Dynamics of exoplanetary systems, links to their « habitability »

19/05/15
FNRS Contact Group "Astronomie & Astrophysique"
Astronomy day of the Royal Observatory of Belgium

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Exoplanets discoveries

Exoplanets discoveries

~1900 exoplanets!

Exoplanets discoveries

The holy grail…

Exoplanets discoveries

The holy grail…

Exoplanets discoveries

The holy grail…

Rocky planet…

Exoplanets discoveries

The holy grail…

Rocky planet…

…around a Sun-like star…

Exoplanets discoveries

The holy grail…

Rocky planet…

…around a Sun-like star…

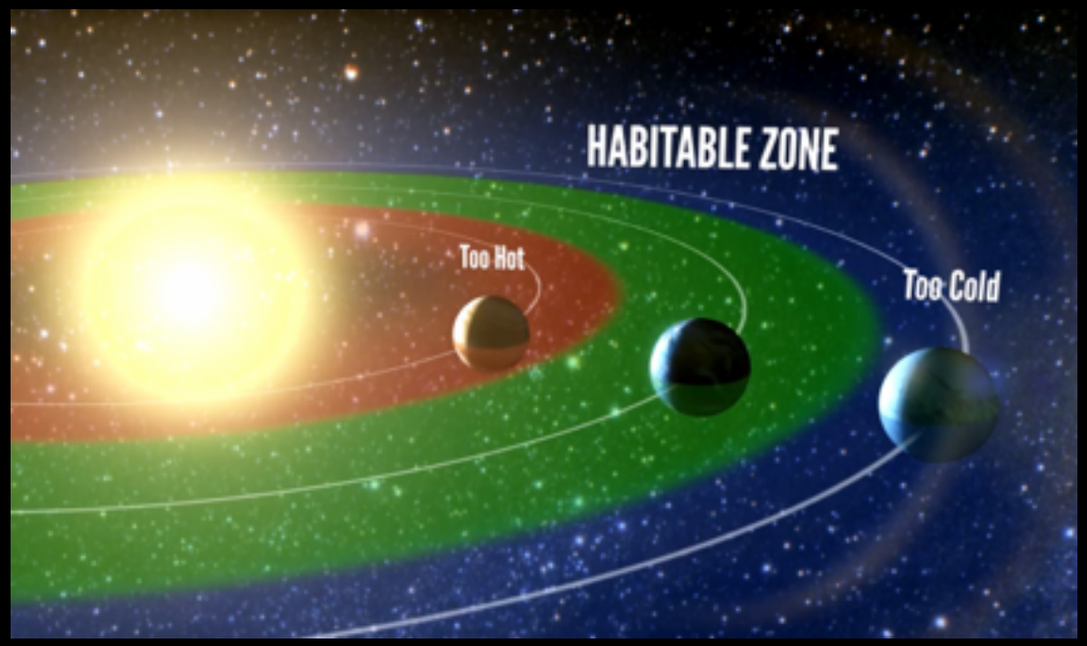
…with surface liquid water.

Habitable zone planets

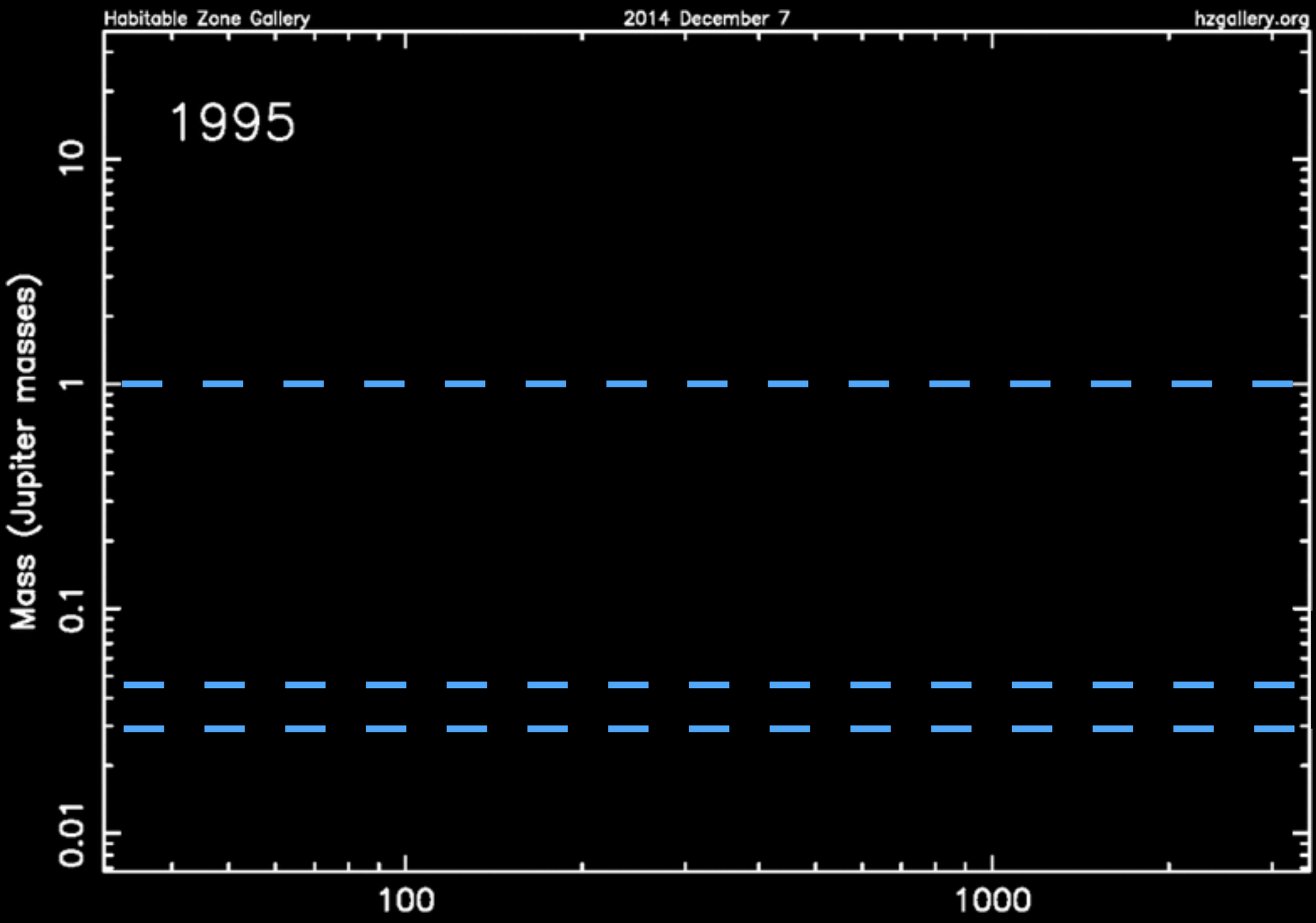
Habitable zone planets

« Habitable zone »

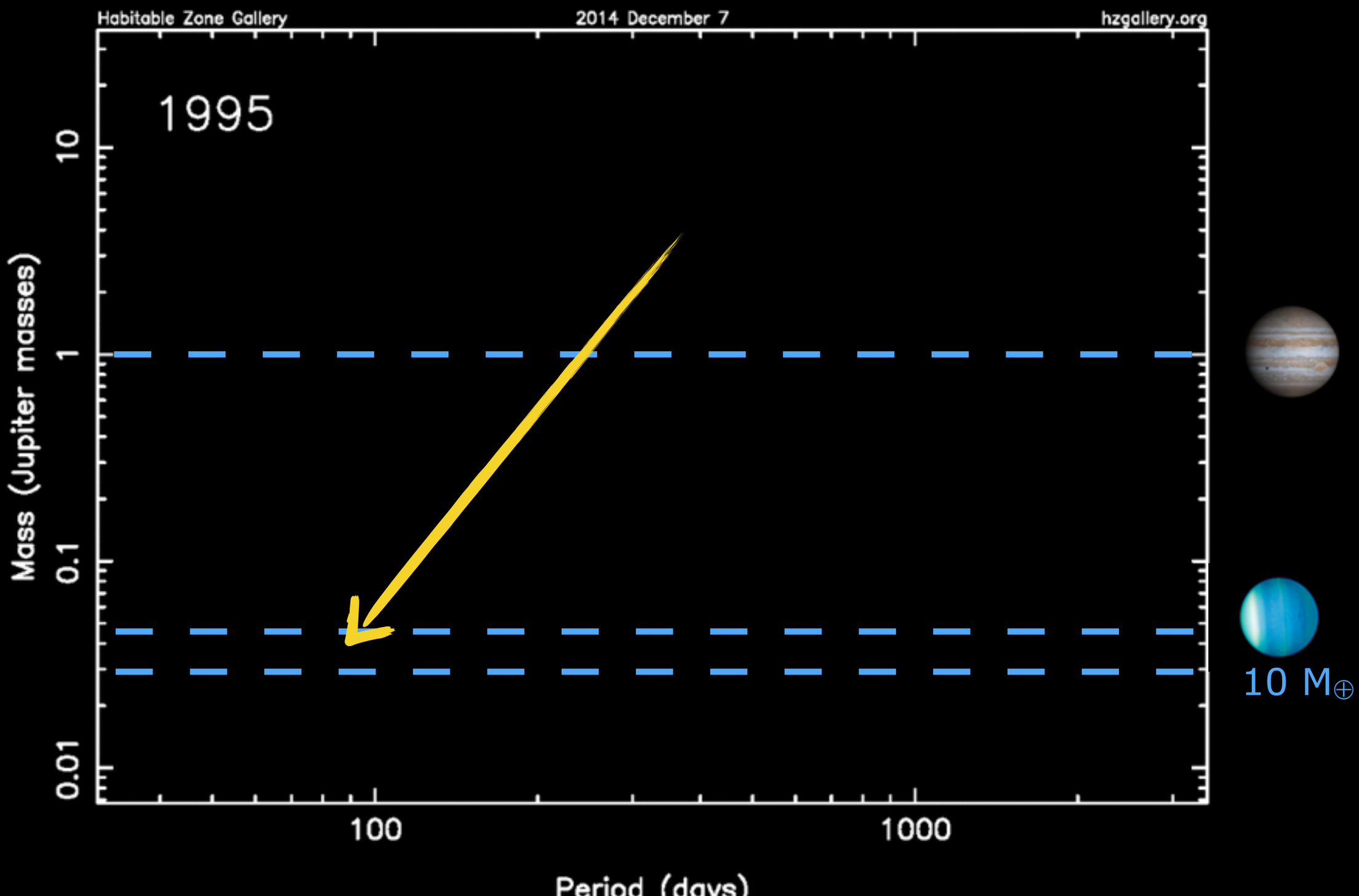
region around a star in which a planet with an atmosphere could potentially host surface liquid water



Habitable zone planets



Habitable zone planets



Tides and climate

Climate

Tides and climate

orbital distance

↓

Climate

Tides and climate

orbital distance

insolation

Climate

Tides and climate

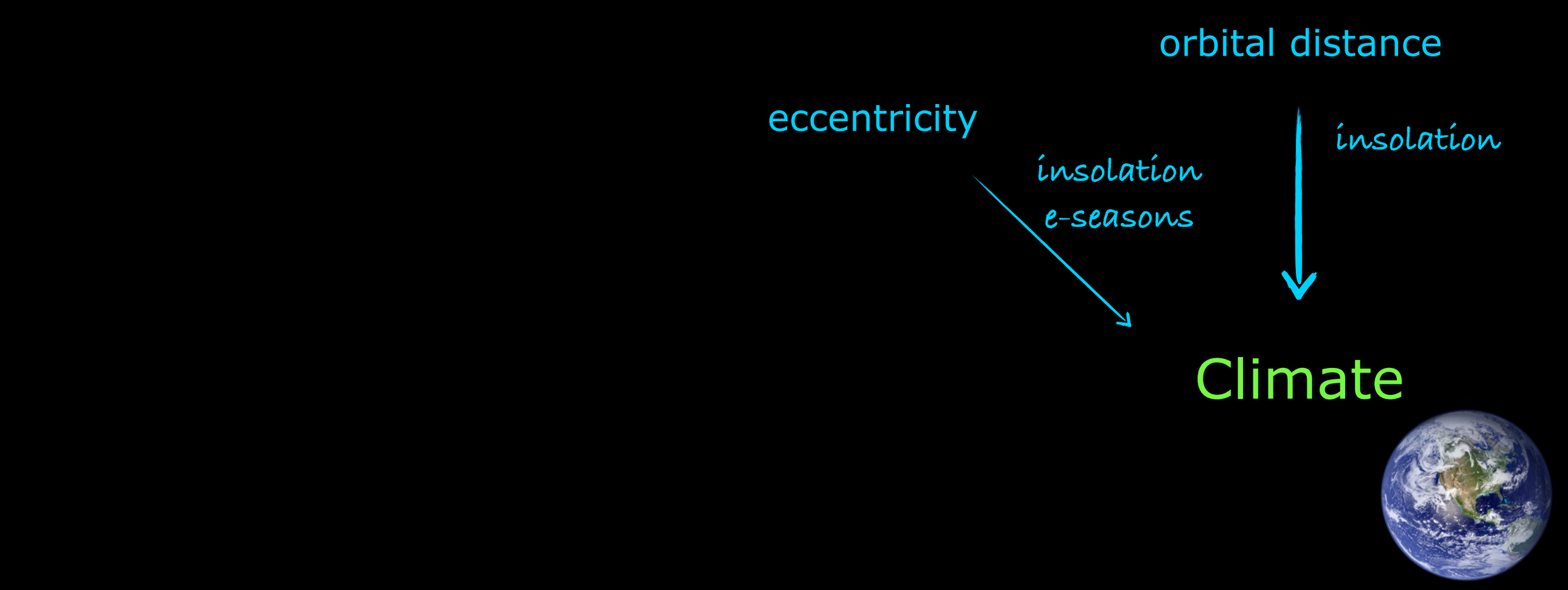
orbital distance

eccentricity

insolation

Climate

Tides and climate



Tides and climate

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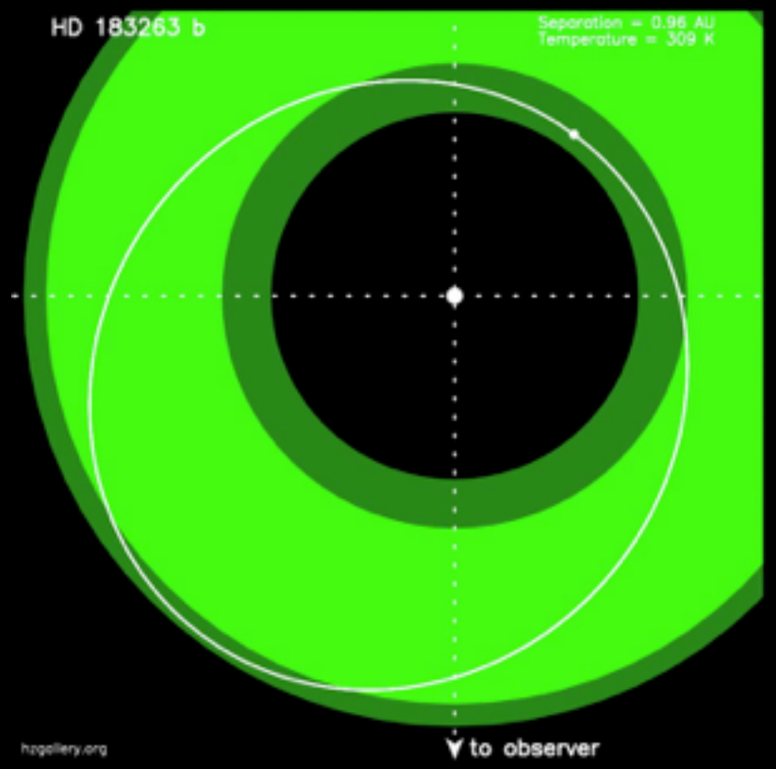

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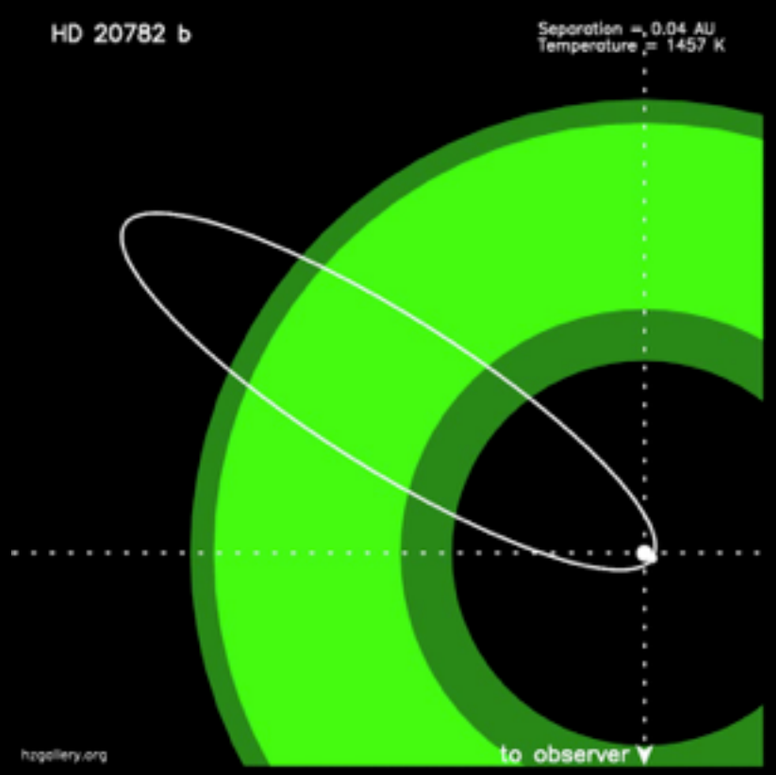


orbital distance

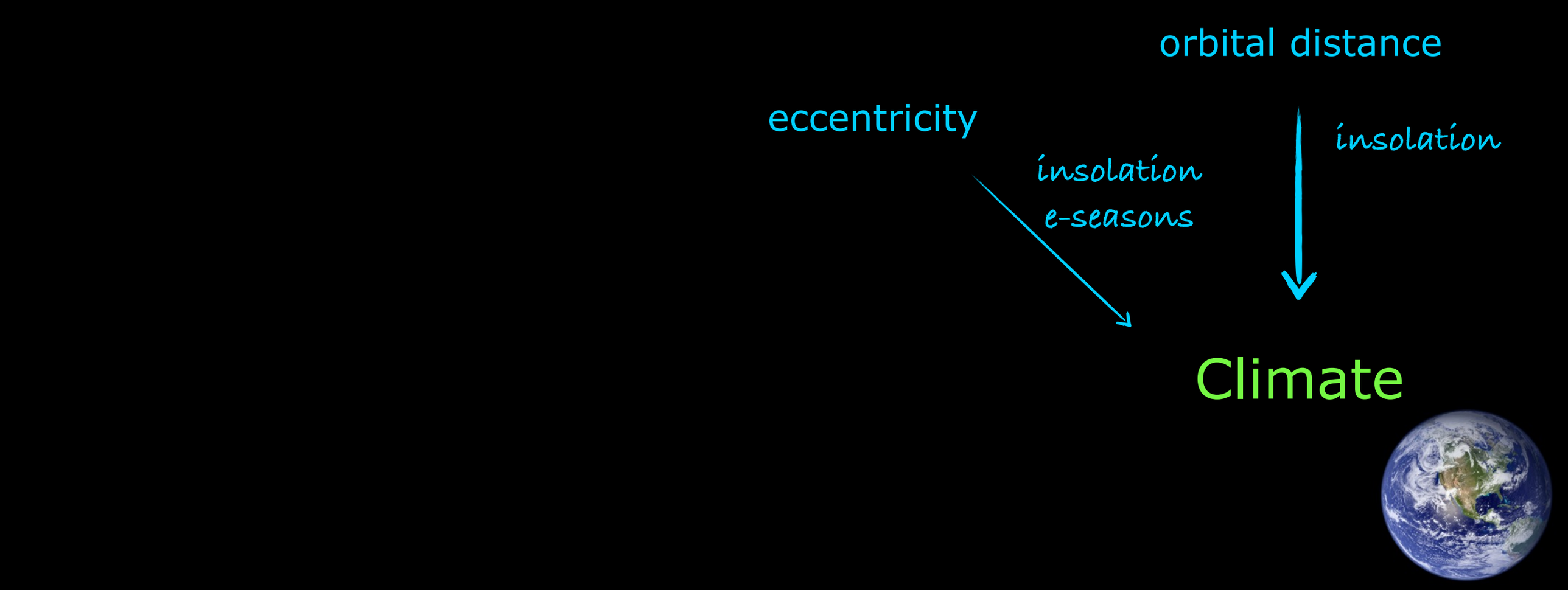
eccentricity

insolation

insolation
e-seasons

Climate

Tides and climate



Tides and climate

Insolation
Habitable zone

orbital distance

eccentricity

insolation
e-seasons

insolation

Climate

Tides and climate

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Habitable zone

orbital distance

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eccentricity

insolation
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obliquity

Climate

Tides and climate

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cold trap
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tidal heat flux

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tidal heat flux

insolation +

Climate

Tides and climate

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Habitable zone

orbital distance

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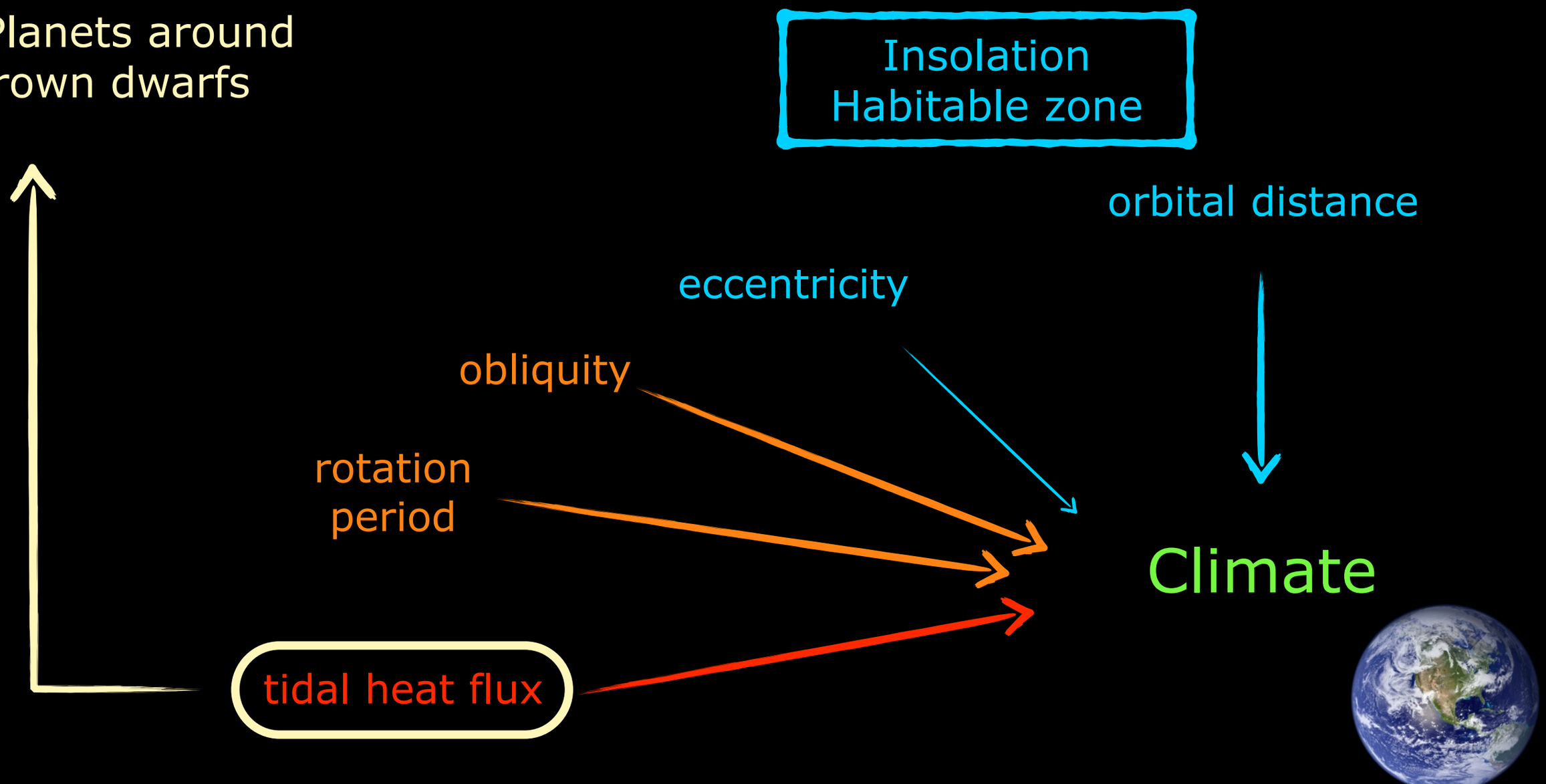
Climate

