Modeling mass independent of anisotropy

A tool to test galaxy formation theories

arXiv: 0908.2995

Joe Wolf (UC Irvine)

September, 2009
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Team Irvine:

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Ricardo Munoz
Motivation

Describe our mass modeling technique

Derive a new mass estimator that is independent of anisotropy

Apply the new mass estimator

New spectroscopic observations of M31 dSphs

The future: SIM & proper motions
• I want to understand how galaxies form.

• Need to create a large scale simulation that implements hydrodynamics originating from first principles.

• Really hard to implement. Important feedback operates on many different scales. Galaxy properties sensitive to small changes. E.g. AGN: pc scales, Reionization: Mpc scales.
Galaxies sit deeply embedded inside of DM halos (White & Rees 78), which formed hierarchically: small halos merge to form large halos.

Kyle Stewart et al. 2008
Basic Picture: Via Lactea

$z=11.9$

800 x 600 physical kpc

Diemand, Kuhlen, Madau 2006
Basic Picture

- The observed sizes, shapes, dispersions, and metallicities of today’s MW dwarf galaxies are most likely similar to the time of infall (maybe).
Basic Picture

• The observed sizes, shapes, dispersions, and metallicities of today’s MW dwarf galaxies are most likely similar to the time of infall (maybe).

• Some hints of the relationship between today’s dwarfs and the buildup of the MW stellar halo
Galactic Archaeology

Today’s population: Survivors + first infall

Evan Kirby et al. 2008
Galactic Archaeology

Today’s population: Survivors + first infall

Evan Kirby et al. 2008
• But I’m not convinced.
• As Hans-Walter likes to point out:

Bell et al. 2003
Interesting conversations

- There conversations are interesting, but I still have looming questions (which I won’t discuss here).
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Lesson: we don’t have a consensus on the nature of dwarf galaxies. Not good...these are the simplest objects and we need to understand them first.
Interesting conversations

• There conversations are interesting, but I still have looming questions (which I won’t discuss here).

• Lesson: we don’t have a consensus on the nature of dwarf galaxies. Not good...these are the simplest objects and we need to understand them first.

• Scarier: While LCDM works well at reproducing the large-scale structure of the universe, it doesn’t do so well on small scales...or maybe it does? Depends on feedback prescriptions. 😐
More issues

• LCDM simulations generally agree (unlike hydrodynamic simulations).
  Still, two significant problems exist:
More issues

- LCDM simulations generally agree (unlike hydrodynamic simulations).
  Still, two significant problems exist:

  1. Overabundance of substructure $\rightarrow$ ”Missing Satellites problem” (MSP).

  2. Disagreements between inner density shape: LCDM produce cusps. LSBG rotation curves prefer cores.
More issues

• LCDM simulations generally agree (unlike hydrodynamic simulations). Still, two significant problems exist:

  1. Overabundance of substructure ➔ ”Missing Satellites problem” (MSP).

  2. Disagreements between inner density shape: LCDM produce cusps. LSBG rotation curves prefer cores.

• WDM a possible solution. Need accurate mass estimates to attempt to solve both problems.
Looking at MSP w/o masses

- Foreground junk in SDSS turns out to remind us how little we actually know.

- Many over-densities turn out to be bound, DM-dominated objects.
The Local Group

The dwarf galaxy pond before SDSS:

Figure: Roen Kelly / Astronomy
The Local Group

The dwarf galaxy pond after SDSS:

Figure: Roen Kelly / Astronomy
Our understanding of the local group has changed radically in the past four years, and current/future surveys (LSST, Pan-STARRS, PAndAS, SEGUE II, SMS, etc) are going to continue to help answer questions (and most likely will pose new problems).
Looking at MSP w/o masses

- SDSS only looked at $\sim \frac{1}{4}$ of the sky. $\sim 10$ new dwarfs found $\rightarrow$ $\sim 30$ more dwarfs should exist.
- But what if faint objects exist at large radii also? Need to correct for incompleteness.

Figure: Tollerud et al. 2008

Lines: Koposov et al. 2007

Shaded region: Walsh, Willman, & Jerjen 2008
Looking at MSP w/o masses

Tollerud et al. 2008

Koposov et al. 2008
Sounds tough...
Sounds tough...

Sorry 😞
Sorry 😞

But maybe there’s hope?

