Flexible Stellar Density Profiles of Dwarf Spheroidal Galaxies

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Summary

- **Current Dwarf Spheroidal (dSph) stellar density models are either restrictively simple or computationally expensive**
- **Our combination of 3 generalized Plummer stellar profiles allows us to detect cuspy inner slopes and steep outer profiles**
- **We find evidence for steep outer slopes in 4 observed dSphs, but no evidence for cuspy inner slopes**

1: Background

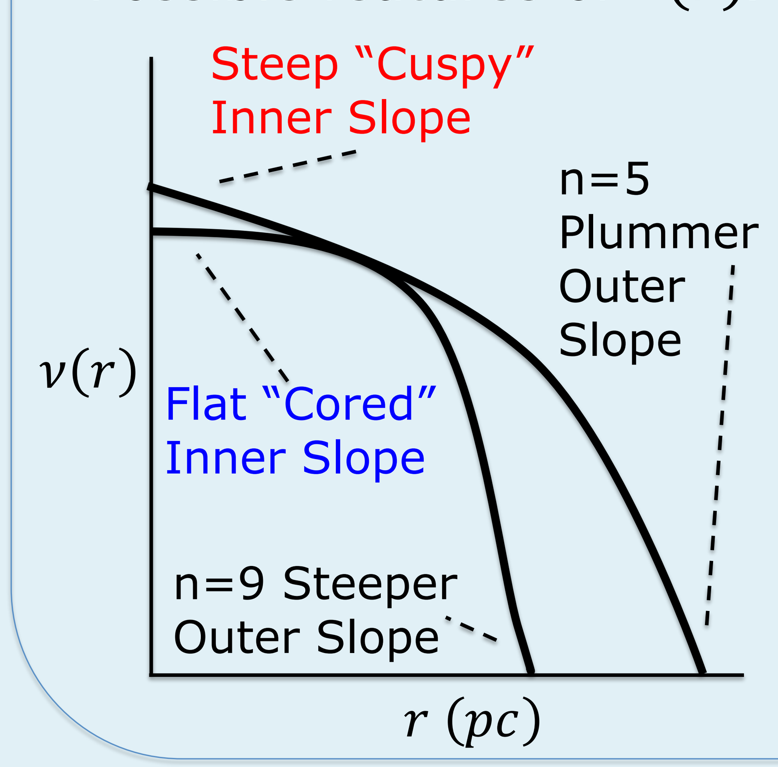
- The number of known Milky Way satellite Dwarf Spheroidal galaxies (dSphs) has quadrupled since the advent of large-scale surveys.
- Their small, dark-matter dominated masses makes their properties sensitive to theories of galaxy formation, dark matter, and cosmology.
- The shape of their dark matter mass density profiles has been studied in detail, **however:**
- Stellar position data provides half of the phase-space information used to measure the dark matter halo shape.
- Despite this important role in mass measurement, the shape of the stellar density profile $\nu(r)$ has received markedly little attention.
- Models of $\nu(r)$ often assume a set inner or outer profile slope, rather than allowing for any value.
- Past flexible models lack analytic integrals, needlessly impacting computation-intensive modeling.

We follow the work of Read & Steger (2017) and implement a generalization of the commonly-used Plummer profile as a 3-component basis function:

