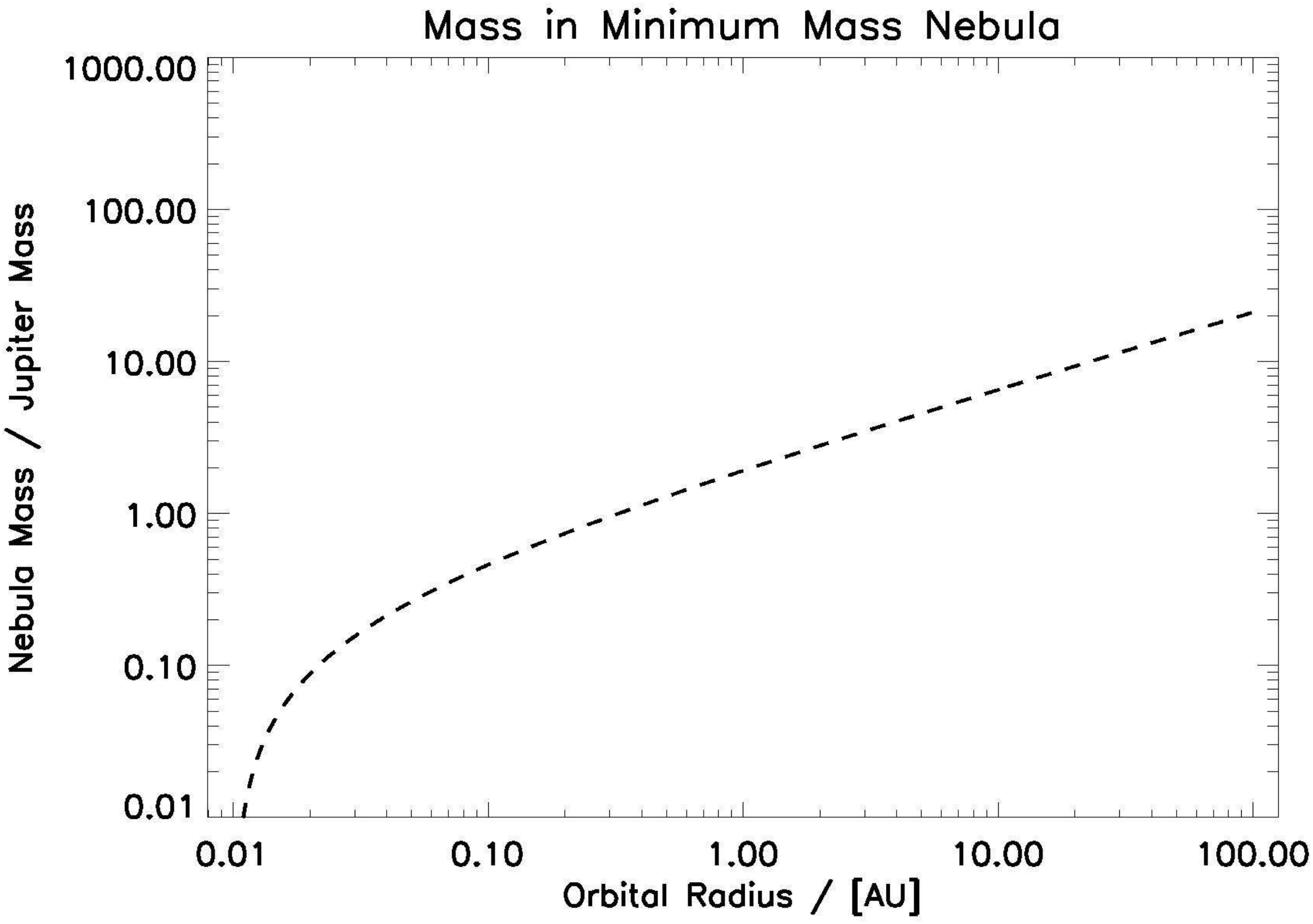
collapse

rebounce peak

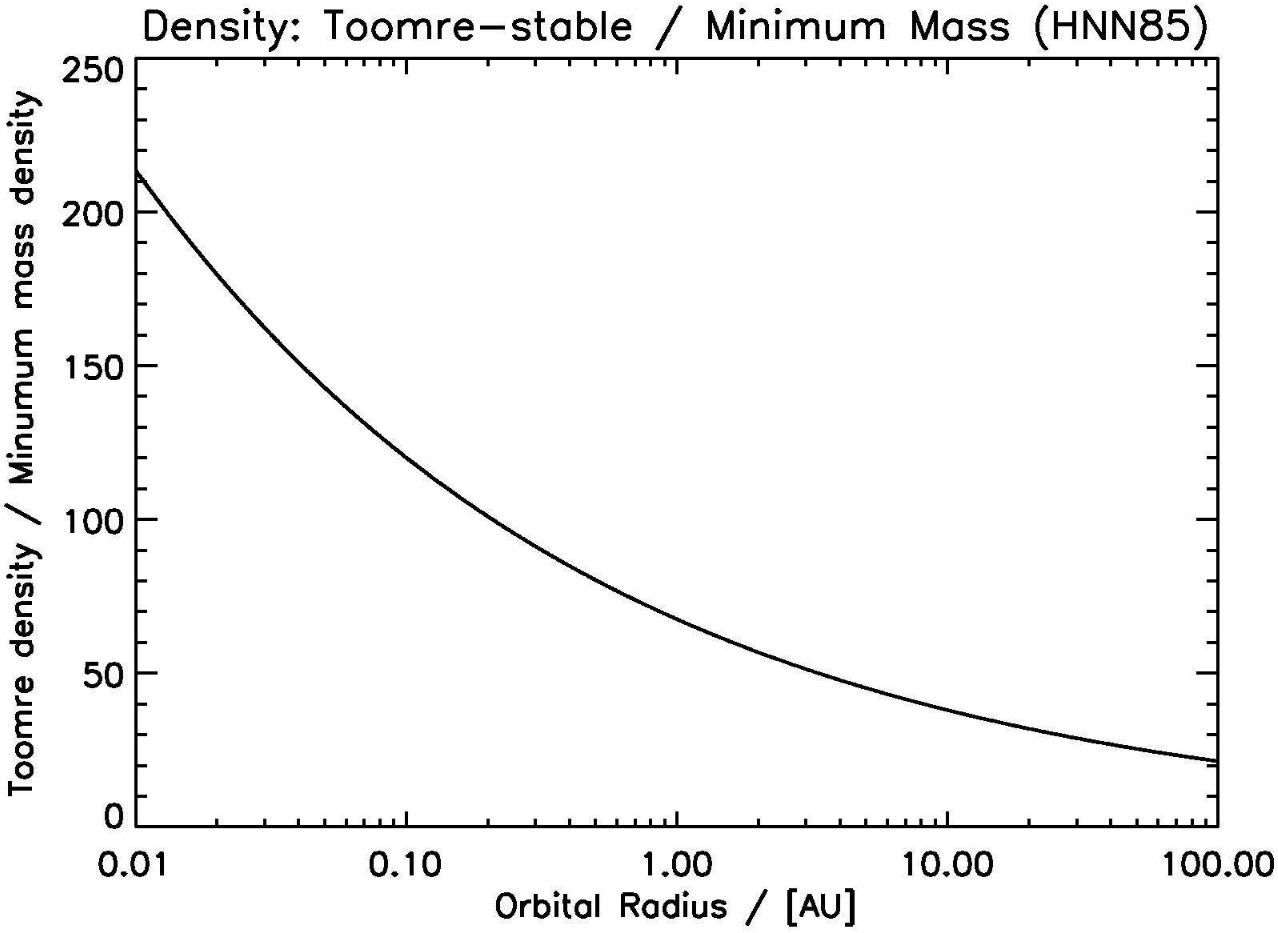
Are assumptions about feeding masses OK?

Is there a plausible nebula with sufficient mass close-in?

