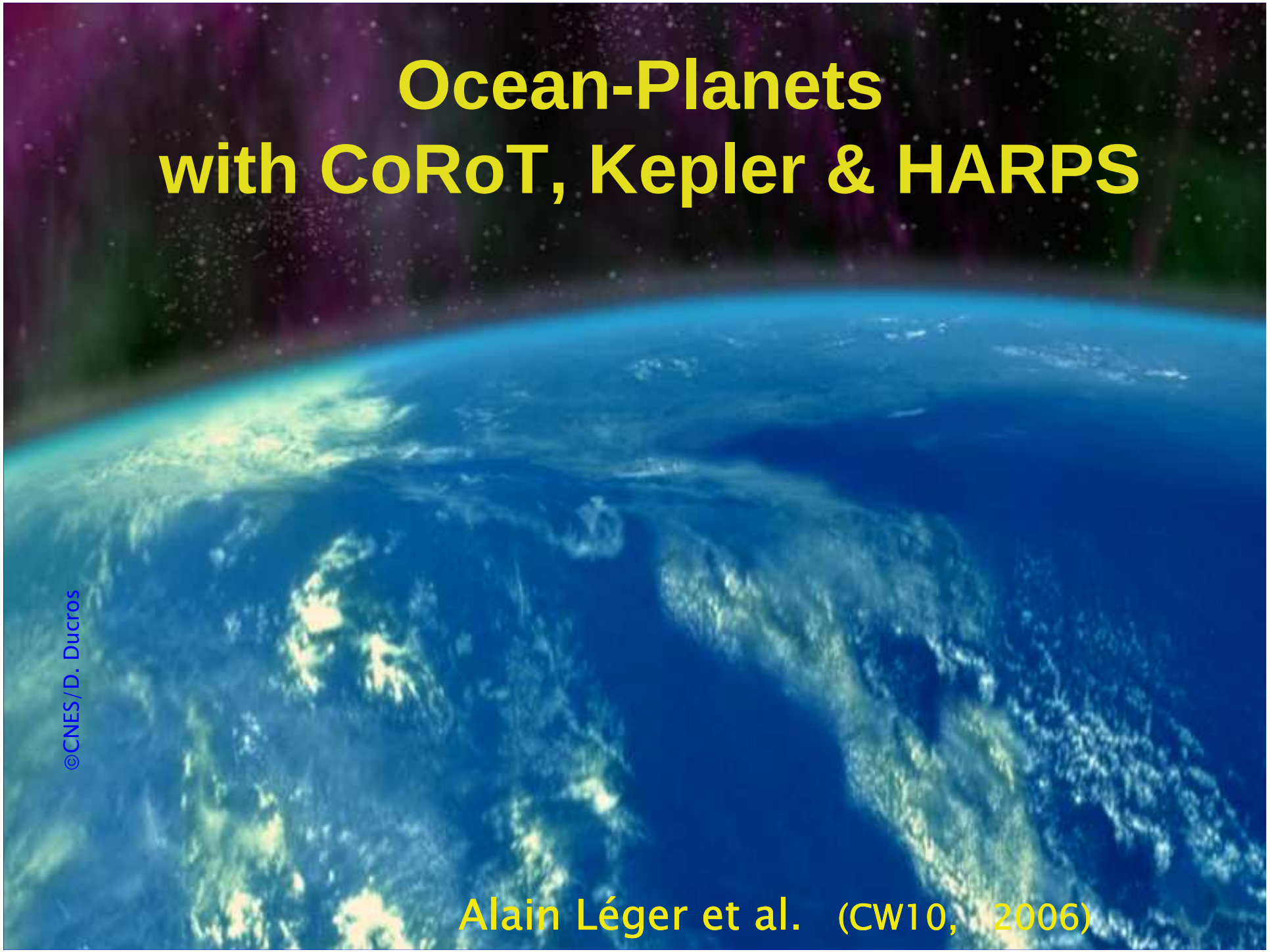
Ocean-Planets
with CoRoT, Kepler & HARPS



Alain Léger et al. (CW10, 2006)