Let’s see if any improvements can be made with mass determinations?
Very important for comparing observations to simulations.
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The future: SIM & proper motions
With stellar kinematics, common techniques are:

1. \( V^2 = \frac{GM}{r} \)
2. Virial Theorem
3. Orbit modeling
4. Distribution function modeling
5. Jeans Equation

#1 only works for rotational-supported systems.
#3 and #4 need quality data to provide good constraints.
#2 and #5 are simple and can be used with limited data sets.

Consider the simplest assumption: spherical symmetry
Unfortunately, the spherically symmetric SVT is not very useful given the data most observers obtain.

The SVT only provides large bounds on the mass within an often not well-defined stellar extent (see Merritt 1987):

\[
\frac{\langle \sigma_{\text{los}}^2 \rangle}{\langle r_*^{-1} \rangle} \leq \frac{G M_{\text{lim}}}{3} \leq \frac{r_{\text{lim}}^3 \langle \sigma_{\text{los}}^2 \rangle}{\langle r_*^2 \rangle}
\]
Unfortunately, the spherically symmetric SVT is not very useful given the data most observers obtain.

The SVT only provides large bounds on the mass within an often not well-defined stellar extent (see Merritt 1987):

\[
0.7 \langle \sigma^2_{\text{los}} \rangle \leq \frac{GM_{\text{lim}}}{r_{\text{lim}}} \leq 20 \langle \sigma^2_{\text{los}} \rangle
\]

Assuming a King stellar distribution with \( r_{\text{lim}}/r_{\text{core}} = 5 \)
Many gas-poor dwarf galaxies have a significant, usually dominant hot component. They are dispersion-supported, not rotation-supported.

Consider a spherical, dispersion-supported system whose stars are collisionless and are in equilibrium. Let us consider the Jeans Equation:

$$ r \frac{d\left(\rho_\star \sigma_r^2\right)}{dr} = -\frac{GM(r)}{r} \rho_\star(r) - 2\beta(r) \rho_\star \sigma_r^2 $$

\[ \beta \equiv 1 - \frac{\sigma_t^2}{\sigma_r^2} \]

Free function

- We want mass
- Unknown: Anisotropy
- Assume known: 3D deprojected stellar density
- Radial dispersion (depends on beta)
Basic idea behind Jeans analysis:

(Note the one-way arrow)
Mass modeling of hot systems

Jeans Equation

\[ \frac{d(\rho_\star \sigma_r^2)}{dr} = -\frac{GM(r)}{r} \rho_\star(r) - 2\beta(r)\rho_\star\sigma_r^2 \]

Velocity Anisotropy (3 parameters)

\[ \beta(r) = (\beta_\infty - \beta_0) \frac{r^2}{r_\beta^2 + r^2} + \beta_0 \]
Mass modeling of hot systems

Jeans Equation

\[
\frac{d(\rho_* \sigma^2_r)}{dr} = -\frac{GM(r)}{r} \rho_* (r) - 2\beta(r) \rho_* \sigma^2_r
\]

Velocity Anisotropy

(3 parameters)

\[
\beta(r) = (\beta_\infty - \beta_0) \frac{r^2}{r^2_\beta + r^2} + \beta_0
\]

Mass Density

(6 parameters)

\[
\rho(r) = \frac{\rho_s e^{-r/r_{cut}}}{(r/r_s)^c [1 + (r/r_s)^a]^a} (b-c)/a
\]
Mass modeling of hot systems

Jeans Equation

\[ r \frac{d(\rho_\star \sigma_r^2)}{dr} = -\frac{GM(r)}{r} \rho_\star(r) - 2\beta(r)\rho_\star \sigma_r^2 \]

Velocity Anisotropy

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Mass Density

(6 parameters)

\[ \rho(r) = \frac{\rho_s e^{-r/r_{cut}}}{(r/r_s)^c [1 + (r/r_s)^a]^{(b-c)/a}} \]

Using a Gaussian PDF for the observed stellar velocity distribution, we marginalize over all free parameters (including photometric uncertainties) using a Markov Chain Monte Carlo (MCMC).
MCMC algorithm picks favorable combinations of $M$ and $\beta$ that produce dispersions that match the observed velocities. $\beta$ is not constrained from just LOS data, but $M$ may be constrained...if we are clever.
Mass-Beta Degeneracy

\[ \sigma_p \text{ [km s}^{-1}\text{]} \]

\[ r_{\text{core}} = 0.15 \text{ kpc} \]

NFW

Core

Cusp

Looking at MSP with masses

• What can we learn by deriving accurate masses?

Strigari et al. 2007
Looking at MSP with masses

- What can we learn by deriving accurate masses?

