The detectability of Saturn-like exoplanetary rings by PLATO

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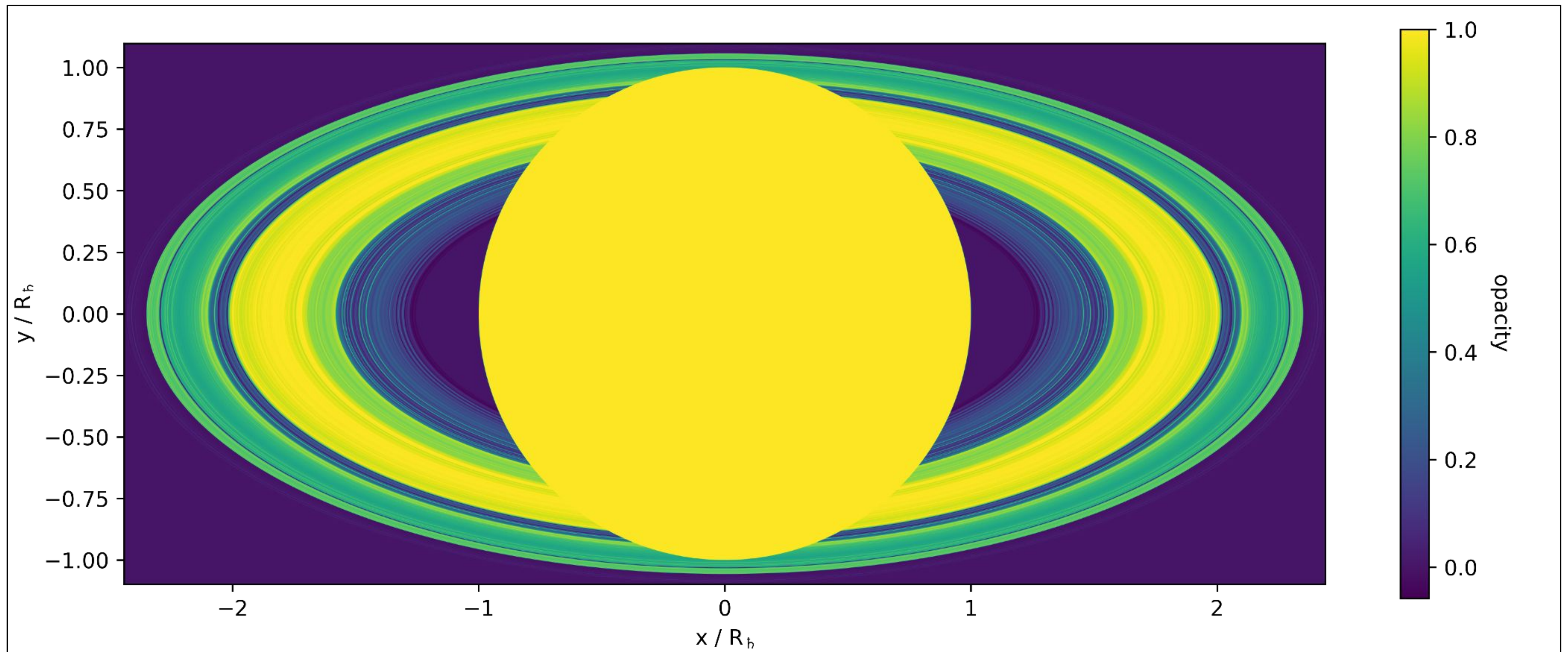
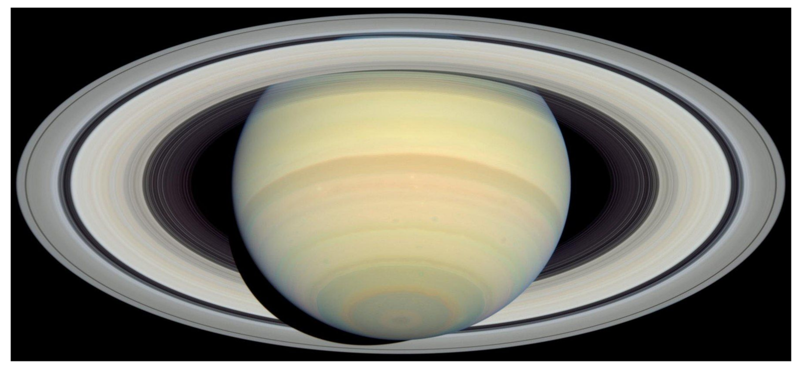
All long-period gas giant planets (and at least one minor planet) in the Solar System host rings. PLATO's superb photometric sensitivity and long dwell time make it ideal for study of the population of similar such exoplanets that might also be expected to host rings.