Ocean-Planets

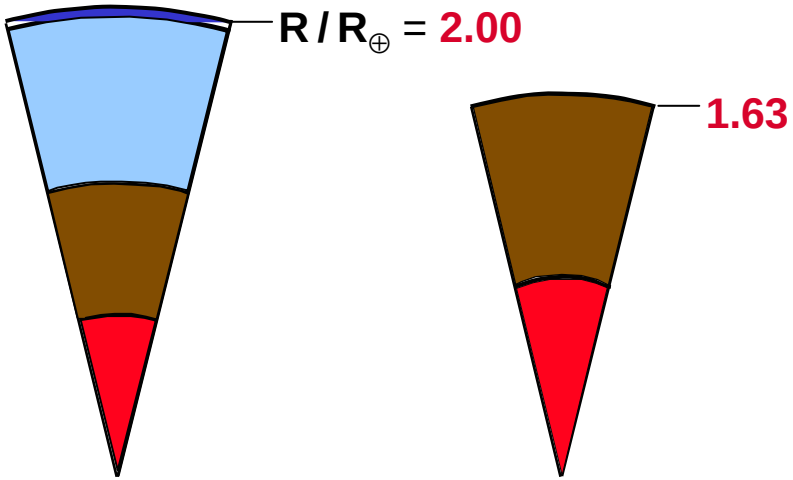
Accretion: $a > a_{ice}$ (~ 4AU) ==> 50% ice +50% rocks (in mass)

+ migration ---> HZ: Ocean-Planet

closer: "Sauna-planet"