Strigari et al. 2007
Thought Experiment

Given the following kinematics...

\[ R_{\text{eff}} \]

\[ R_{\text{limit}} \]

(Ignore)

Thought Experiment

Given the following kinematics, will you derive a better constraint on mass enclosed within:

a) $0.5 \times r_{1/2}$  
b) $1.0 \times r_{1/2}$  
c) $1.5 \times r_{1/2}$

Where $r_{1/2}$ is the derived 3D deprojected half-light radius of the system. (The sphere within the sphere containing half the light).

A CAT scan of 50 mass likelihoods at different radii:

Confidence Intervals:
Cyan: 68%
Purple: 95%

Joe Wolf et al.,
0908.2995
It turns out that the mass is best constrained within $r_{1/2}$, and despite the given data, is less constrained for $r < r_{1/2}$ than $r > r_{1/2}$.

Confidence Intervals:
Cyan: 68%
Purple: 95%

Joe Wolf et al., 0908.2995
Anisotropy

Radial Anisotropy
Isotropic
Tangential

Joe Wolf et al., 0908.2995
Center of system: Observed dispersion is radial

Edge of system: Observed dispersion is tangential

Radial Anisotropy
Isotropic
Tangential

Joe Wolf et al., 0908.2995
Center of system: Observed dispersion is radial

Edge of system: Observed dispersion is tangential

Radial Anisotropy
Isotropic
Tangential

Newly derived analytic equations predict that the effect of anisotropy is minimal near $r_{1/2}$ for observed stellar densities:

$$M(< r; 0) - M(< r; \beta) = \frac{\beta(r) r \sigma^2_r(r)}{G} \left( \frac{d \ln \rho_*}{d \ln r} + \frac{d \ln \sigma^2_r}{d \ln r} + \frac{d \ln \beta}{d \ln r} + 3 \right)$$
We have found a way to invert the problem*: 

\[ M(r) \]  
\[ \beta(r) \]

* Mamon & Boué 0906.4971: Independent derivation.
We have found a way to invert the problem*:

\[ I \sigma^2_{los}(R) + \beta(r) \Rightarrow M(r) \]

* Mamon & Boué 0906.4971: Independent derivation.
Motivation

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New spectroscopic observations of M31 dSphs

The future: SIM & proper motions
To get this in the form of an Abel inversion, need to get rid of R in the integrand (but needed, as is, inside of the kernel)
\[ I_\star \sigma^2_{los}(R) = \int_{R^2}^{\infty} \rho_\star \sigma_r^2(r) \left[ 1 - \frac{R^2}{r^2} \beta(r) \right] \frac{dr^2}{\sqrt{r^2 - R^2}} \]

\[ \int_{R^2}^{\infty} \frac{\rho_\star \sigma_r^2}{r^2} \frac{(1 - \beta)r^2 + \beta(r^2 - R^2)}{\sqrt{r^2 - R^2}} dr^2 \]

Simple, but not obvious

Invertible

Maybe Invertible?
\[ I_{\sim\sigma^2_{los}}(R) = \int_{R^2}^{\infty} \rho_\star \sigma^2_r(r) \left[ 1 - \frac{R^2}{r^2} \beta(r) \right] \frac{d\bar{r}^2}{\sqrt{\bar{r}^2 - R^2}} \]

\[ \int_{R^2}^{\infty} \frac{\rho_\star \sigma^2_r}{r^2} \left( 1 - \beta \right) r^2 + \beta (r^2 - R^2) \frac{d\bar{r}^2}{\sqrt{\bar{r}^2 - R^2}} \]

\[ \int_{R^2}^{\infty} \frac{\rho_\star \sigma^2_r (1 - \beta)}{\sqrt{\bar{r}^2 - R^2}} \frac{d\bar{r}^2}{\sqrt{\bar{r}^2 - R^2}} - \left( \sqrt{\bar{r}^2 - R^2} \int_{r^2}^{\infty} \frac{\beta \rho_\star \sigma^2_r}{\bar{r}^2} d\bar{r}^2 \right) \bigg|_{R^2}^{\infty} \]

\[ + \int_{R^2}^{\infty} \left( \int_{r^2}^{\infty} \frac{\beta \rho_\star \sigma^2_r}{\bar{r}^2} d\bar{r}^2 \right) \frac{1}{2} \frac{d\bar{r}^2}{\sqrt{\bar{r}^2 - R^2}} \]
No more $R$ dependence in the brackets!