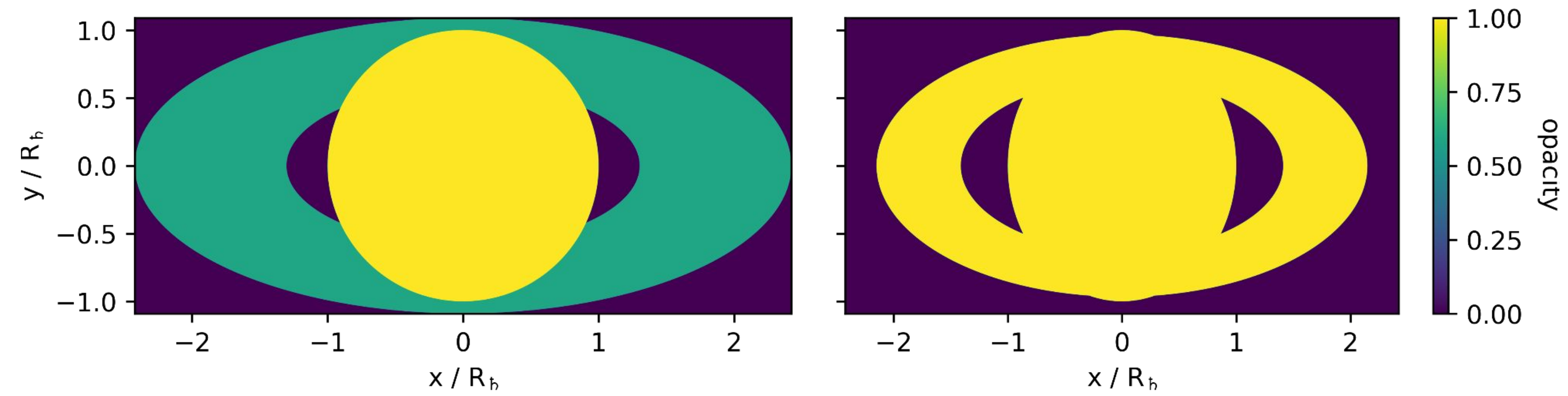




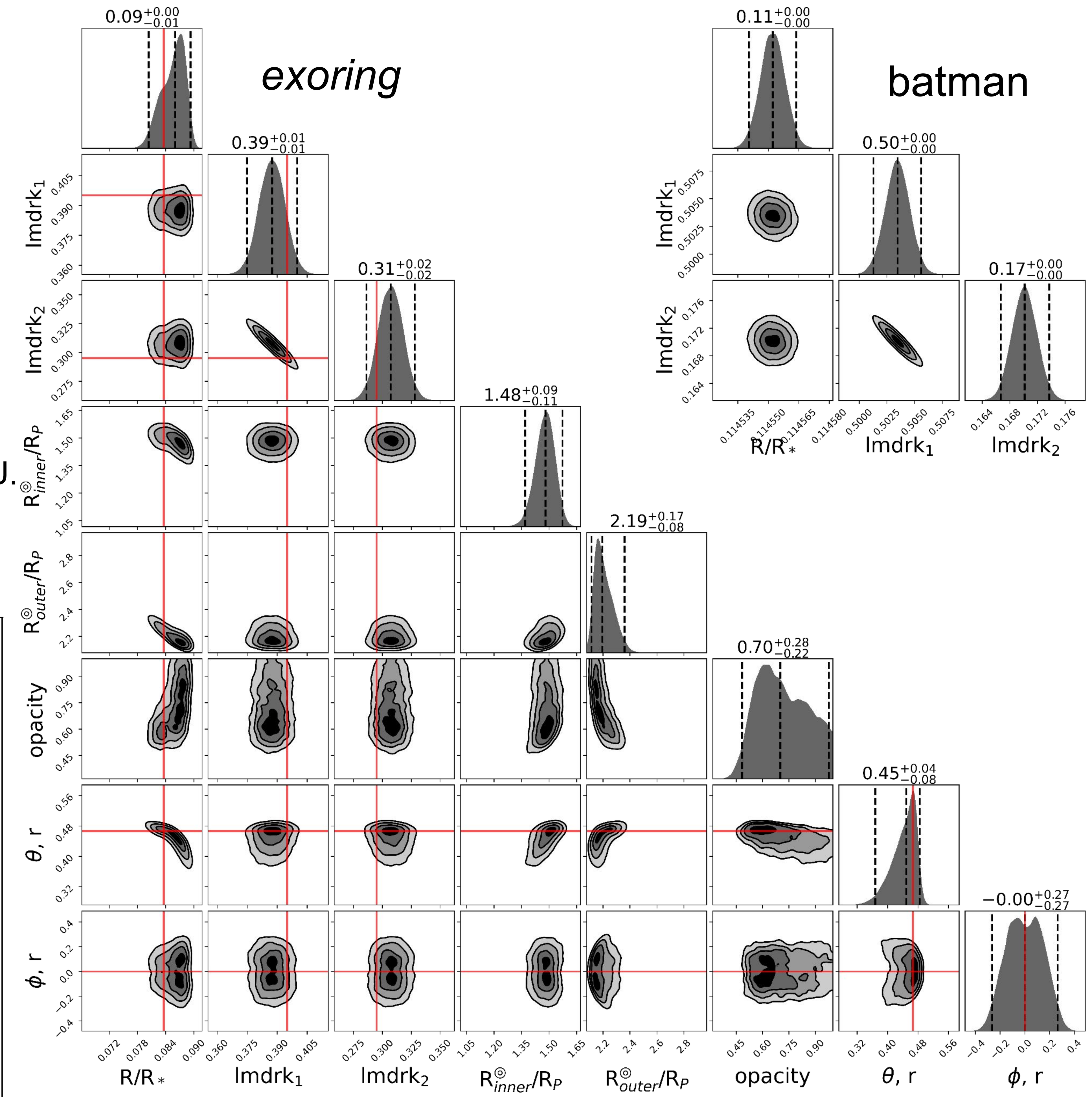
Above: The 0.9 μm normal optical depth profile of Saturn's rings [1] was binned into 690 ringlets, each 100 km wide, and the 2D opacity profile at inclination equal to that of Saturn's obliquity was then generated using the *exoring* python package. This compares well visually to the Cassini image in reflected light, right.