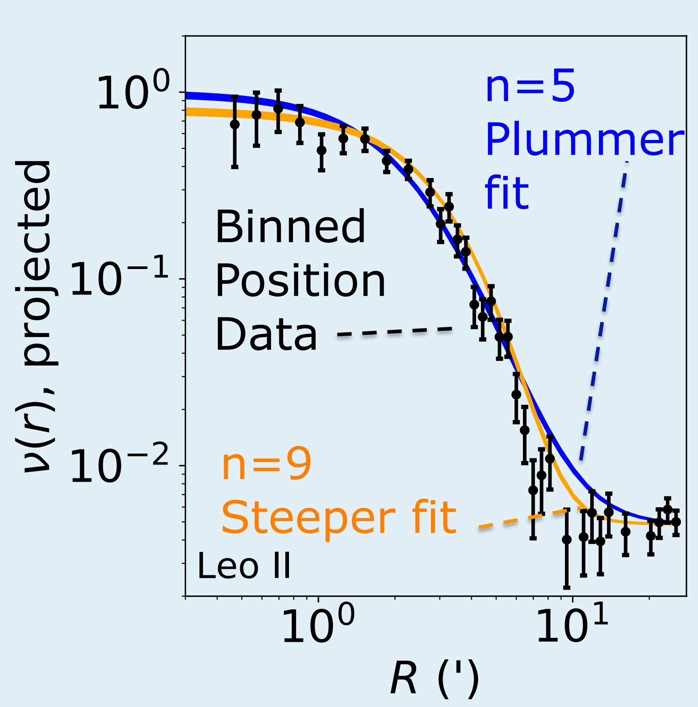
$$\nu(r) = \frac{\Sigma_{i=1}^{3} w_i b_i^{n-3}}{(b_i^2 + r^2)^{n/2}}$$

Using values of both n=5 ("plummer") and n=9 ("steeper") simultaneously allows for flexible inner and outer slopes while retaining analytic integrals.

Possible features of $\nu(r)$:



A real fit to stellar positions:



2: Validation with Mock Data

We created 1000 mock galaxies from αβγ (Zhao 1996) stellar profiles using the following parameters:

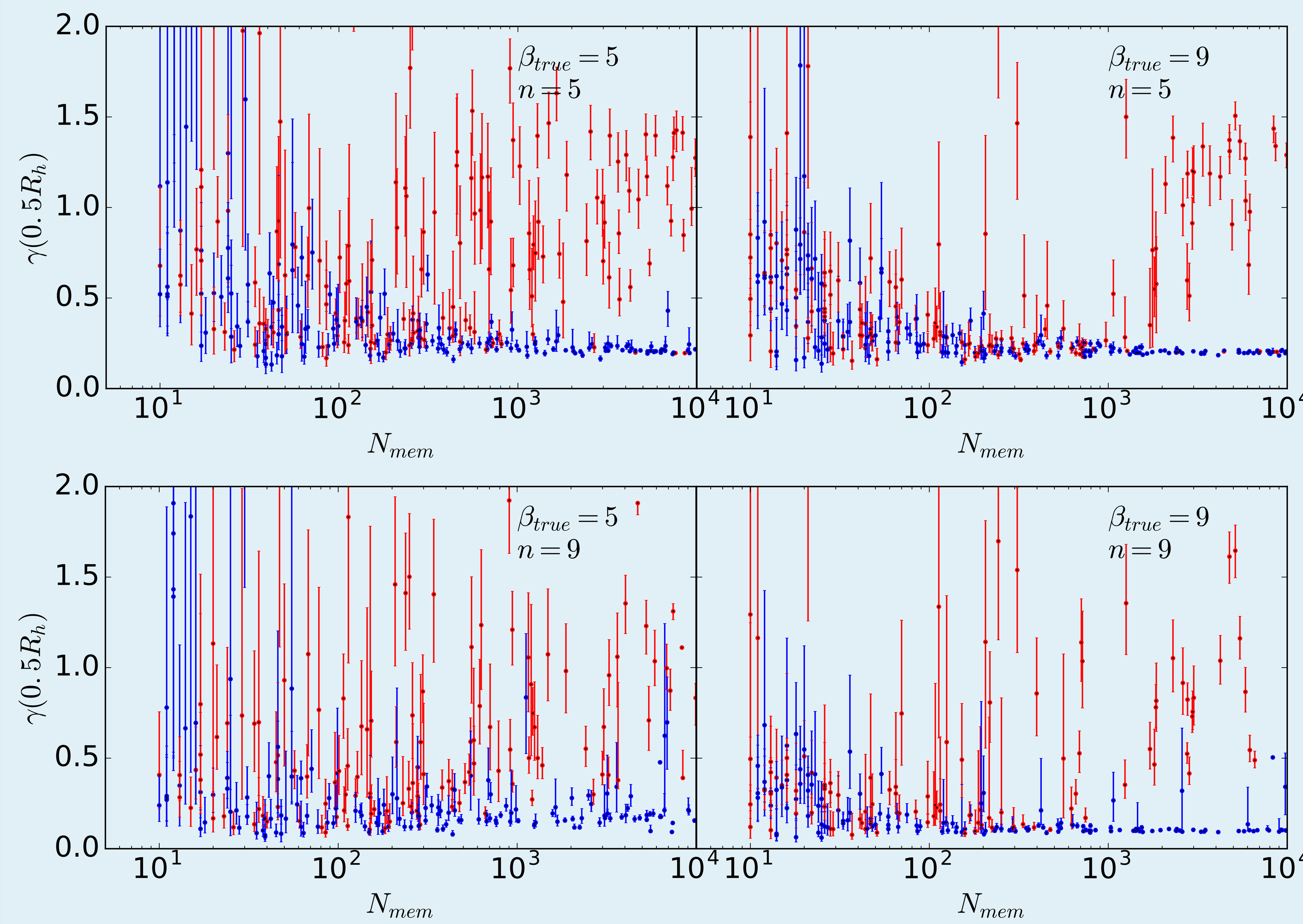
Inner Slope: γ_{true}=1 ("cusped") or 0 ("cored")

