Surviving in the Neptune Desert

The ultra-short period Neptune **LTT 9779 b** survived thanks to an unusually X-ray faint host star

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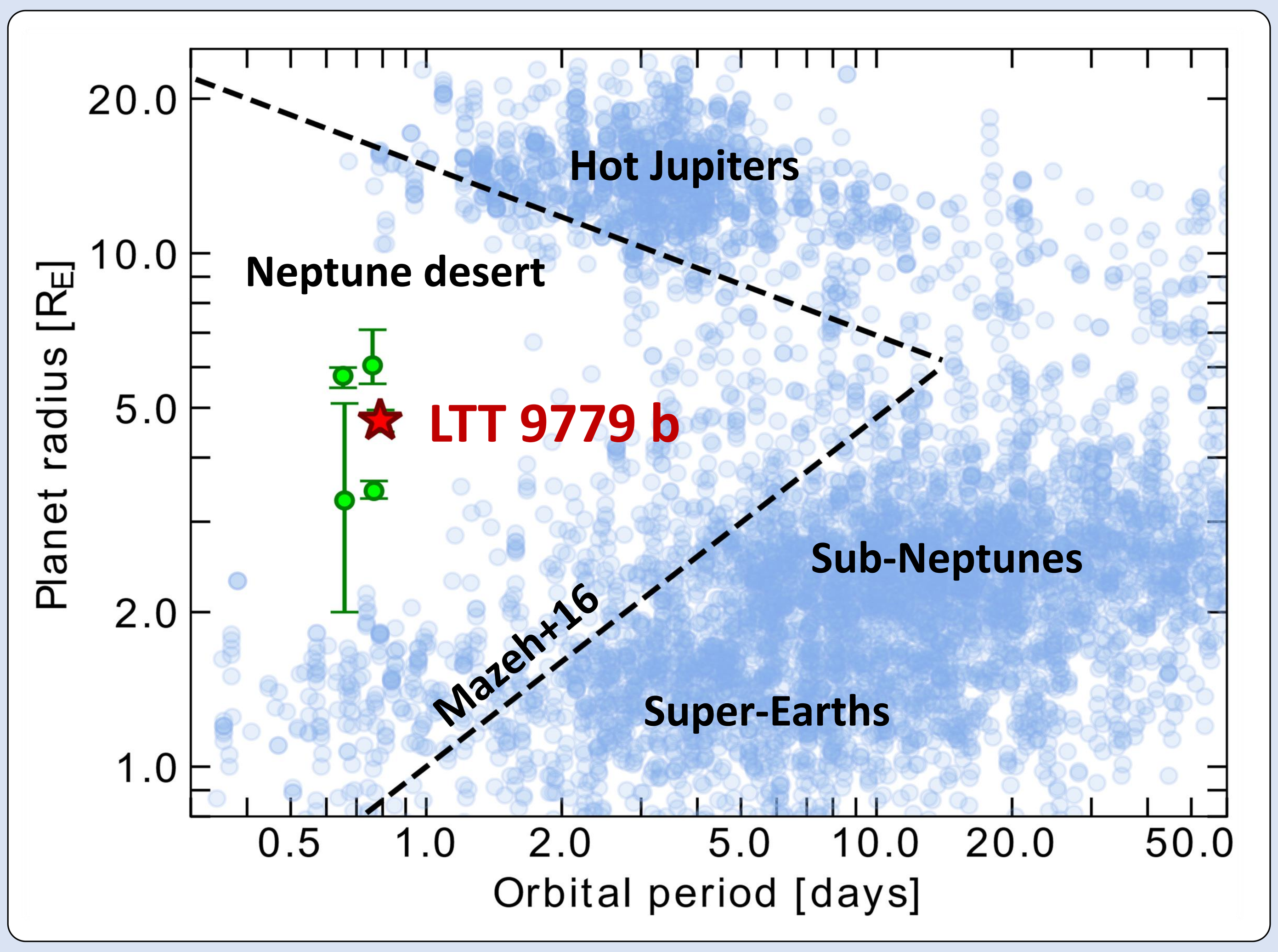
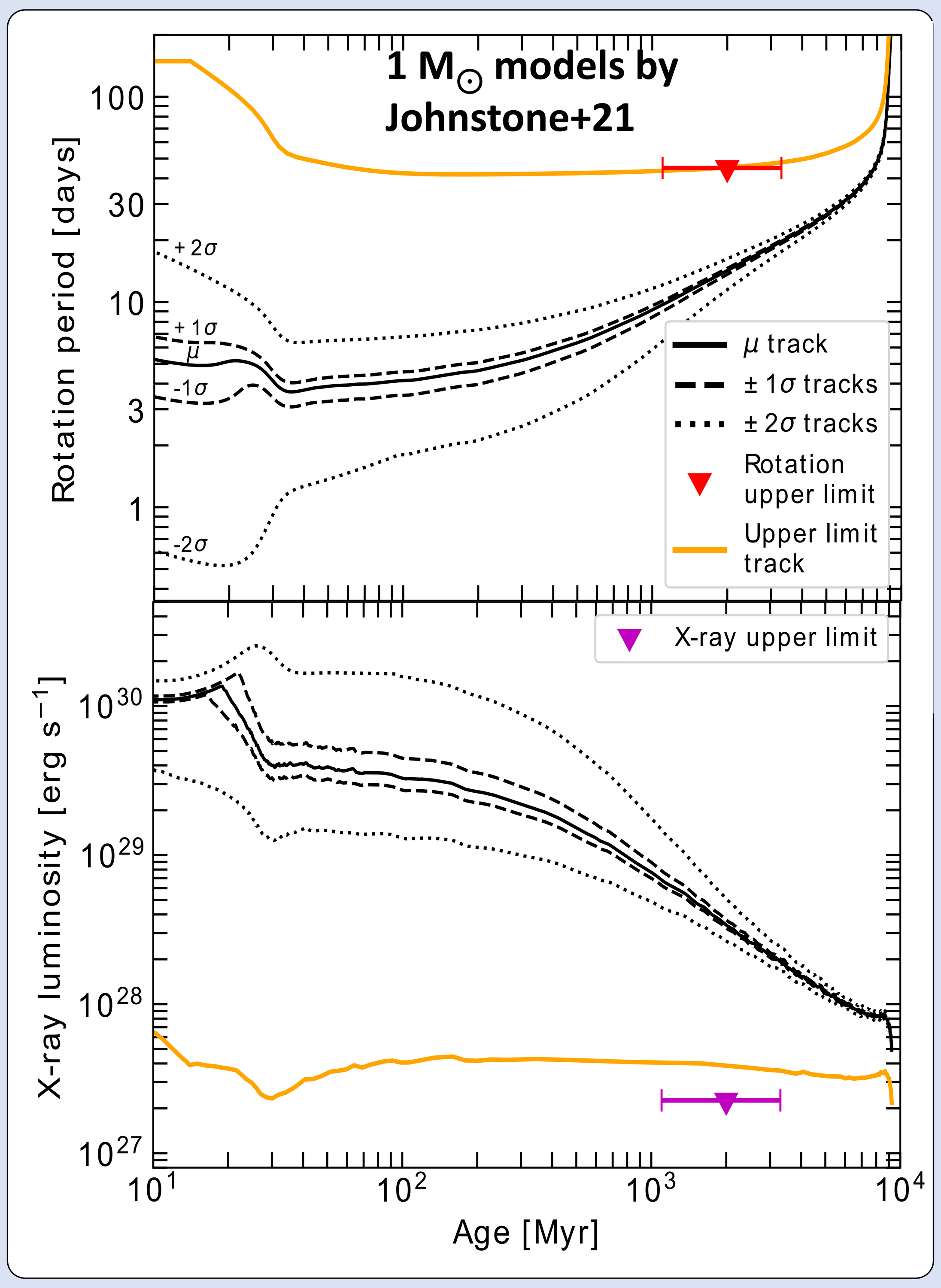