Tides and climate

1) Planets around
brown dwarfs



Tides and climate

1) Planets around brown dwarfs

2) Kepler-186f

Insolation
Habitable zone

orbital distance

eccentricity

obliquity

rotation period

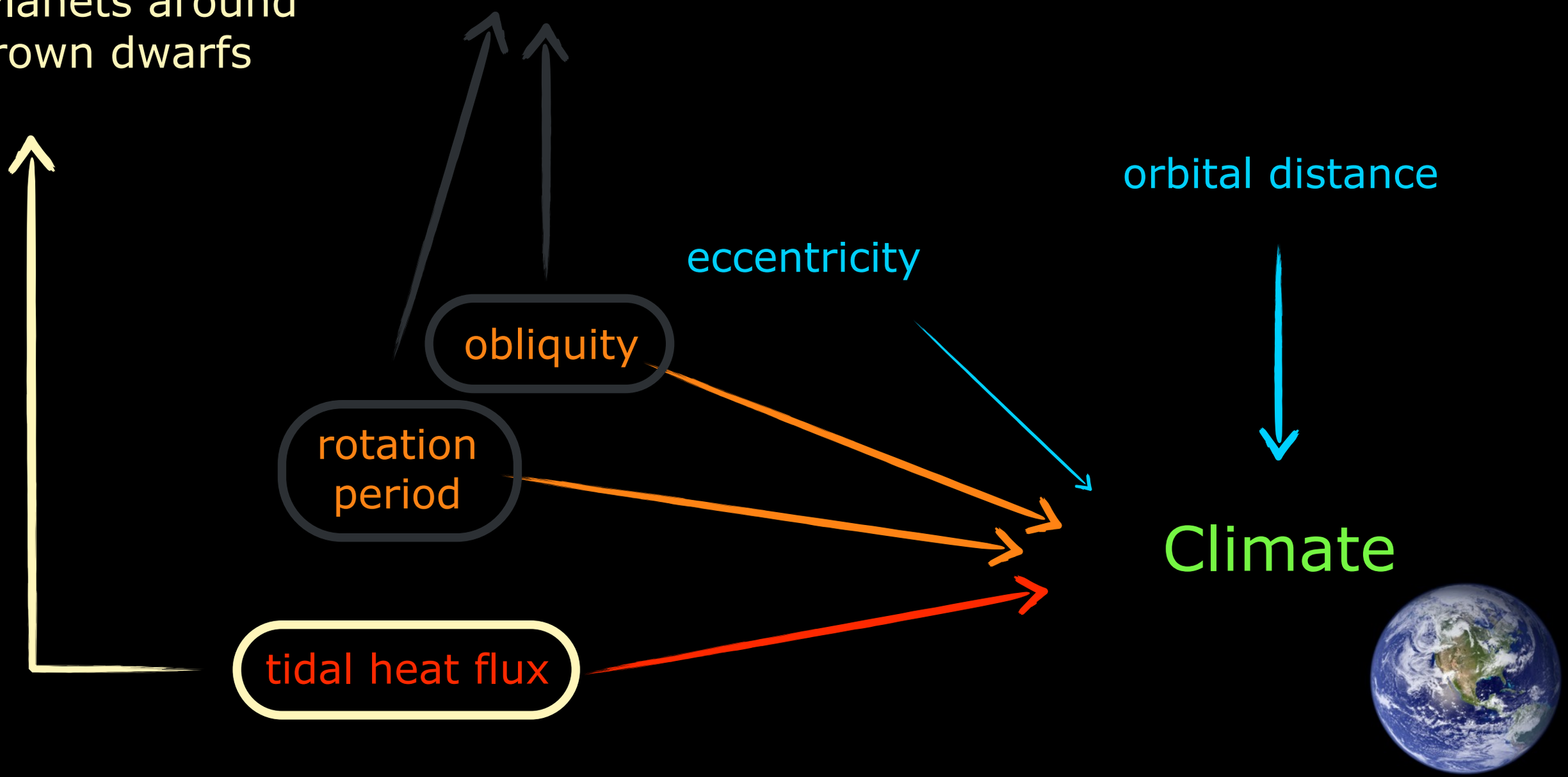
tidal heat flux

Climate

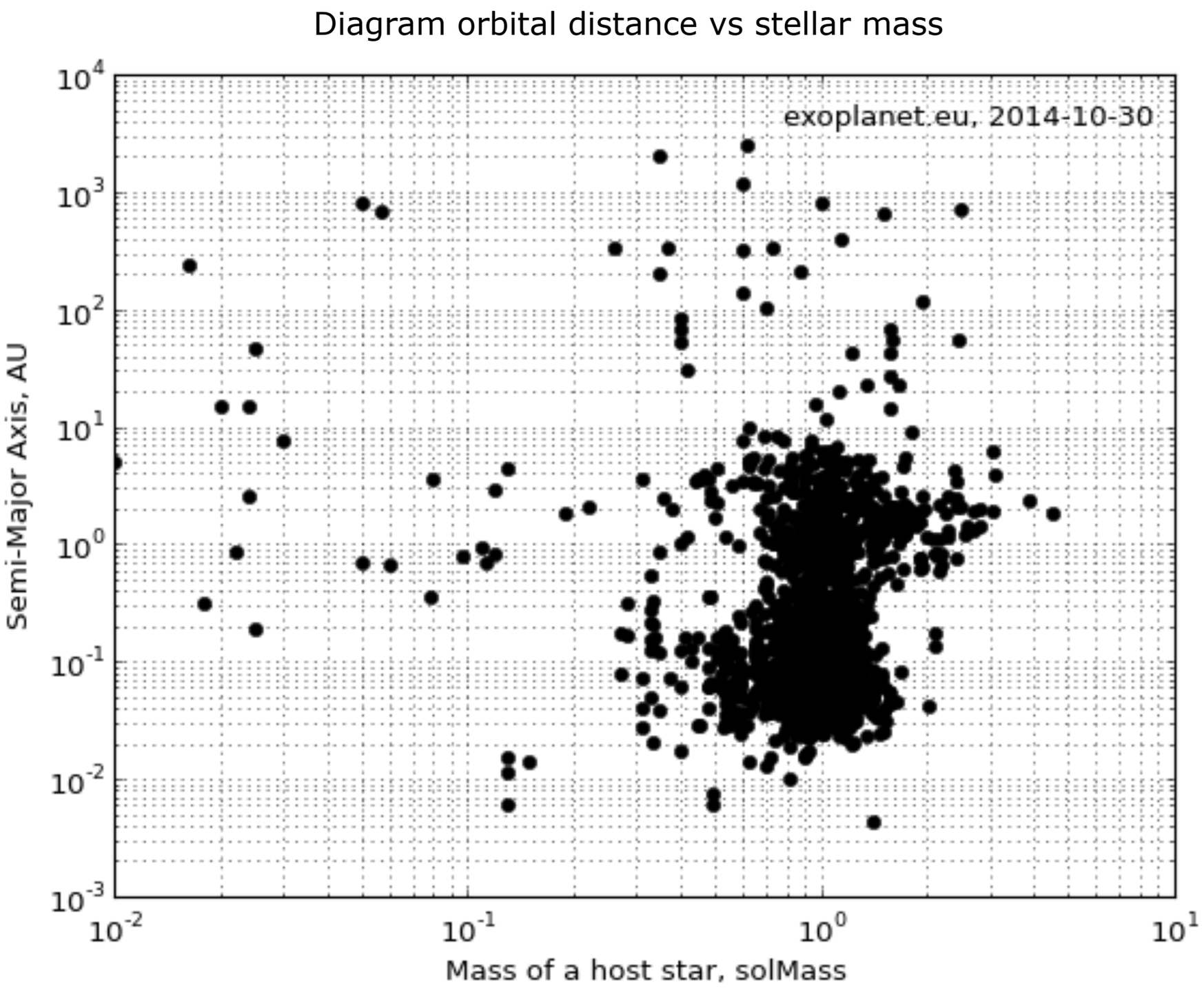
Tides and climate

1) Planets around brown dwarfs

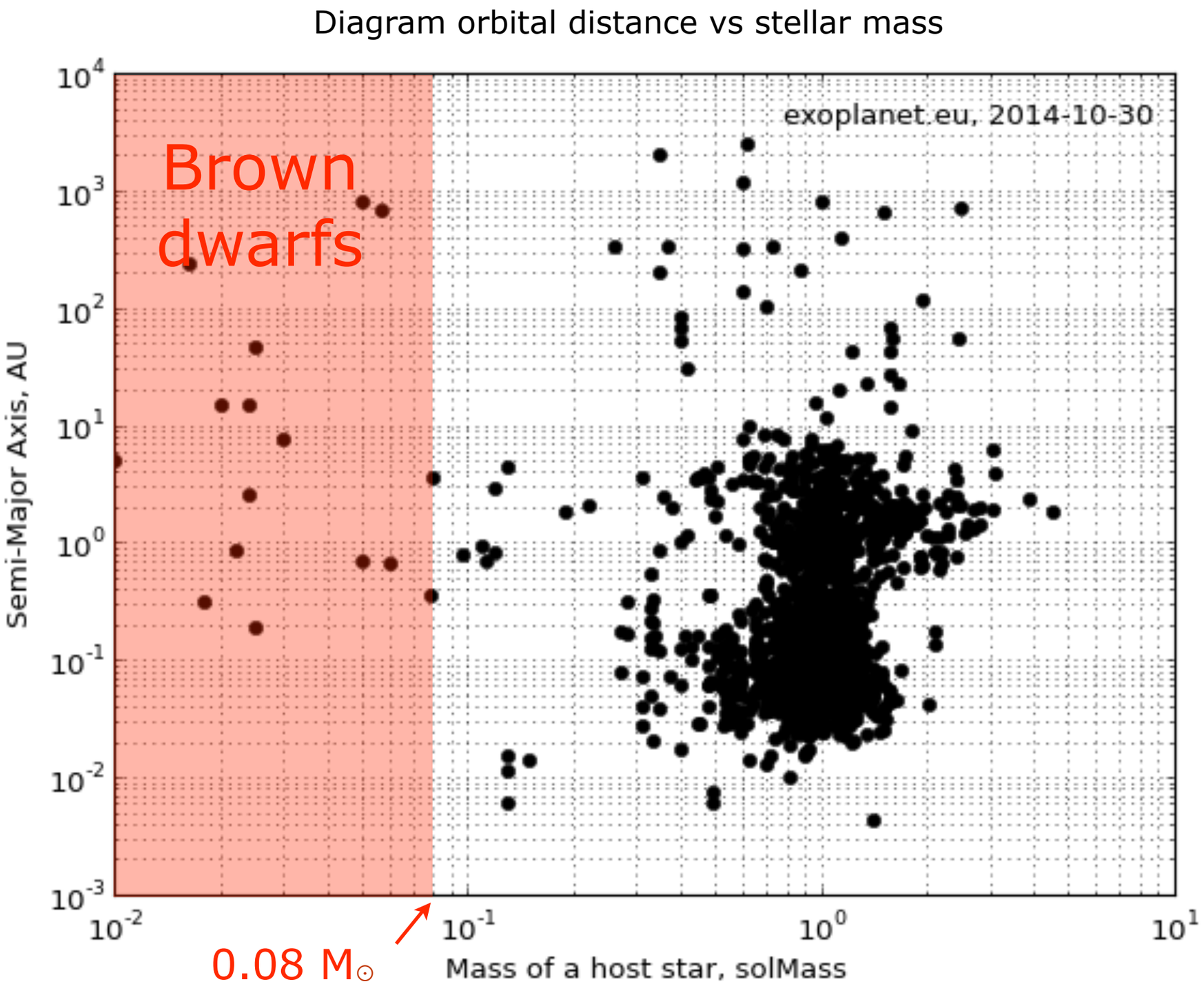
2) Kepler-186f



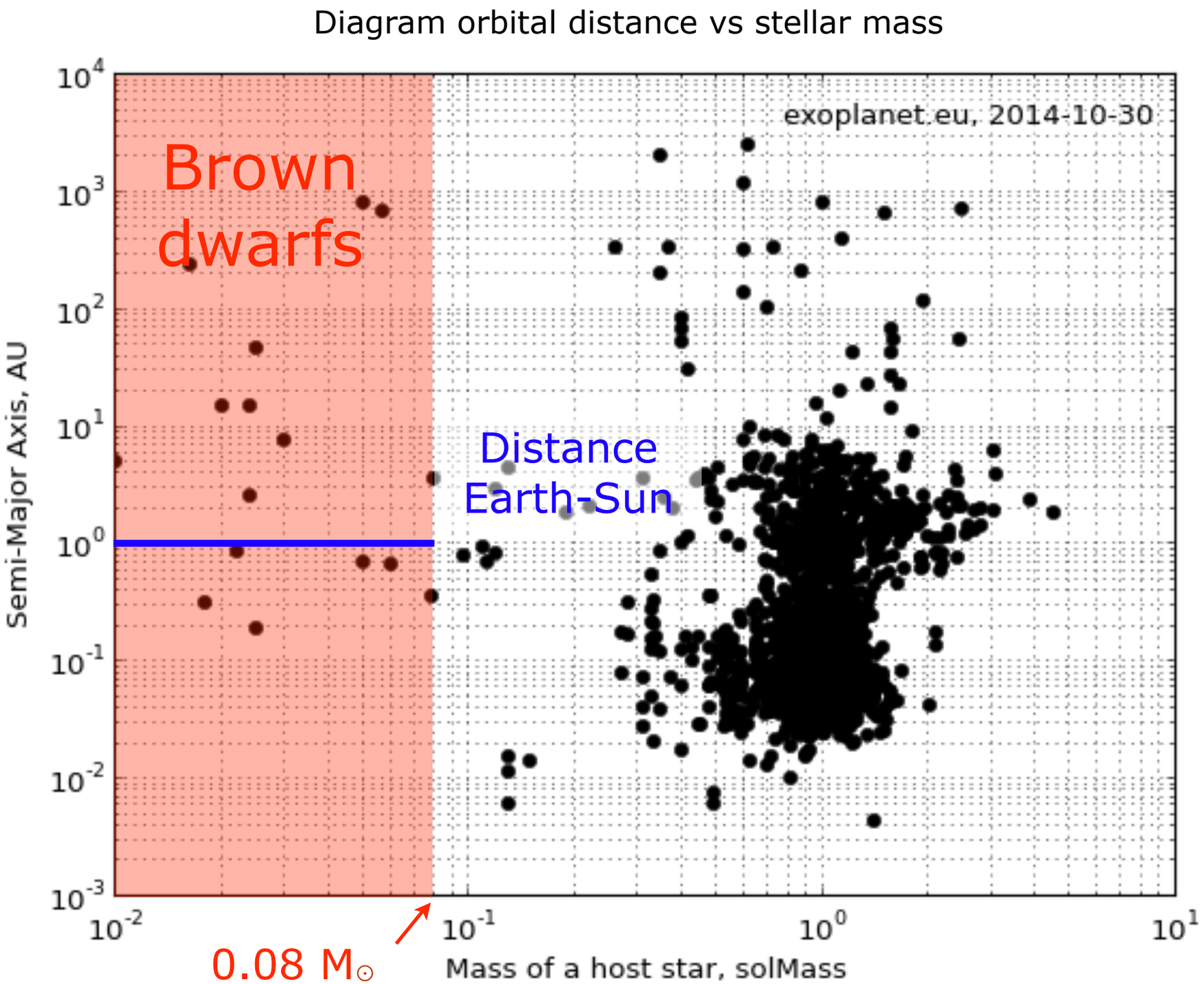
Planets around brown dwarfs



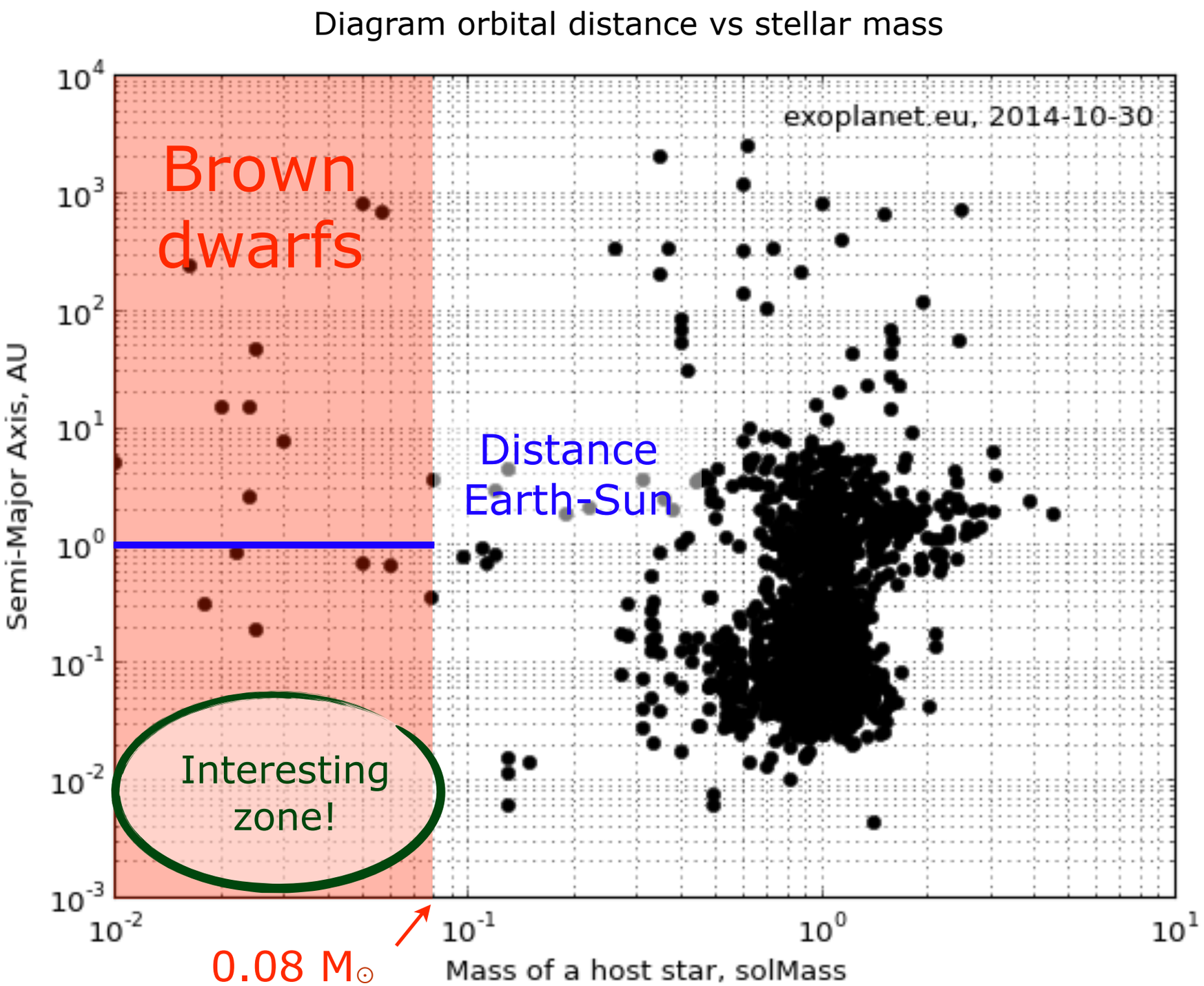
Planets around brown dwarfs



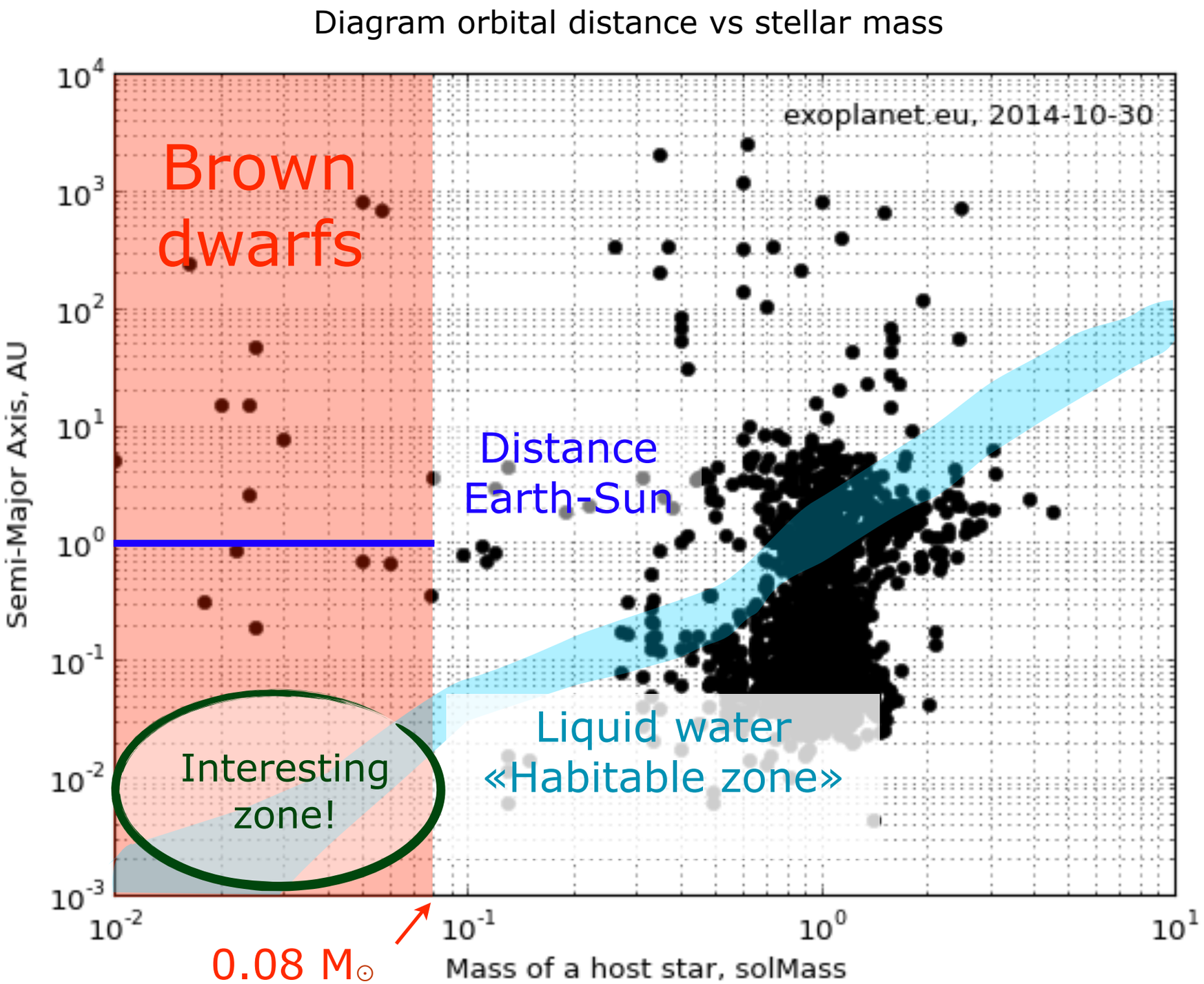
Planets around brown dwarfs



Planets around brown dwarfs

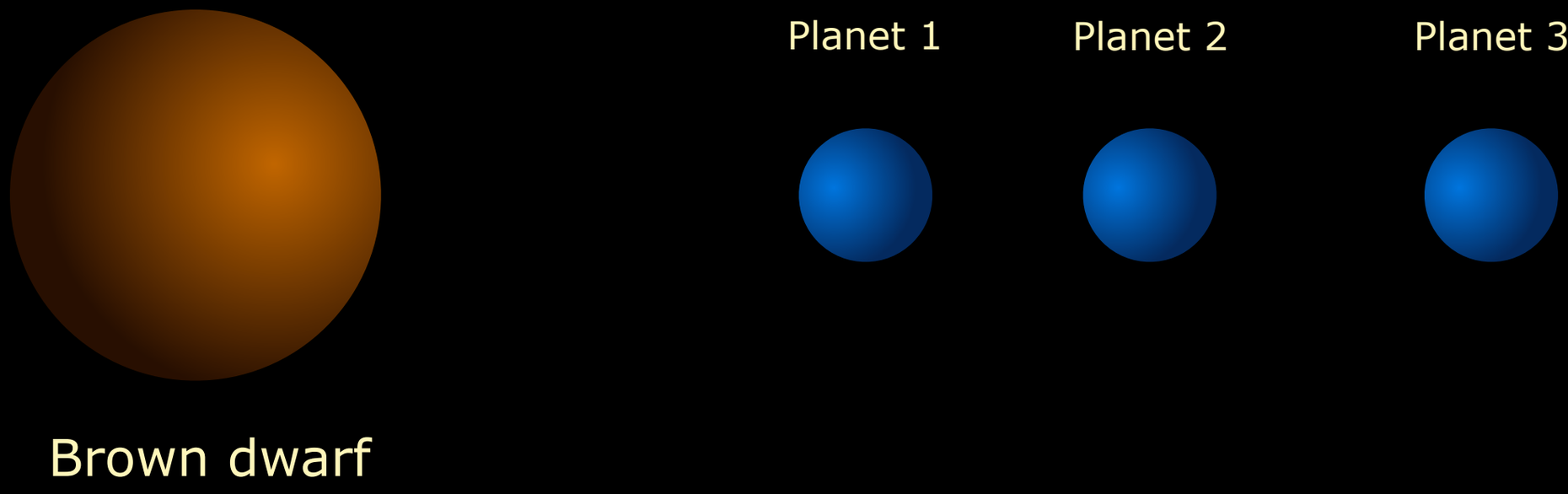


Planets around brown dwarfs



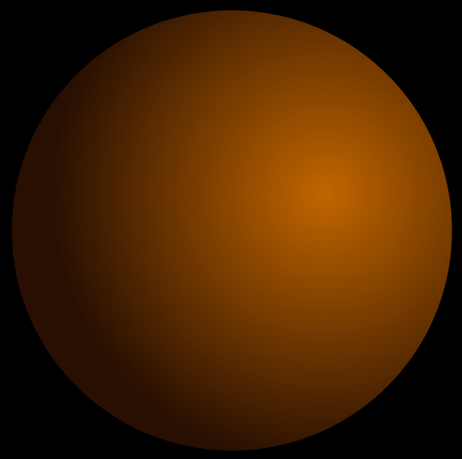
Planets around brown dwarfs

Tidal effects in multi-planet systems

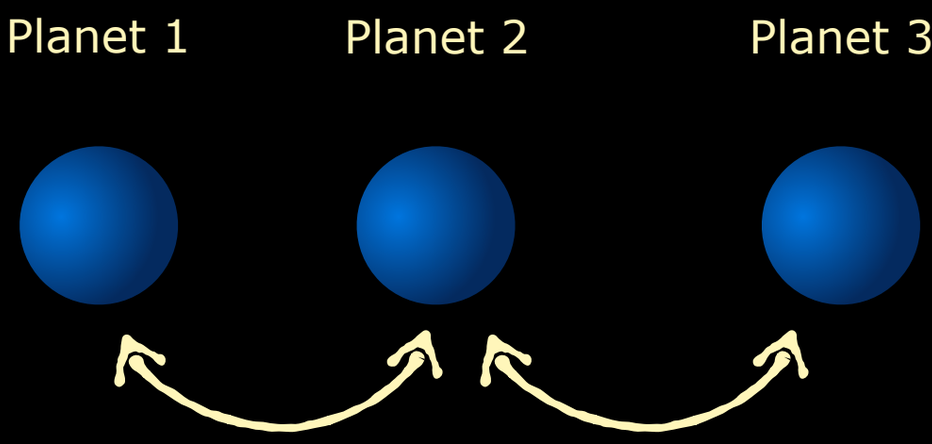


Planets around brown dwarfs

Tidal effects in multi-planet systems



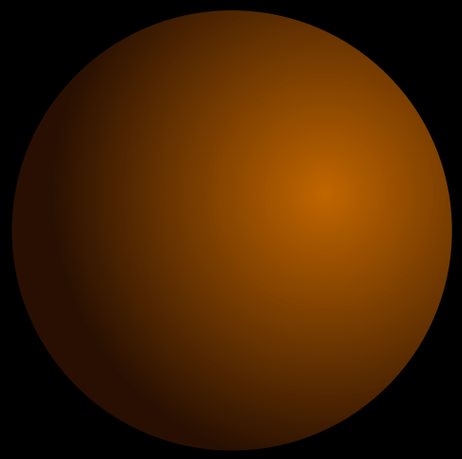
Brown dwarf



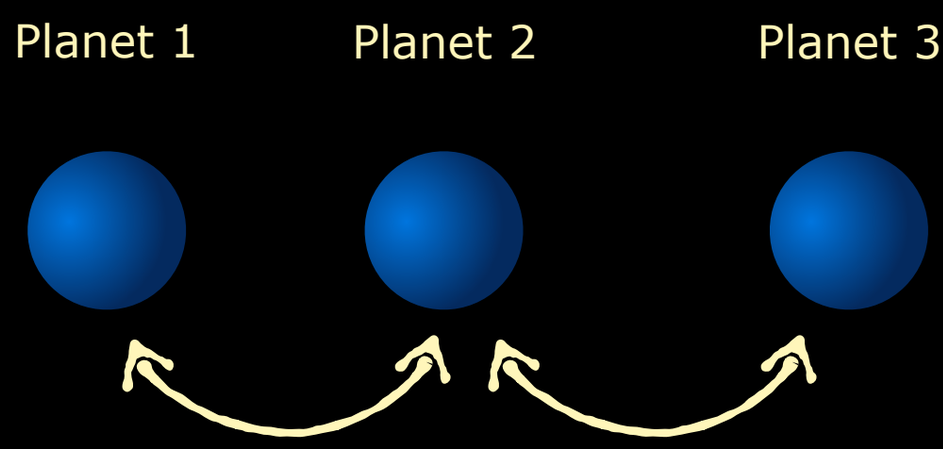
Gravitational interactions between planets