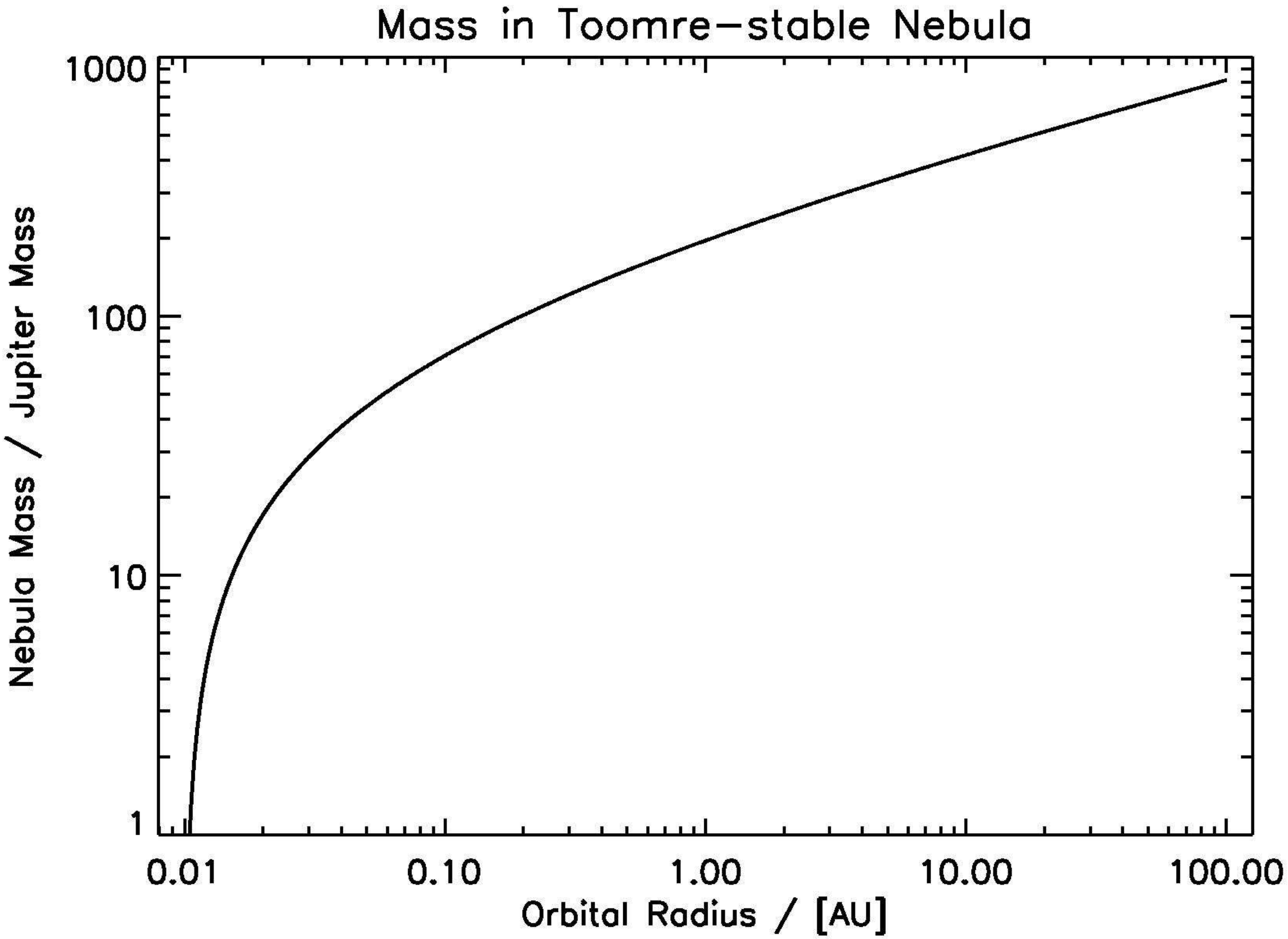
Nebula-mass interior of orbit radius



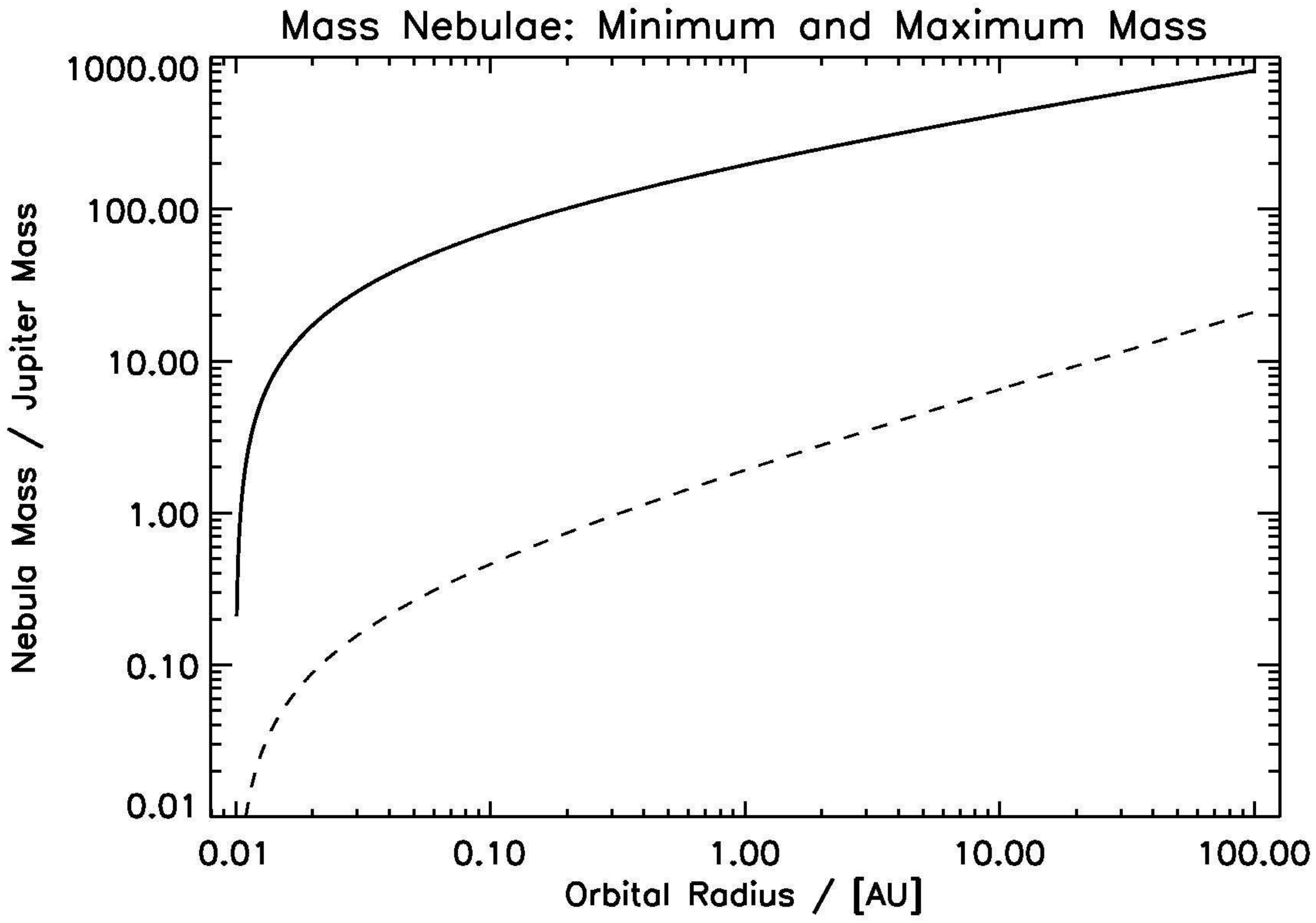