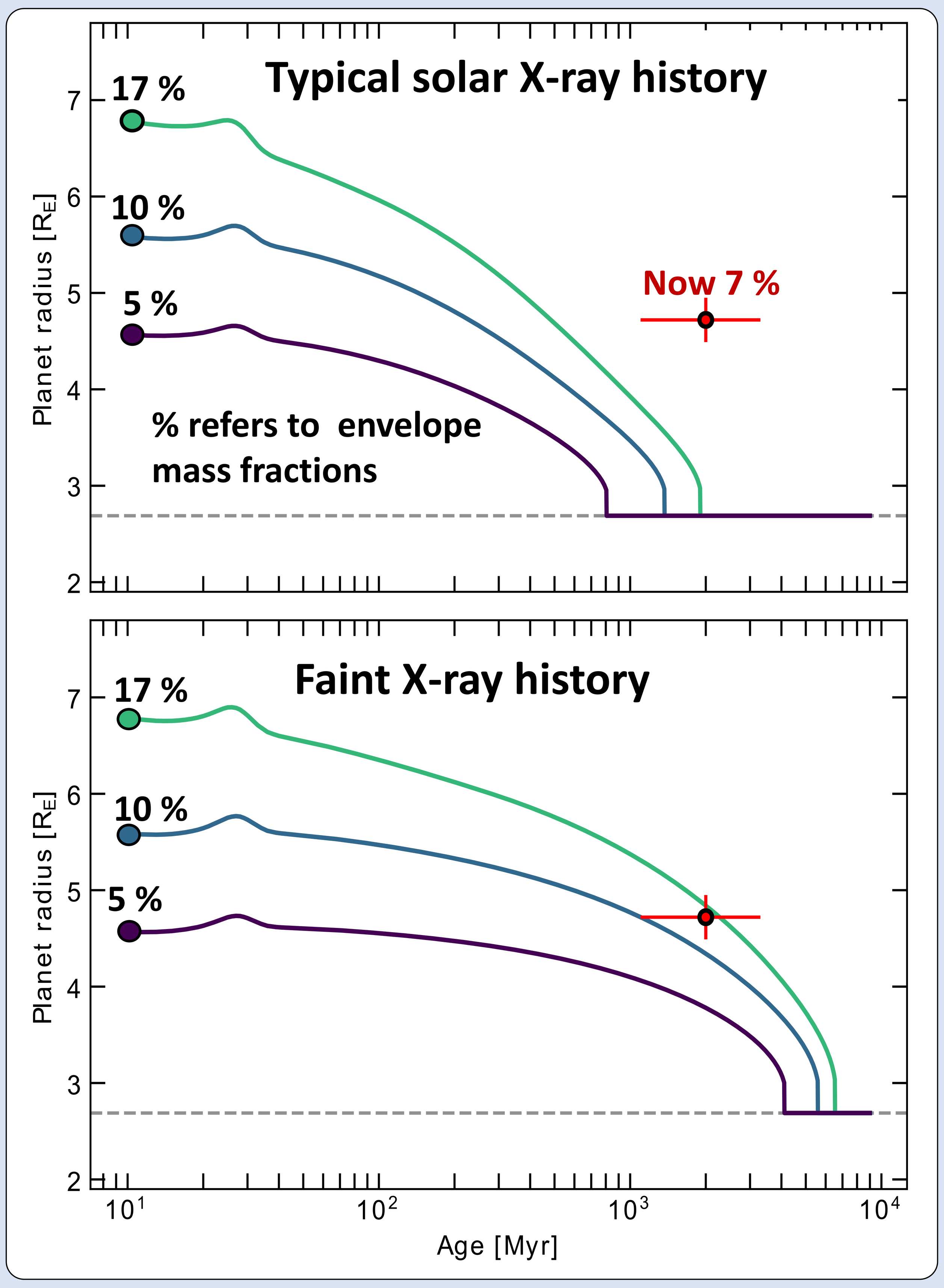
A planet that shouldn't exist

- The **Neptune desert** is a region in planet populations with very few exoplanets. It is thought to be cleared out by stellar high energy radiation evaporating planet atmospheres down to a rocky core.
- **LTT 9779 b** is a truly **unique planet** – the only known planet deep in the Neptune desert that maintains a **gaseous atmosphere**. Other planets (green points), are either completely rocky (TOI-849b), or lack mass measurements or precise radii (K2-266b, K2-399b).
- **How did it survive?** The star's low rotational velocity (*vsini)* hints towards a spin period slower than expected and thus a faint X-ray emission, which could have failed to evaporate the planet's atmosphere.
- I present a **faint X-ray upper limit** for LTT 9779 from *XMM-Newton* observations, which we use to constrain the **planet's evaporation history**, and find that it could have survived due to an **unusually low X-ray luminosity**.

Around a slowly spinning star

- **LTT 9779** is a Sun-like star about 2 Gyr old. Its only transiting planet, LTT 9779 b, orbits with a period of only 19 hours (**Johnstone+20**) and hosts a gaseous envelope consisting of 7% of its mass.
- Such close-in planets are expected to be **stripped of their atmospheres** via X-ray driven **photoevaporation** down to their rocky cores (**Owen+17**). The survival of this planet, however, presents a challenge to this model.
- The star's **X-ray emission history** (bottom right) can be estimated from its **spin evolution** (top right) using the rotation-activity relation (**Wright+11**), which we estimate using the models by **Johnstone+21** (black lines).
- We expect that the **typical X-ray history** for a Solar-mass star (bold black line) should have **evaporated the planet's atmosphere.**
- The measured rotational velocity (*vsini)*, however, suggests a very slowly spinning star, and thus a **much fainter X-ray emission history** (orange line).
- We obtained an **X-ray luminosity upper limit** from *XMM-Newton* observations (magenta data point), which agrees with the spin upper limit and suggests a faint X-ray history.
- We compared the evaporation pasts from the expected and faint X-ray histories.





Could its atmosphere survive?

- We set up three scenarios for the starting structure of the planet with different envelope mass fractions. We evolved their evaporation histories using the method of **Fernández+23** (left-hand figure), and the mass loss model by **Kubyshkina+18**.
- The X-ray history from a **typical solar-mass star evaporates the envelopes in all three scenarios** before the current time (top panel), making it inconsistent with the survival of the Neptune.
- A **much fainter X-ray history** motivated by the spin and X-ray upper limits, however, is consistent with **the planet's envelope surviving to this day** (bottom panel).
- LTT 9779 b is a **key example** of the survival of an atmosphere under faint X-rays, strongly supporting the idea that **photoevaporation sculpts the Neptune desert**.

References

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