Outer Slope: β_{true}=5 ("plummer") or 9 ("steeper")

Other parameters for our mock data sets were assigned values consistent with observed dSphs.

Cusp / Core Detection

We calculated each fit's logarithmic slope, $\gamma(r) = d\log\nu(r)/d\log r$, at ½ the half-light radius (R_h) of the galaxy.



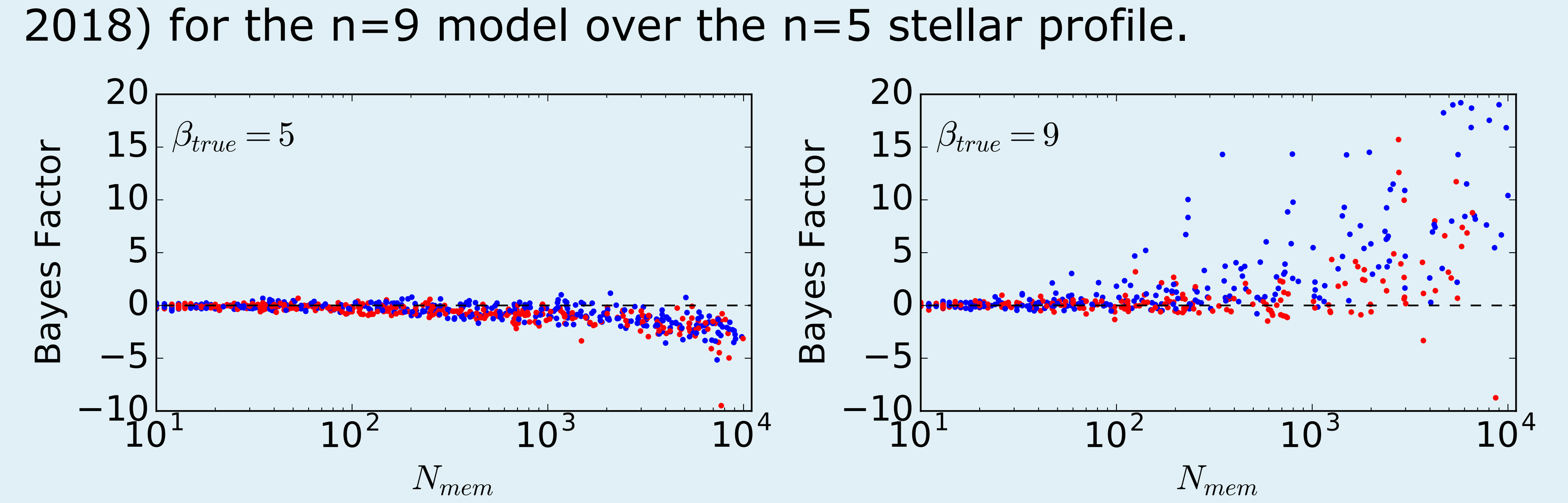
We find that this measurement allows us to separate fits to cusped mock data sets (red points) from fits to cored mock data sets (blue points).