Density-factor for nebula instability



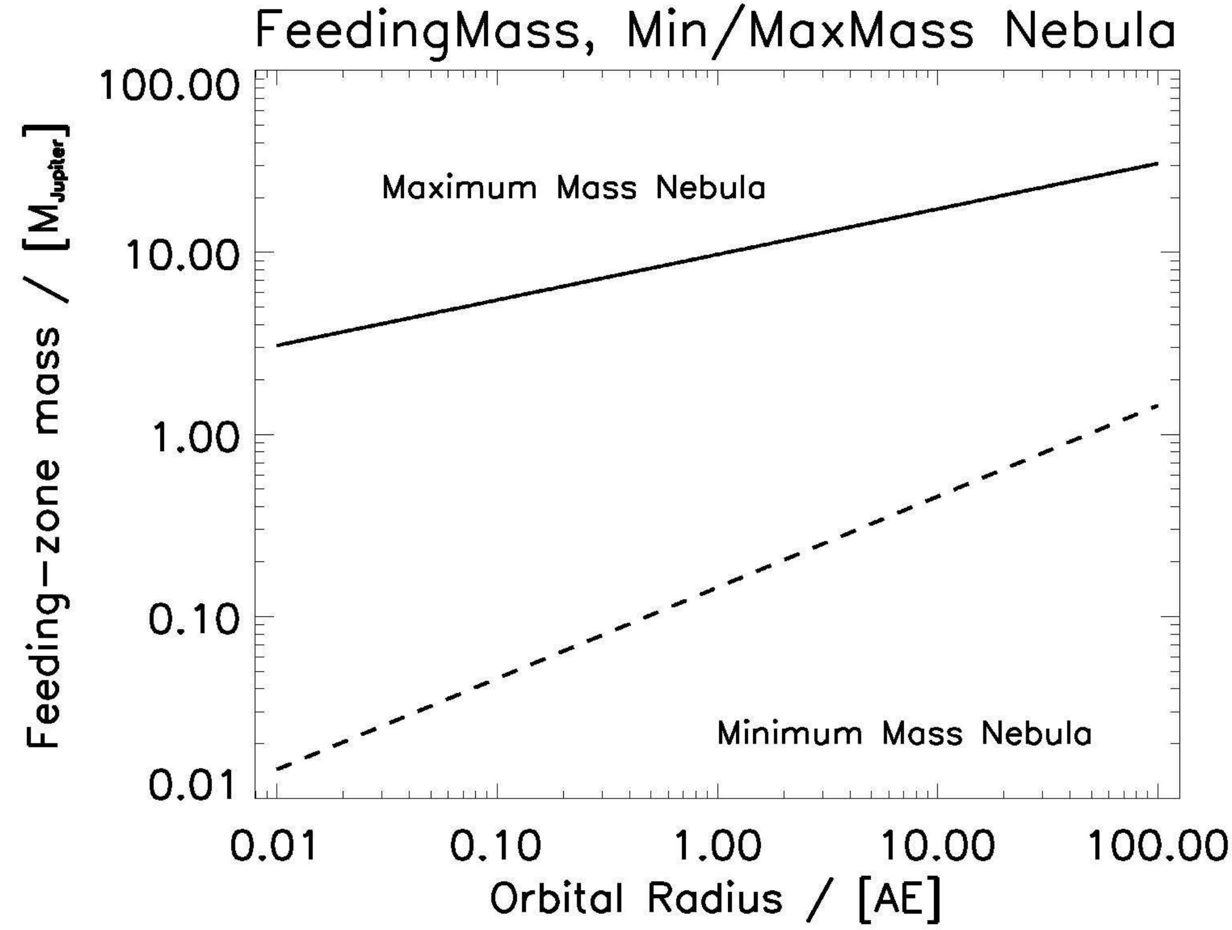
Nebula-mass interior of orbit at marginal stability



