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Constraints on exomoon habitability

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Why bother about exomoon habitability?

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The firstly detected exomoons will be roughly Earth-sized, i.e. have masses $\gtrsim 0.2 M_\oplus$ (Kipping et al. 2009).

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They could be numerous.

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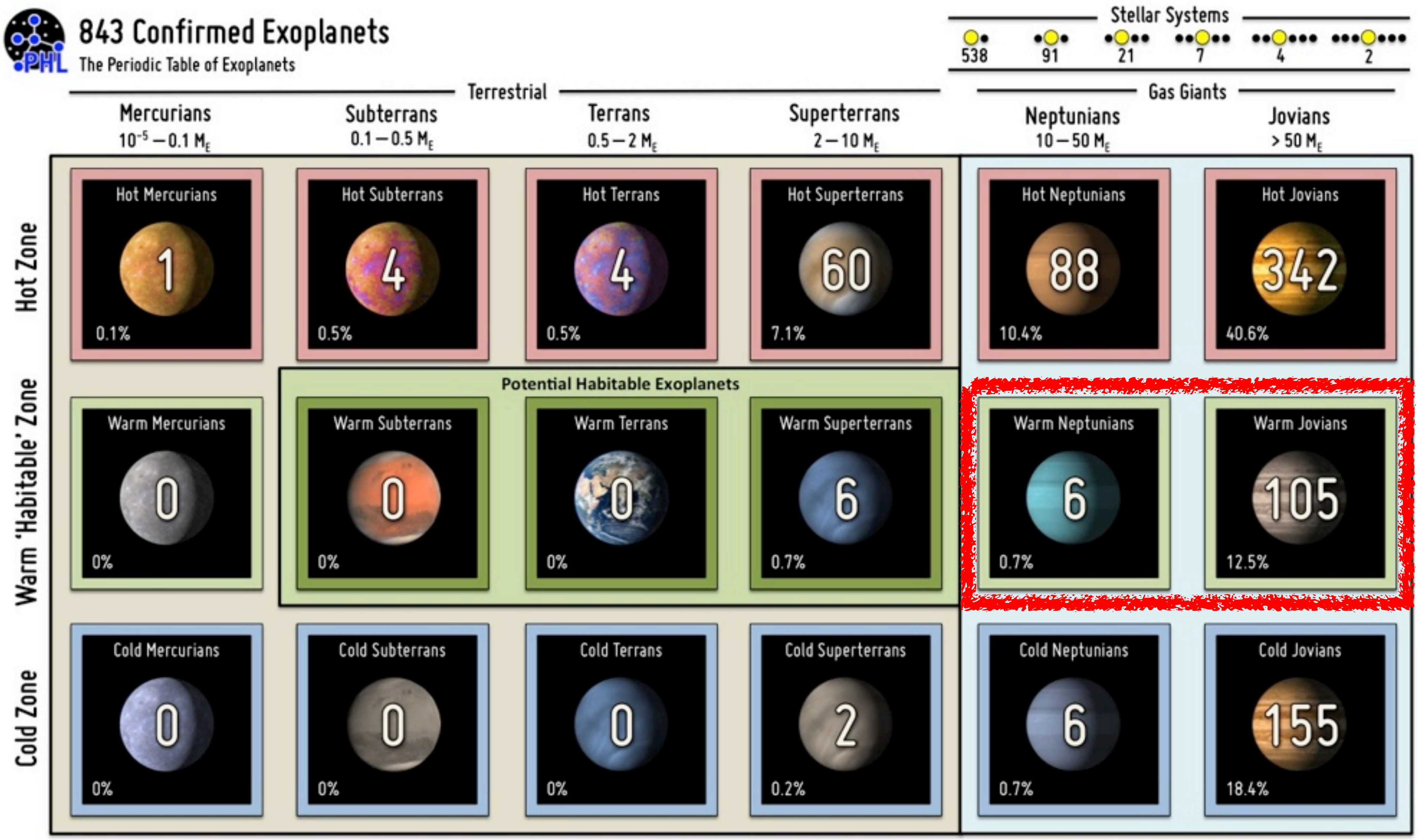

CREDIT: Habitable Exoplanets Catalog, PHL @ UPR Arecibo (phl.upr.edu) Oct 2012

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last update September 17, 2012

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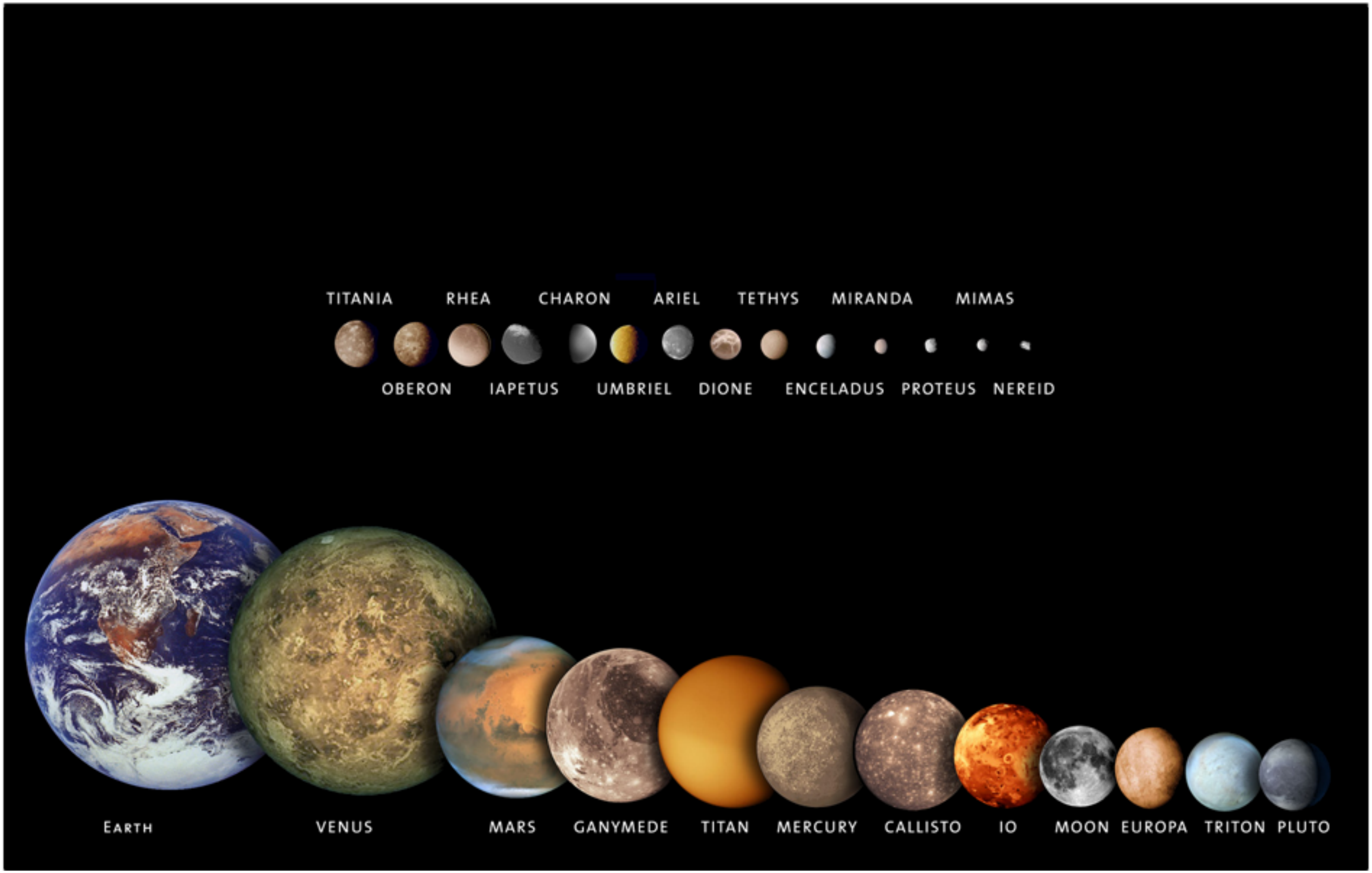
Solar system moons



