

VPLANet: The Virtual Planet Simulator

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Overview. VPLANet is software to simulate the evolution of an arbitrary planetary system for billions of years. Since planetary systems evolve due to a myriad of processes, VPLANet unites theories developed in Earth science, stellar astrophysics, planetary science, and galactic astronomy. VPLANet can simulate a generic planetary system, but is optimized for those with potentially habitable worlds. VPLANet is open source and includes support software for 1) exploring large parameter spaces, 2) plotting, and 3) data compression and analysis. Full documentation, numerous examples, continuous integration, and a modular software design facilitate transparency, reproducibility, and quick calculations. VPLANet is publicly available at <https://github.com/VirtualPlanetaryLaboratory/vplanet>.

Scientific Capabilities. The following “modules” (bundles of equations that can be applied to any object in a system) are currently available:

- *STELLAR*: Stellar evolution (radius, luminosity, and mass concentration) from Baraffe et al. (2016), XUV luminosity from Ribas et al. (2005), magnetic braking laws from Repetto & Nelemans (2014), Reiners et al. (2008), Matt et al. (2015).
- *ThermInt*: Thermal interior evolution of Earth and Venus from Driscoll & Bercovici (2013, 2014), including magnetic field generation, eruption rates, and inner core nucleation.
- *RadHeat*: Radiogenic heating from ²⁶Al, ⁴⁰K, ²³²Th, ²³⁵U, and ²³⁸U.
- *AtmEsc*: Energy-limited and diffusion-limited escape to track escape rates and/or water photolysis from Watson et al. (1981), Erkaev et al. (2007), Hunten et al. (1987), Bolmont et al. (2017), Lopez et al. (2013), and Lehmer & Catling (2017).
- *EqTide*: Tidal evolution from Ferraz-Mello et al. (2008) and Leconte et al. (2010).

- *BINARY*: Orbital evolution of a circumbinary planet from Leung & Lee (2013).
- *GalHabit*: Evolution of wide binaries due to the galactic tide and passing stars (Heisler & Tremaine 1986; Rickman et al. 2008; Kaib et al. 2013).
- *SpiNBody*: N-body integrator.
- *DistOrb*: 2nd and 4th order secular models of orbital evolution (Murray & Dermott 1999).
- *DistRot*: Rotational evolution due to inclination evolution and the stellar torque (Kinoshita 1977).
- *POISE*: Energy balance climate model that includes dynamic ice sheets (North & Coakley 1979, Huybers & Tziperman 2008).

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