Nebula-mass: Min vs. Max

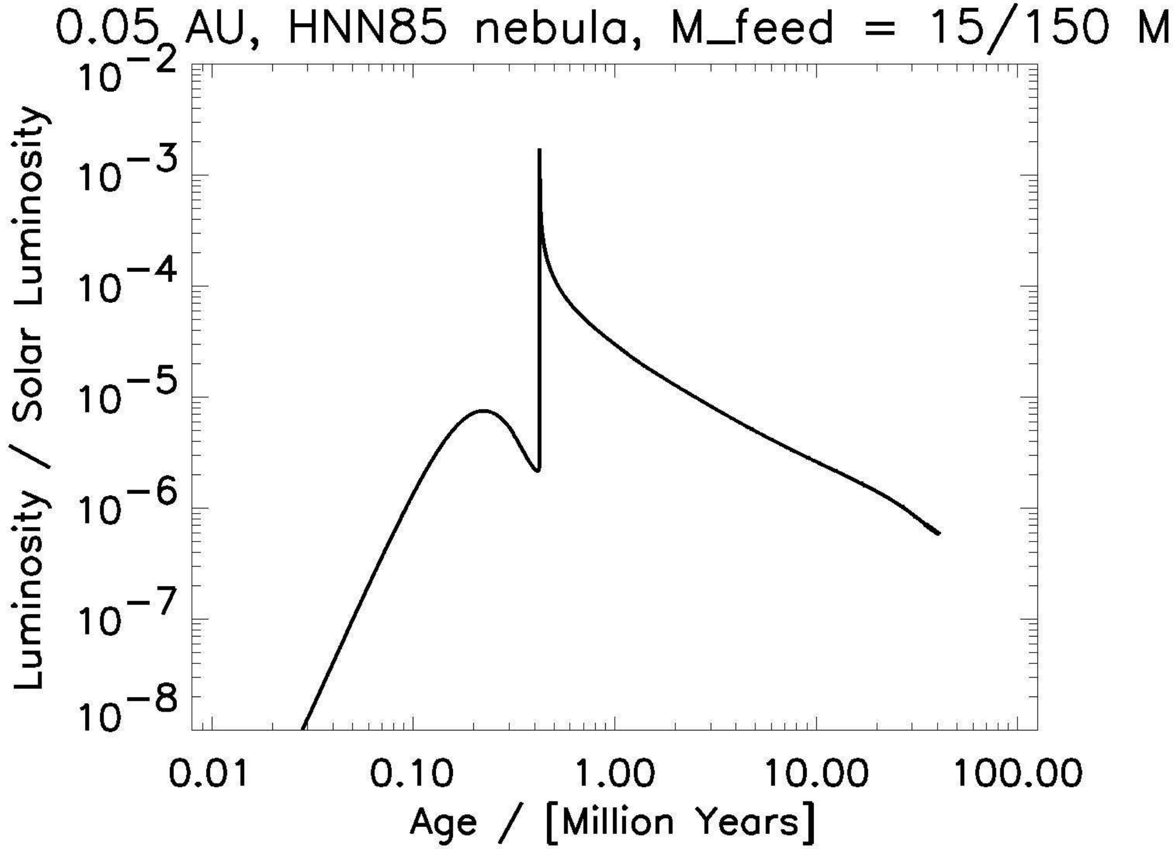


Nebula-mass in Jupiter mass feeding-zone

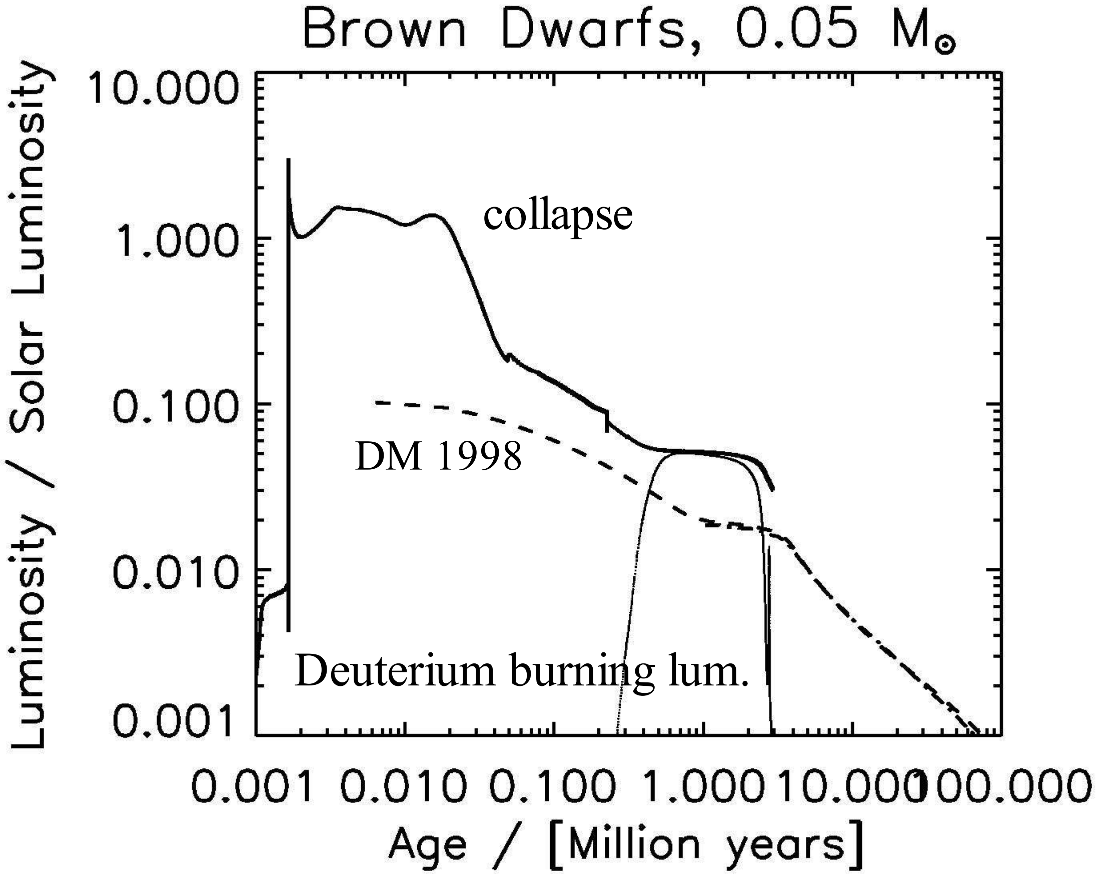


Properties of young planets

PEGASI-PLANET

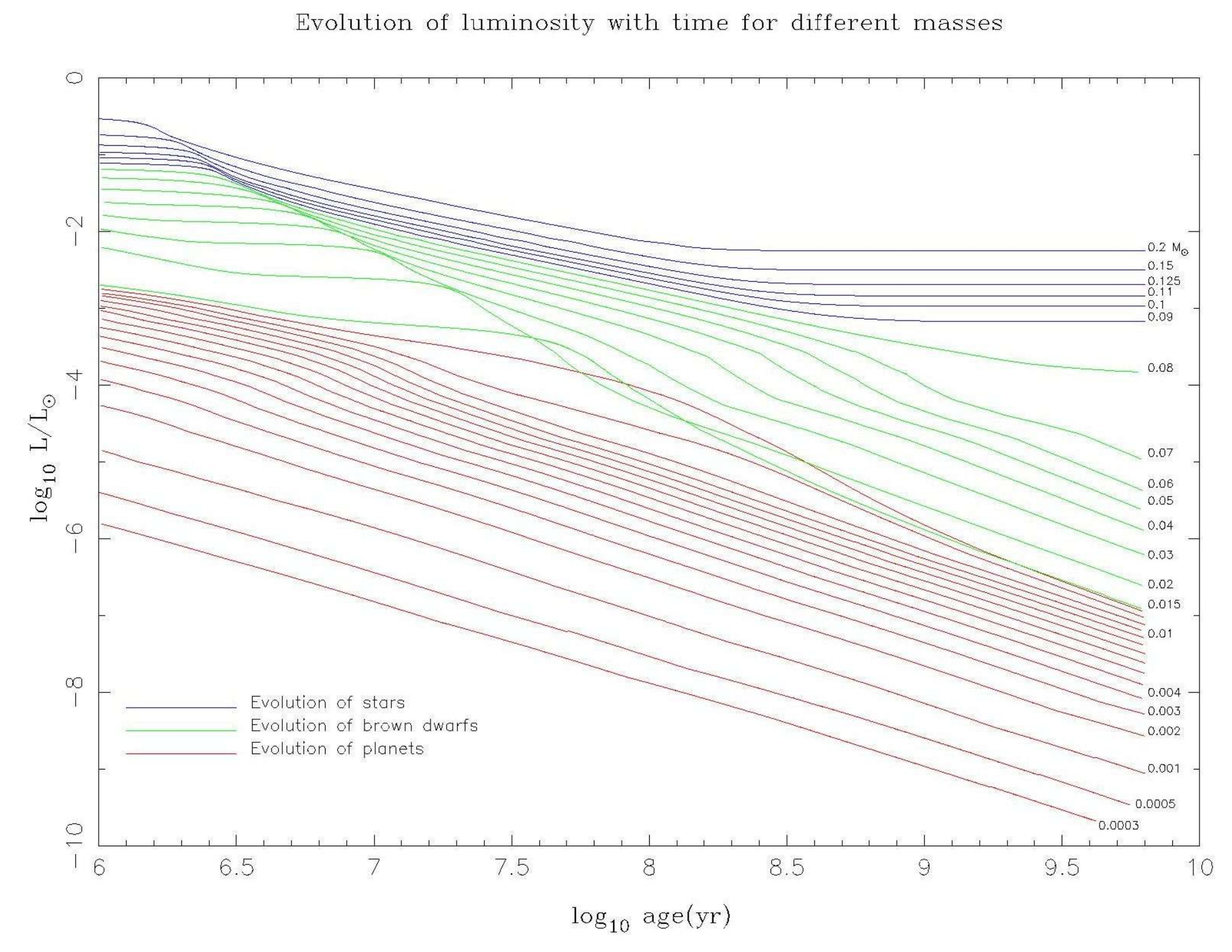