🡻 **new kind of telluric-like planets**

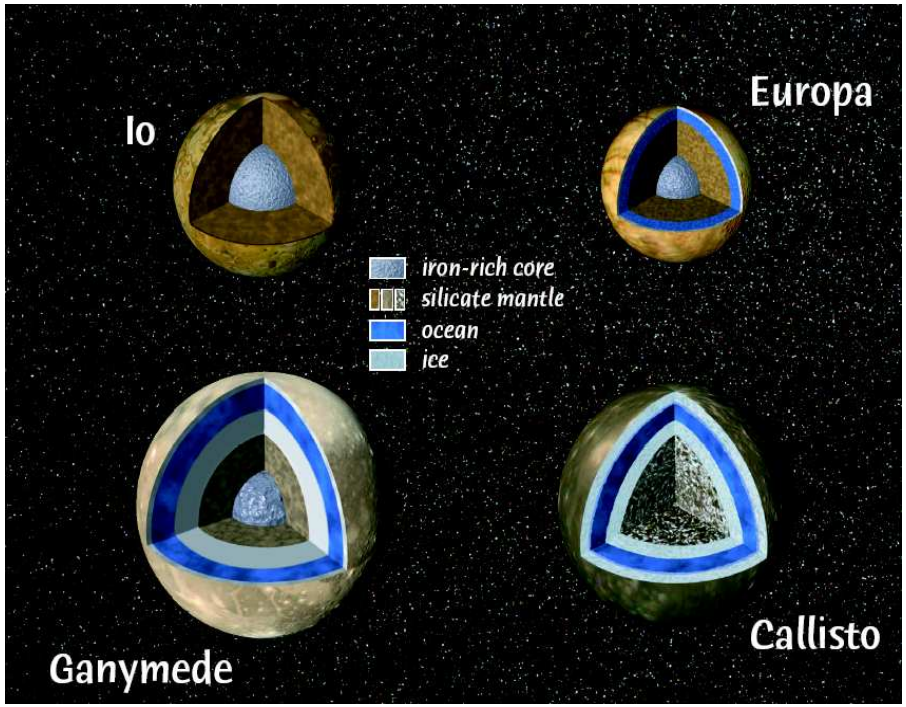
Internal structure



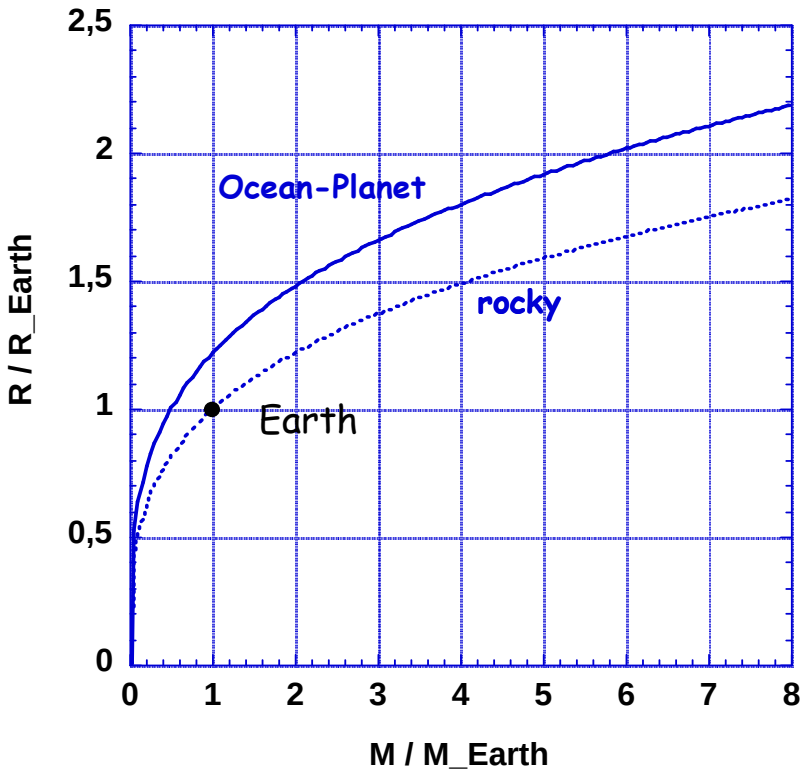