Planets around brown dwarfs

Tidal effects in multi-planet systems

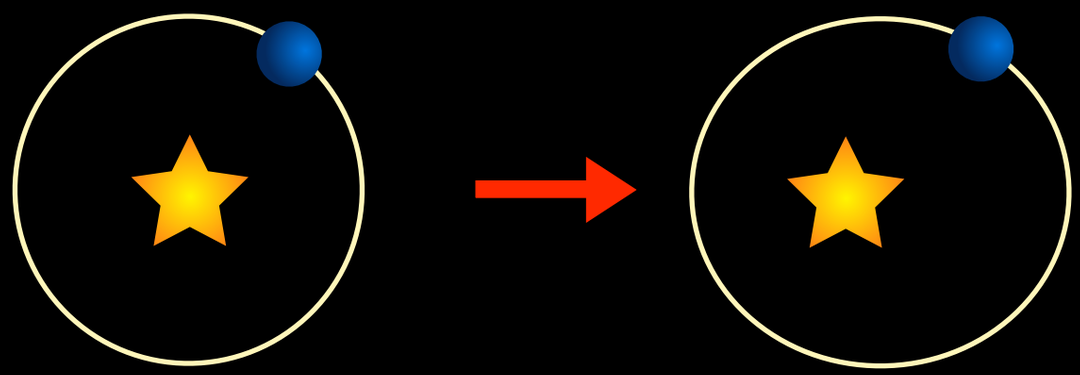


Brown dwarf



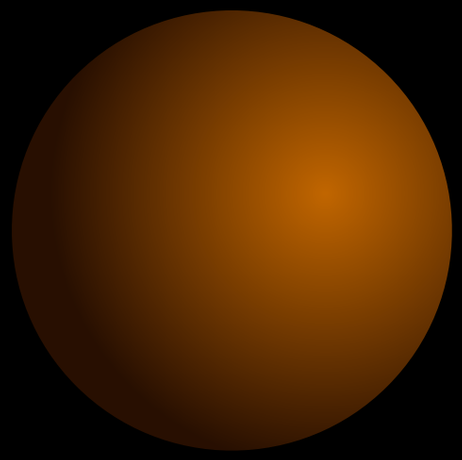
Gravitational interactions between planets

No Resonances

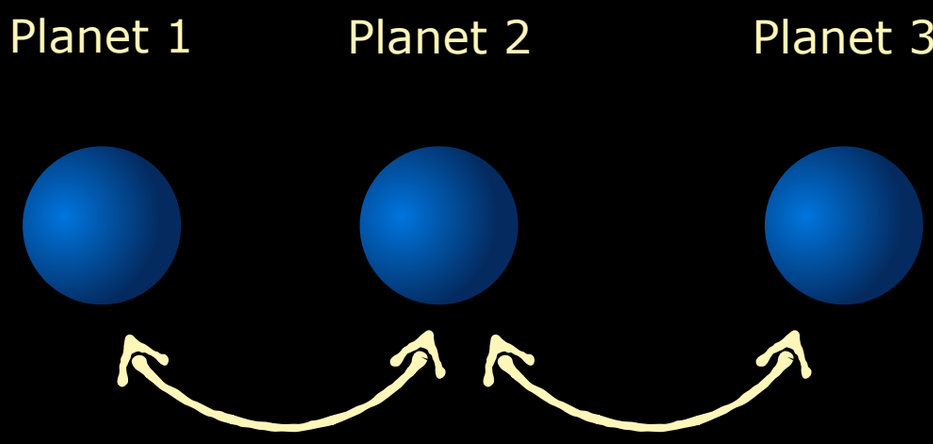


Planets around brown dwarfs

Tidal effects in multi-planet systems

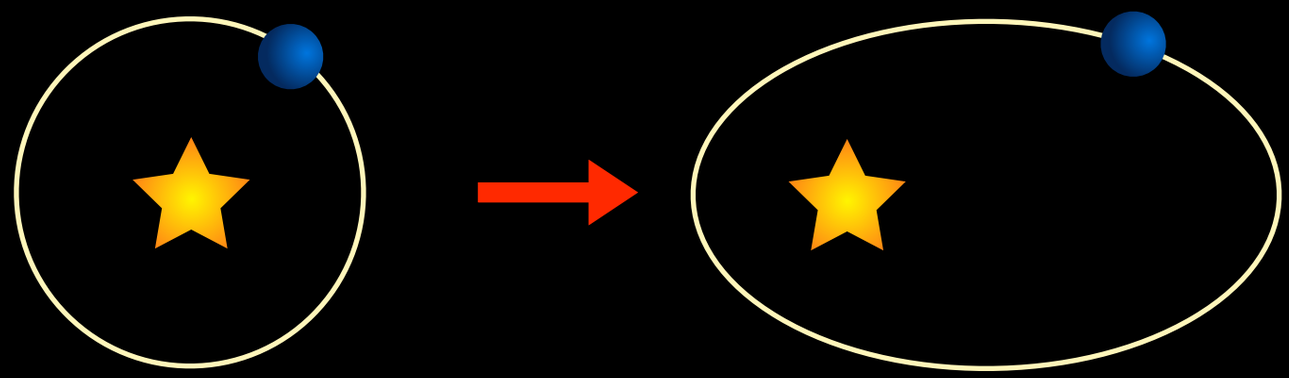


Brown dwarf



Gravitational interactions between planets

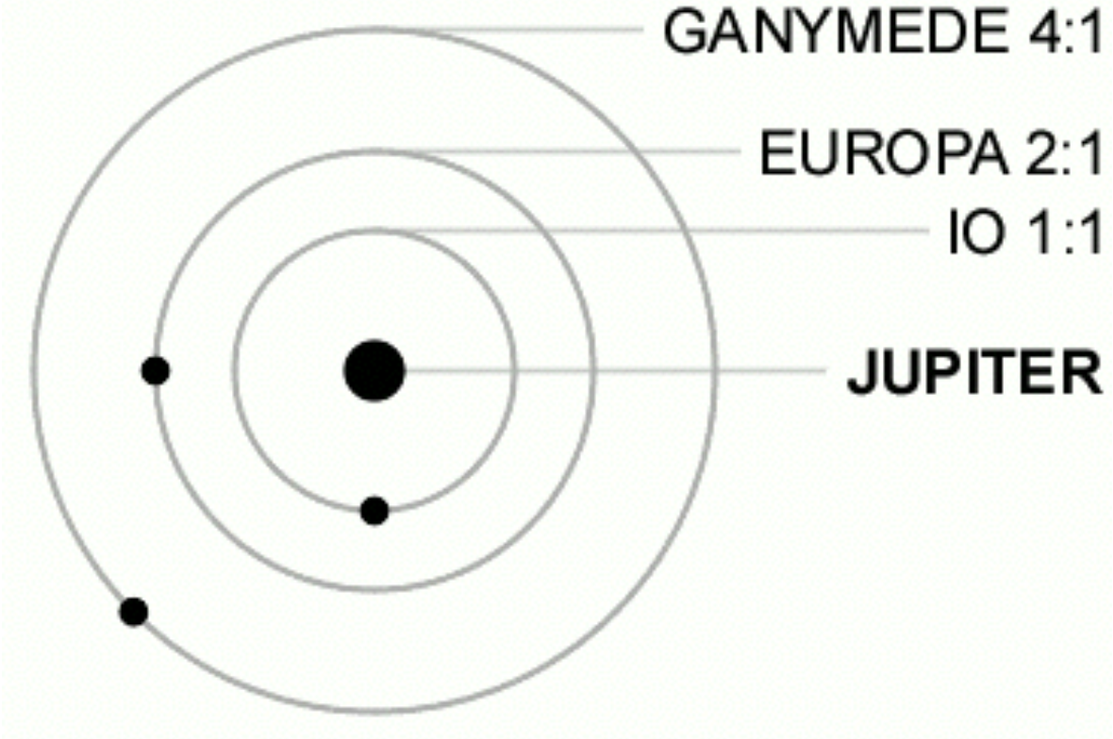
Resonances



Planets around brown dwarfs

Tidal effects in multi-planet systems

Resonances in the
Jupiter system



Planets around brown dwarfs

Tidal effects in multi-planet systems

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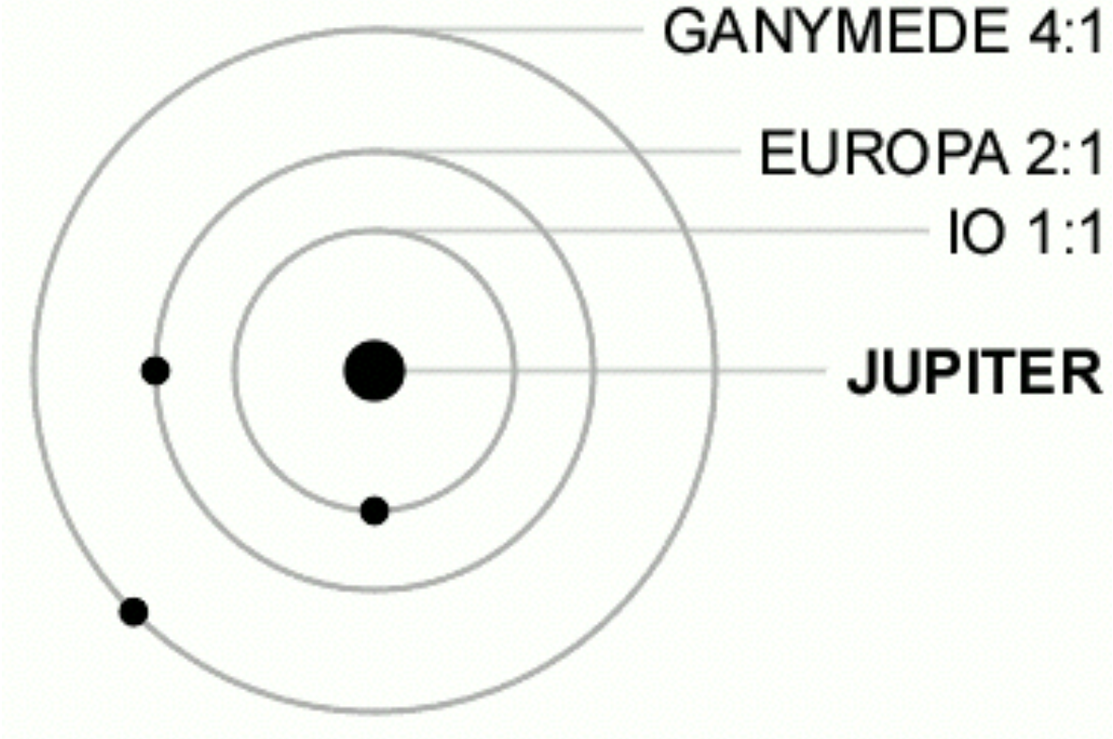
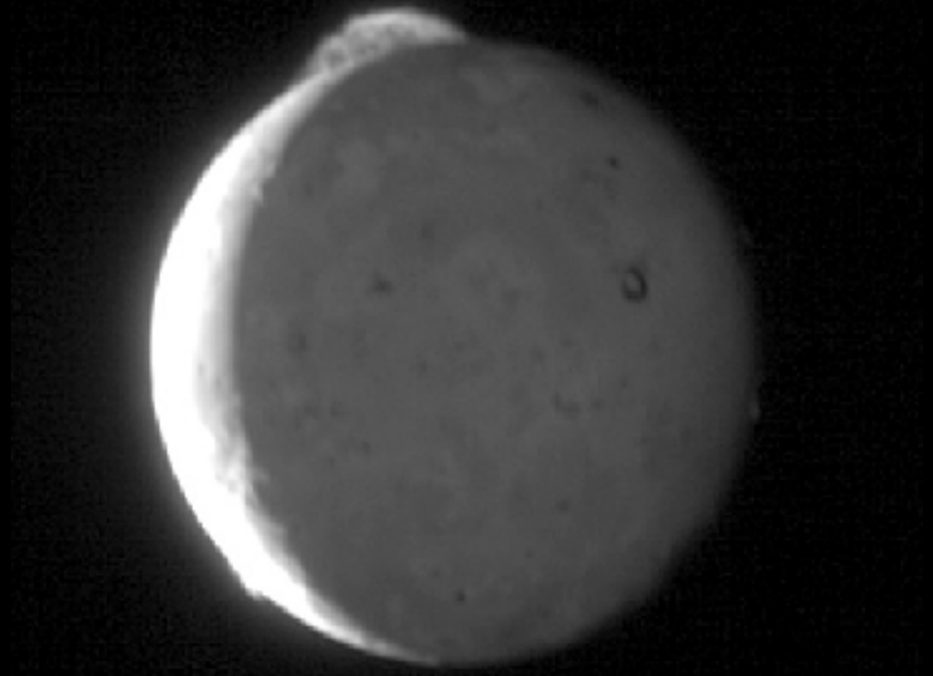


Planets around brown dwarfs

Tidal effects in multi-planet systems

Tidal effect in Io → strong volcanism

Tidal heat flux is ~3 W/m^2



Images from *New Horizons* showing volcano Tvashtar

Planets around brown dwarfs

Tidal effects in multi-planet systems

Tidal effect in Io → strong volcanism

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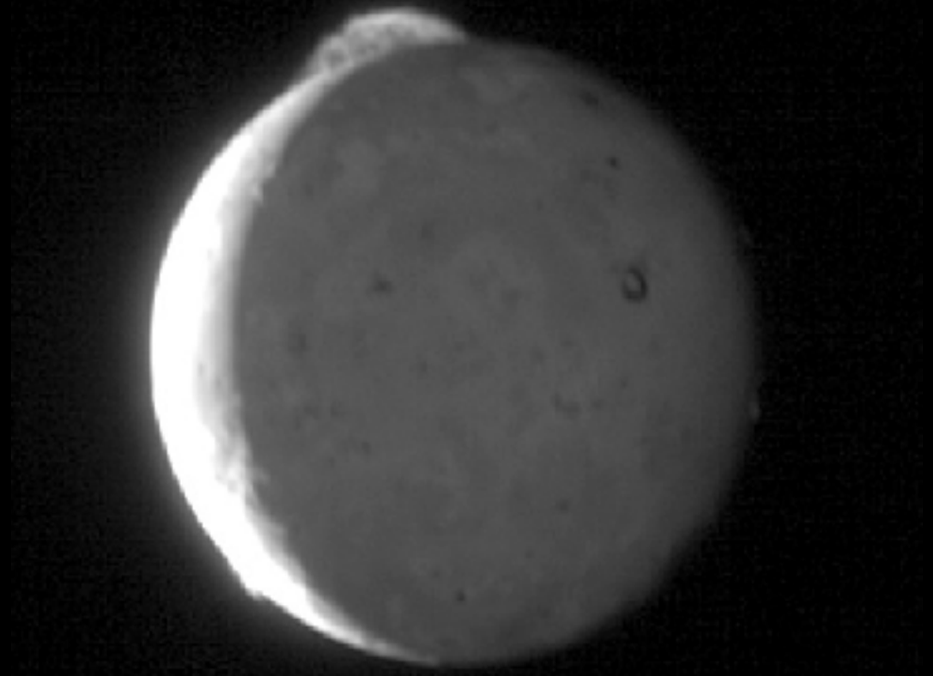


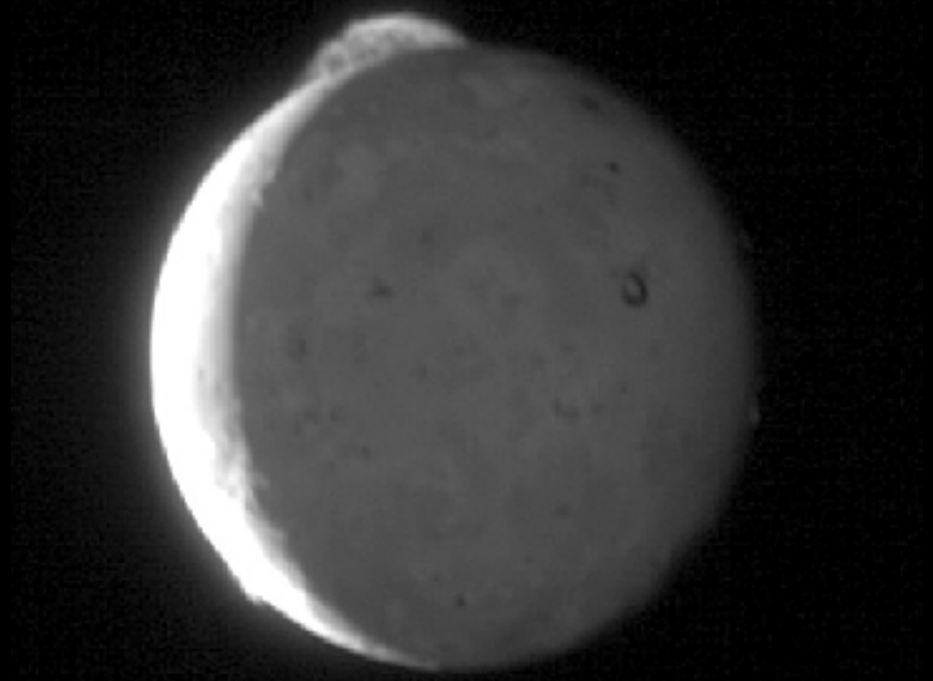
Images from *New Horizons* showing volcano Tvashtar

Planets around brown dwarfs

Tidal effects in multi-planet systems

Tidal effect in Io → strong volcanism

Tidal heat flux is ~3 W/m^2 > ~40 x Earth's flux (radioactivity)



