The XUV Radiation Impact of Near AGNs ($z < 0.5$) on the Atmospheres of Milky Way Planets

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Abstract

We present the first analysis, using real data, of planetary atmospheric erosion due to the activity of the nearest AGNs to the Milky Way Galaxy, including it's own central supermassive black hole, Sgr A*. We compiled data for 53 exoplanets, of which 16 reside in the the Galactic bulge, and for $\sim$ 33000 AGNs from the SDSS database. We employed two models concerning the fraction of incident power ϵ available to heat the atmosphere: $\epsilon = 0.1$ and where ϵ is dependent on the incident flux. Our estimate of mass loss for $\epsilon = 0.1$ defines an upper mass loss limit for our sample of exoplanets.

Background

High energy photon flux (X-ray and UV) can induce hydrodynamical winds in planetary atmospheres resulting in mass loss over the exposure time, t_o.

$$M_{lost} = \frac{3\epsilon}{4G\rho_p} F_{XUV} t_o \propto \eta_X L_{bol} t_o \rho_p^{-1} d^{-2}$$

where η_X is the fraction of the high energy photons, ϵ is the fraction of incident power available to heat the atmosphere and L_{bol} is the AGN bolometric luminosity.

We quantified the accumulated planetary atmospheric mass loss due to radiation emitted by the AGNs ($z < 0.5$) and Sgr A*, under the assumption that $\tau = 0$ at all times and that $\eta_X = 0.7$ remained constant. Assuming the black hole accretes at the maximum rate, $L = L_{Edd}$, its active phase is estimated to last $\sim$ 50 Myrs.

Models

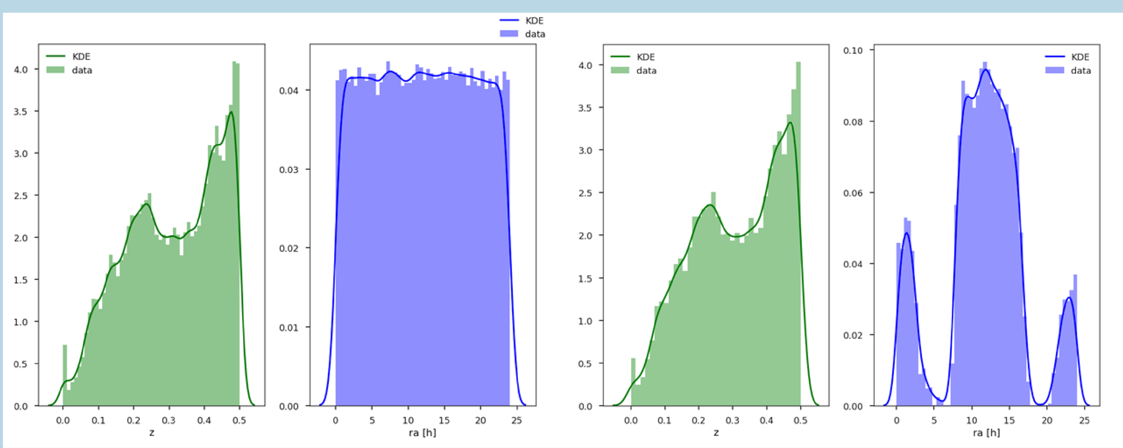
We considered two models:

1. ϵ to be of order 10 % a theoretical estimate over a wide range of fluxes,
2. ϵ is flux dependent, $\epsilon = \epsilon(F_{XUV})$,

noting that there exists a minimum flux, $F_{XUV} = 0.1\ ergs^{-1}cm^{-2}$, required to drive a hydrodynamic wind.

AGN Data

Figure 1. The KDEs of the SDSS sample **(right)** and of the generated, full sky sample **(left)**. The two dips in the RA of the AGN distribution are due to lack of observations in those directions. We used the data available through the SDSS to generate a full sky sample of AGNs.