This separation is strongest when there are more than 500 member stars (N_{mem}) in the mock galaxy.

Plummer / Steeper Detection

We can determine which stellar model (n=5 or n=9) better fits the outer slope by using the ratio of both models' marginalized likelihoods, which is also known as the the Bayes Factor.

A Bayes Factor of ½ is considered "substantial" support (Held & Ott 2018) for the n=9 model over the n=5 stellar profile.

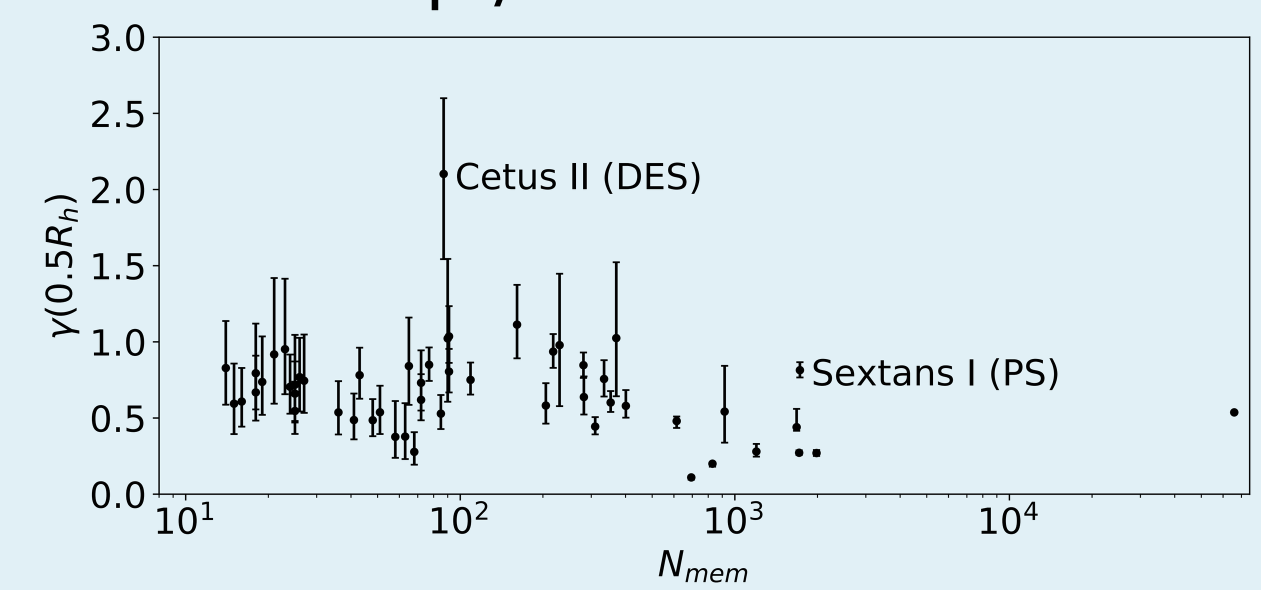


As expected, the Bayes Factor is positive if the mock data is built from a β_{true}=9 steeper-like distribution (right hand panel) and negative if the mock data is built from a β_{true}=5 plummer-like distribution (left).

3: Application to Known Milky Way Satellites

We applied our models to 38 dSphs using data from the PanStarrs-1 (PS) survey, Sloan Digital Sky Survey (SDSS), Dark Energy Survey (DES), and the imaging of Munoz et al. 2018 (M18).