Images from *New Horizons* showing volcano Tvashtar

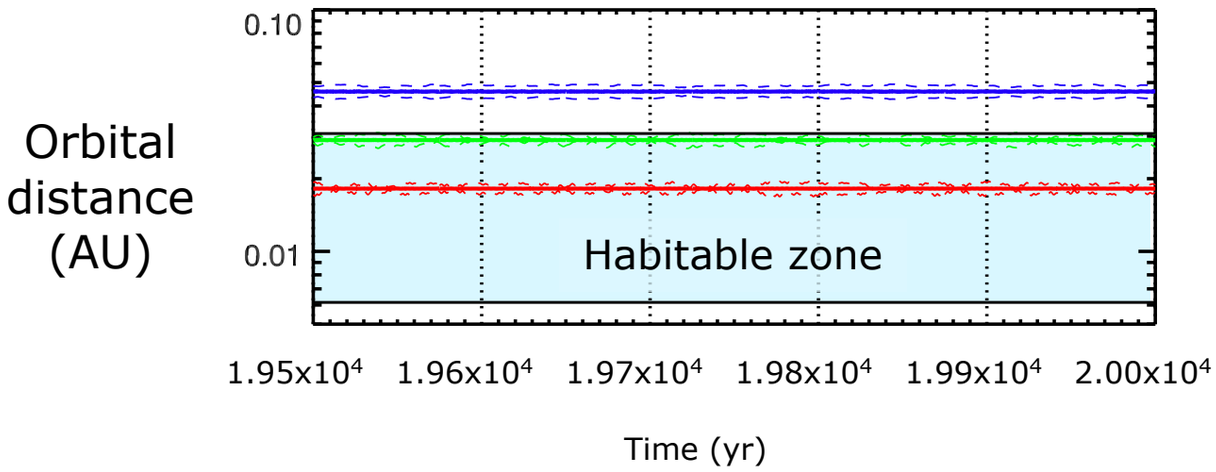
Planets around brown dwarfs

Tidal effects in multi-planet systems

Planets around brown dwarfs

Tidal effects in multi-planet systems

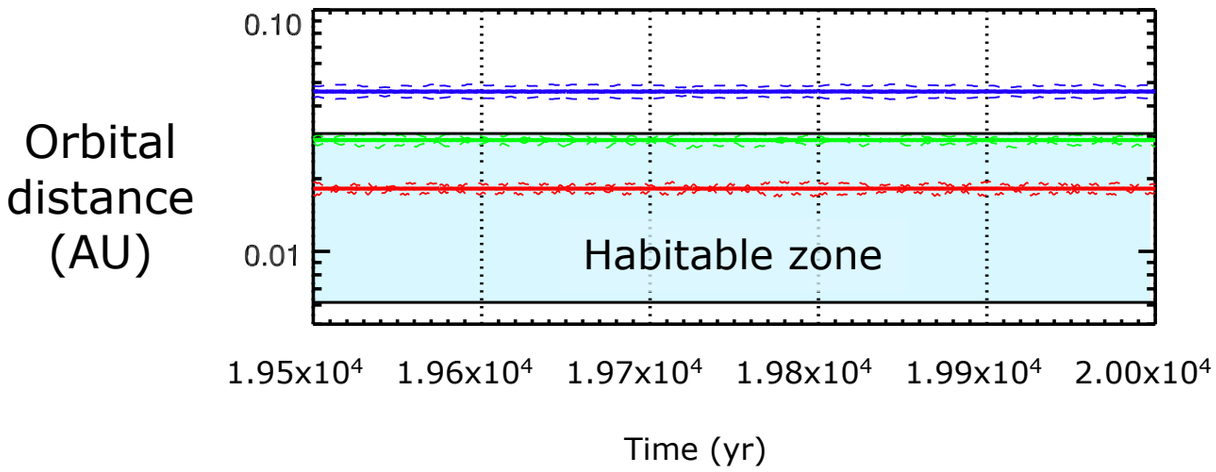
Non resonant system



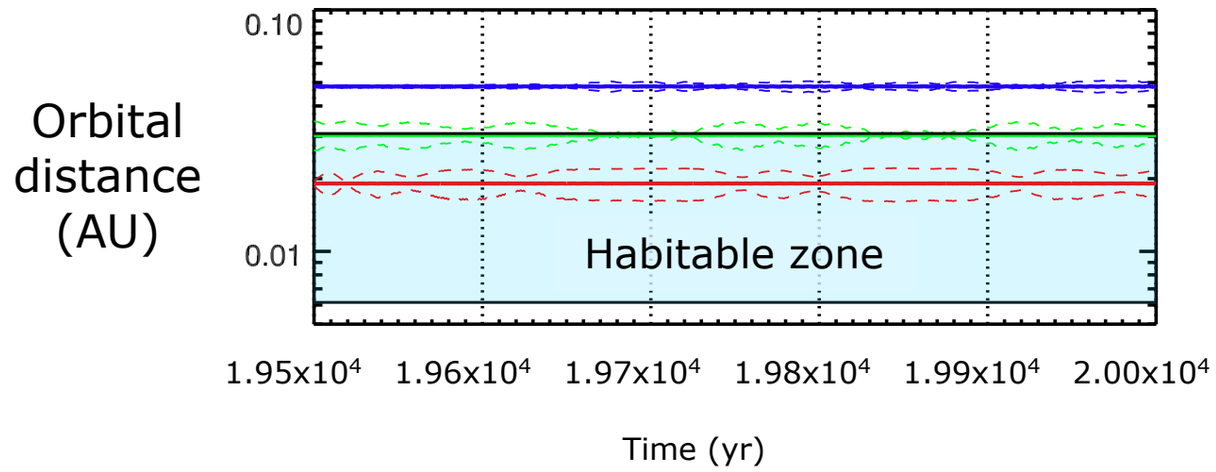
Planets around brown dwarfs

Tidal effects in multi-planet systems

Non resonant system



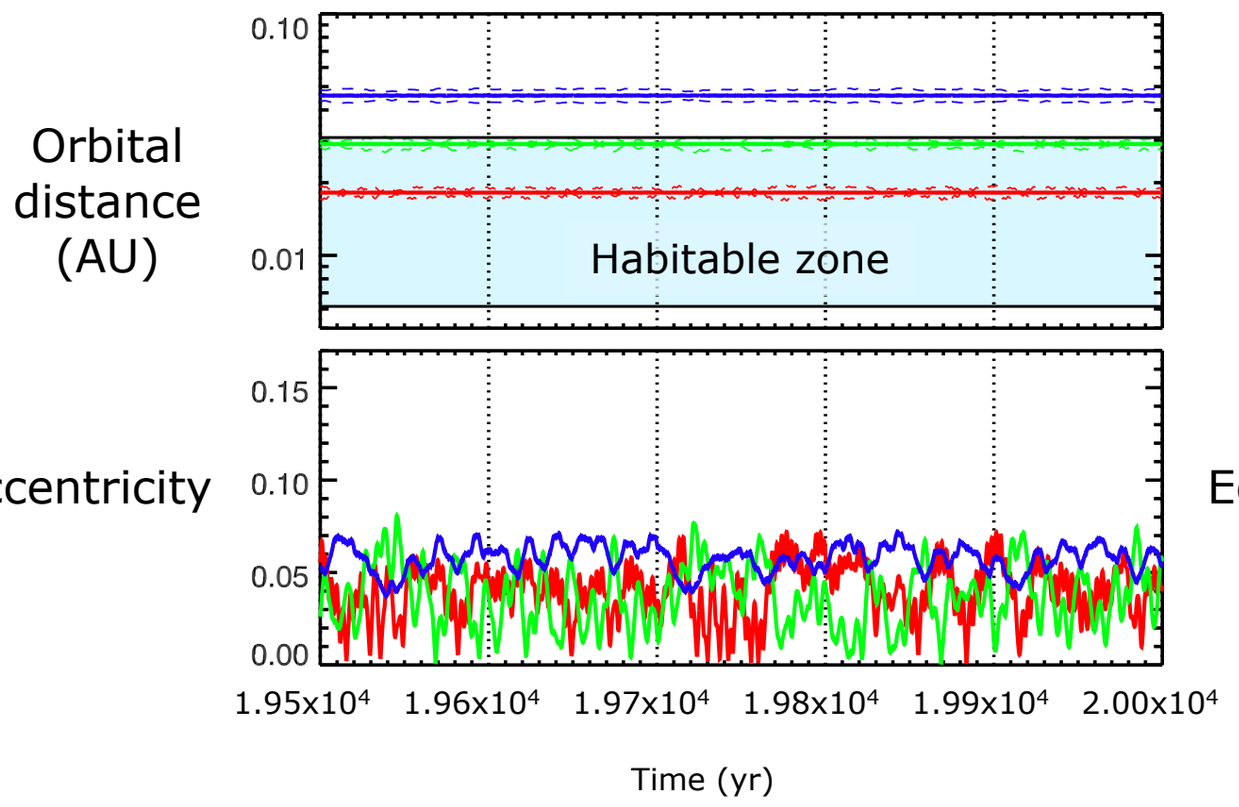
Resonance 2:1



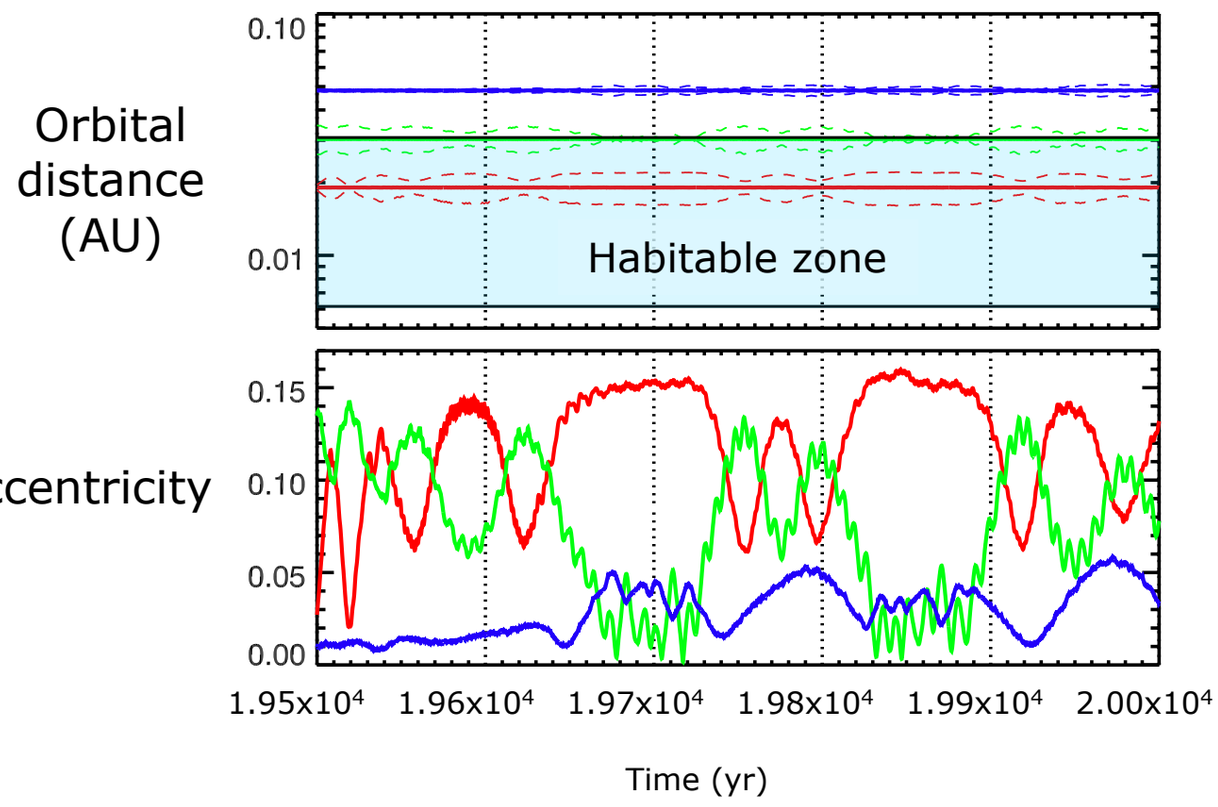
Planets around brown dwarfs

Tidal effects in multi-planet systems

Non resonant system



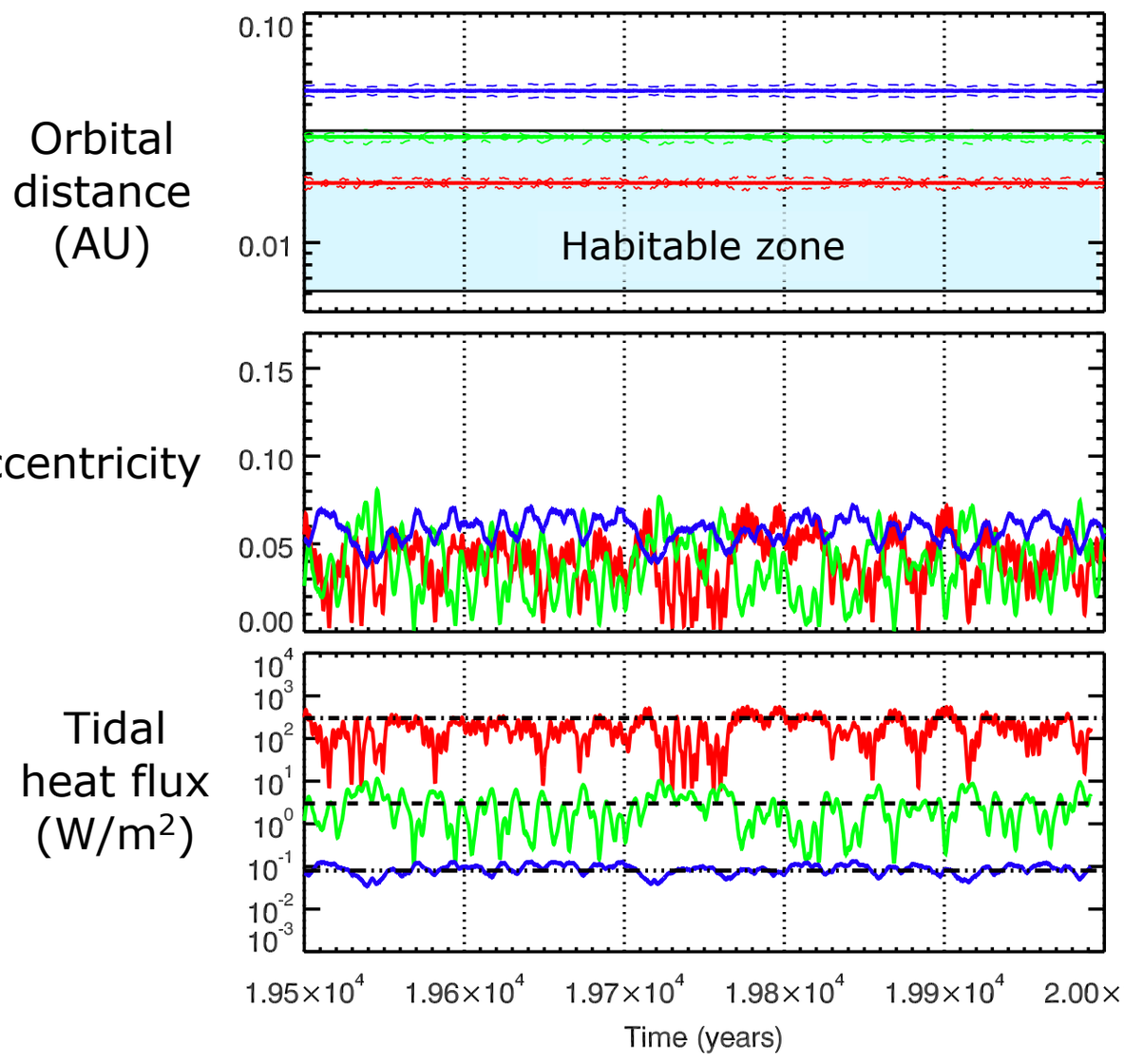
Resonance 2:1



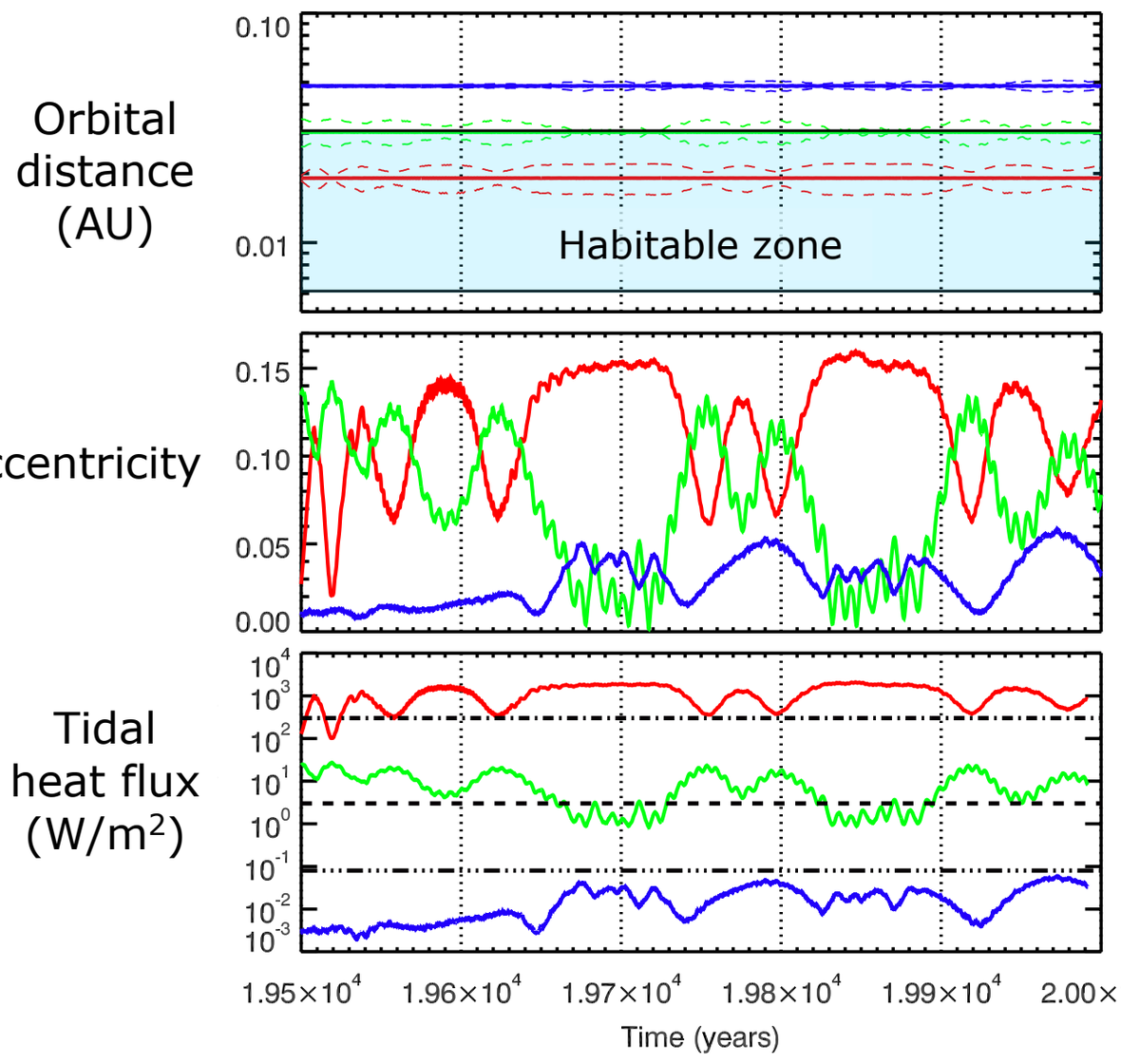
Planets around brown dwarfs

Tidal effects in multi-planet systems

Non resonant system



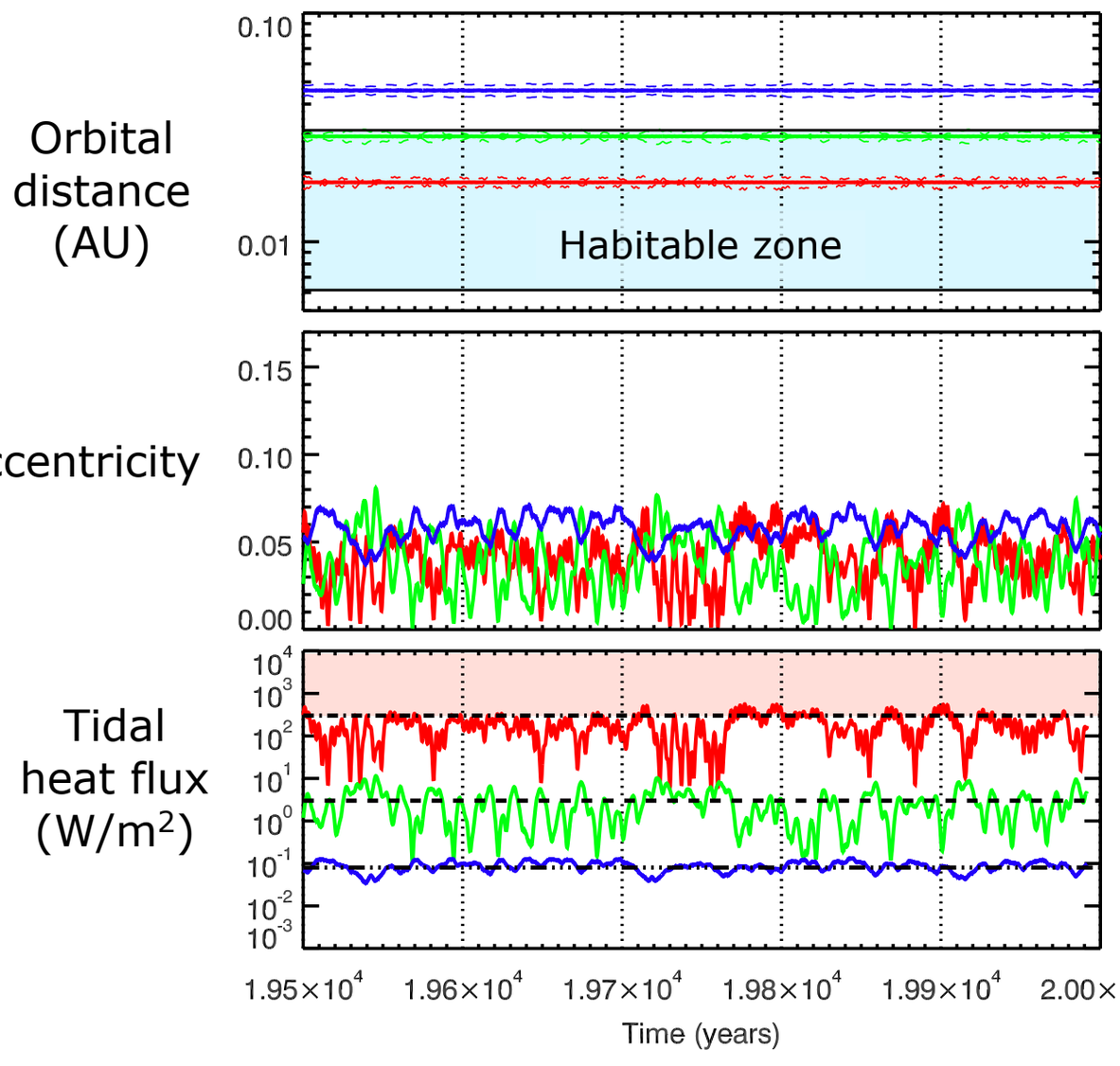
Resonance 2:1



Planets around brown dwarfs

Tidal effects in multi-planet systems

Non resonant system



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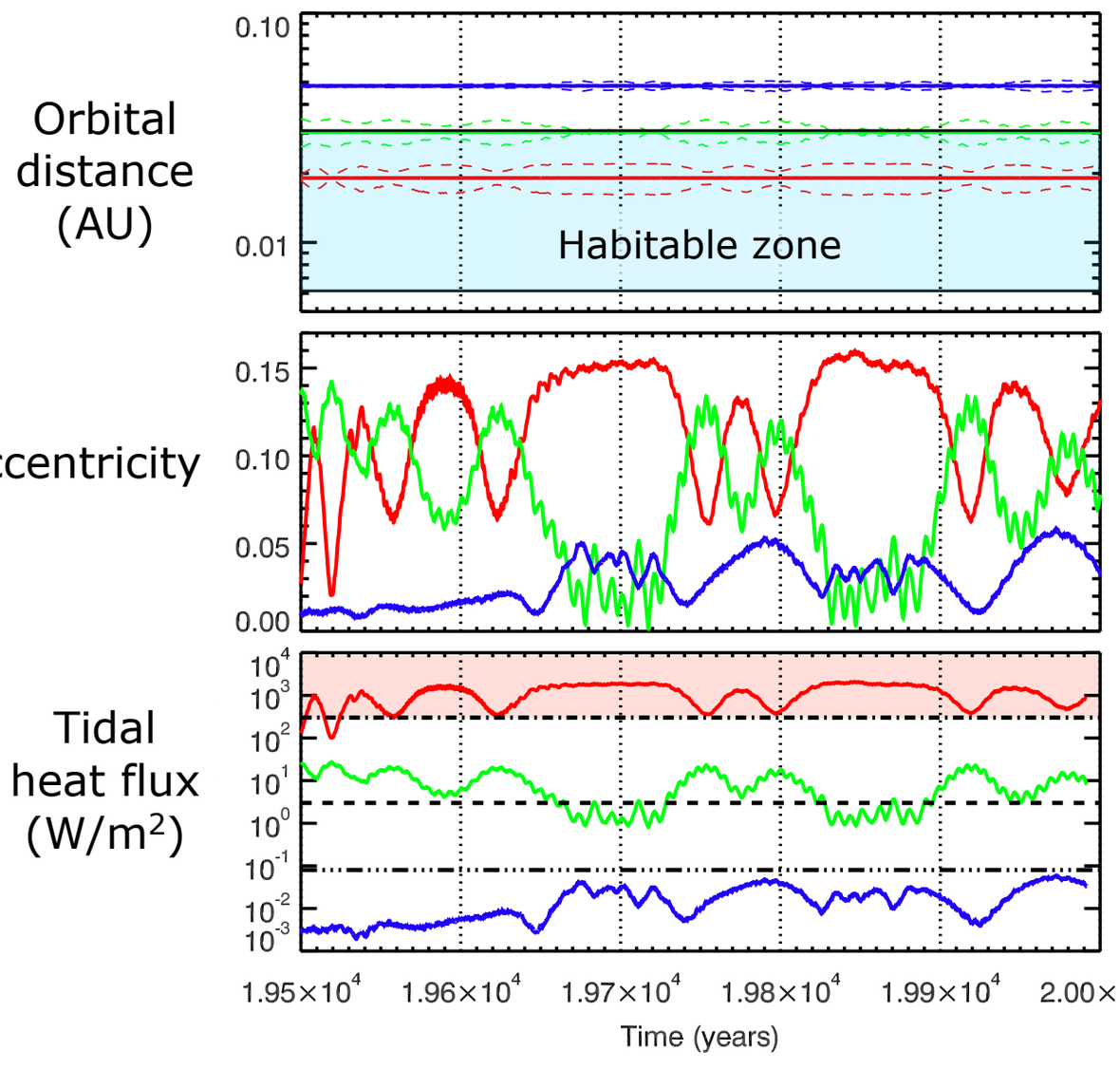


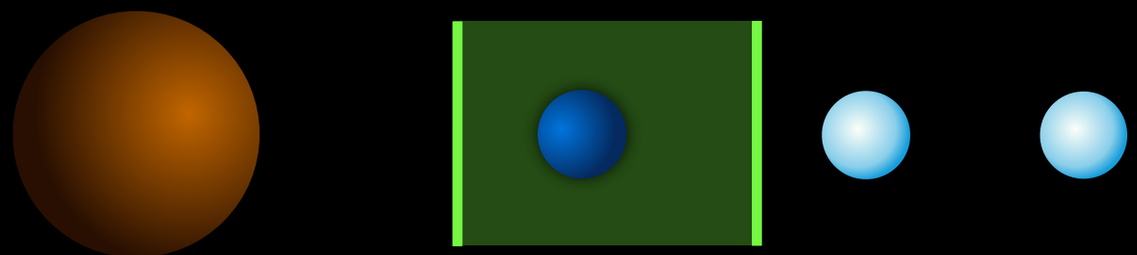
Planets around brown dwarfs

aquability?

Planets around brown dwarfs

aquability?

- $(\Phi_{\star} + \Phi_{tides})_{avg} < 300$ W/m^2, aquability

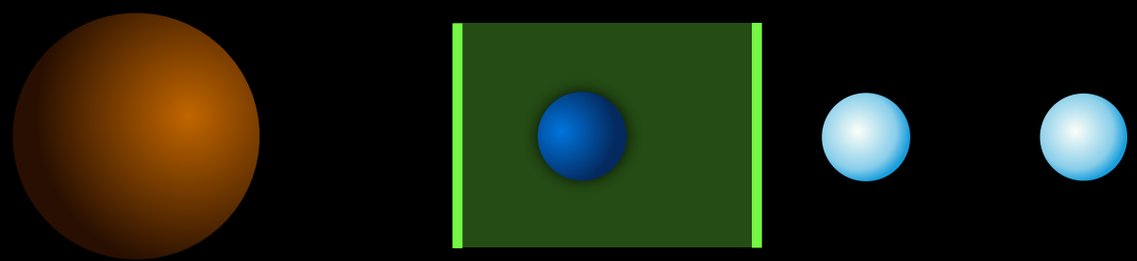


Several planets
no resonances

Planets around brown dwarfs

aquability?