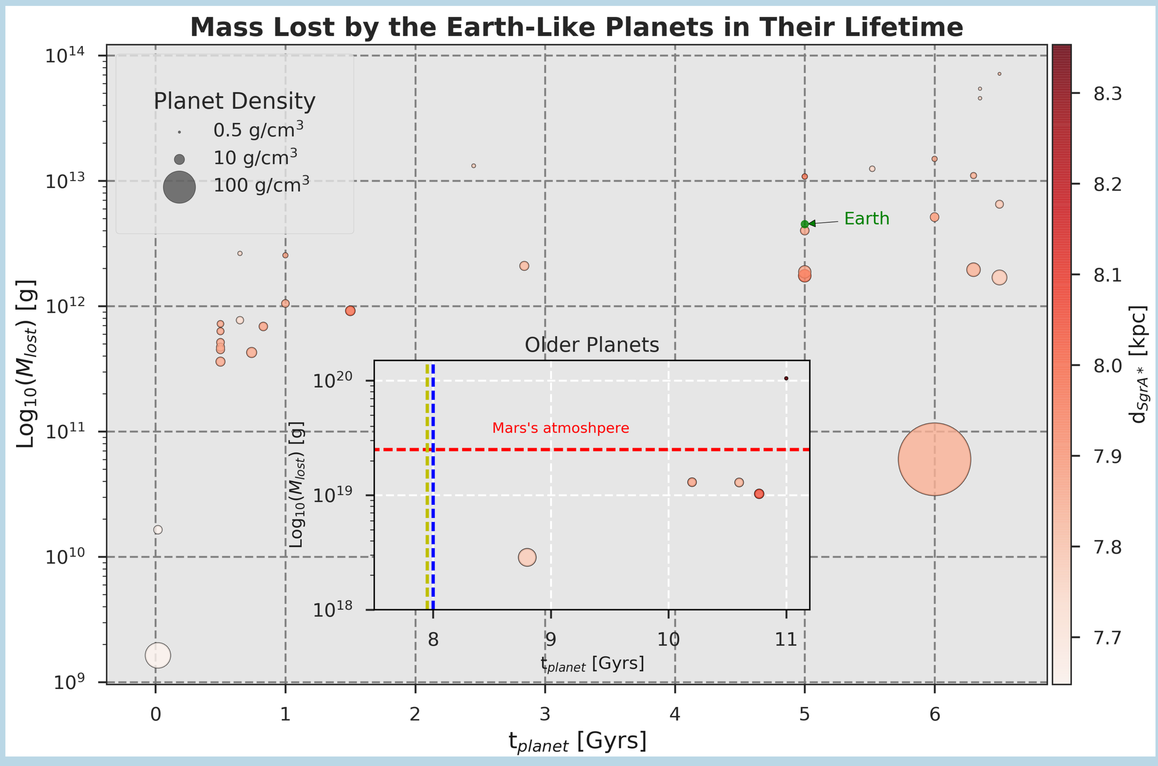


References

J. C. Forbes & A. Loeb (2018). "Evaporation of planetary atmospheres due to XUV illumination by quasars". Monthly Notices of the RAS 479.1, pp. 171-182.

Sgr A* and the Milky Way Planets

The mass loss of the Earth-like planets is significantly lower, with the assumption of $\epsilon = 0.1$, when in reality the F_{XUV} is never strong enough to induce a wind, Figure 6. Figure 7 shows the cumulative effect of all AGNs ($z < 0.5$) on planetary mass loss of the Earth-like planets. We observe that with the right numbers, the AGNs could have had an effect on the development of planetary systems