6 $M_\oplus$ Ocean-Planet

6 $M_\oplus$ Rocky Planet

~ jovian satellites



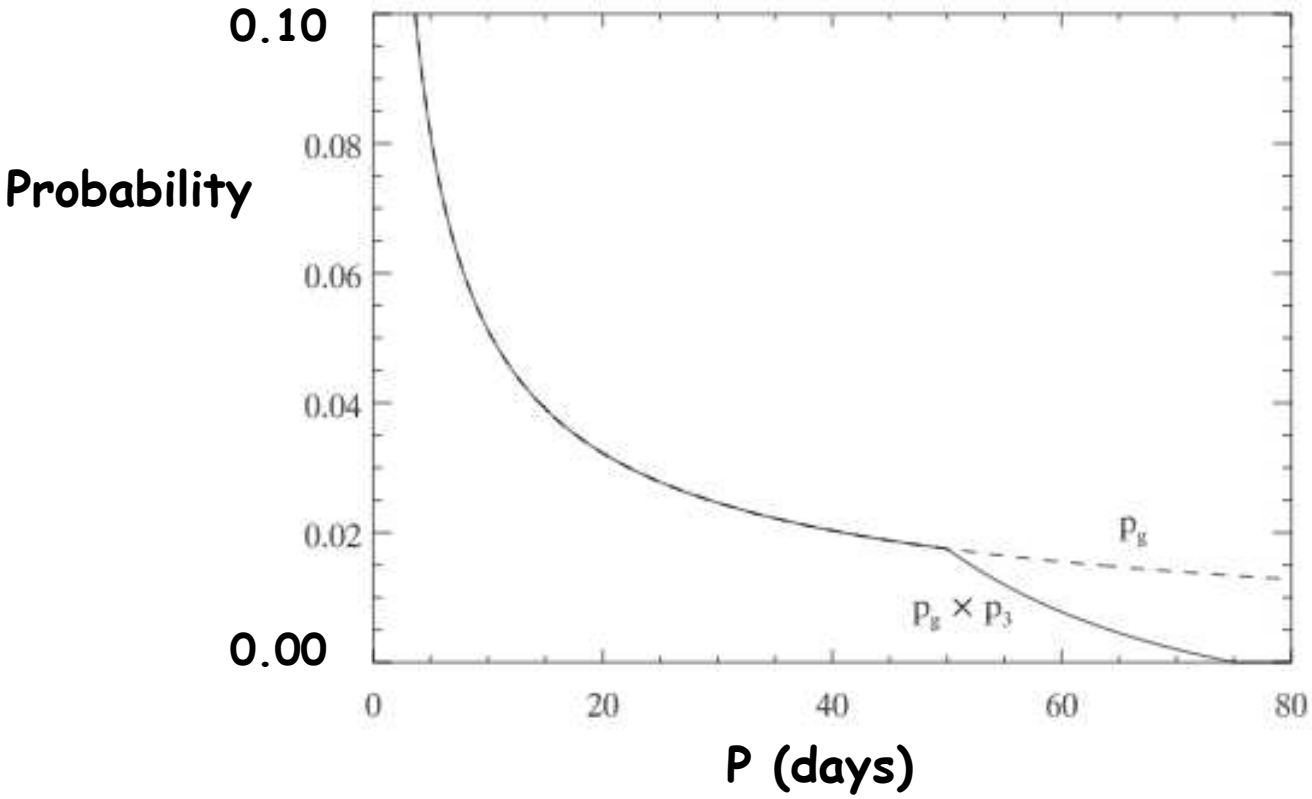
R_{pl} (M_{pl})