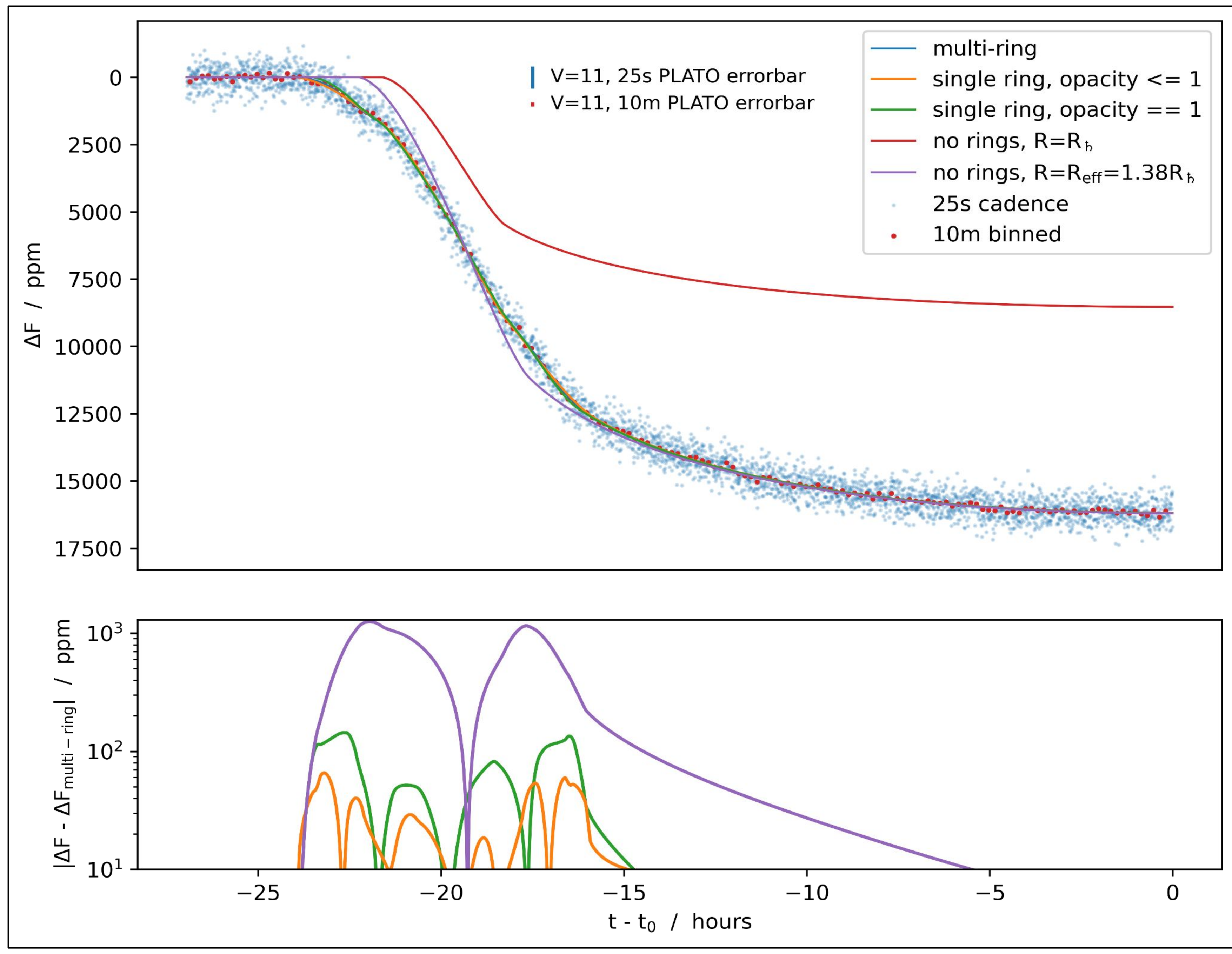
The *effective* radius (R_{eff}) of this system, i.e. the non-ringed planetary radius required to produce a transit of the same depth, is 38% larger than the radius of the planet itself. This is the radius we obtain on fitting a transit with standard transit modelling codes (see right), leading to a density estimate 2.6x smaller than reality.