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Solar system moons

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The odd illumination of exomoons

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The odd illumination of exomoons

We consider three contributions to illumination:

1. direct starlight (f_*)

1b. eclipses (x_s)

2. reflected starlight from the planet (f_r)

3. thermal radiation from the planet (f_t)

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The odd illumination of exomoons

Imagine standing on the sub-planetary point on a moon.

This is how you would see your host planet.

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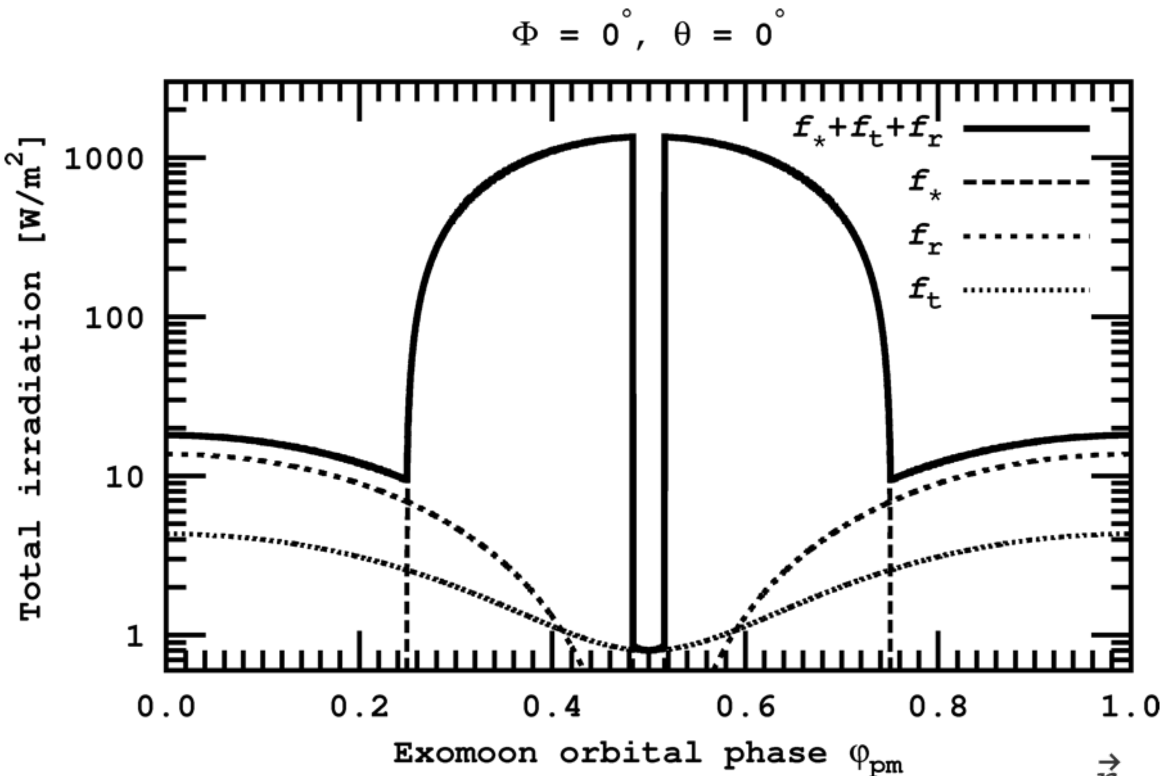
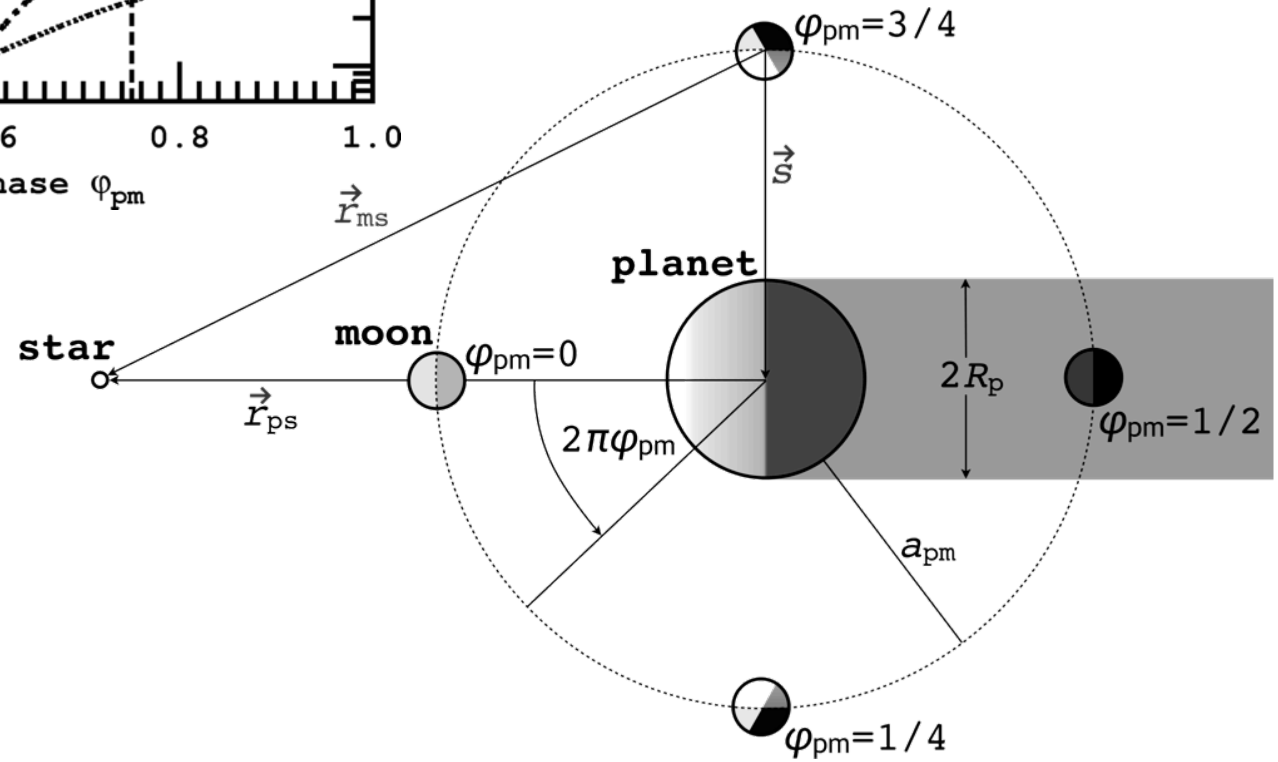
The odd illumination of exomoons