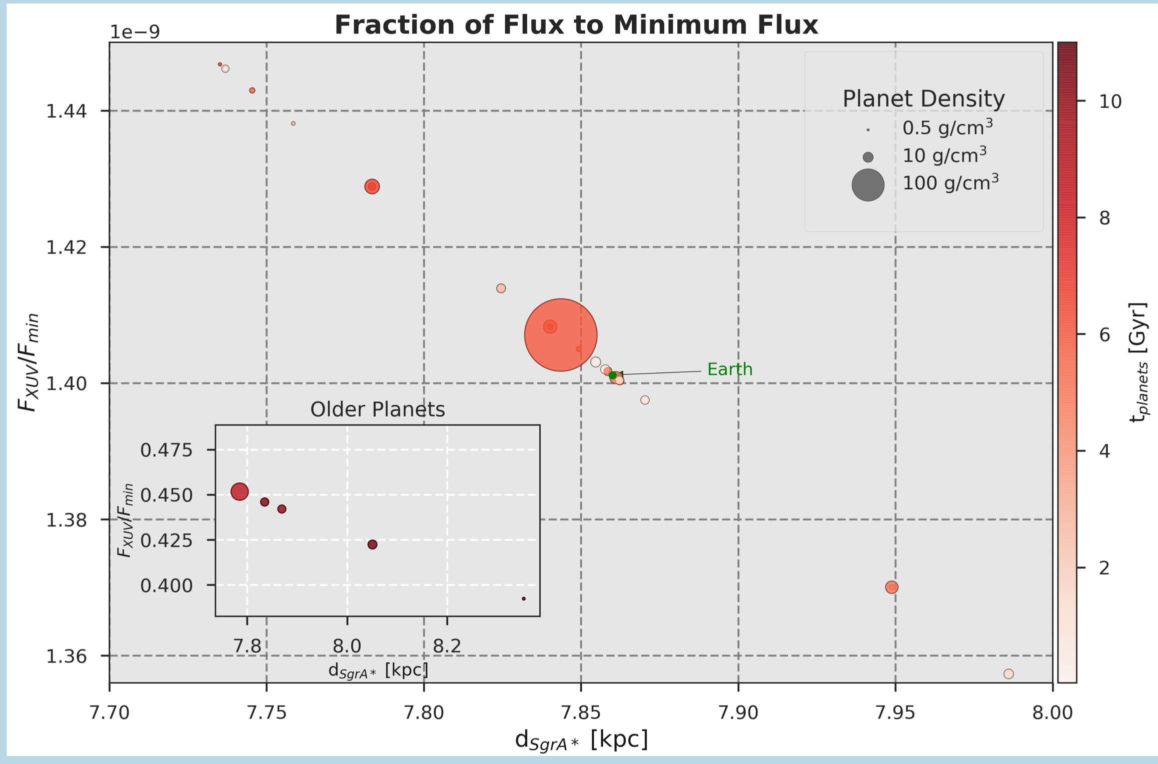


Figure 2. Left - total atmospheric mass loss of the rocky exoplanets as a function of age, density and distance, for the case where $\epsilon = 0.1$. The horizontal red line indicates the mass of Mars's atmosphere, the vertical blue and yellow lines represents the onset and the end of Sgr A*'s active phase. **Right** - fraction of flux reaching the planets to minimum flux required to cause any damage to the atmosphere. **Inserts** - the results for the older planets (< 8 Gyrs) in the sample.