If we simplify the multi-ring system on the left to that of a single ring with the same R_{eff} we obtain the below 2D opacity profiles below. Left with optical depth as a free parameter, right with infinite optical depth. These three model systems produce *almost* the same transit (*see bottom left*).



Planet parameter retrieval from the multi-ring model transit light curve (5m binned, see bottom left) using *exoring*, batman and dynesty [3]. Exoring is able to recover reasonable single-ring and planet parameters. Batman retrieves R_{eff} and incorrect limb darkening parameters. Exoring uses CUDA GPUs to provide rapid light curve models and likelihoods. (This retrieval took ≈24 hours on a Tesla V100 GPU. In both cases the planetary orbital parameters were fixed.)



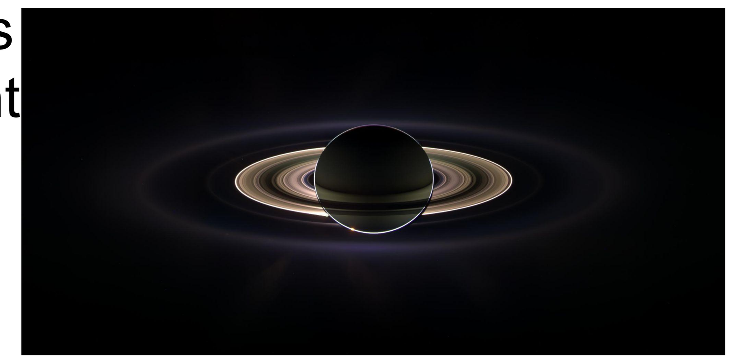


Upper left: Model transits of the above systems across a V=11 Sun-like star in an idealised case: zero impact parameter, ring inclination is equal to Saturn's obliquity (≈27°), long transit time thanks to Saturn's 29 year orbit. (The light curve is symmetric about t_0.)

Representative 25s and 10m binned PLATO-like light curves are included, assuming independent random Gaussian noise only.

Lower left: The $R=R_{eff}$ non-ringed transit (purple, courtesy of batman [2]) shows ≈1000 ppm residuals relative to the multi-ringed model. The opaque single ring (green) reduces these to ≈100 ppm, and allowing a semi-transparent ring further reduces to ≈50 ppm.

Caveat: Forward scattering by rings is not currently modelled but its impact may be significant depending on ring grain makeup, see [4] and Saturn in silhouette (right, Cassini).



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References:
[1] Nicholson P. D., et al., 2000, Icarus, 145, 474
[2] Kreidberg L., 2015, PASP, 127, 1161
[3] https://dynesty.readthedocs.io/en/latest/index.html
[4] Barnes J. W., Fortney J. J., 2004, ApJ, 616, 1193
See also:
Jorge I. Zuluaga et al 2015 ApJL 803 L14

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