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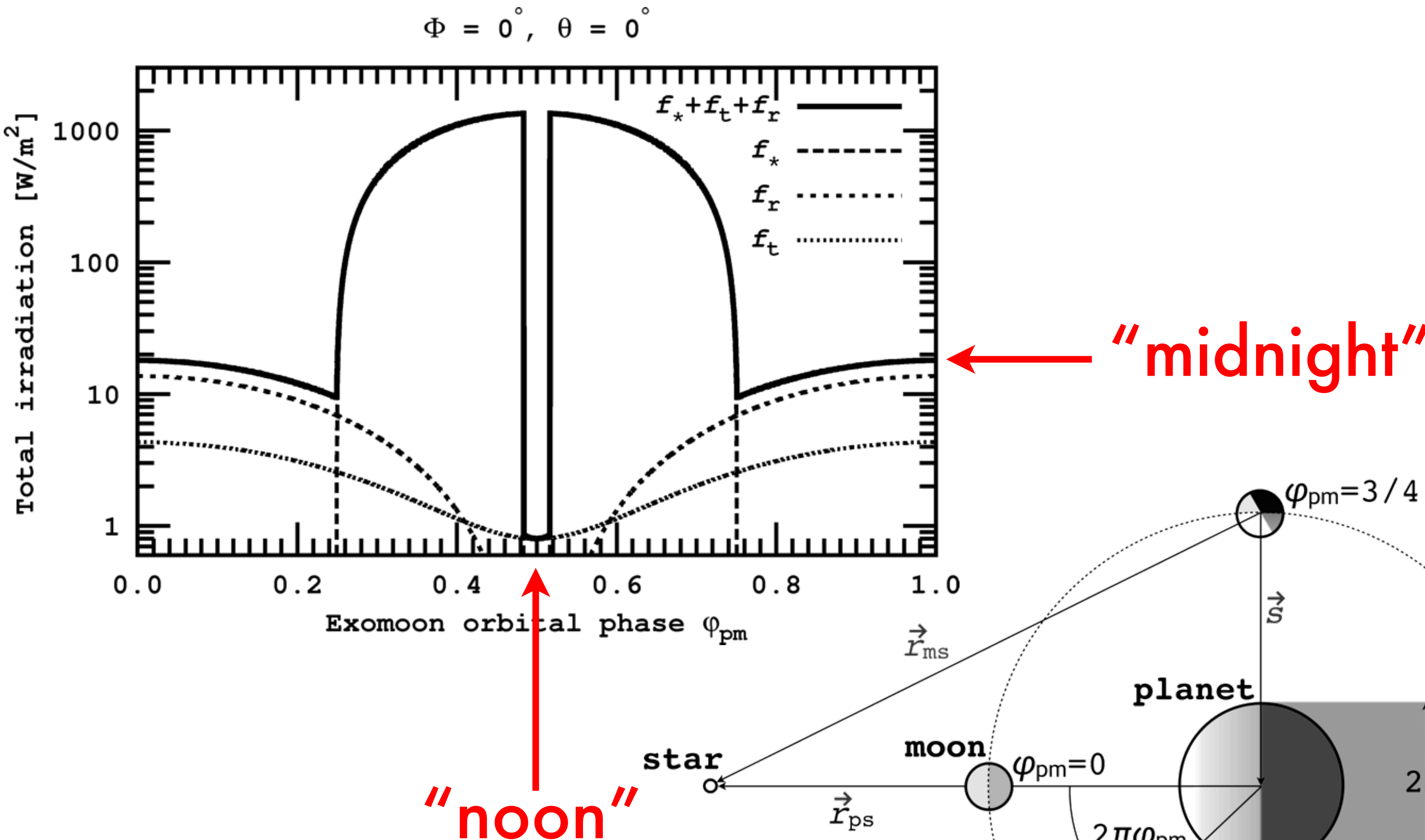
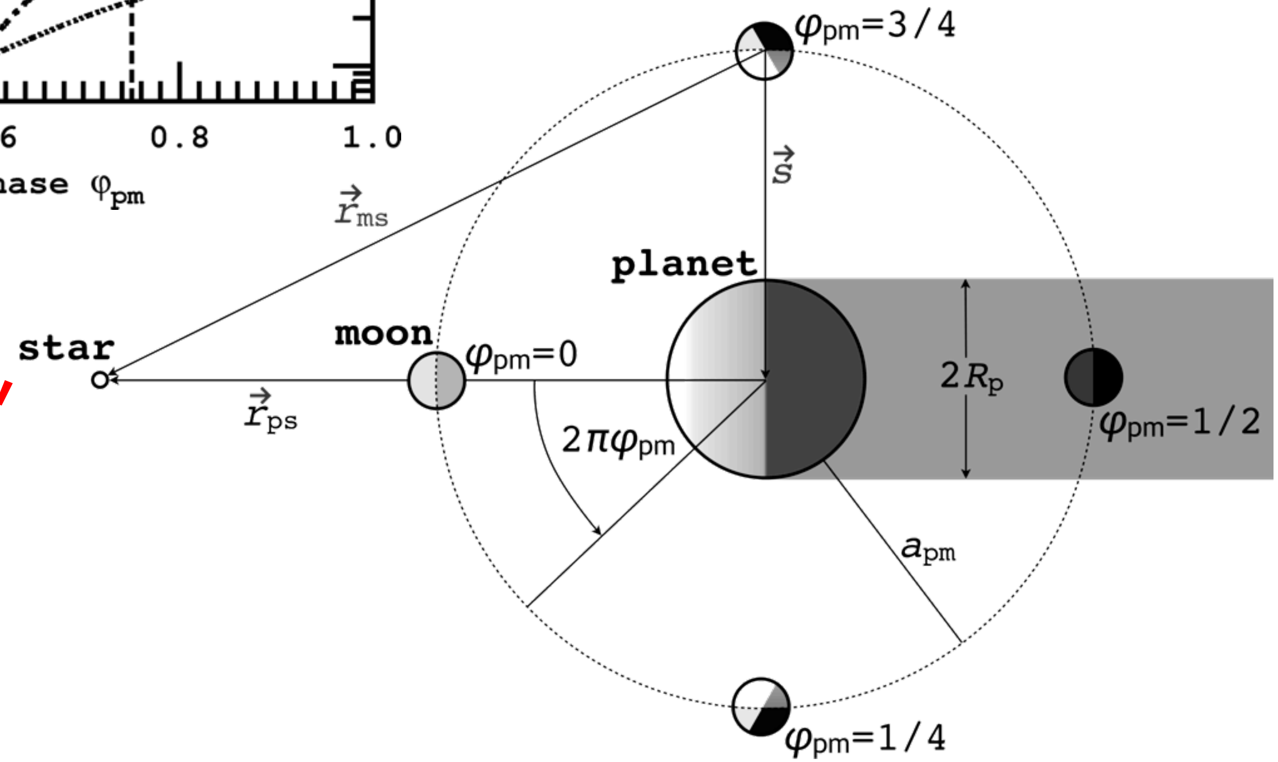
The odd illumination of exomoons