- $(\Phi_{\star} + \Phi_{tides})_{avg} < 300$ W/m^2, aquability



Several planets
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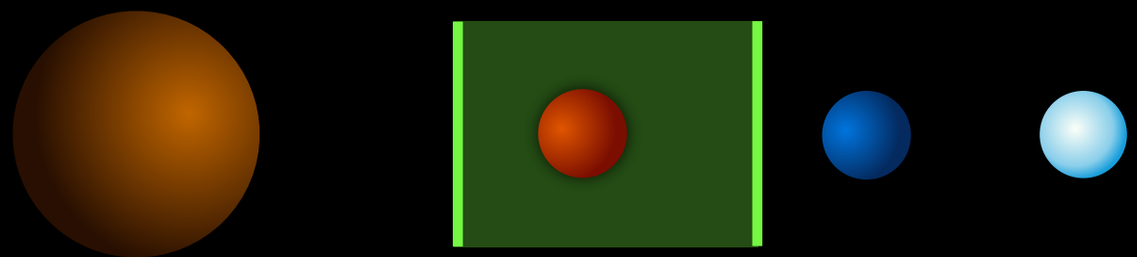


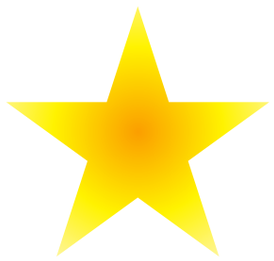
Several planets
resonances

Planets around brown dwarfs

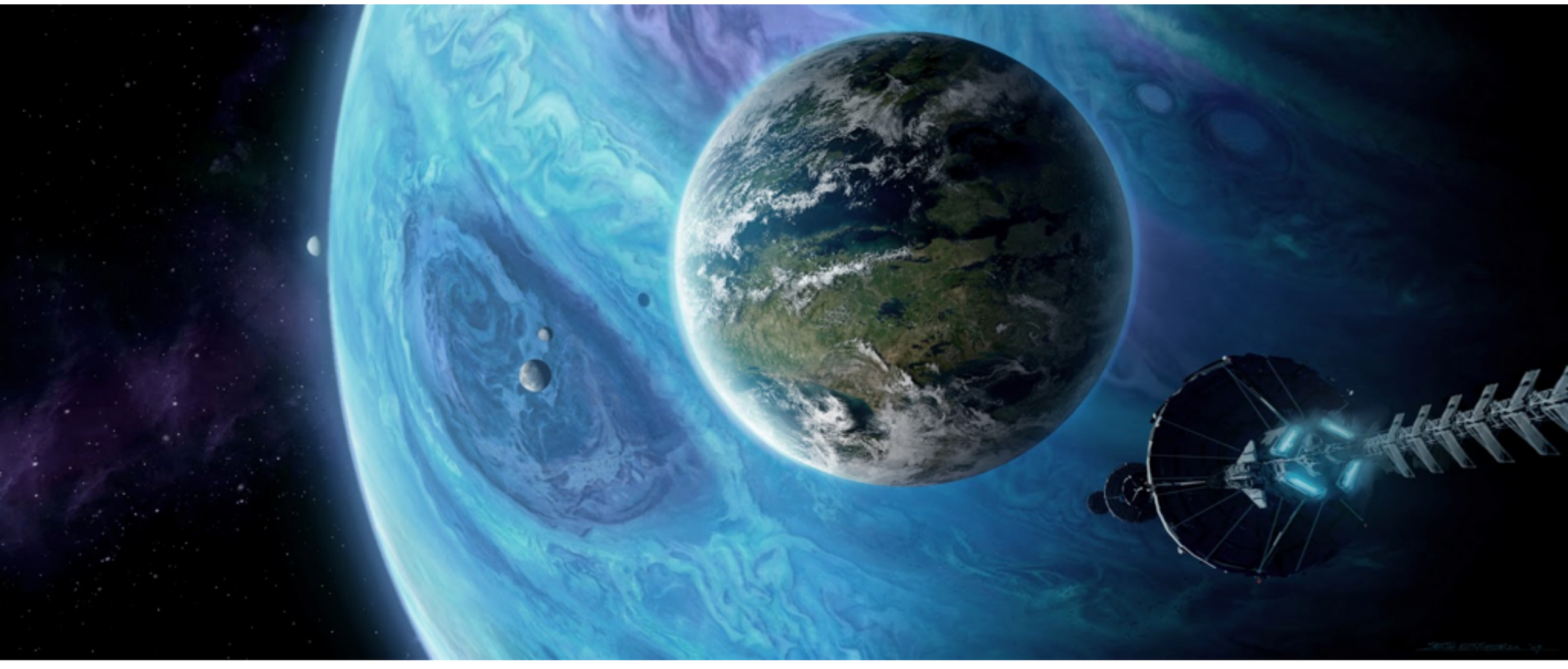
This is also relevant for...

Planets around brown dwarfs

This is also relevant for...

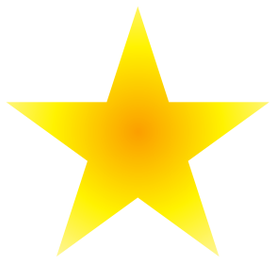


Exomoons!



Planets around brown dwarfs

This is also relevant for...



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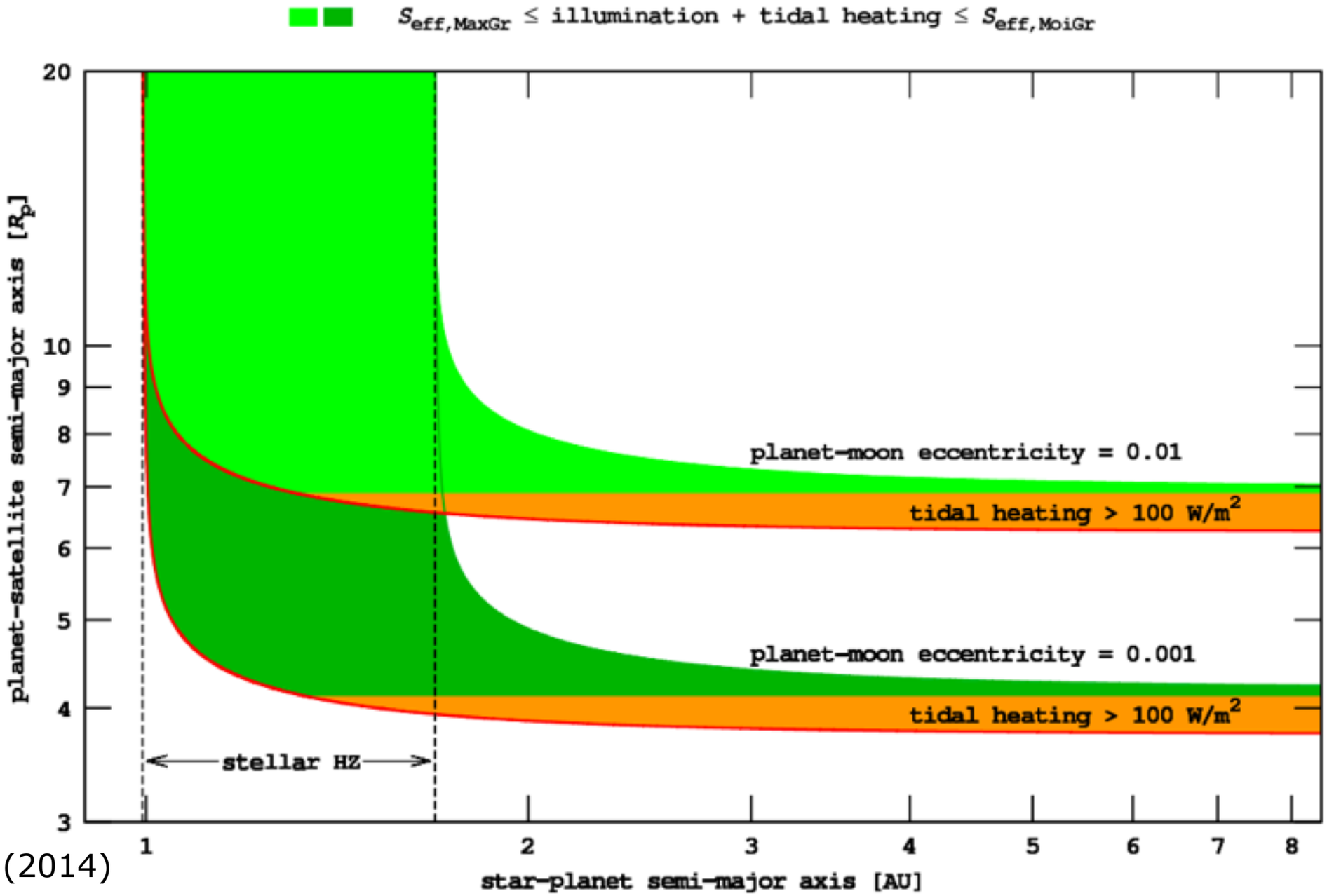
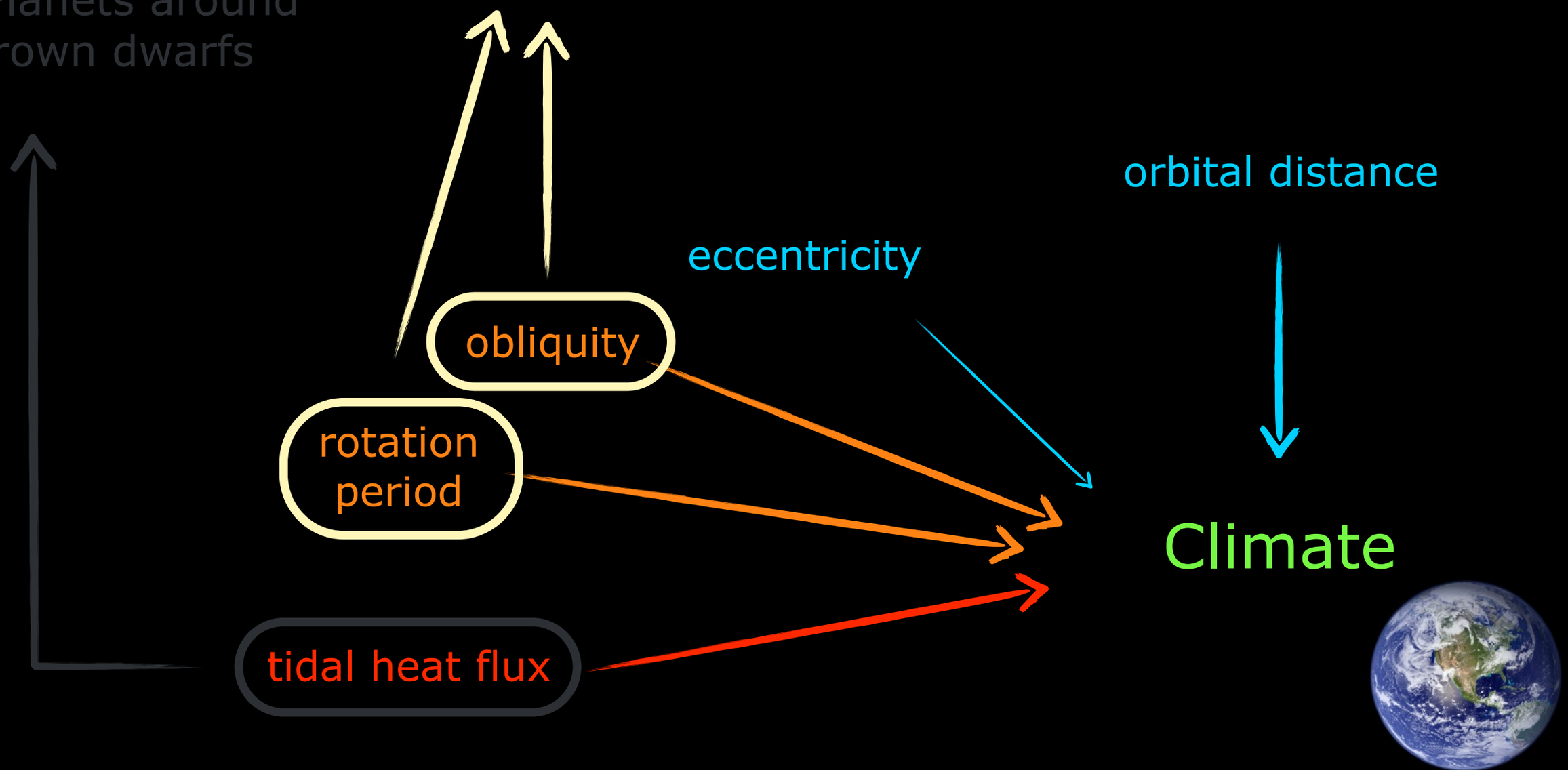


Heller et al. (2014)

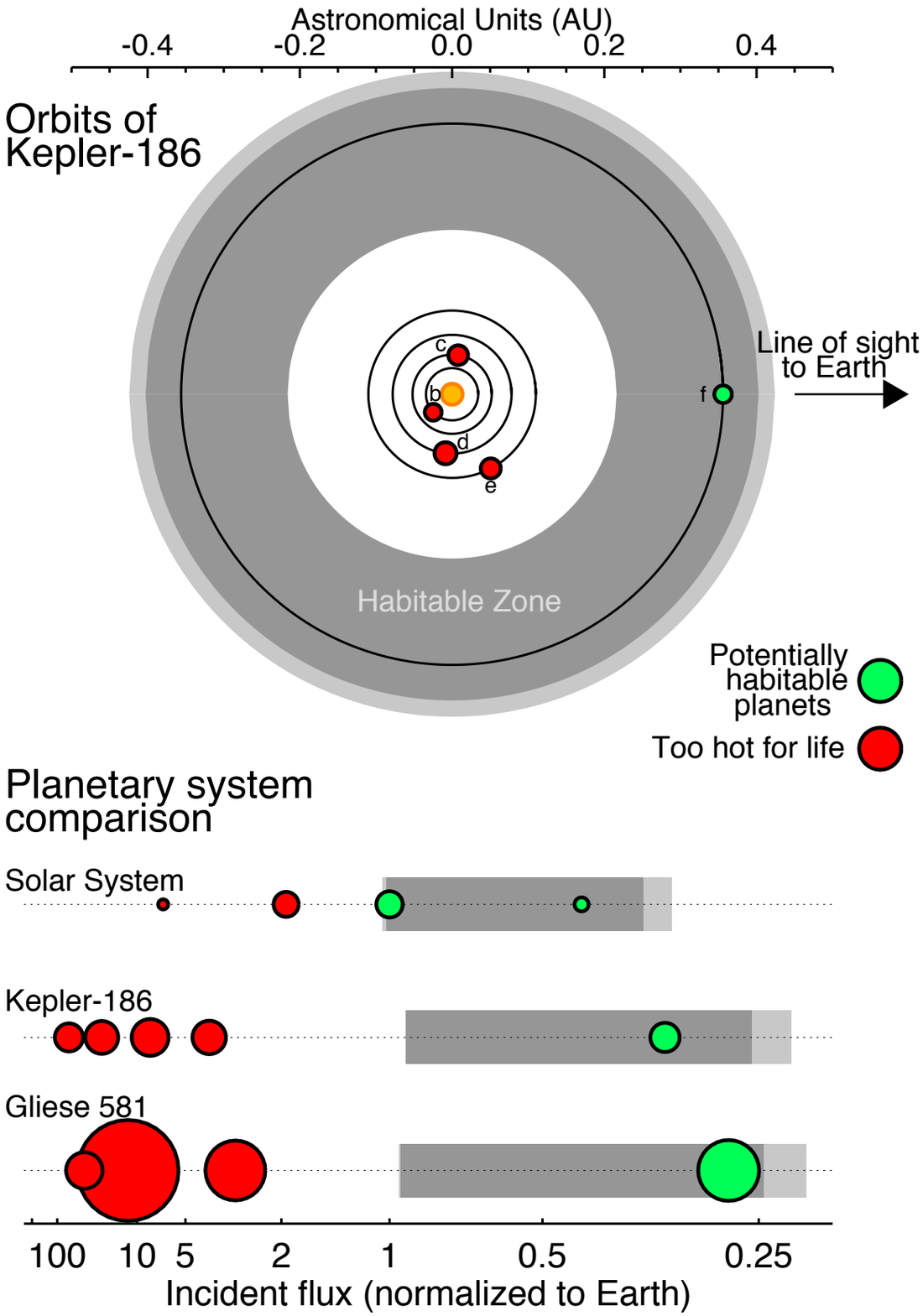
Tides and climate

1) Planets around brown dwarfs

2) Kepler-186f



Kepler-186



Quintana et al. (2014)

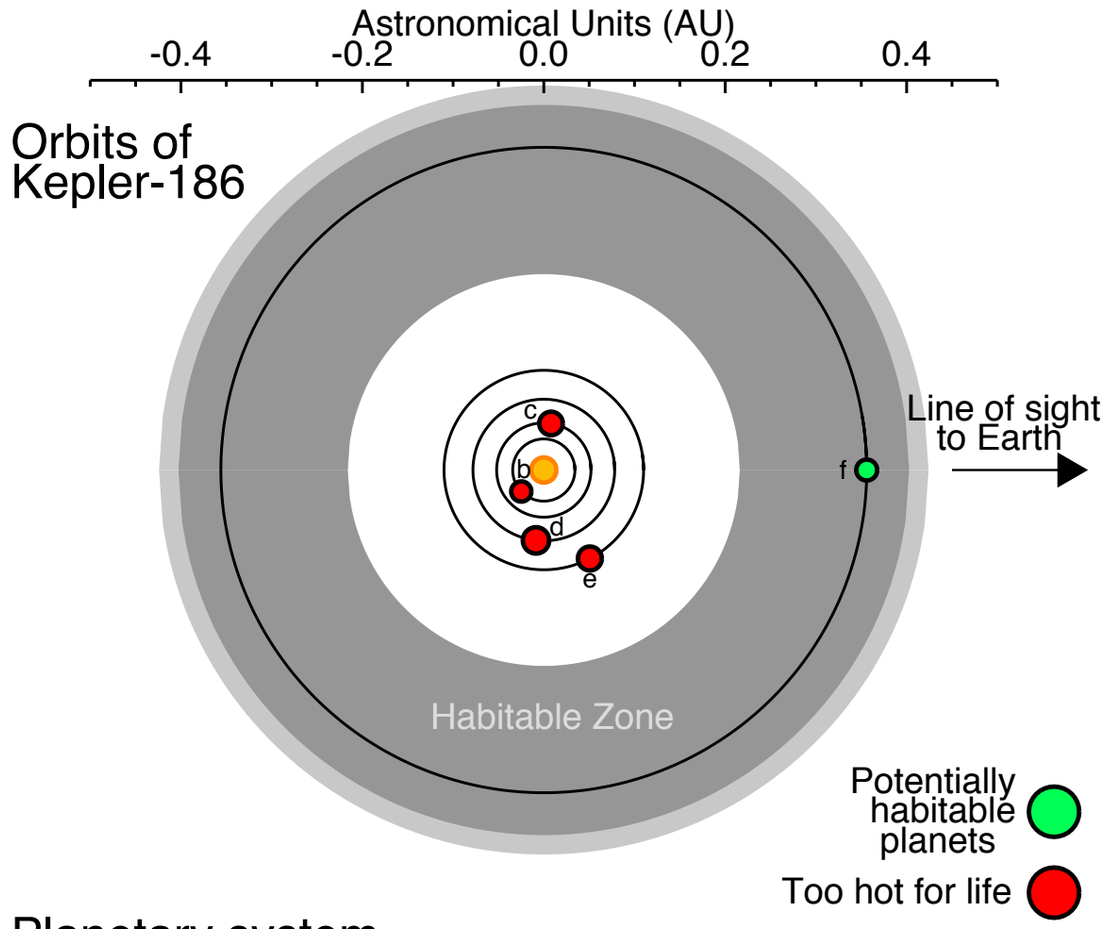
Bolmont et al. (2014)

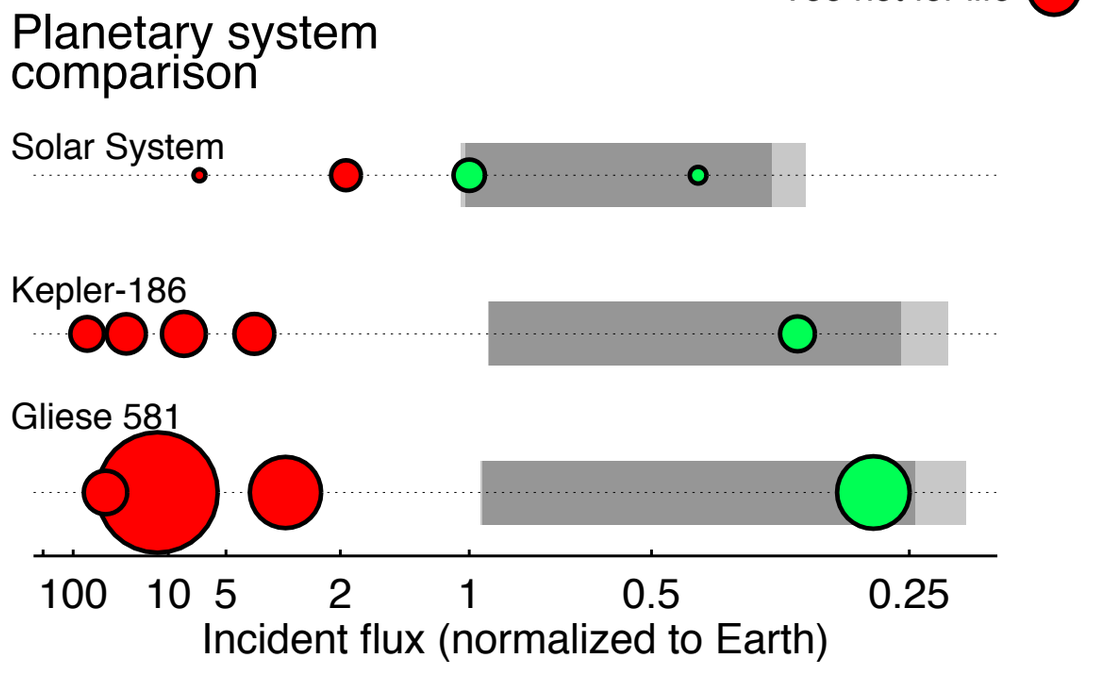
Kepler-186

Star: 0.48 $M_\odot$

Planets: $1 < R_p/R_\oplus < 1.4$

$0.04 < a/AU < 0.4$



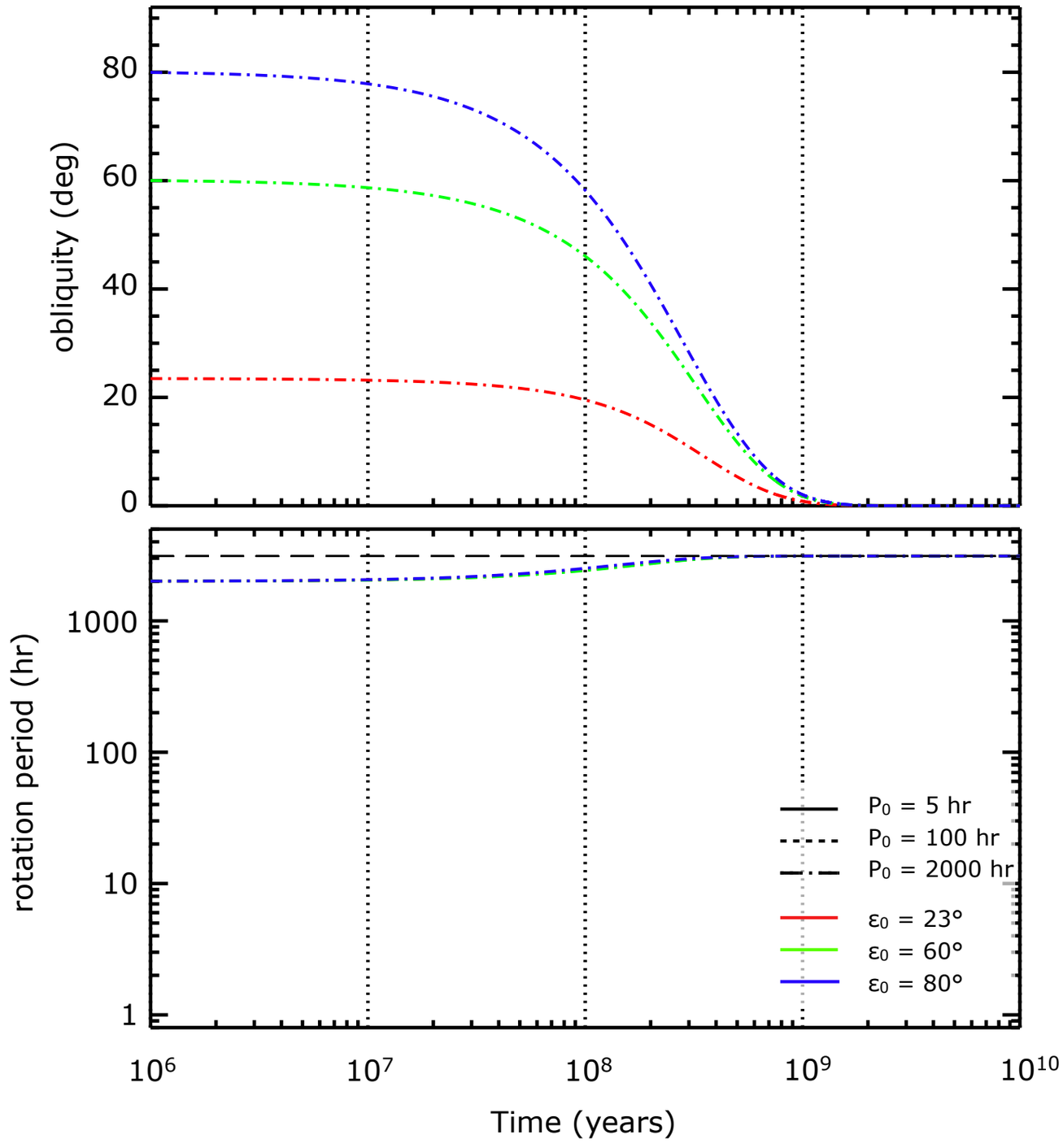


Quintana et al. (2014)

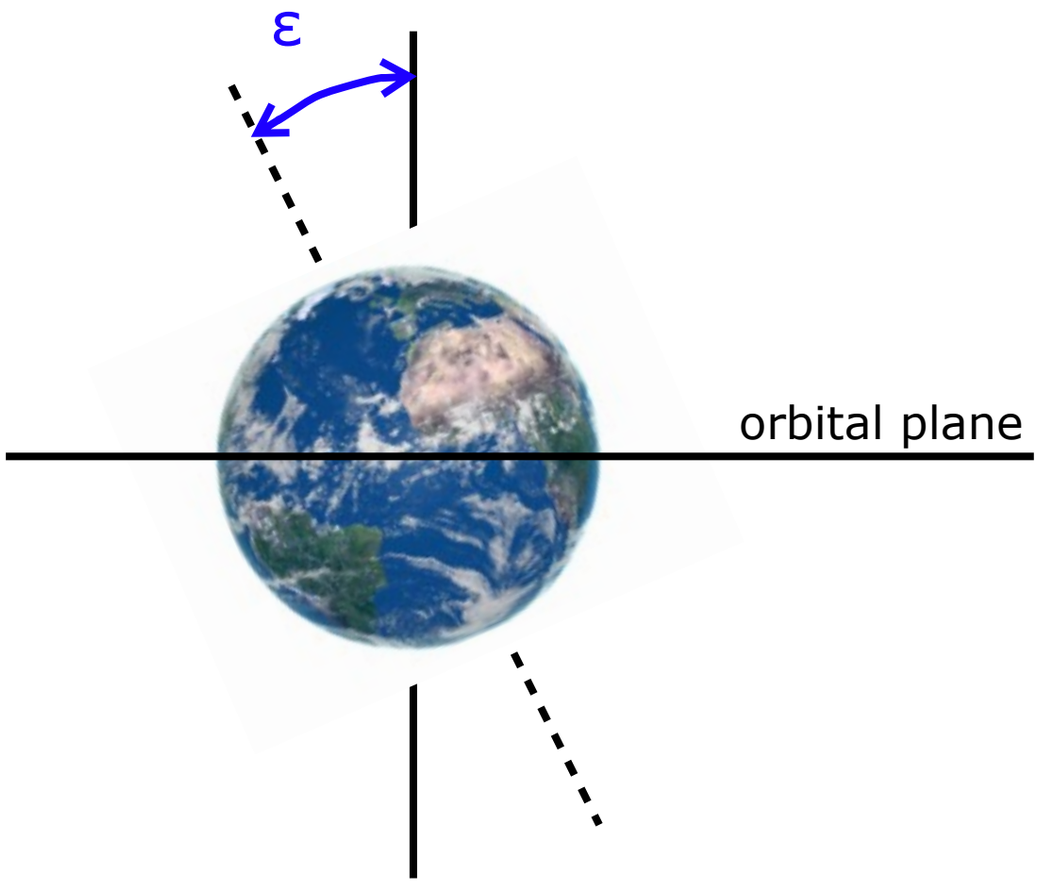
Bolmont et al. (2014)

Kepler-186

Aquability of Kepler-186f ?