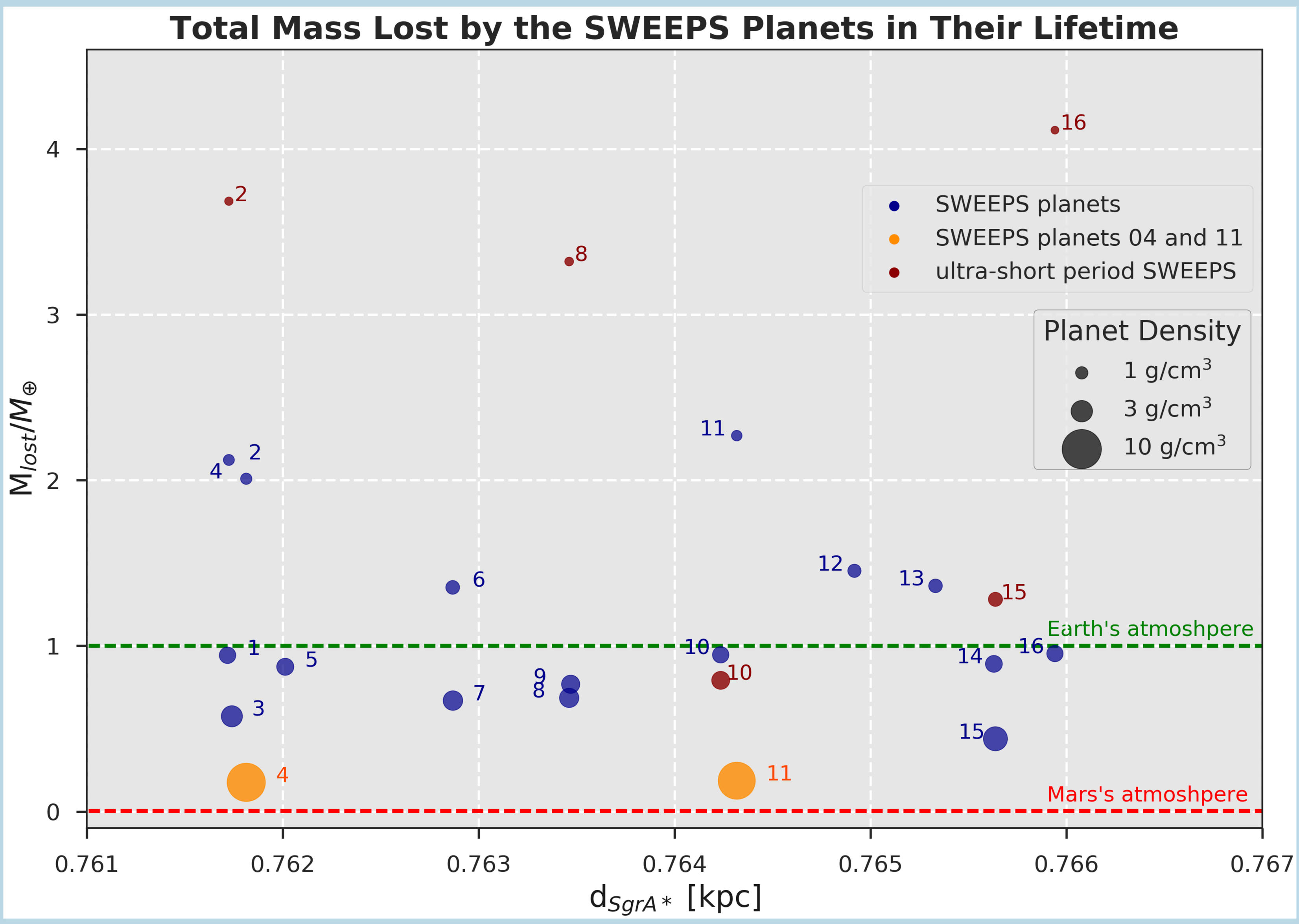
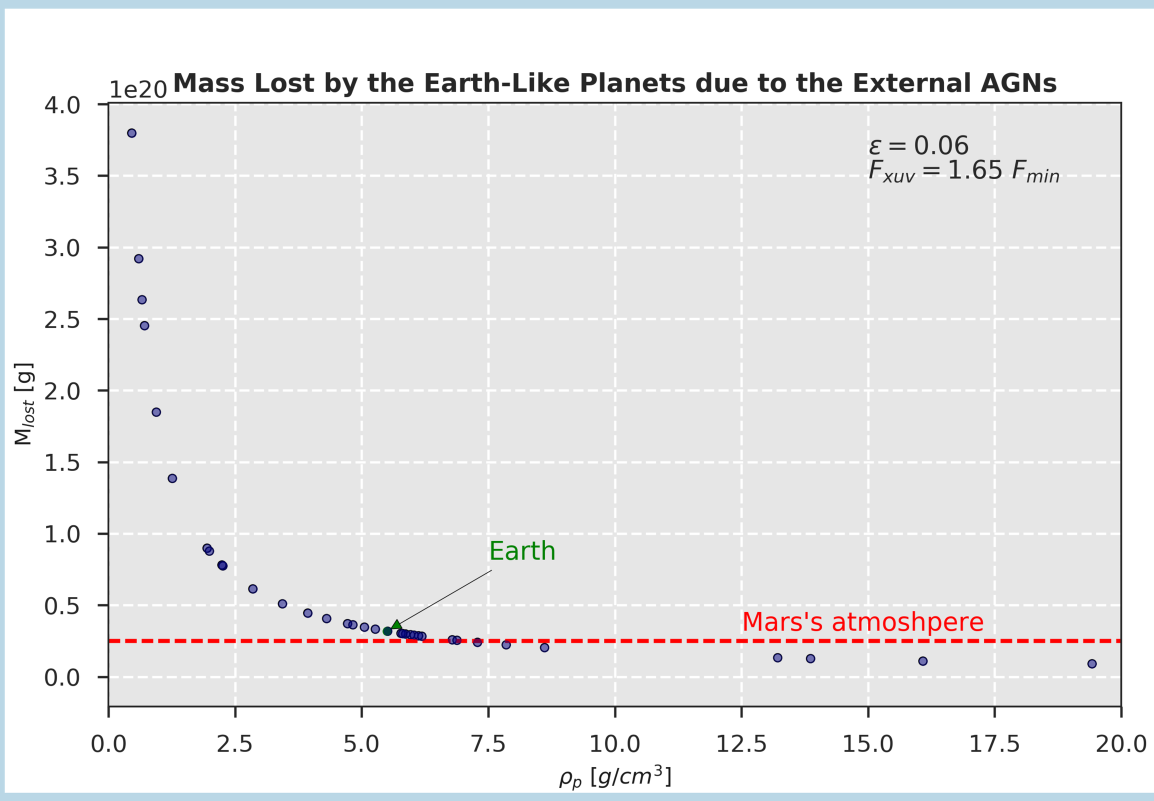


Figure 3. All of the bulge planets have estimated ages of 10 Gyrs. The yellow points represent the only confirmed planets with mass and radius parameters. The blue points represent whole sample with masses estimated from the mass-period relation for hot Jupiters and the red points represent the sub-sample of the ultra-short-period planets with mass estimates from the period-mass-radius relation for Roche-lobe overflowing objects.