↓ can we discriminate OP / rocky P with:

COROT / Kepler (R_{pl}) + Doppler F-U (M_{pl}) ?

COROT



P = 50 days, GV

==> a = 0.27 AU

==> how small *a* can be ?

OP fate when a➢

1. Swelling ?

$P = P_0 e^{-h/H}$, $H = kT/\mu g$ ~ 15 - 20 km for μ = 18 (H_2O *not* H_2)

P: 1 --> 10^3 bar (condensed) for $\Delta h = [Ln(1000) - Ln(1)].H$

~ 130 km for T= 600K << R_{pl}

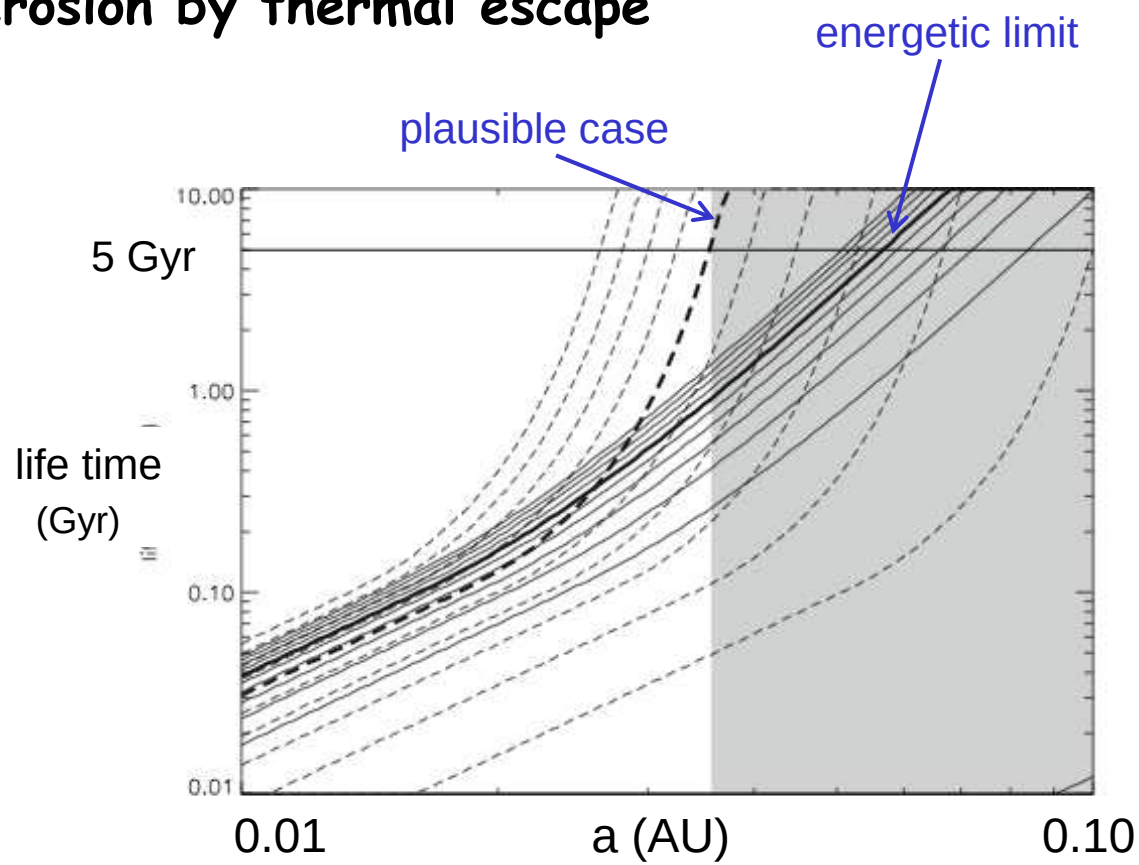
e.g. 2 R_E , $\Delta h / R_{pl}$ = 1%

==> swelling not essential

OP fate when a➢ (2)

2. Atmosphere erosion by thermal escape

exosphere
heating
by X, UX



a ≥ 0.05 AU ==> H_2O should remain

Fate when a➢ (3)

3. **Atmosphere erosion by stellar wind**
   can be shown < thermal erosion

a ≥ 0.05 AU ==> most H_2O should remain

⇦ Could COROT identify Ocean-Planets ?

Accuracy / R_{pl} & M_{pl}

$\langle\rho\rangle = (3/4\pi)\, M\, R_{pl}^{-3}$ $\qquad$ $R_{pl} = R_{star}\, (\Delta F / F)^{1/2}$

model --> $$\frac{\Delta\rho^{1/3}}{\rho^{1/3}} = 20.6\hat{E}\%$$

uncertainties: $$\left(\frac{\sigma_{\rho^{1/3}}}{\rho^{1/3}}\right)^2 = \left(\frac{1}{3}\,\frac{\sigma_M}{M}\right)^2 + \left(\frac{\sigma_{R_{star}}}{R_{star}}\right)^2 + \left(\frac{1}{2}\,\frac{\sigma_{\Delta F/F}}{\Delta F/F}\right)^2$$

a **2σ** detection (95% confidence) ==> $$\frac{\sigma_{\rho}^{1/3}}{\rho^{1/3}} \leq 10.3\hat{E}\%$$

Accuracy / R_{pl} & M_{pl} (2)

(1) $$\frac{\sigma_{R_{star}}}{R_{star}} \approx 5\%$$

(2) $$\frac{\sigma_{\Delta F/F}}{2\ \Delta F/F}$$

Reference case:
- COROT
- $m_V = 12$
- $R_{pl} = 2\ R_E$
- $a = 0.10$ AU

==> **4%**

Kepler ==> 0.4%

Accuracy / R_{pl} & M_{pl} (3)