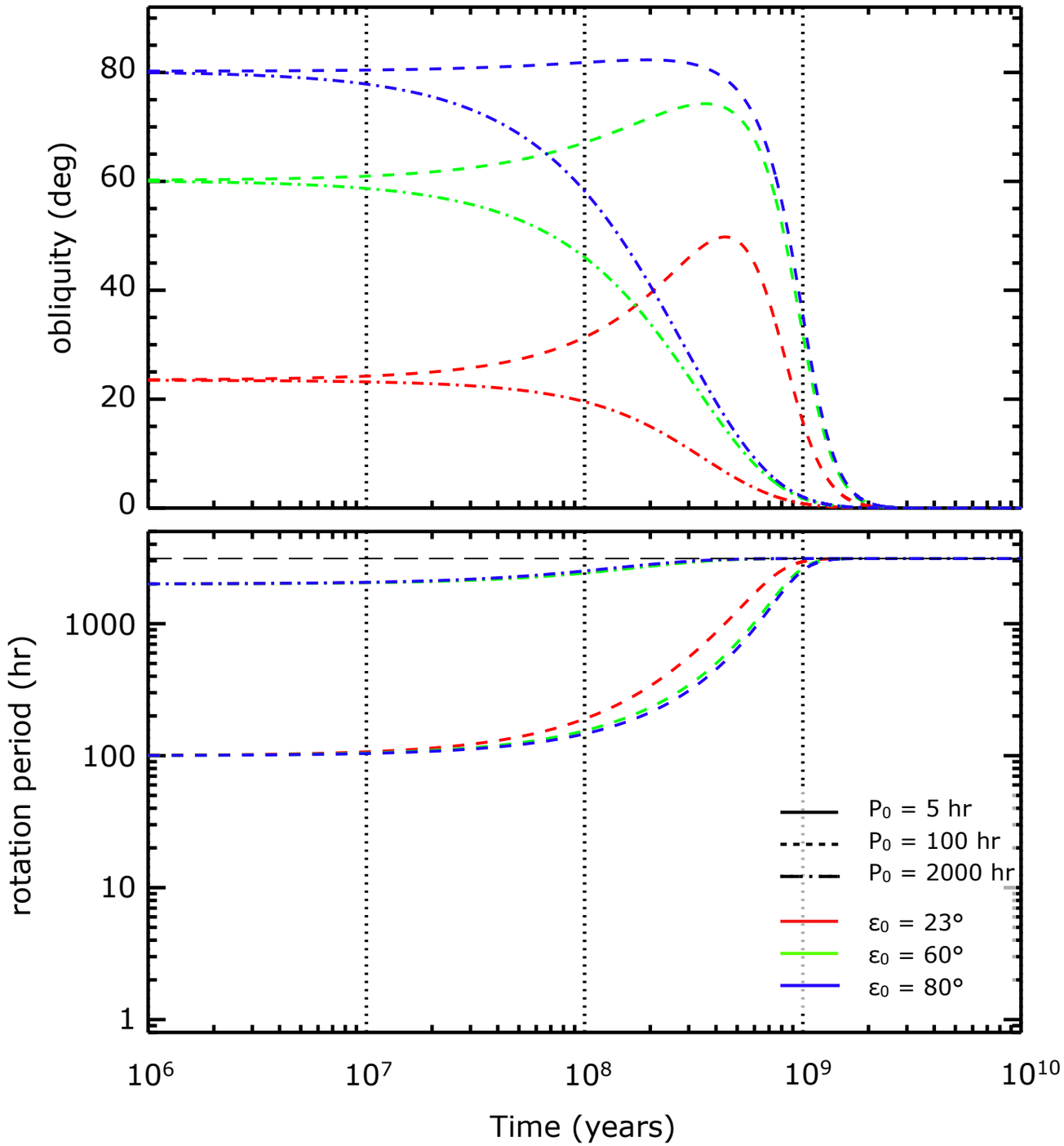
Bolmont et al. (2014)

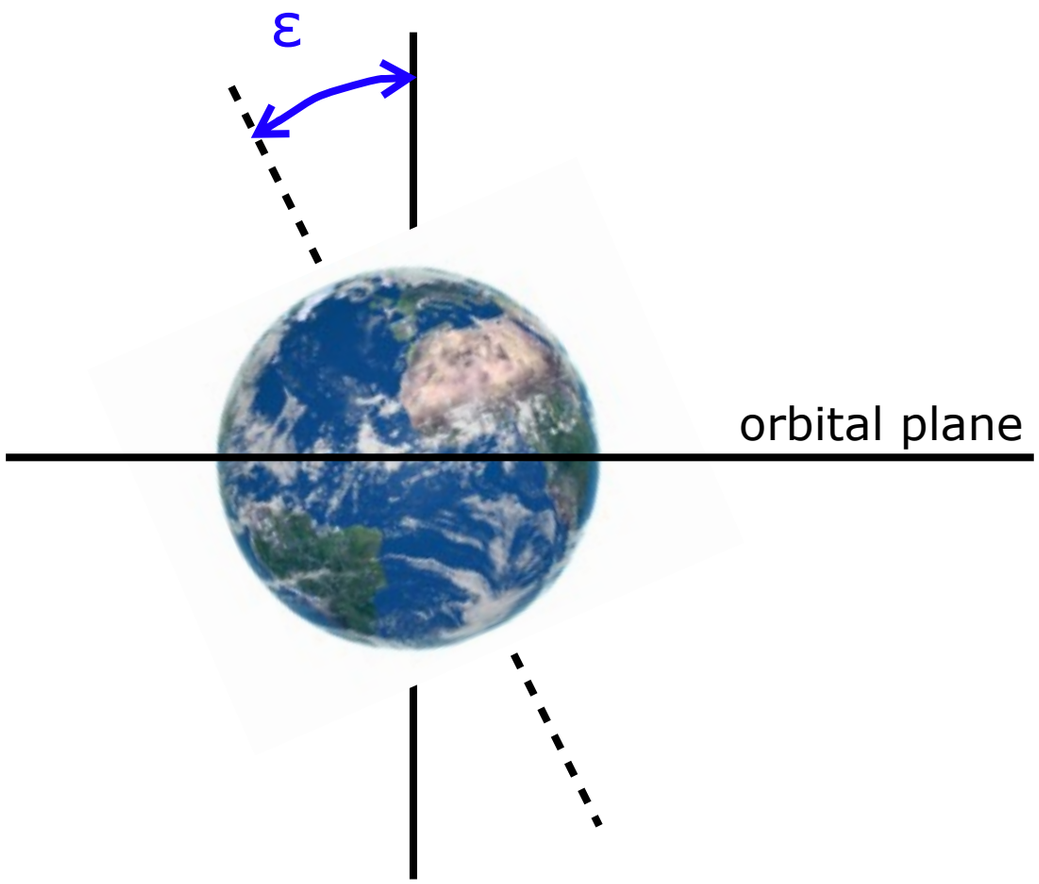


Assuming Earth composition
Assuming Earth dissipation

Kepler-186

Aquability of Kepler-186f ?



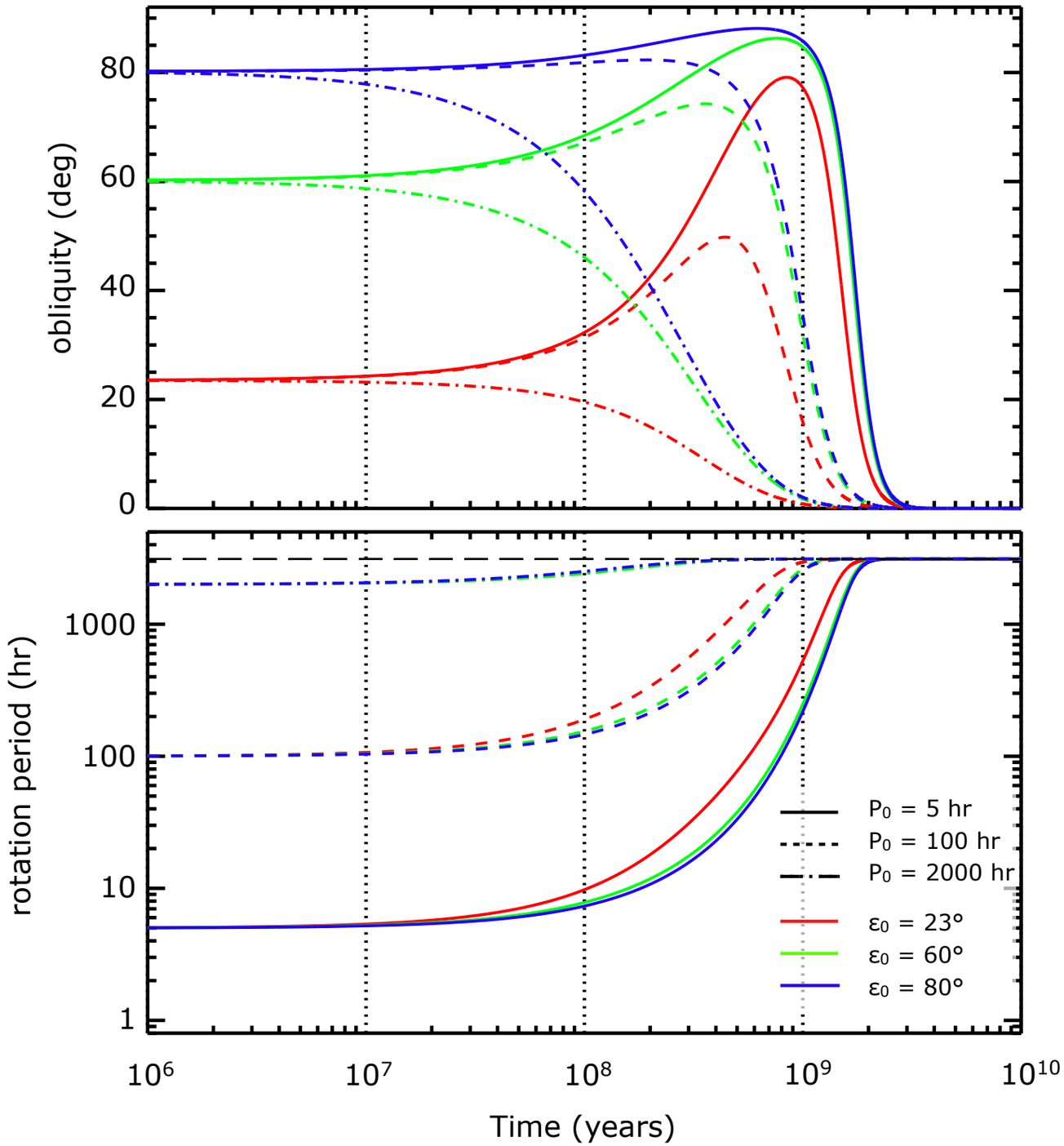


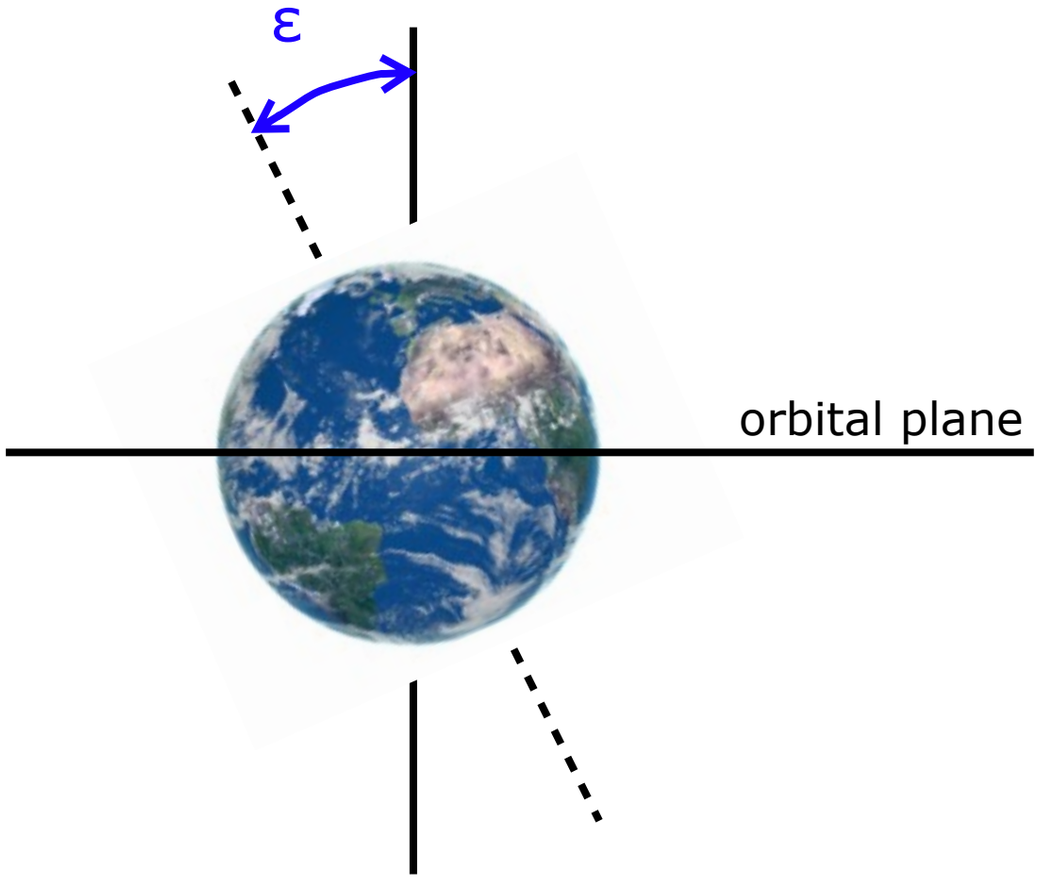
Assuming Earth composition
Assuming Earth dissipation

Bolmont et al. (2014)

Kepler-186

Aquability of Kepler-186f ?





Assuming Earth composition
Assuming Earth dissipation

Bolmont et al. (2014)