For the SWEEPS planets we observe significant mass loss in the active phase of Sgr A*, where ϵ reached 0.1.

External AGNs and the Milky Way Terrestrial Planets

In Figure 4 we observe noticeable mass loss of the Milky Way Terrestrial planets due to the surrounding AGNs, assuming $\tau = 0$. When $\epsilon = 0.1$ the mass loss is overestimated by a factor of $\sim$ 2.



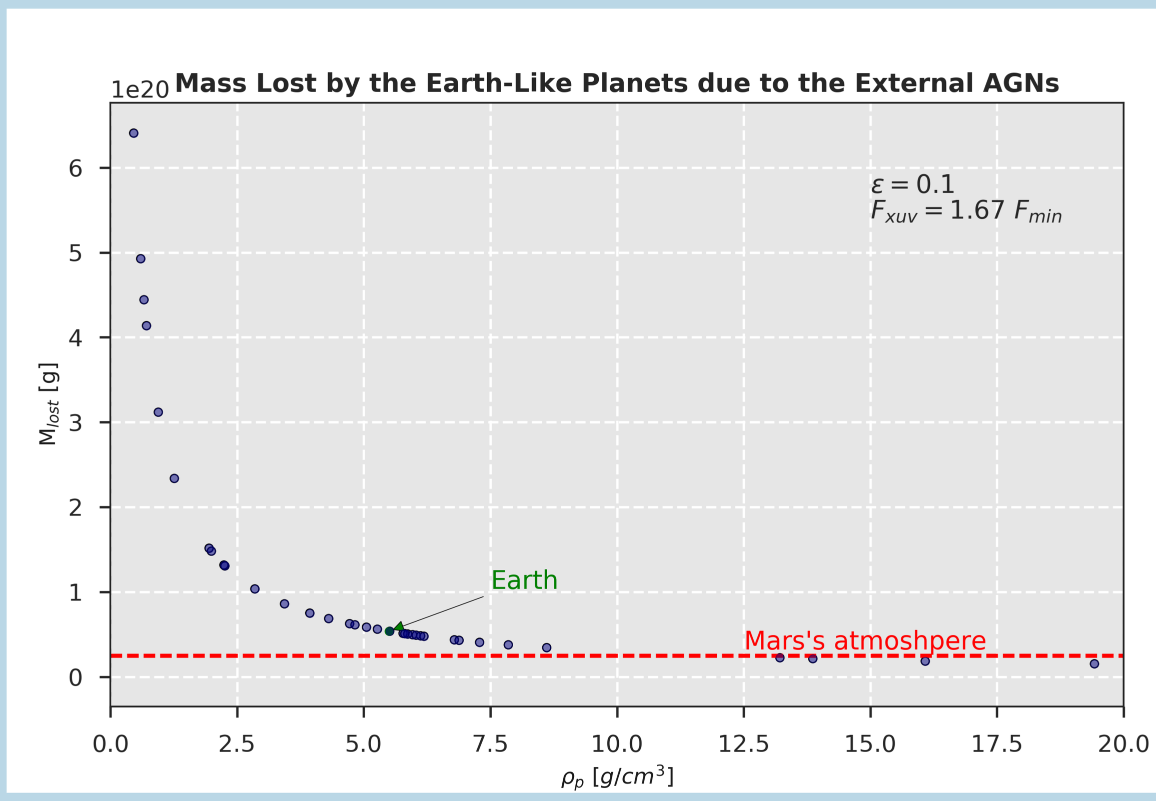


Figure 4. The total mass loss experienced by the planets over a timescale of 50 Myrs. In this plot the mass loss is due to the total flux of all the AGNs ($n \sim 107214$) up to $z = 0.5$ for the case where $\epsilon = 0.06$ - corresponding to the XUV flux **(right)**, and where $\epsilon = 0.1$ **(left)**. The F_{XUV} arriving at the Milky Way amounts to $\sim$ 165% of the F_{min}.