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Irregular moons: Lost and Found

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Abstract

We have generated a method to diagnose on-sky orbital uncertainty for planetary satellites. We have verified the utility of this method by targeting a sample of irregular moons of the giant planets with moderate uncertainties; the method's predictions for ephemeris uncertainty are verified. We conclude that more than a dozen irregular moons (of Jupiter and Saturn) should now be considered 'lost' because their on-sky uncertainties are comparable to the size of the planet's Hill sphere as seen on the sky.

1. Introduction

In the decade starting 1997 there was an explosion of irregular moon discovery (see [1] for a review), which took the field from ∼10 to slightly more than the 100 irregulars moons now known. However, follow-up tracking of these discoveries has been erratic, meaning that the preliminary orbits have been getting steadily less reliable for ephemeris prediction. Compounding this is the fact that there is not a readily accessible (nor accepted!) way to determine the current on-sky ephemeris uncertainty for a given moon, perhaps leading some to believe that the orbits are more secure than they are in reality. We are aware of at least one Cassini spacecraft attempt to target the nominal position of a named saturnian satellite with moderate uncertainty; the observation did not find the moon in the field of view (the non-recovery makes sense given our results below as the uncertainty was many times the camera's field of view).

We have been developing a method to diagnose which planetary irregular moons are in need of futher observation, and to observe those for whom additional targetd observations are not hopeless.

2. Prediction Method

Our model for the satellite orbits is a numerical integration of their equations of motion. The formulation is in Cartesian coordinates centered at the planetary system barycenter and referenced to the International Celestial Reference Frame (ICRF). The modelled dynamics include the asphericity of planet, the pertubations due to the major satellites of the planet, and the perturbations due to the Sun and outer planets. Gravitational effects of the inner planets are taken into account by augmenting the solar mass with their masses. Once best-fit orbits are obtained, we propagate to the observing epoch and a covariance matrix allows determination of the on-sky positions and their dispersion on the sky. Moons with uncertainties of a few arcseconds or less are considered secure, but those whose uncertainties grow to tens or hundreds of arcseconds are considered in danger of being lost and became our targets for an observational campaign. There is also a set of moons whose uncertainties are now comparable to the projected Hill Spheres of the planets, and thus should be considered lost, likely needing a complete re-survey of the environs of the planet.

3. Observations

Over the last 3 years we have conducted an observational campaign to track irregular moons, mostly at the Palomar Hale 5-meter telescope with at 24 arcmin diameter field of view. (Alexandersen et al, this meeting, report some of this work). We selected targets with a range of predicted ephemeris uncertainties from a few arcseconds to 30 arcminutes and targeted them. Observations consisted of optical imaging with sufficient inter-exposure spacing to see the moons move against the stellar background. All but two of our targets were recovered (see Fig 1), at offsets that were comparable to our method's predicted on-sky uncertainty. (Some other moons which happened to be in the mosaic camera's field were recovered, providing some data for objects with predicted uncertainty <1", also shown on Fig 1). The targets that we did not find had a significant fraction of the uncertainty regions off the camera's field of view.

4. Summary and Conclusions

This verification of this ephemeris uncertainty method allows us to identify nine jovian and seven saturnian moons with on-sky uncertainties greater than half a degree on the sky; all of these are moons with provisional designations and should be considered 'lost'. There is another set of (named) moons, whose on-sky uncertainties are measure in tens of arcseconds or even a arcminutes, which need observations in the next few years to prevent their loss.

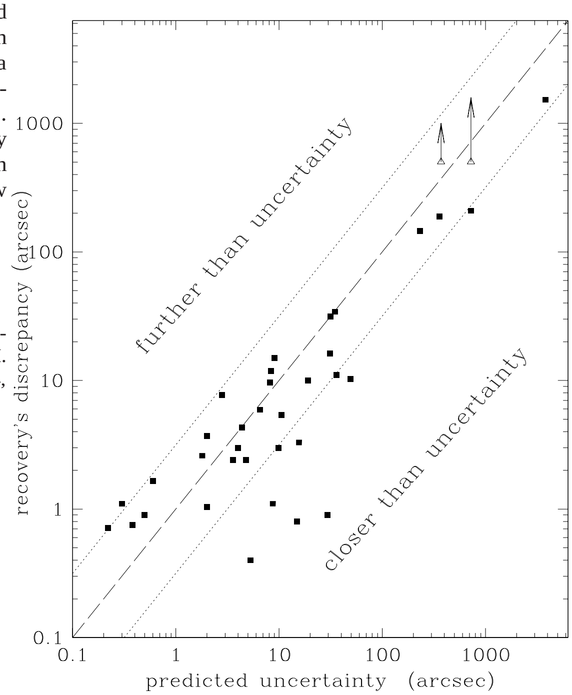

Figure 1: A comparison between our method's predicted (1-sigma) on-sky uncertainty versus the actual discrepancy between the on-sky position and the prediction at the time of recovery. Note that the axis covers 0.1 arcseconds to about 1 degree. The method predicts (to factor of 3; given by the dashed lines) the correct on-sky uncertainty. Two objects are upper limits; the lower limit marks the minimum distance the object must have been from the prediction, given the field of view at the time of attempted recovery.

References

[1] Nicholson, P. et al.: Irregular Satellites of the Giant Planets. In *The Solar System Beyond Neptune*, M. Barucci *et al.* Eds. Univ. of Arizona press, pp. 411–424, 2008. t