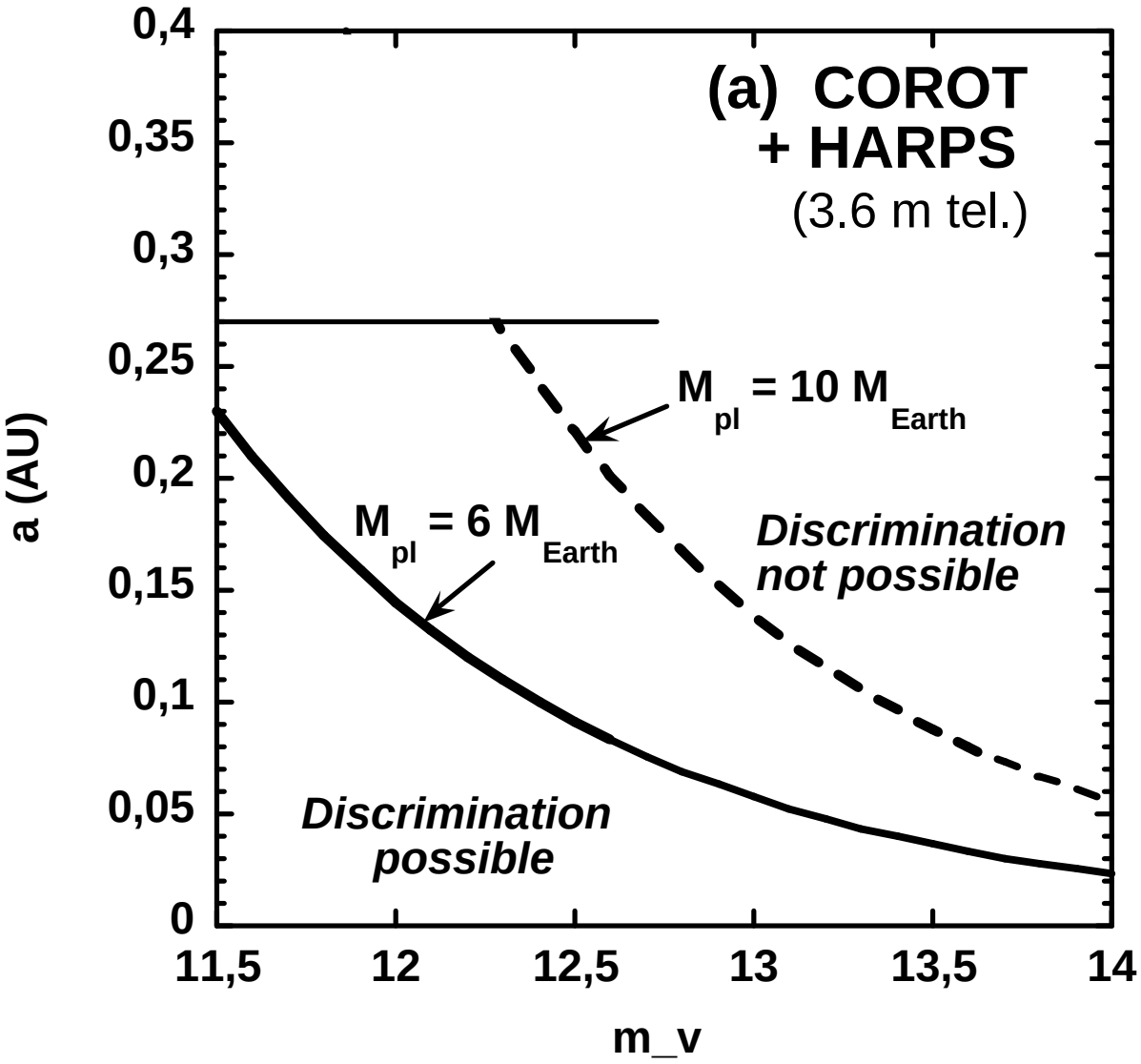
(3) $\frac{1}{3}\frac{\sigma_M}{M}$ Doppler: $K = 0.09 \frac{M_{pl}}{M_E} \frac{a}{1\,AU} \left(\frac{M_{st}}{M_{Sun}}\right)$ m/s