Brown dwarf collapse



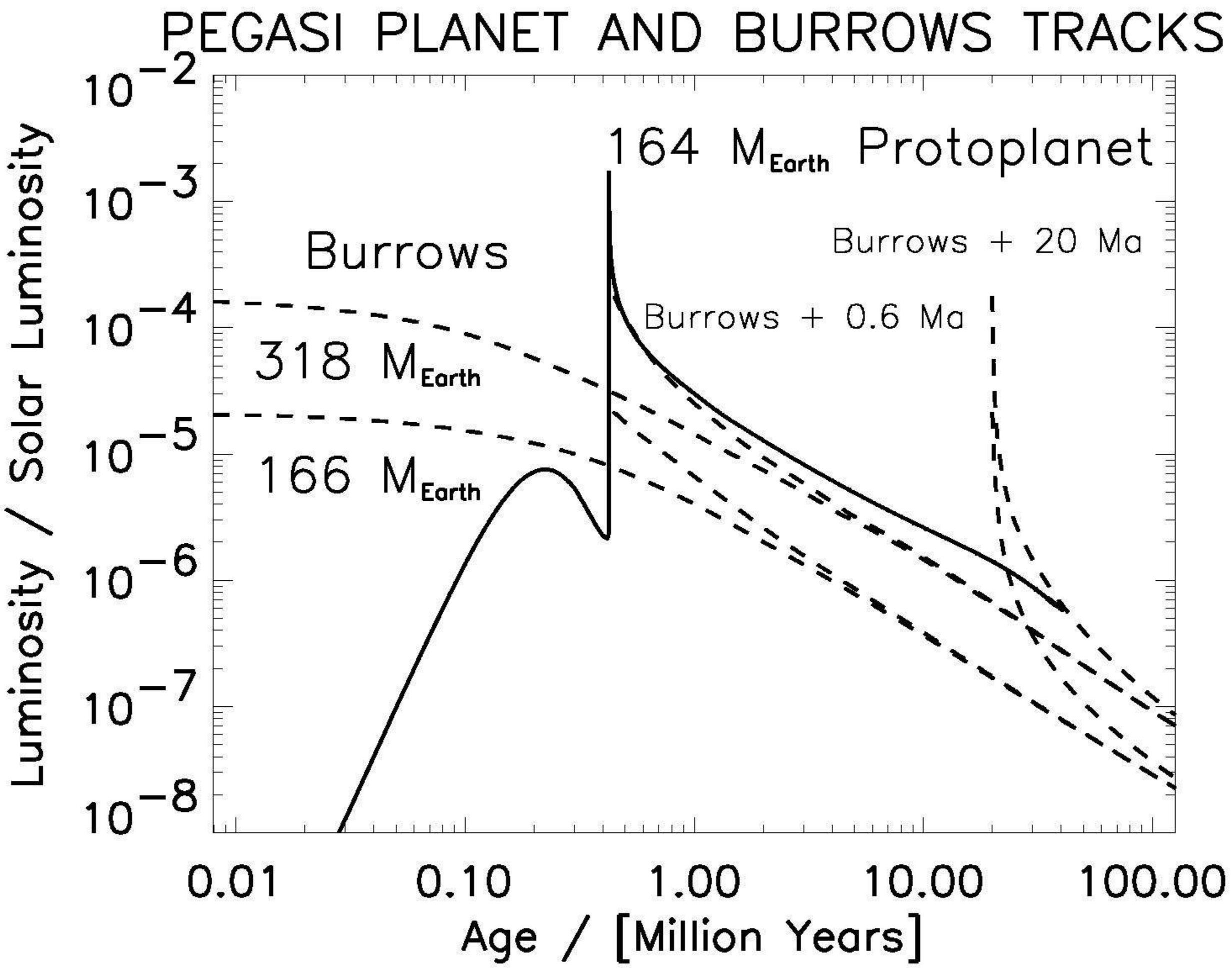
For collapse see „From Clouds to Stars“, Wuchterl and Tscharnuter 2003, A&A, **398**, 1081-1090

Hydrostatic, initially fully convective



Burrows et al. 1993/97

Dynamic and formation vs. hydrostatic and hot



PEGASI-PLANETS

- Pegasi-planets form in-situ if mass is available,
- Nebulae providing sufficient mass in feeding zones are plausible,
- Use formation-models to determine planetary properties for pre-main sequence stellar ages.