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Odd illumination

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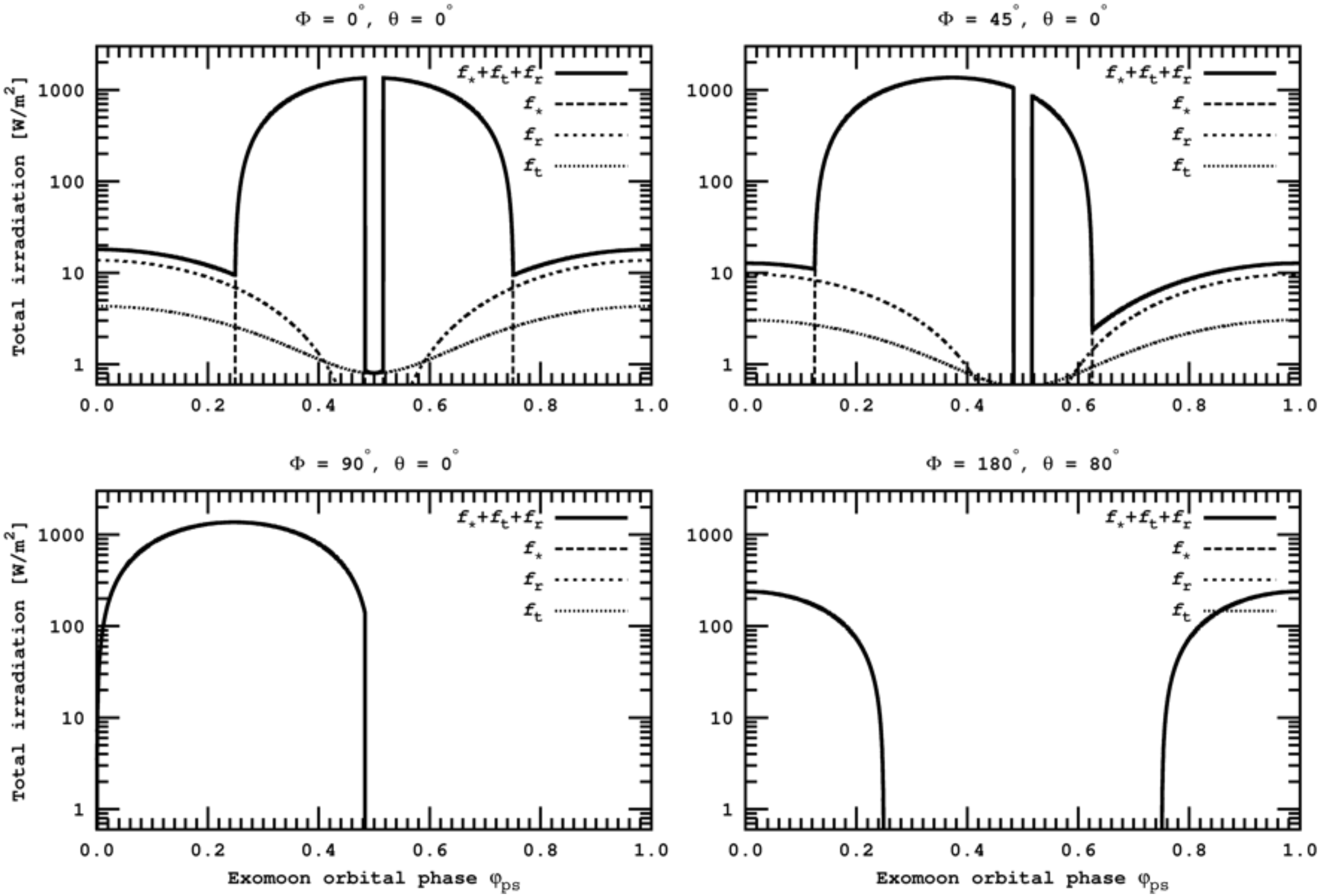