$$\sigma_K = \frac{\sigma_v}{\sqrt{N_{obs}/2}}$$

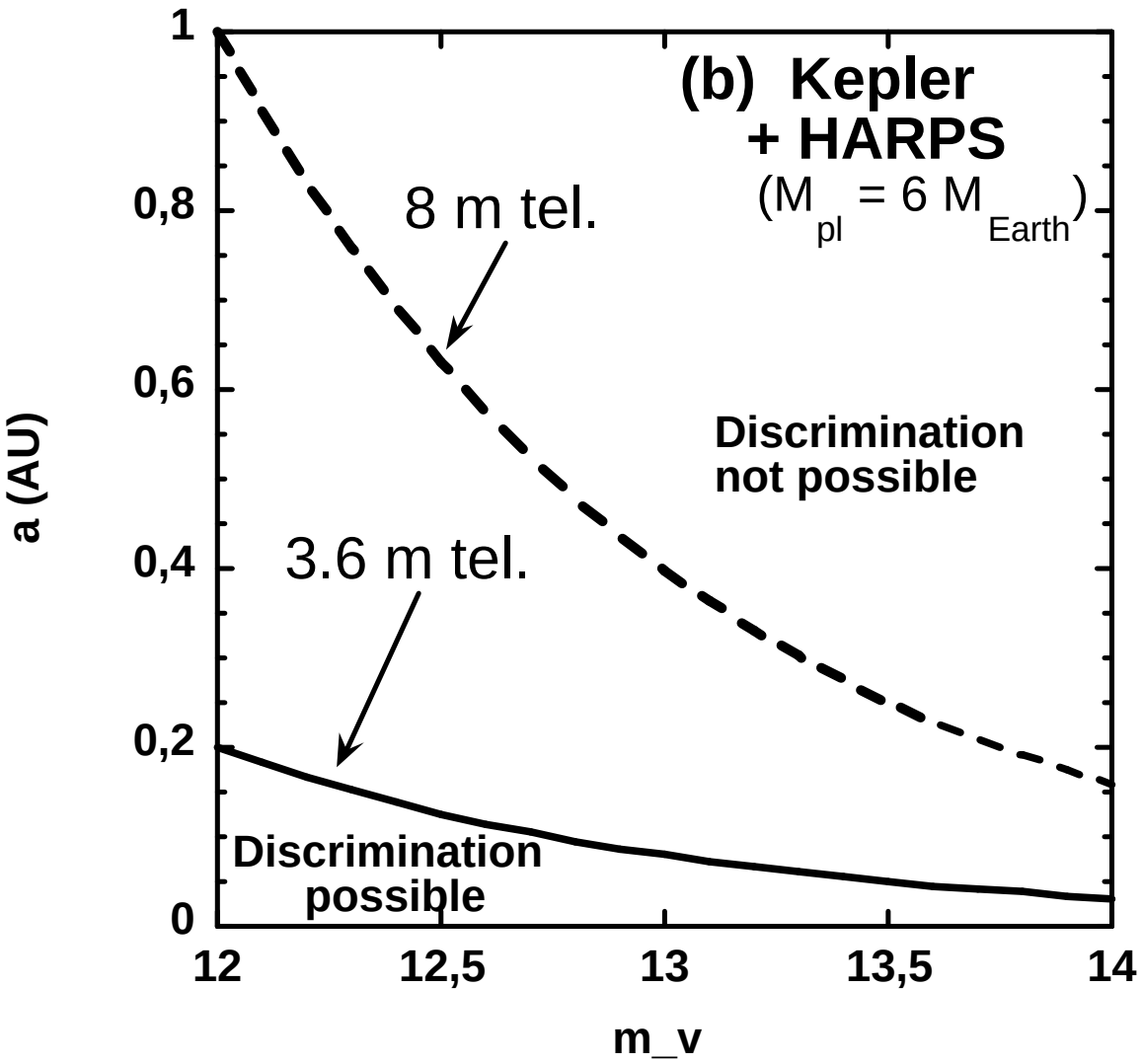
Reference case: HARPS (3.6 m)
m_V = 12
σ_v = 2 m/s (1h)
t = 80 h (10 nights) *a maximum!*

==> 6.3 %

Combining uncertainties



Combining uncertainties (2)



How many detections ?

- If *all* stars had 1 planet with 6 M_E , 0.05 AU

  ==> ~ 100 detections with possible discrimination OP/rocky P

- Conversely, $\geq$ 1 detection if $\eta \geq 1\%$

(Some) CONCLUSIONS

- m_V = 11 stars (weakly saturating) to be worked out *(if possible...)*
- long Doppler integrations needed
- Kepler: new Doppler machine needed

co-workers

F. Selsis [1], B. Chazelas [2], P. Bordé[3], F. Bouchy[4], J-M Griessmeier[5], H. Lammer[6], C. Sotin [7], O. Grasset[7], D. Despois [8], D. Ehrenreich[4], M. Ollivier [2], F. Brachet[2], C. Moutou[9], M. Deleuil[9], P. Barge[9], J. Kasting[10], A. Labèque [2]

large number = some guaranty to avoiding errors ??