Subcritical Proto-Planets

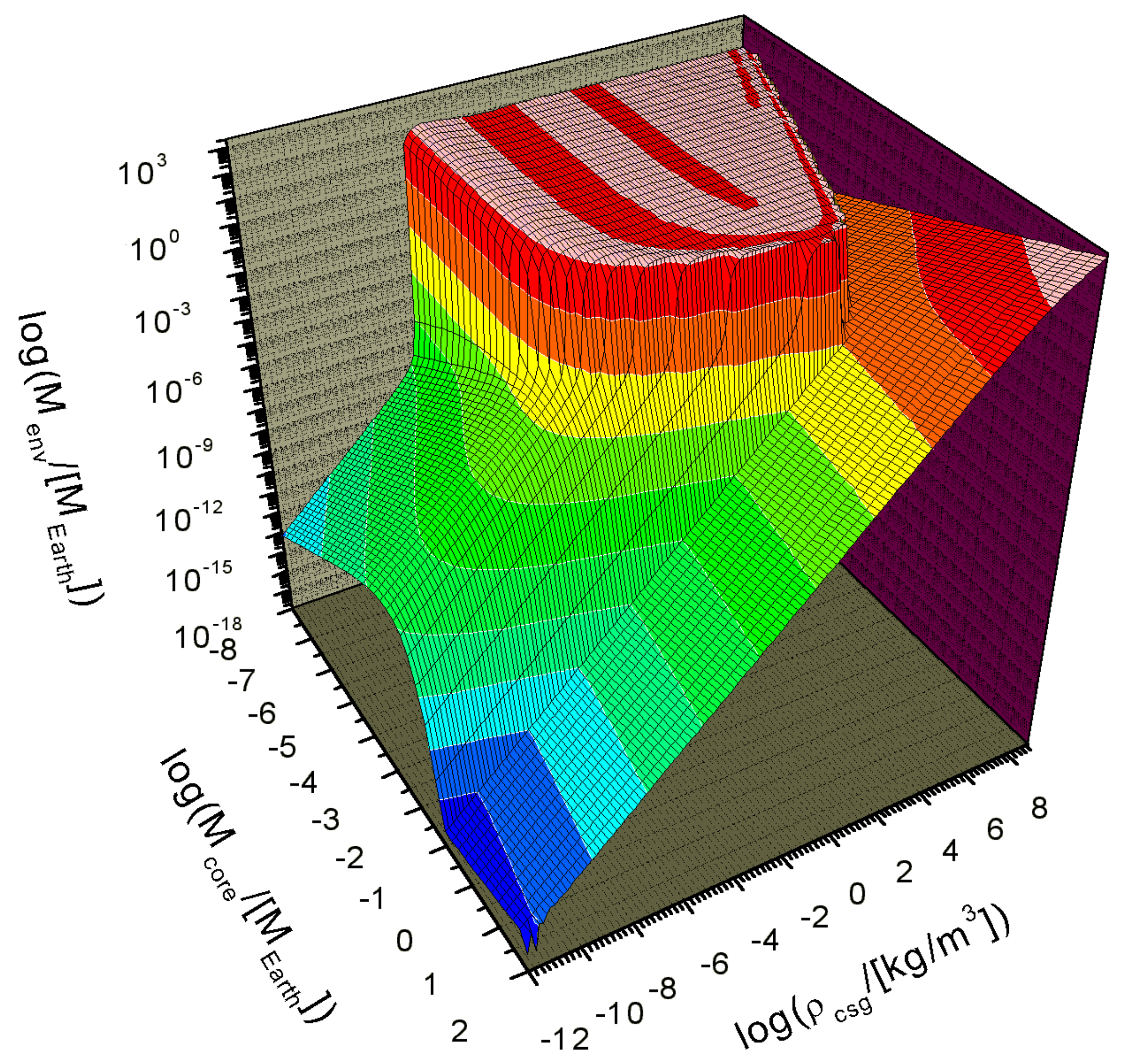
- Hydrostatic to few percent, globally
- Weakly dependent on nebula assumptions for „radiative“ envelopes
- More massive envelope at given core for „convective“ protoplanets