Tides and climate

Climate

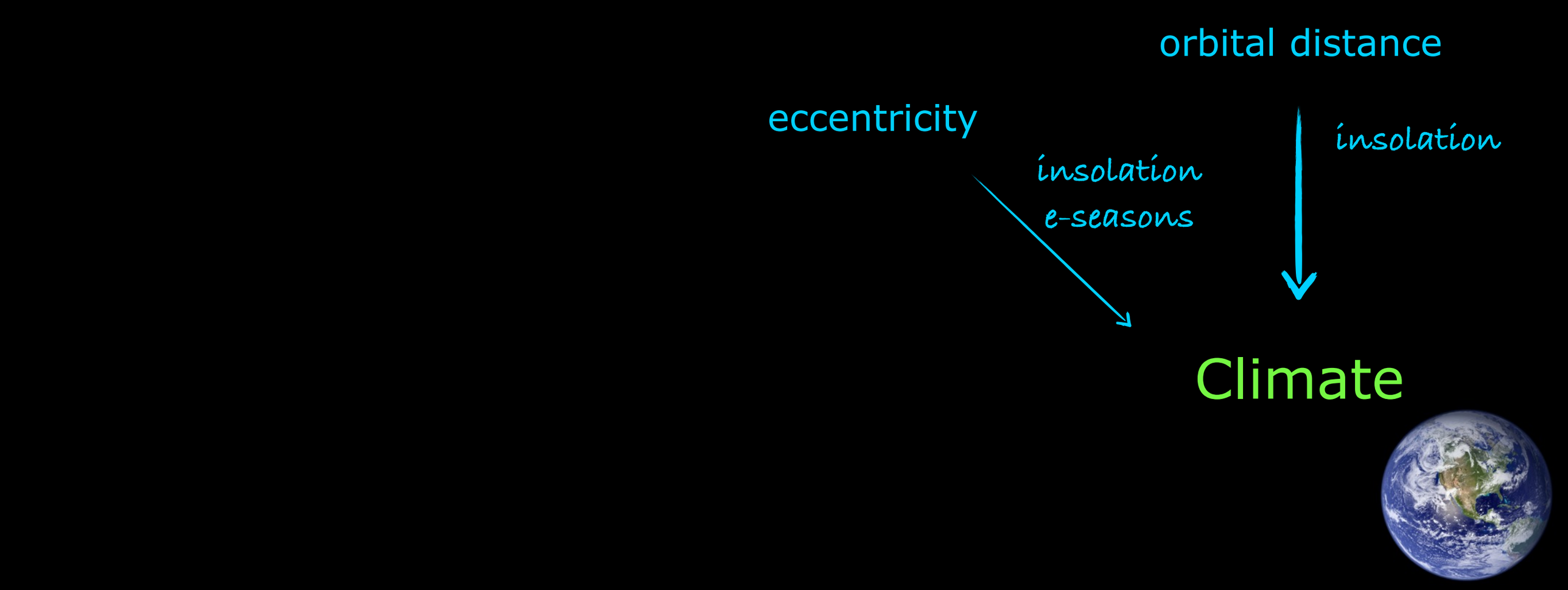
Tides and climate

orbital distance

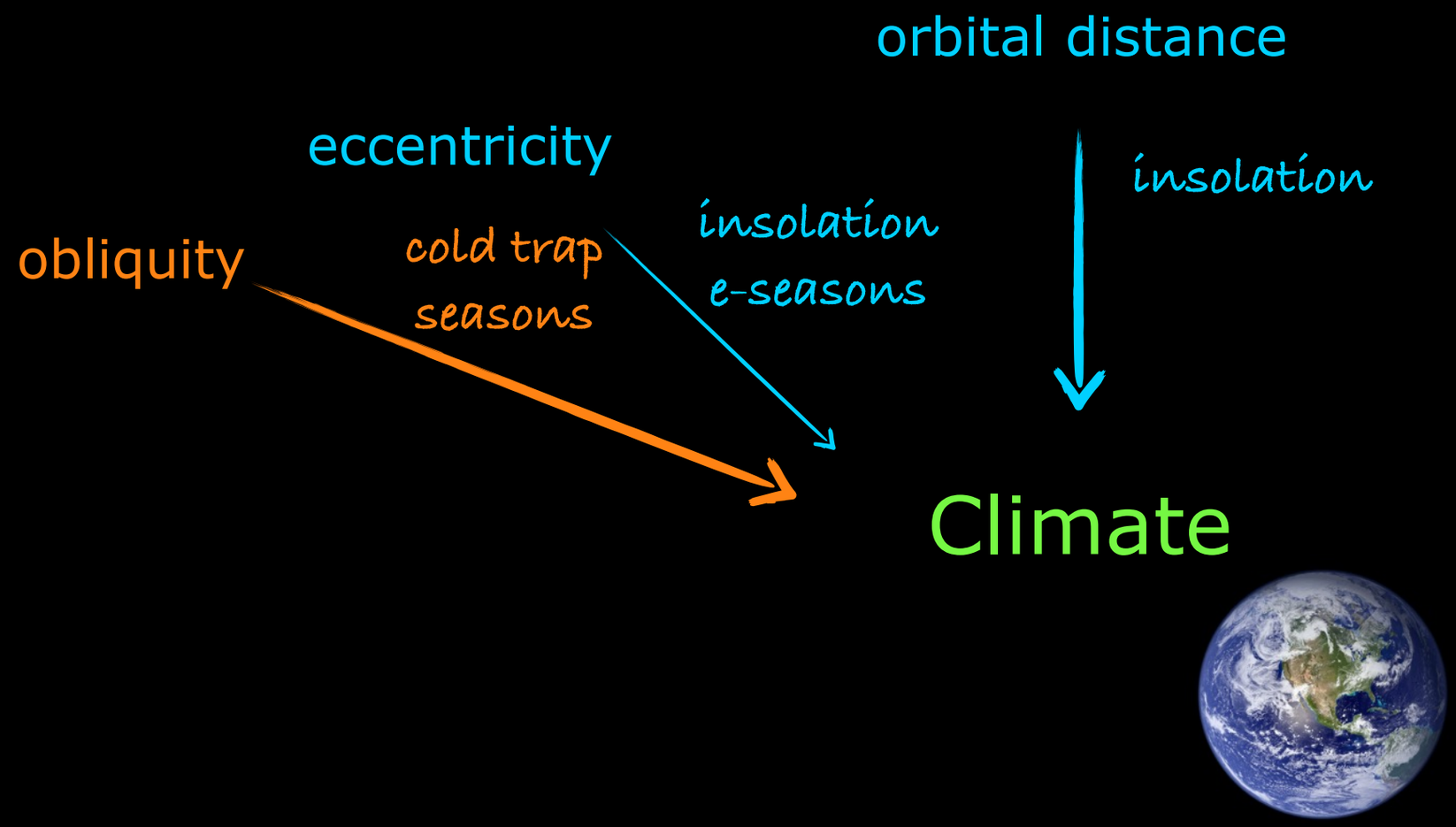
insolation

Climate

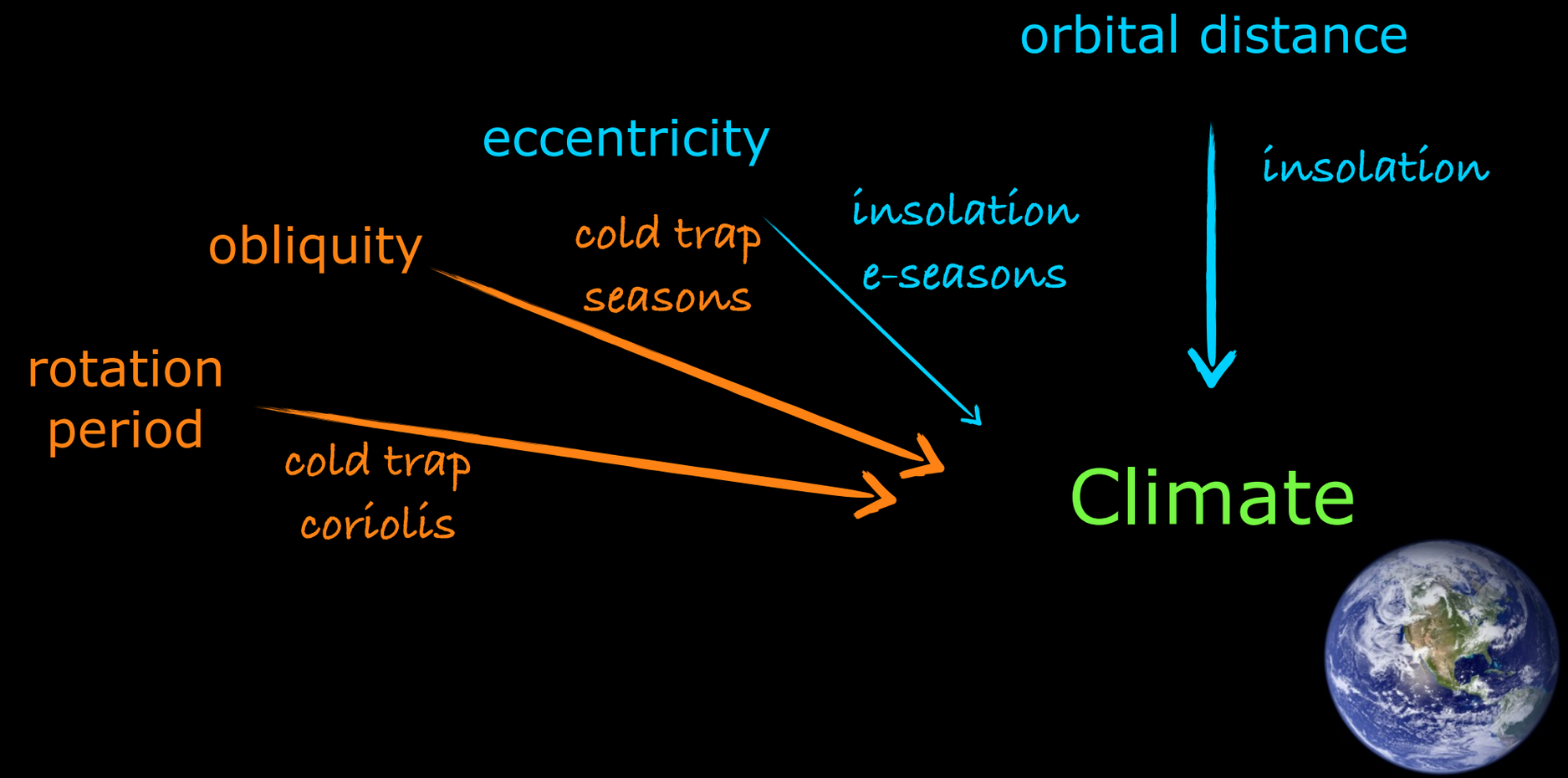
Tides and climate



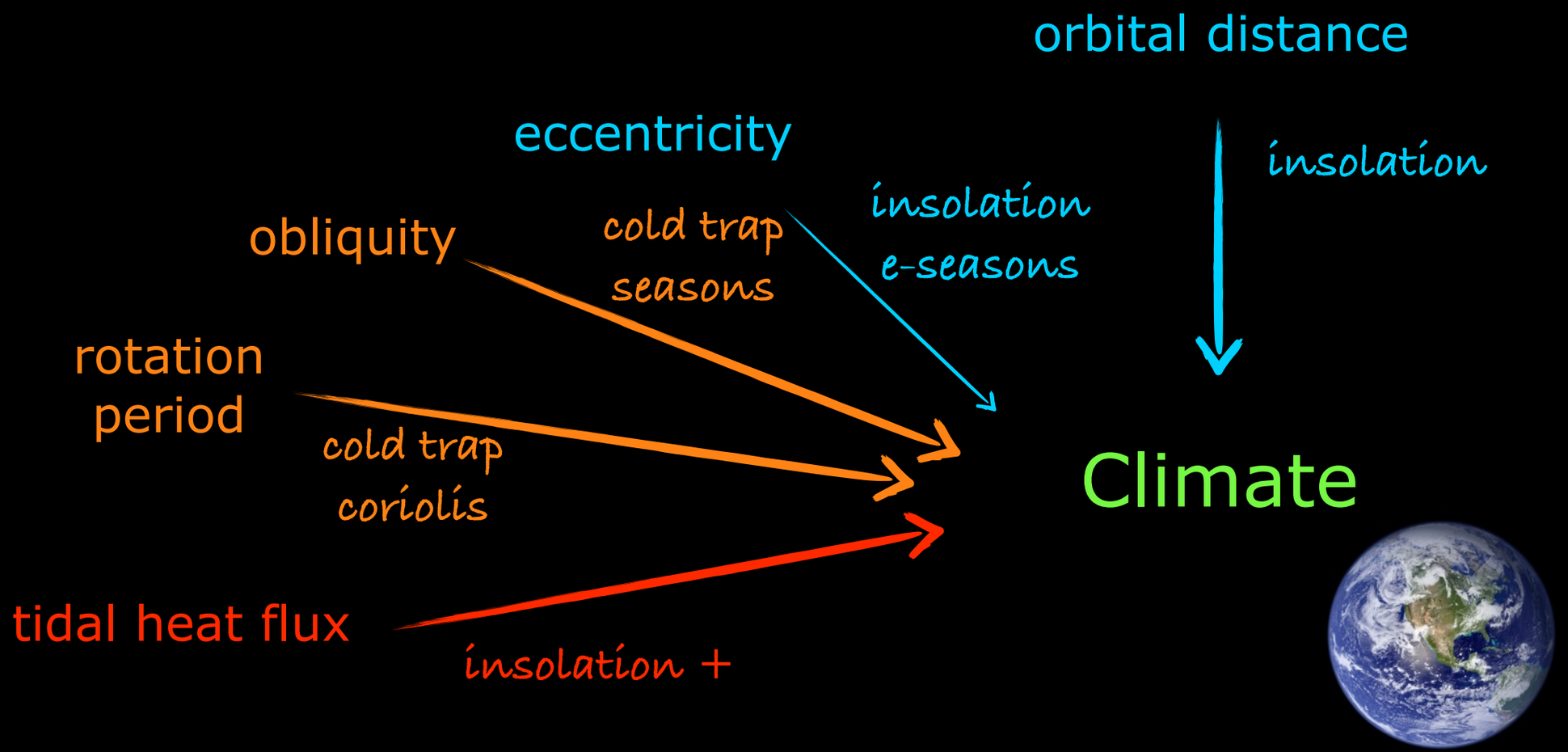
Tides and climate



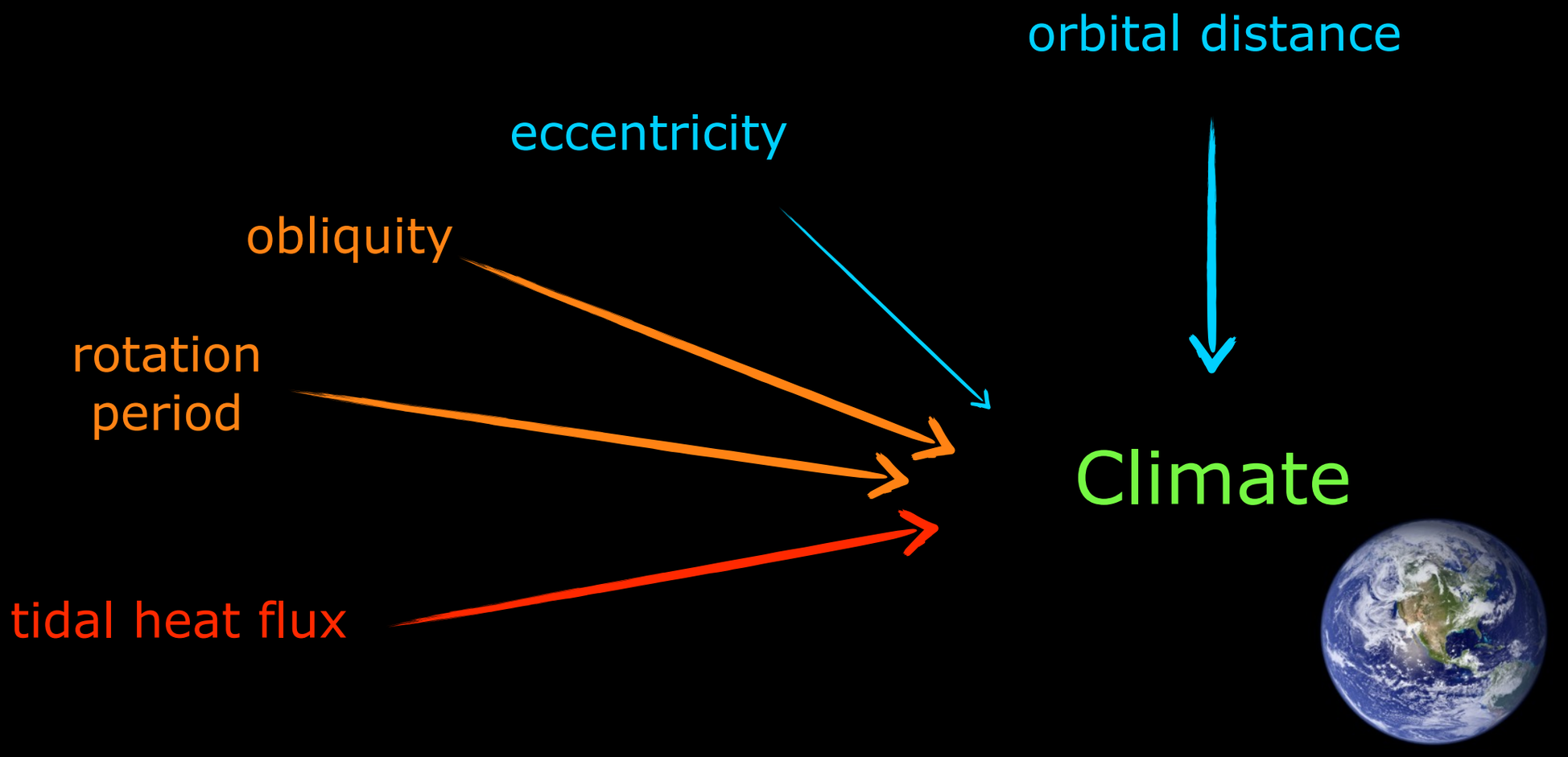
Tides and climate



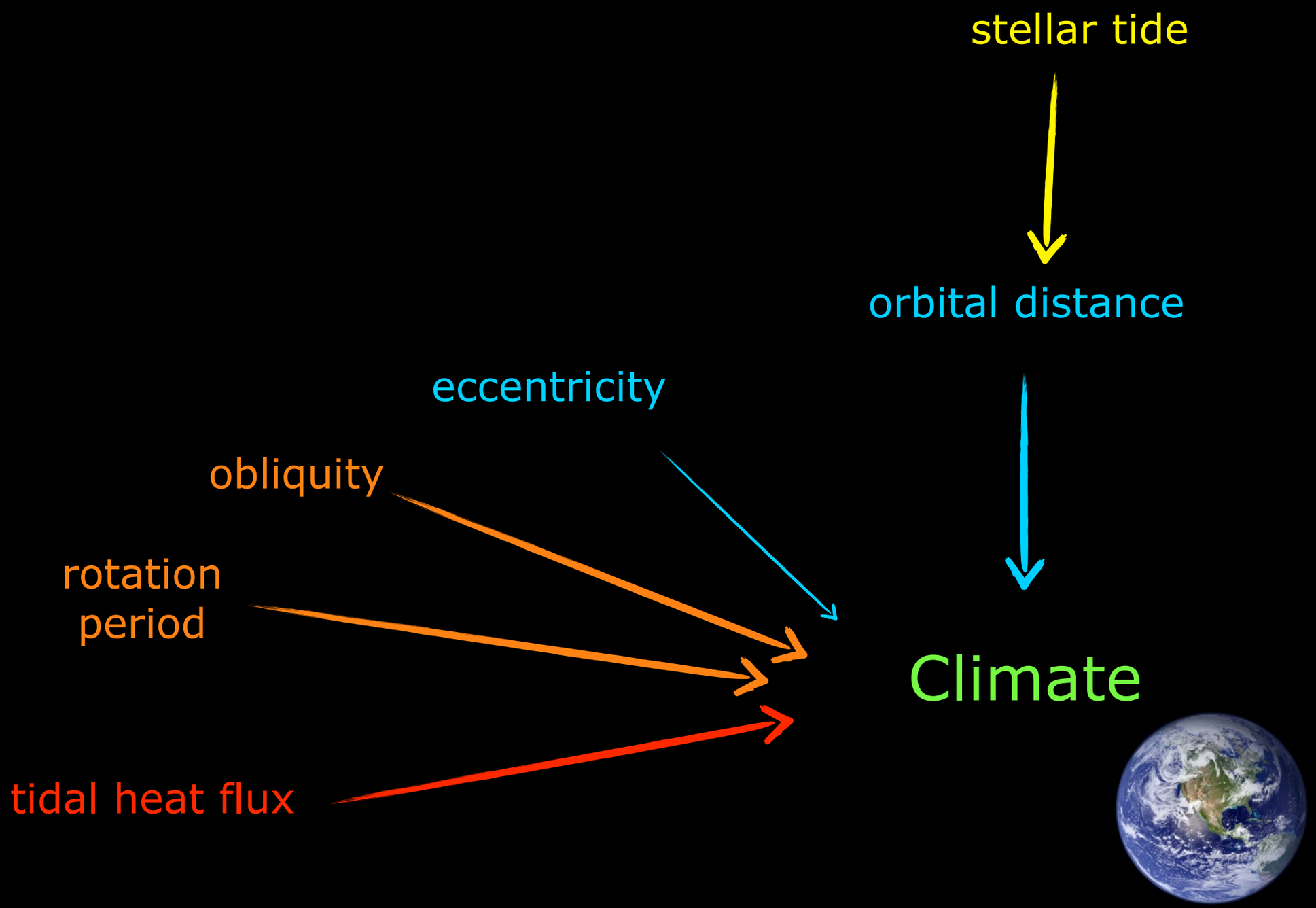
Tides and climate



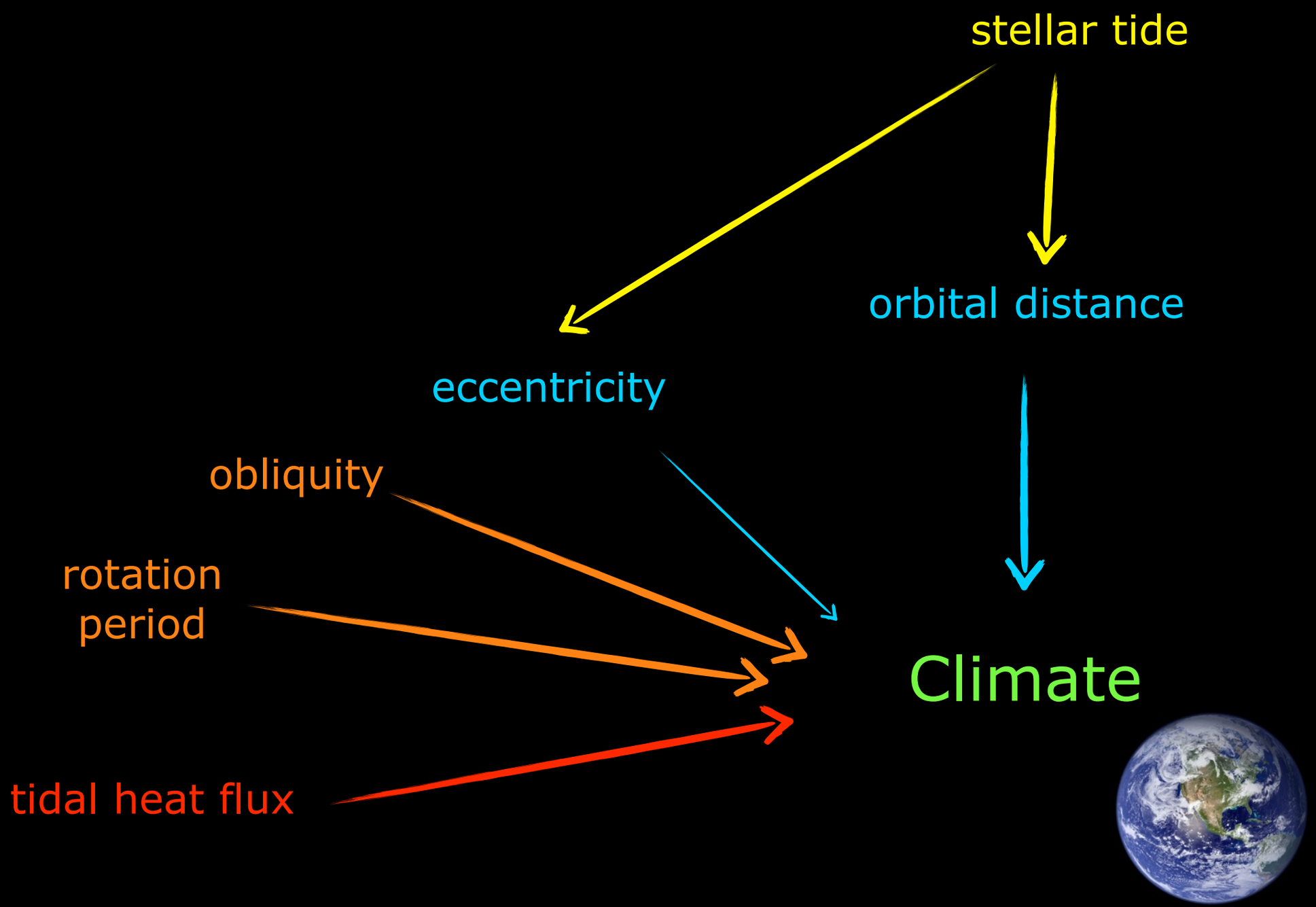
Tides and climate



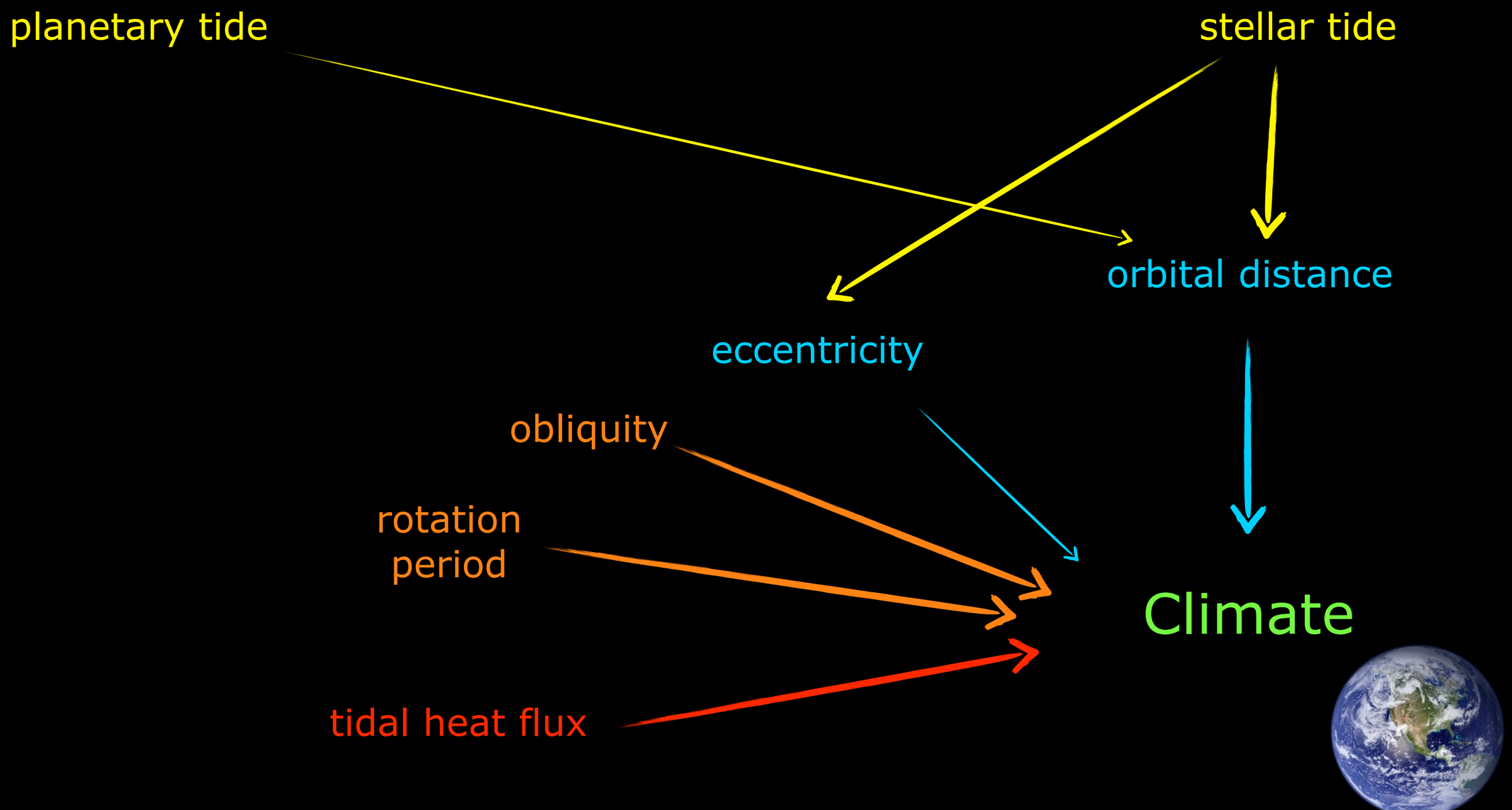
Tides and climate