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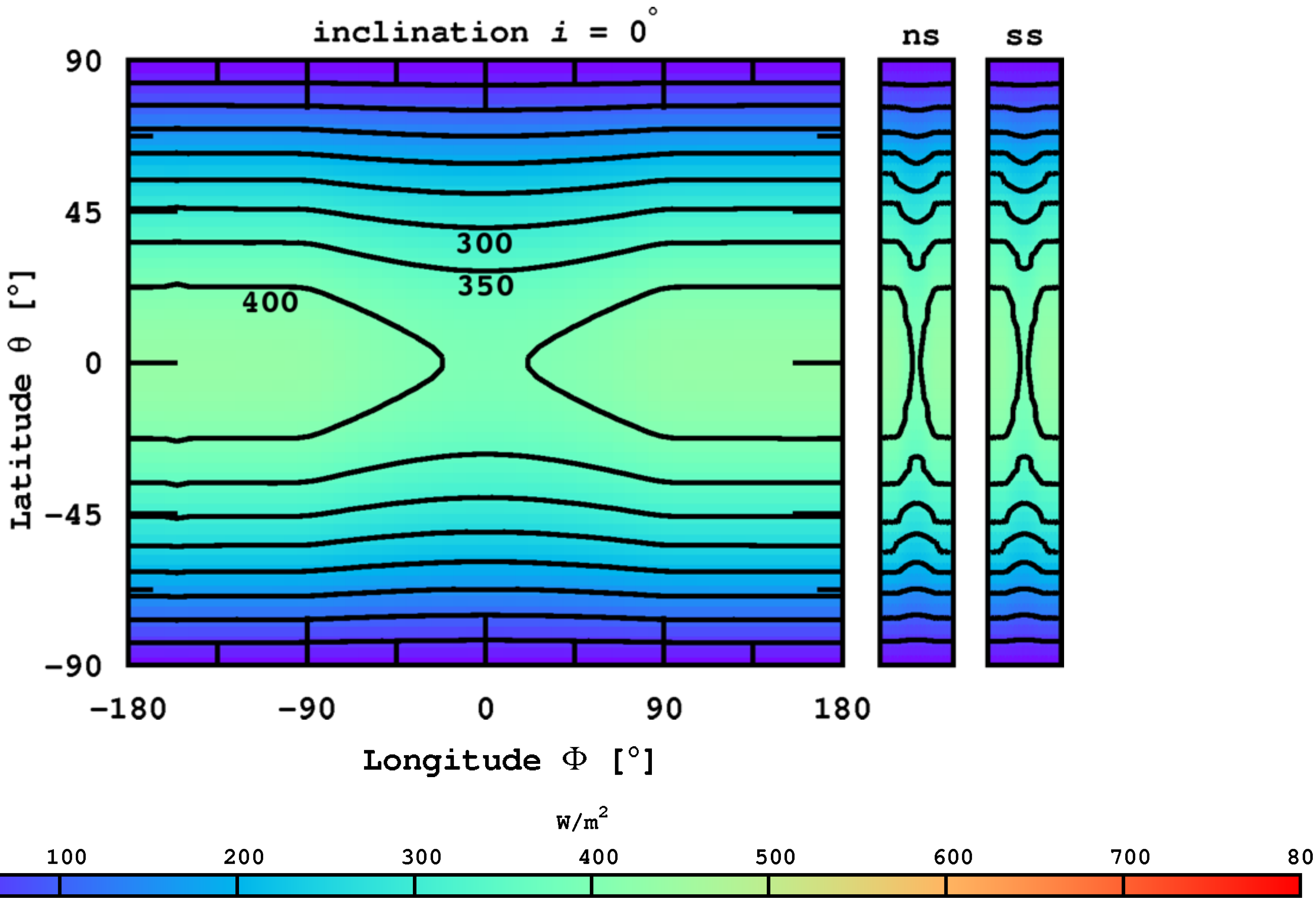

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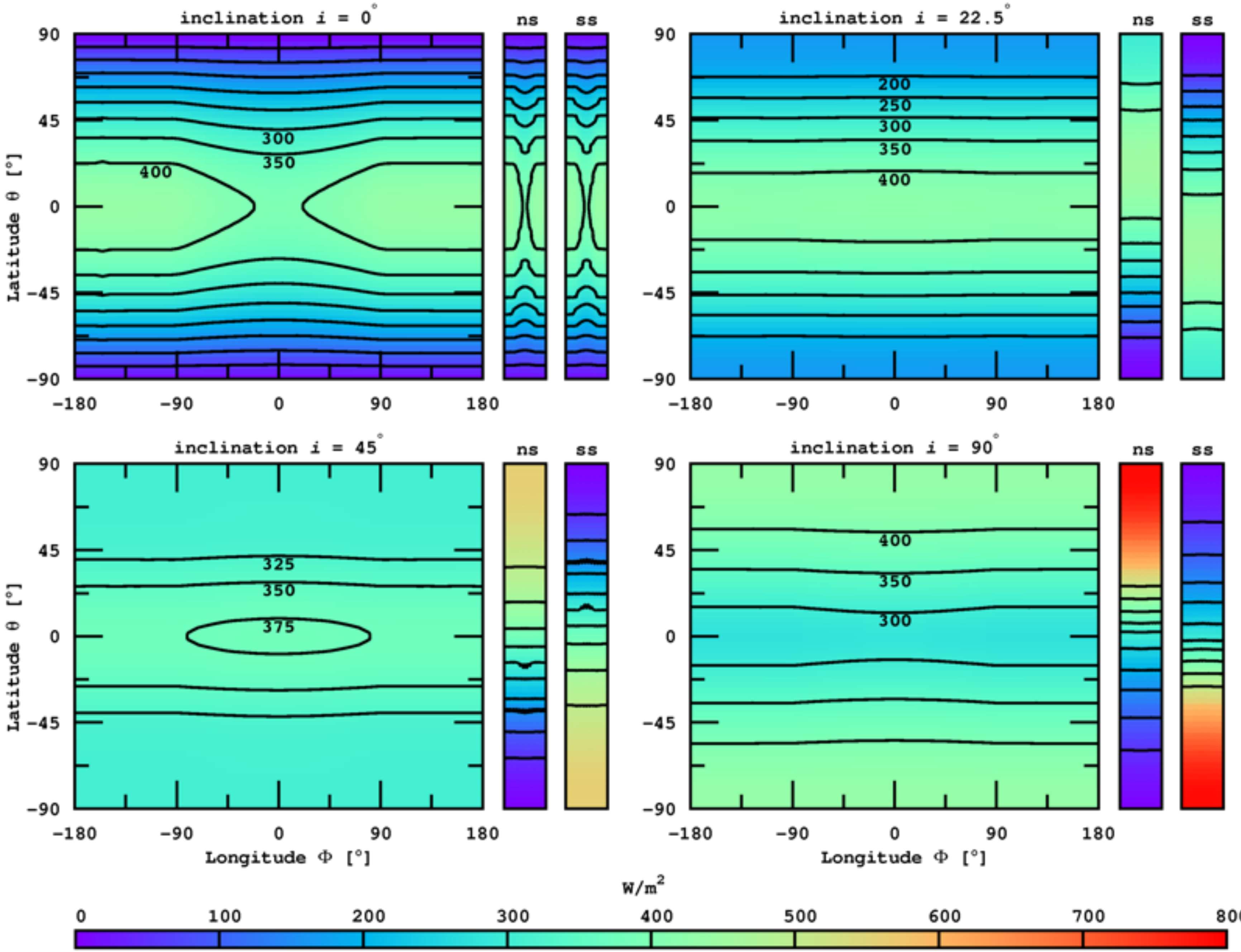
Odd illumination