The global picture

Isothermal protoplanets

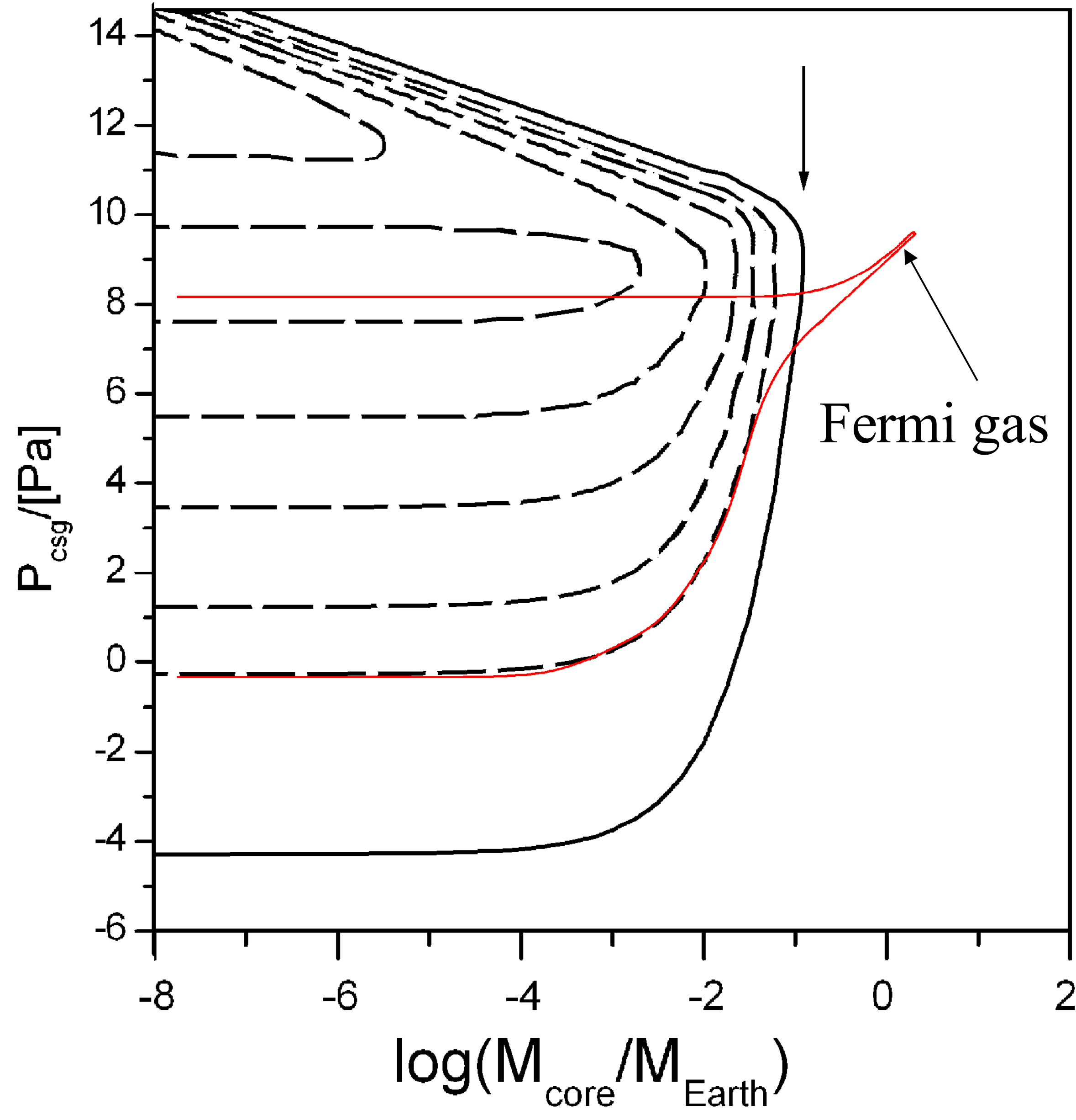
by Bojan Pecnik

All protoplanets at given orbit

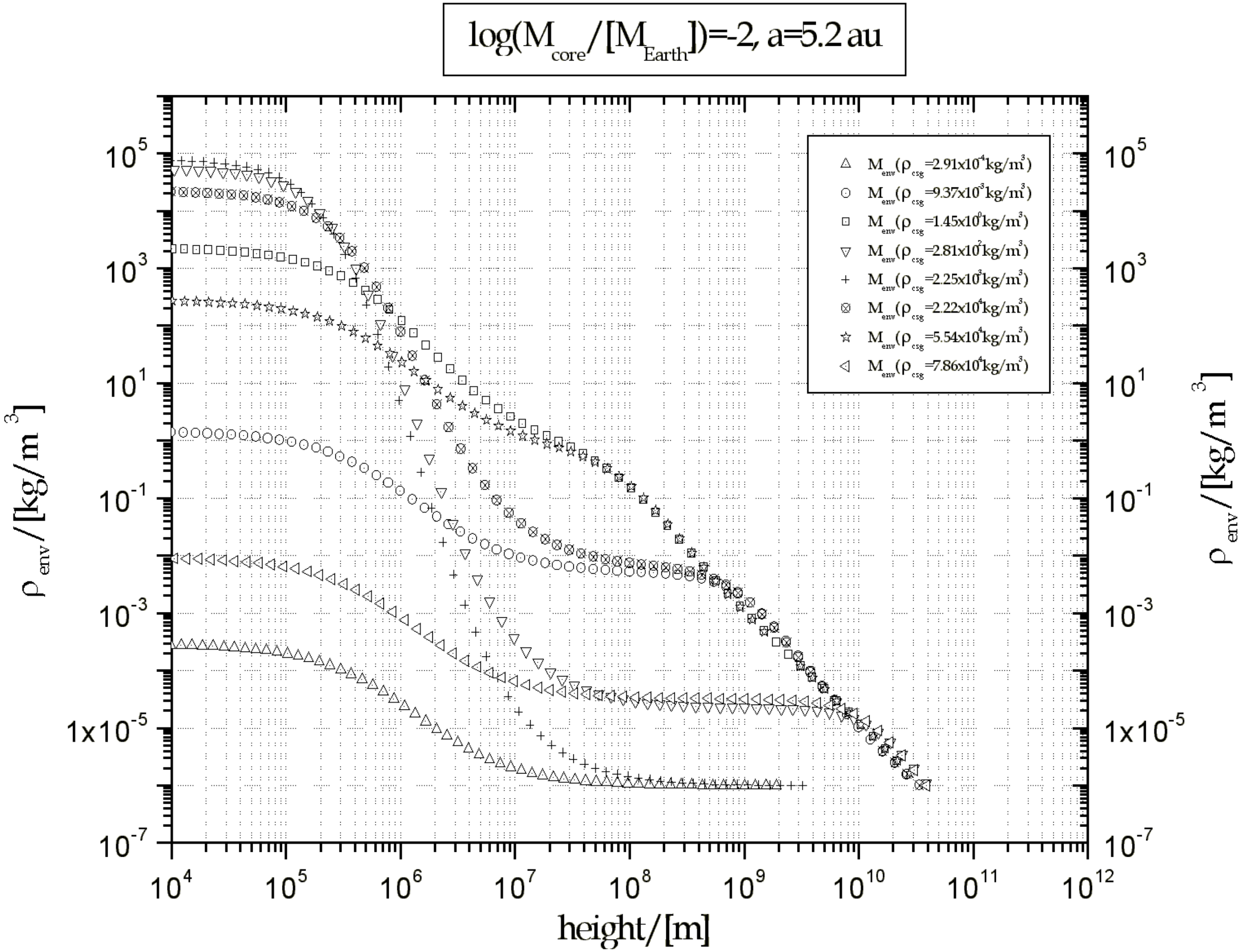


Pecnik 2003. subm.

Local and Global Critical Mass



Multiple Envelope Equilibria



All (isothermal) subcritical protoplanets

- Hydrostatically fill Hill-Sphere
- Few percent corrections for slowly rotating protoplanets (Götz 2003)
- Rotation determined by flow around planet
- Vortex formed by growing protoplanet interacting with ambient quasi-keplerian nebula → Rotation of giant planets

NUR NOCH 25 SEITEN