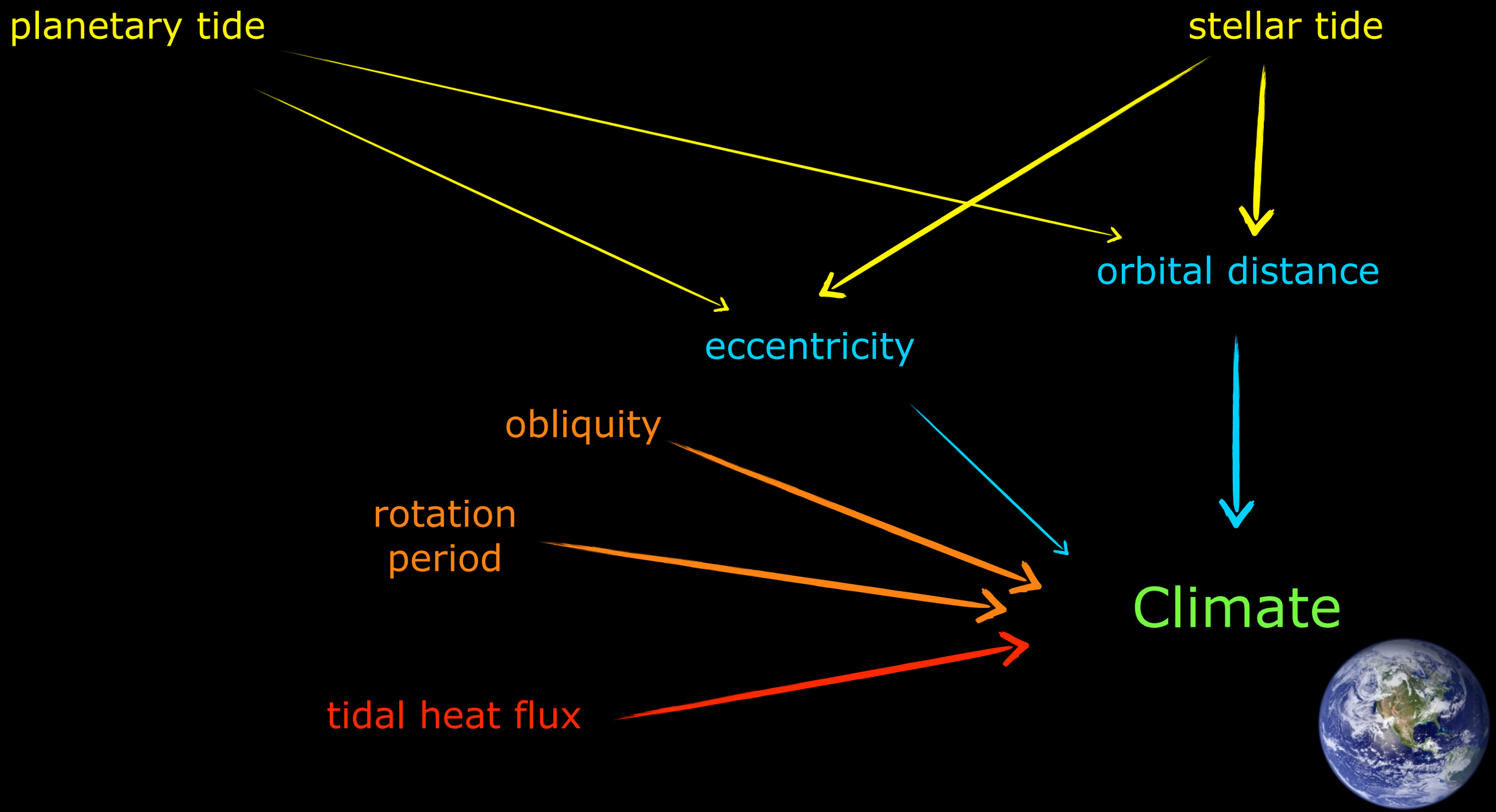
Tides and climate



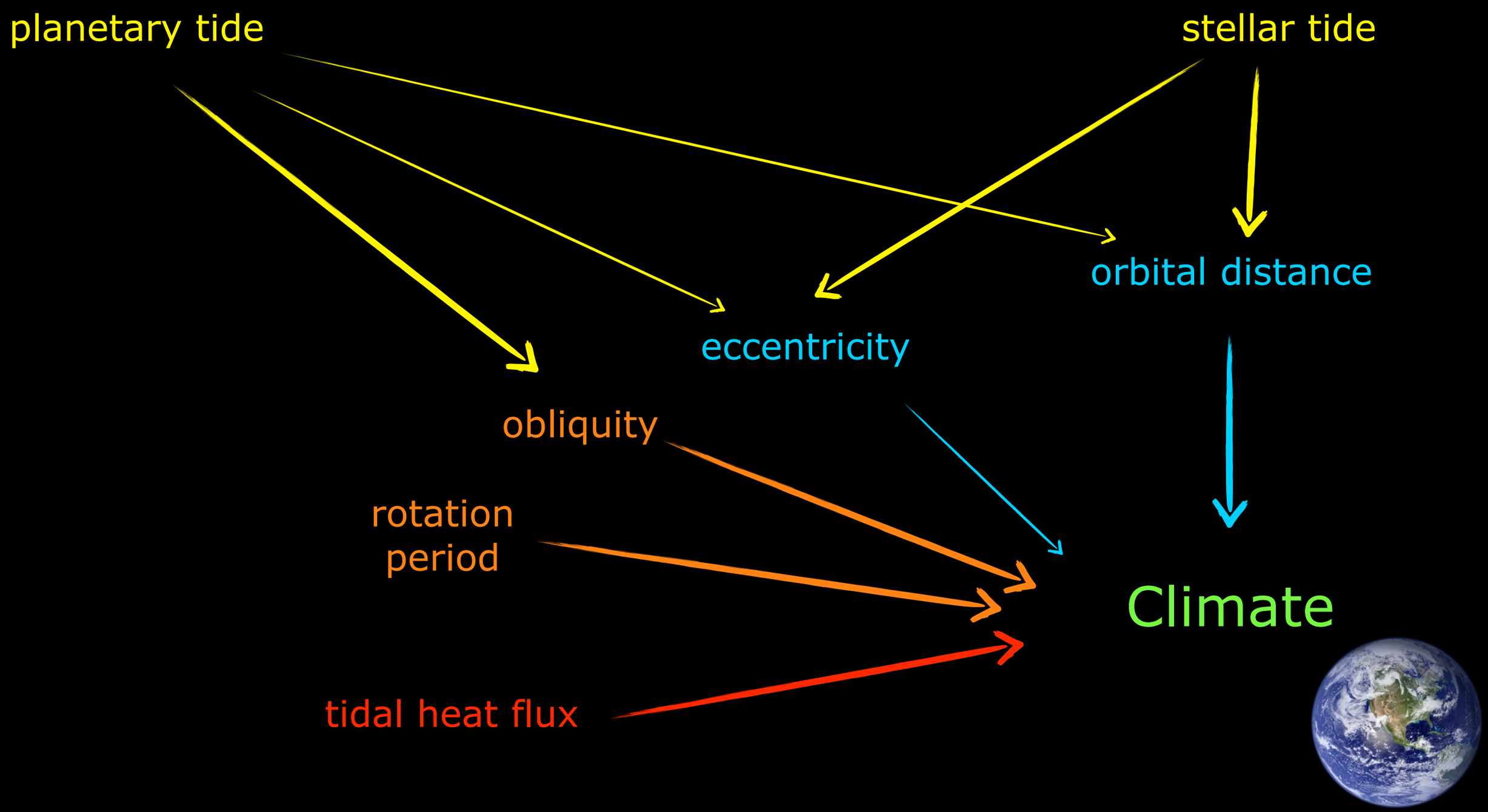
Tides and climate



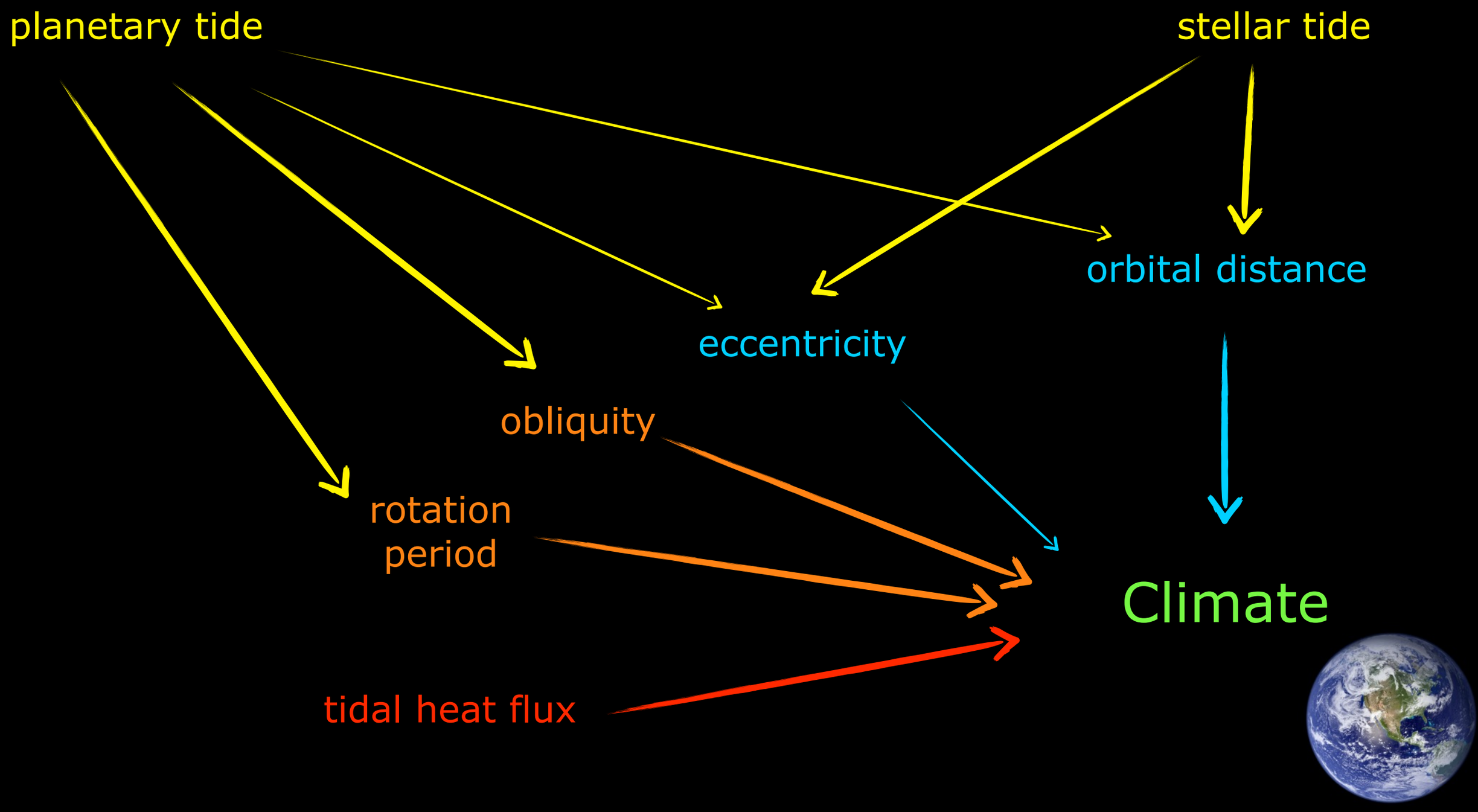
Tides and climate



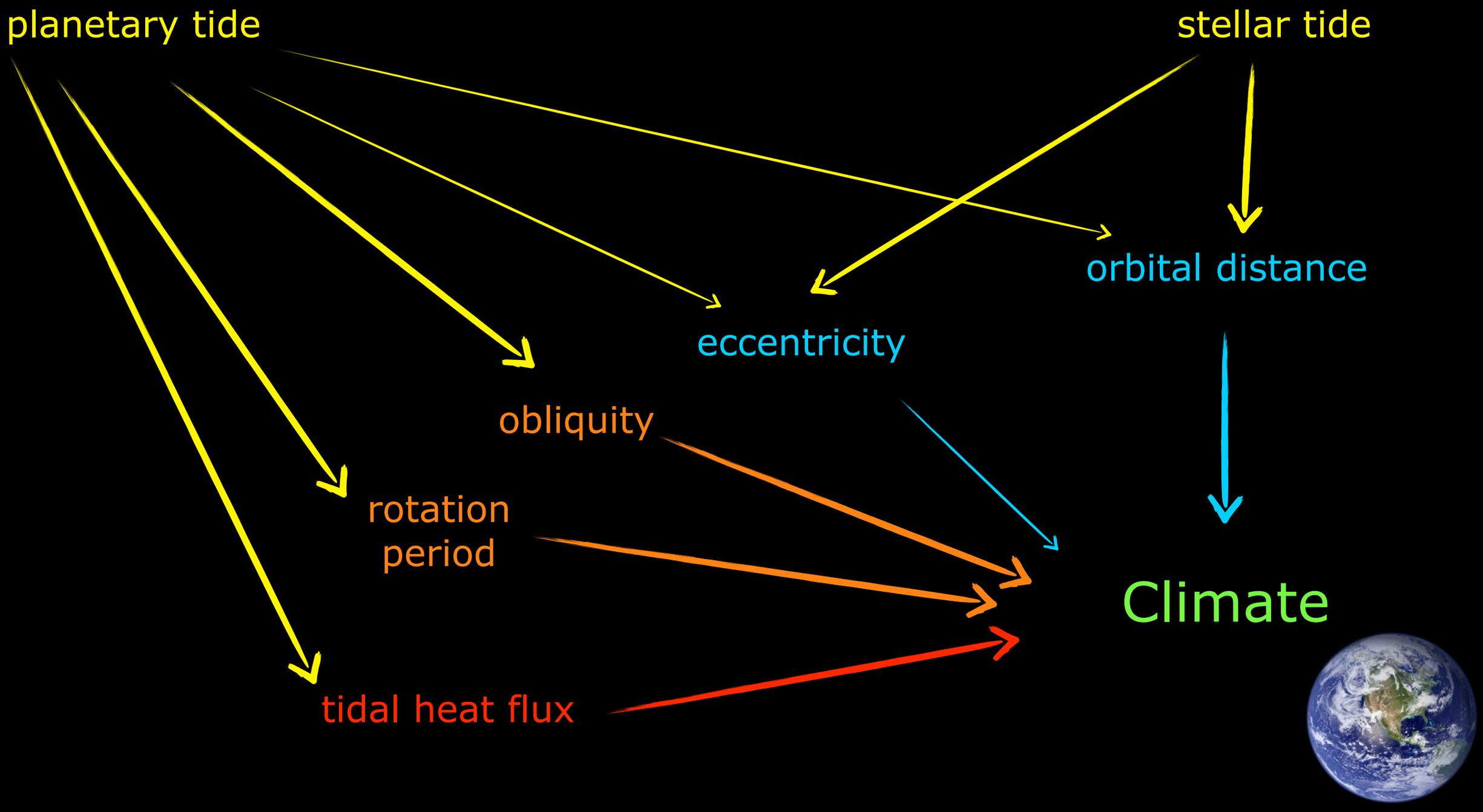
Tides and climate



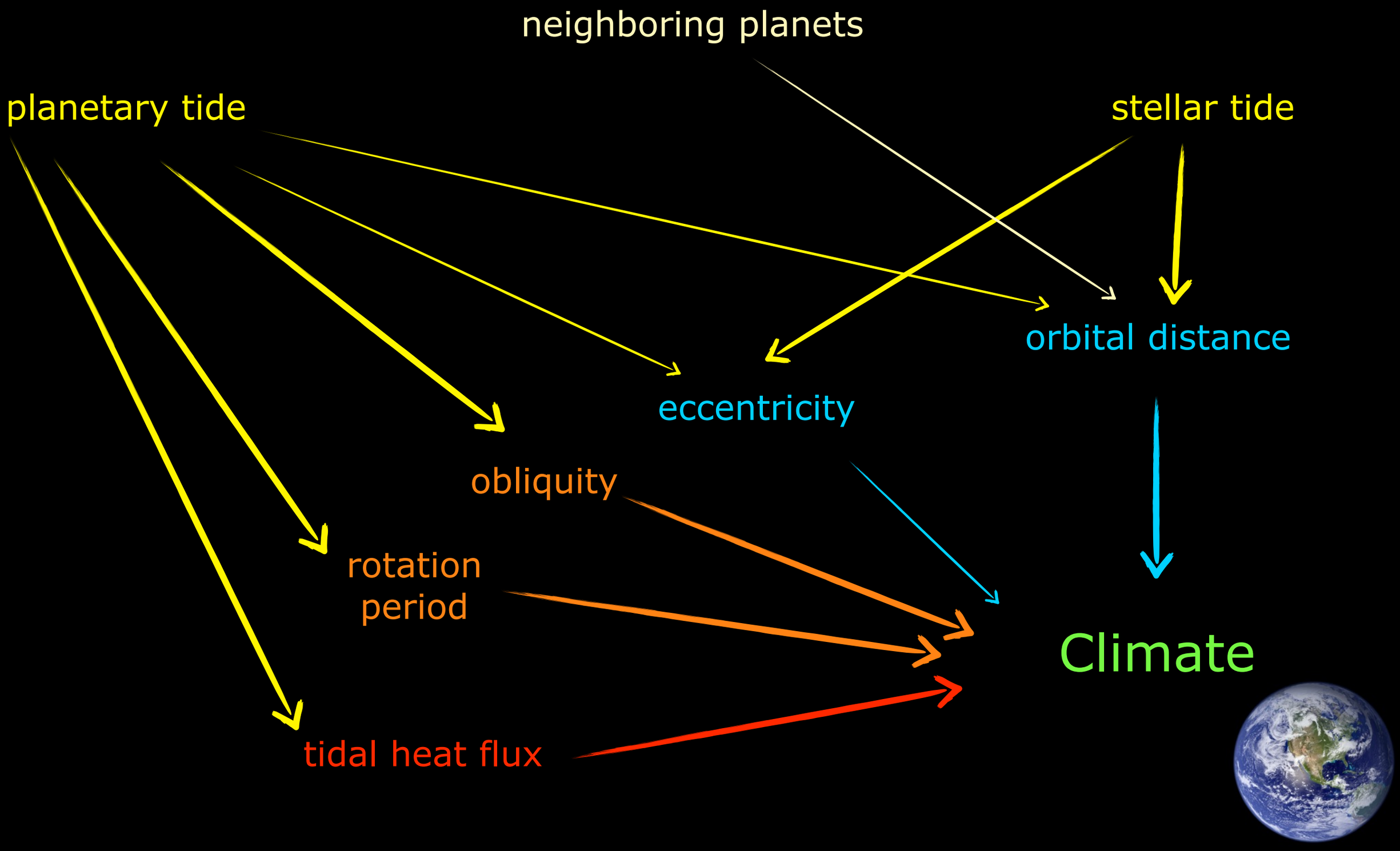
Tides and climate



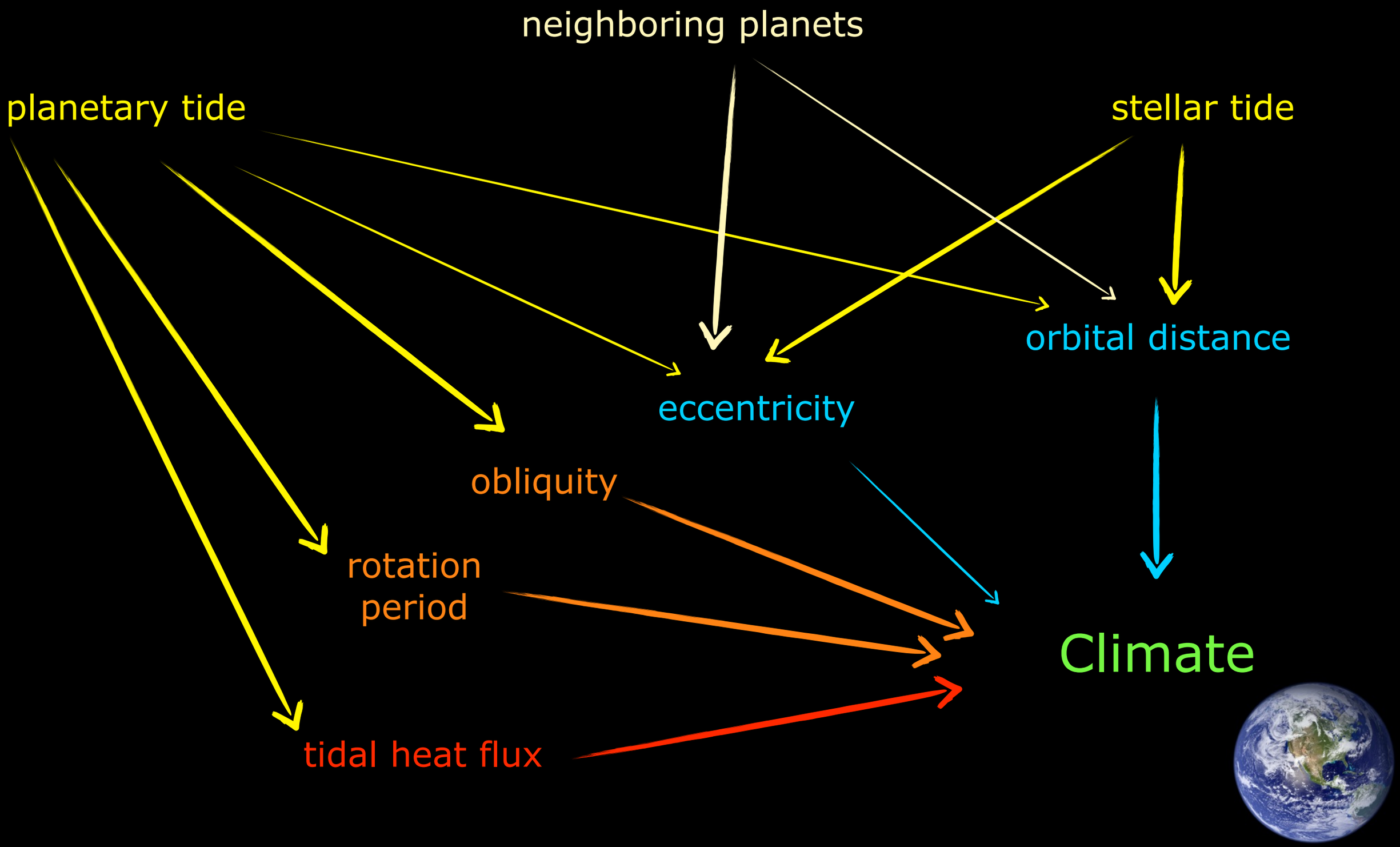
Tides and climate



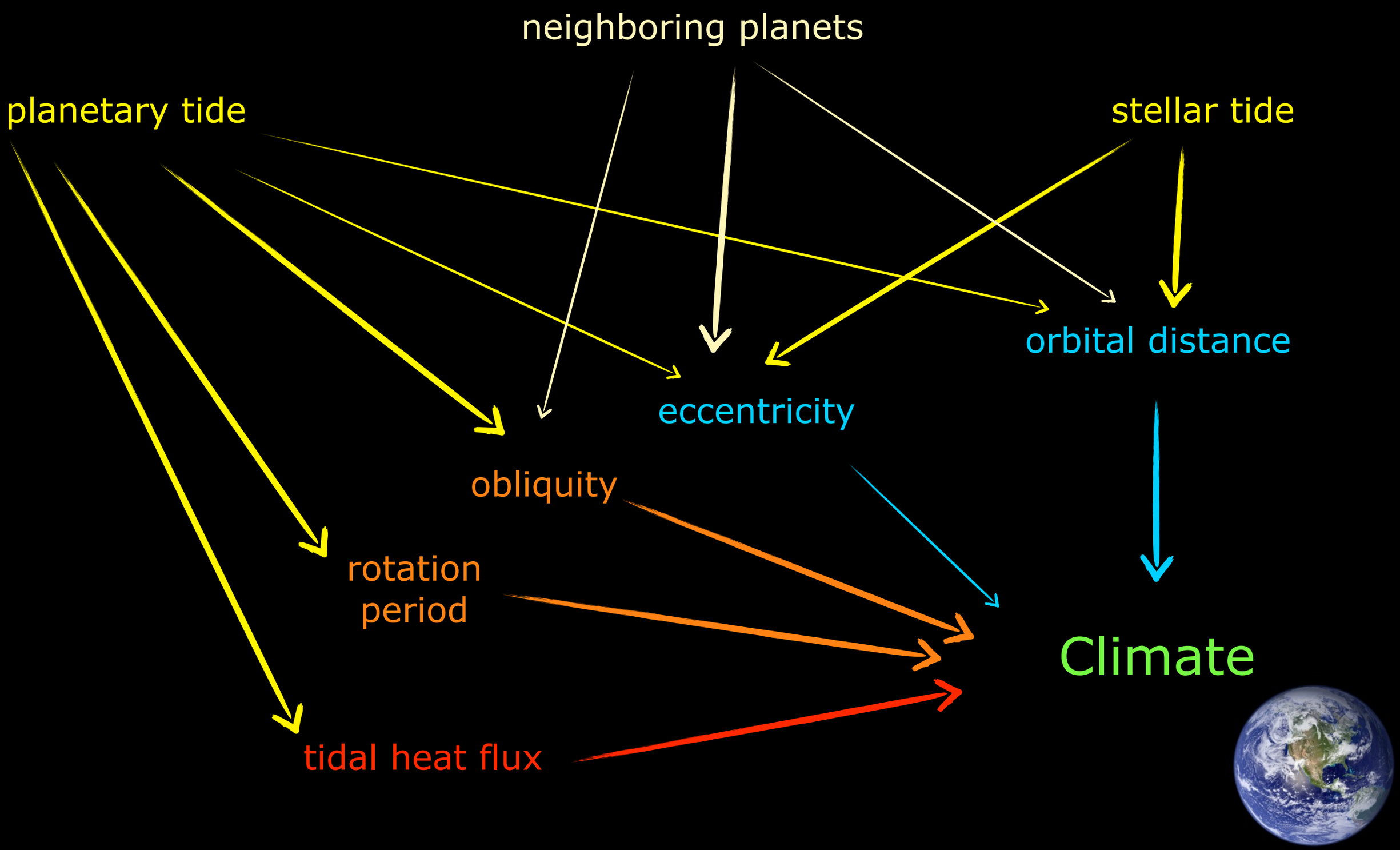
Tides and climate



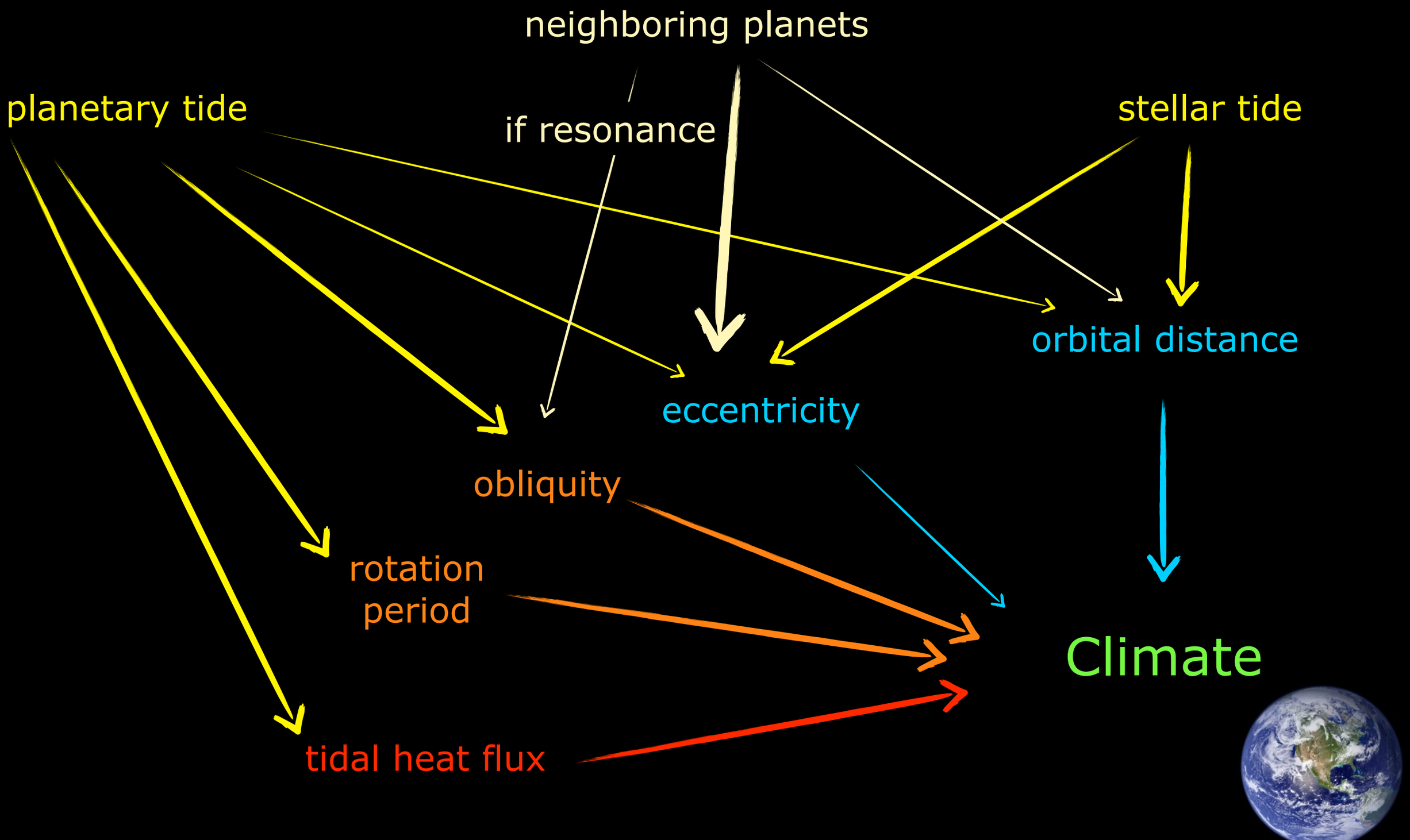
Tides and climate



Tides and climate



Tides and climate



Merci !

Thank you !