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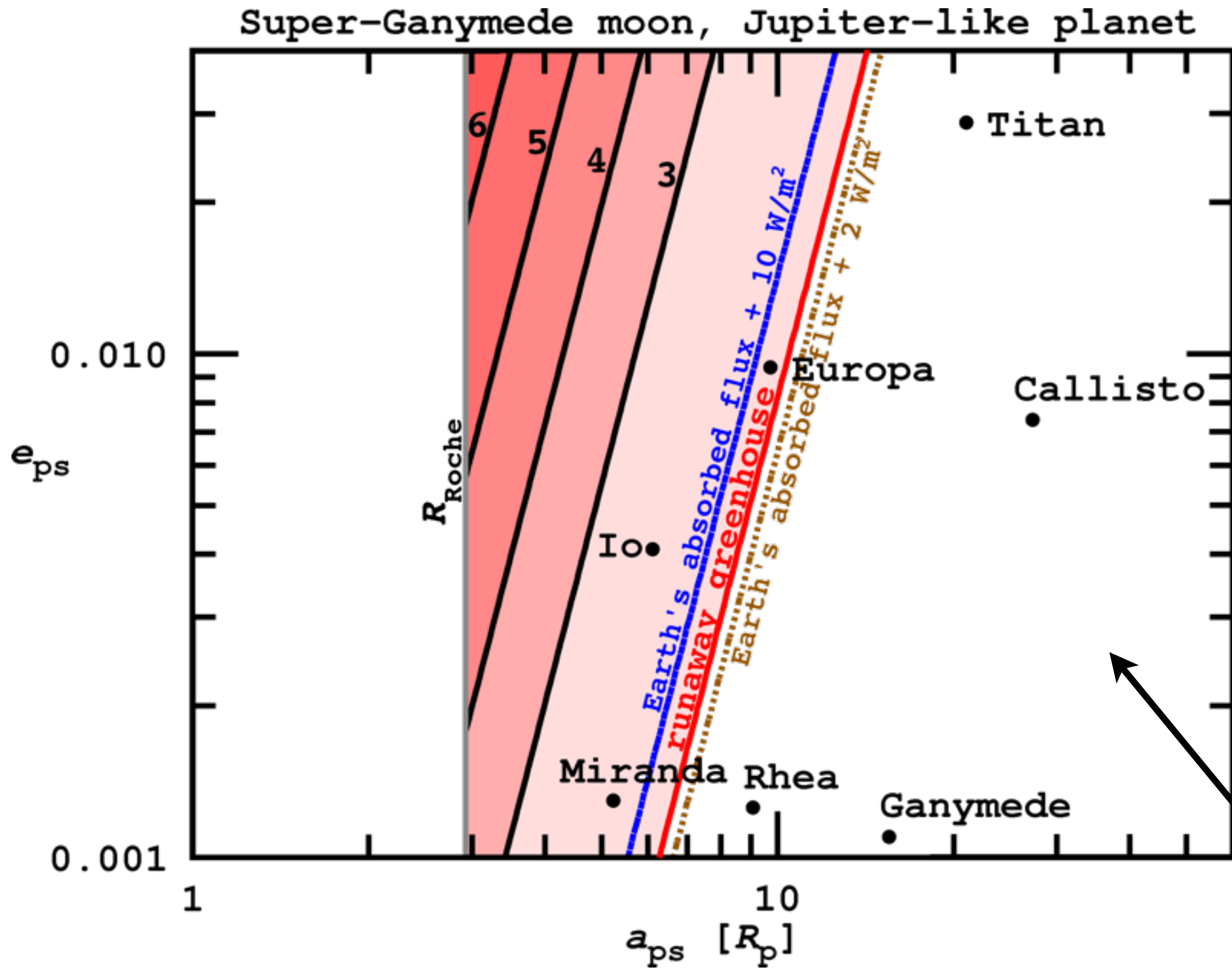
Tidal heating of exomoons



1AU from a Sun-like star

Contours of summed stellar illumination and tidal heating in logarithmic units of W/m^2.

White area: Tidal heating is negligible and absorbed stellar flux is $239 W/m^2$.

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Global average surface flux

$$\bar{F}_{\rm s}^{\rm glob} = \frac{L_*}{16\pi a_{*\rm p}^2 \sqrt{1-e_{*\rm p}^2}} \left((x_{\rm s} - \alpha_{\rm s}) + \frac{(1-\alpha_{\rm s})\ \pi R_{\rm p}^2 \alpha_{\rm p}}{2a_{\rm ps}^2} \right) + \frac{R_{\rm p}^2 \sigma_{\rm SB} (T_{\rm p}^{\rm eq})^4}{a_{\rm ps}^2} \frac{(1-\alpha_{\rm s})}{4} + h_{\rm s}$$

- stellar illumination
- satellite transits
- reflected stellar light from the planet
- thermal emission from the planet
- tidal heating