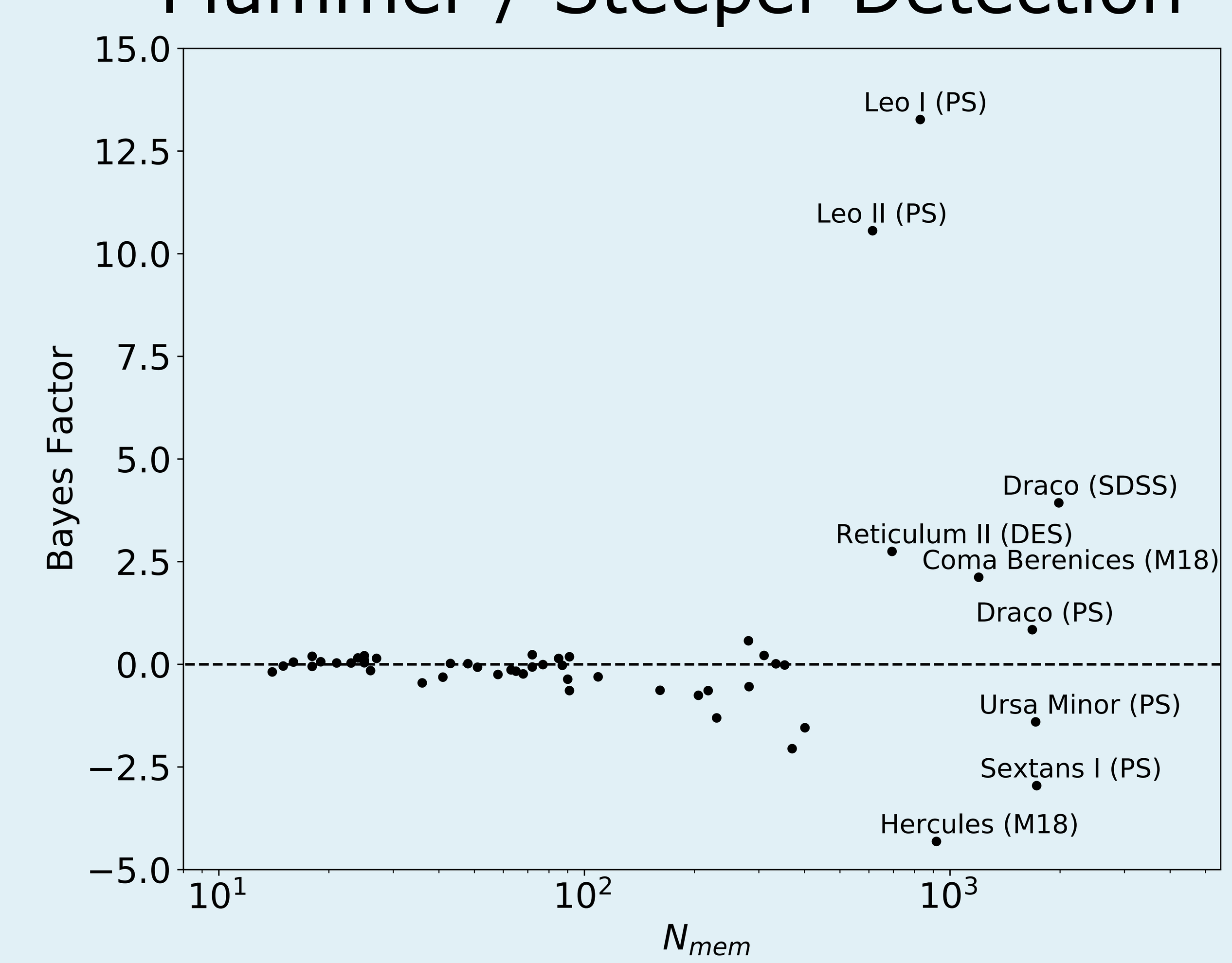
Cusp / Core Detection



We find that, for those dSphs with more than 500 detected member stars, none have a stellar logarithmic slope high enough to categorize them as cuspy when compared to our fits to mock data.

While Sextans I has a logarithmic slope greater than 0.75 in the PS data, this result is not replicated in the fit to data from SDSS.

Plummer / Steeper Detection



We find that stellar fits to five dSphs favor the n=9 model over the n=5 model with a Bayes Factor greater than ½. This is a majority of the dSphs for which we detect more than 500 member stars.

Given current constraints, there is no clear correlation between the Bayes Factor and dSph properties. This includes parameters relevant to tidal stripping, such as perihelion distance to the Milky Way.

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References:
Read, J. I., & Steger, P. 2017, MNRAS, 471, 4541
Zhao, H. 1996, MNRAS, 278, 488
Munoz, R. R., Cote, P., Santana, F. A., et al. 2018, ApJ, 860, 65
Held, L., & Ott, M. 2018, On p-Values and Bayes Factors