L_* stellar luminosity

x_s non-eclipse fraction of the satellite's orbit

α_s satellite's bond albedo

a_{*p} satellite's semi-major axis

e_{*p} satellite's eccentricity

R_p planetary radius

α_s planetary bond albedo

a_{ps} planetary semi-major axis

σ_{SB} Stefan-Boltzmann constant

T_p^{eq} planetary equilibrium temperature

h_s satellite's tidal surface heating

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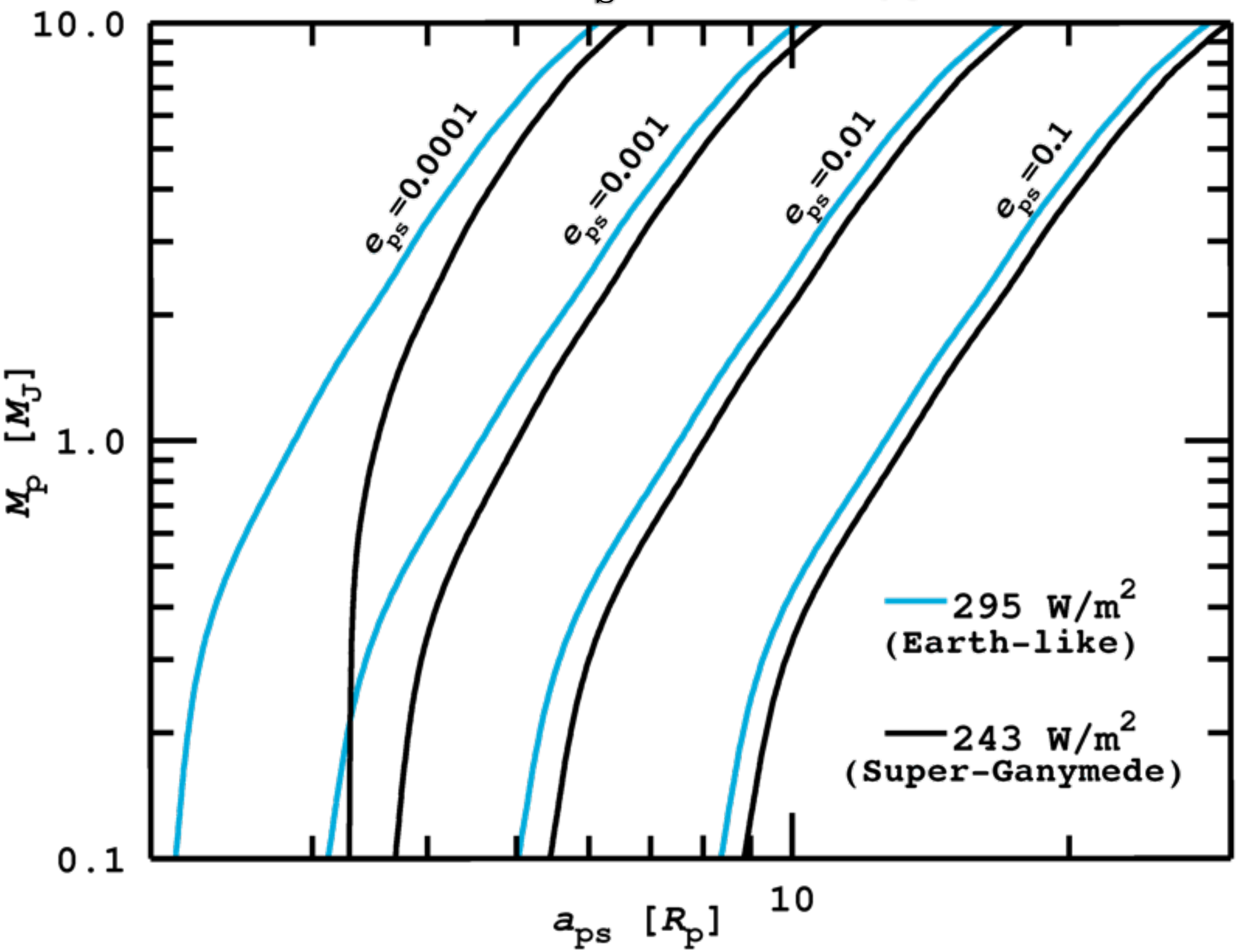
The "Habitable Edge"

$$\bar{F}_{\rm s}^{\rm glob} = F_{\rm RG}$$



Two prototype moons orbiting a giant planet at 1AU from a Sun-like star

Pierrehumbert (2010)

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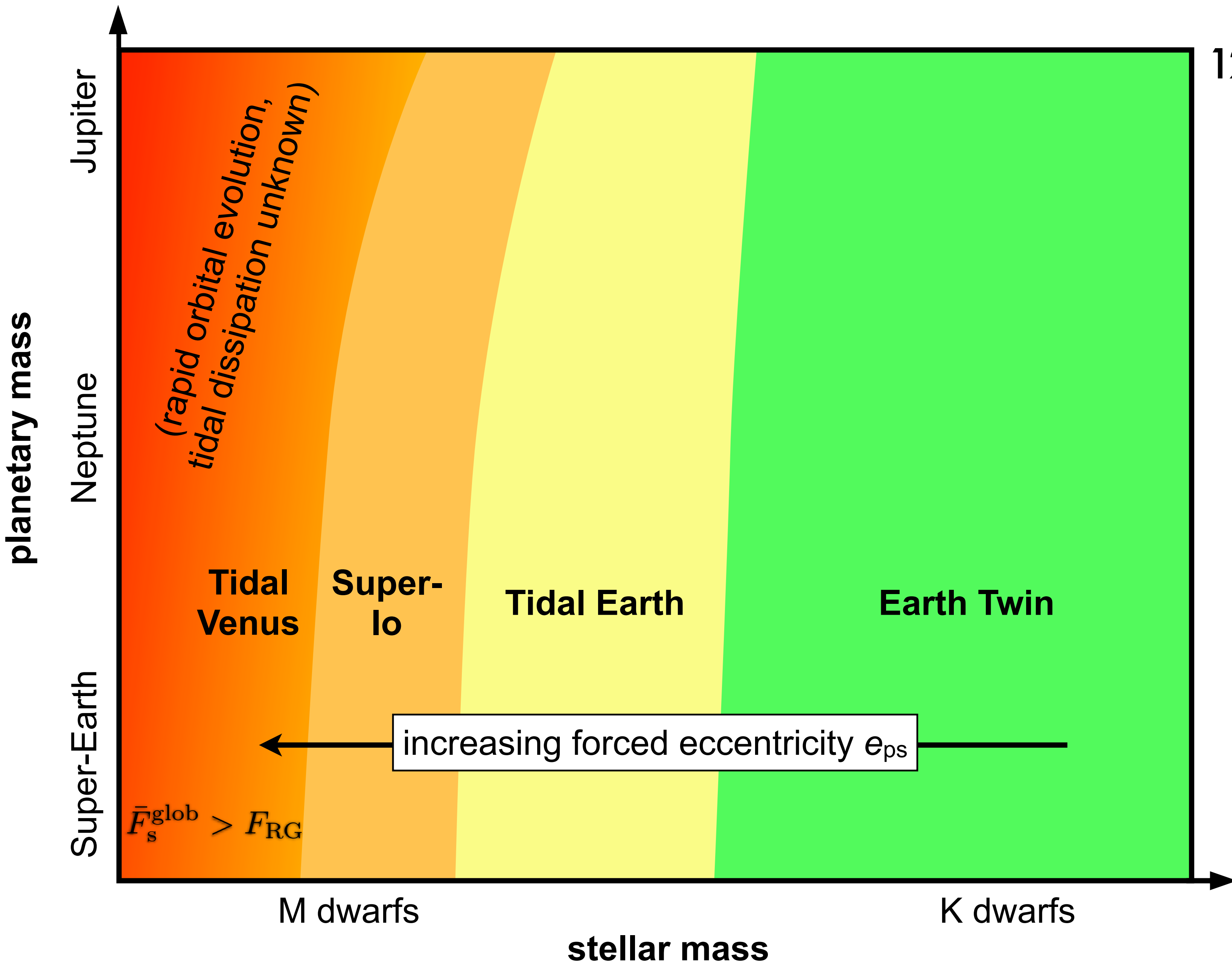
$R_{\rm p}(M_{\rm p})$ from Fortney et al. (2007)

Hot Moons and Cool Stars



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Hot Moons and Cool Stars

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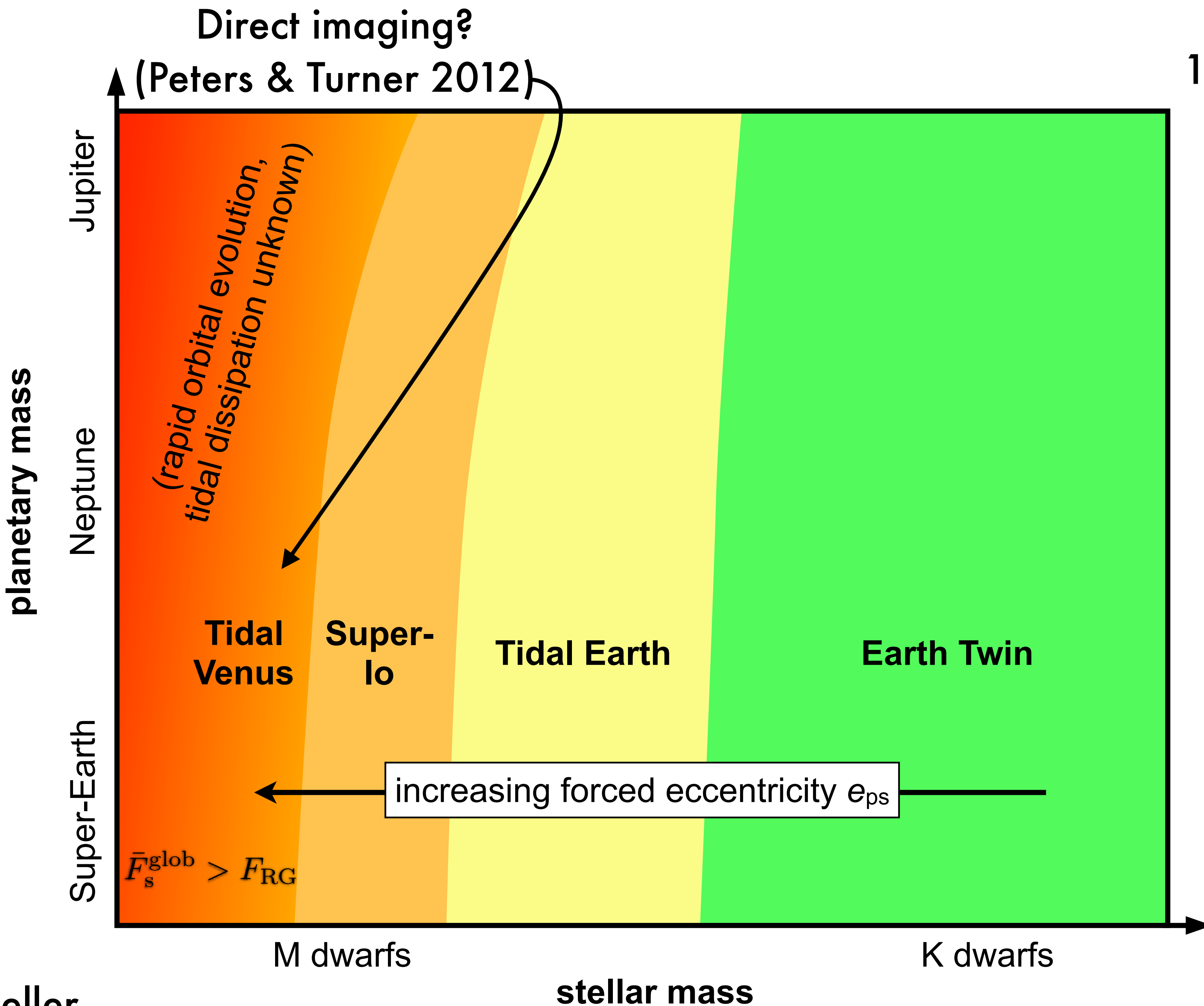

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Hunt for Exomoons with Kepler (HEK)

hek

The Hunt for Exomoons
with Kepler

- Papers by Kipping et al. (2009 – 2012)
- www.cfa.harvard.edu/HEK
  www.facebook.com/HEK.Project
- Key words: TTV, TDV, exomoon transits

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Summary: Constraints on exomoon habitability

1. Moons in the stellar HZ have days much shorter than their year and can have seasons.

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2. Stellar + planetary illumination and eclipses cause an odd surface illumination.

3. Illumination and tidal heating can initiate runaway greenhouse on a moon, making it uninhabitable.

4. The “Habitable edge” defines the innermost satellite orbits to avoid a runaway greenhouse.

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