We can now use an Abel inversion to write the bracketed term as a function of the left-hand side!

It turns out this isn’t very useful, as you will need to know the second derivative of the left-hand side.

(See Appendix A of Wolf et al. 0908.2995 and Mamon & Boué 0906.4971)
What's next?

Given these tools, let’s search for a radius where the mass is independent of the anisotropy.
If the LHS is observable, it must be independent of an assumed anisotropy.
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Since this equation is invertible, a unique solution must exist.
If the LHS is observable, it must be independent of an assumed anisotropy. Since this equation is invertible, a unique solution must exist. Thus, the bracketed terms must be well determined, no matter the assumed anisotropy.
Therefore, we can equate the isotropic integrand with any arbitrary anisotropic integrand:
Take a derivative with respect to $\ln(r)$ and then subtract the Jeans Equation:
We present in depth arguments as to why the middle two terms should be small, and we also demonstrate that the first term $= -3$ near $r_{1/2}$ for most observed galaxies and stellar systems which are in equilibrium.

$$
\rho_* \sigma_r^2 \bigg|_{\beta=0} = \rho_* \sigma_r^2 [1 - \beta(r)] + \int_{r}^{\infty} \frac{\beta \rho_* \sigma_r^2 d\tilde{r}}{\tilde{r}}
$$

Take a derivative with respect to $\ln(r)$ and then subtract the Jeans Equation:

$$
M(<r;0) - M(<r;\beta) = \frac{\beta(r) r \sigma_r^2(r)}{G} \left( \frac{d \ln \rho_*}{d \ln r} + \frac{d \ln \sigma_r^2}{d \ln r} + \frac{d \ln \beta}{d \ln r} + 3 \right)
$$
Mass-anisotropy degeneracy has effectively been terminated at $r_{1/2}$:

Derived equation under several simplifications:

$$M_{1/2} = 3 \, G^{-1} \, r_{1/2} \langle \sigma_{\text{los}}^2 \rangle$$
Mass-anisotropy degeneracy has effectively been terminated at $r_{1/2}$:

Derived equation under several simplifications:

$$M_{1/2} = 3 \frac{G^{-1}}{r_{1/2}} \langle \sigma_{\text{los}}^2 \rangle$$

$$\frac{M_{1/2}}{M_\odot} \approx 930 \frac{R_{\text{eff}}}{\text{pc}} \frac{\langle \sigma_{\text{los}}^2 \rangle}{\text{km}^2 \text{s}^{-2}}$$

$$r_{1/2} \approx \frac{4}{3} \frac{R_{\text{eff}}}{\text{pc}}$$
Isn’t this just the scalar virial theorem (SVT)?

$$M_{1/2} = 3 \ G^{-1} \ r_{1/2} \ \langle \sigma_{los}^2 \rangle$$

Nope! The SVT only gives you limits on the total mass of a system.

This formula yields the mass within $r_{1/2}$, the 3D deprojected half-light radius, and is accurate independent of our ignorance of anisotropy.
Boom!
Equation tested on systems spanning almost **eight** decades in half-light mass after lifting simplifications.
“Classical” MW dwarf spheroidals

Dotted lines: 10% variation in factor of 3 in $M_{\text{Appx}}$

Joe Wolf et al., 0908.2995
Mass Errors: Origins

Error dominated by kinematics
Mass Errors: Origins

Error dominated by kinematics

Error dominated by anisotropy
Mass Errors: 300 stars

![Graph showing mass versus 3D physical radius for Fornax 300.](image)
Mass Errors: 600 stars

![Graph showing mass function for Fornax 600 stars. The x-axis represents 3D physical radius in kpc, and the y-axis represents the mass function in solar masses. The graph includes curves for various radii, with labels for $r_{1/2}$ and $r_{\text{limit}}$.](image)
Mass Errors: 1200 stars

![Graph showing mass versus 3D physical radius for 1200 stars.](Image)
Mass Errors: 2400 stars

![Graph showing the relationship between mass and 3D physical radius for Fornax.](image-url)
Motivation

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Derive a new mass estimator that is independent of anisotropy

Apply the new mass estimator

A word on the effect of binary star systems

New spectroscopic observations of M31 dSphs

Effects of priors \( \rightarrow \) cusp or core?

The future: SIM & proper motions
Applications: dSphs

A common mass scale? \( M(<300) \sim 10^7 M_{\text{sun}} \Rightarrow M_{\text{halo}} \sim 10^9 M_{\text{sun}} \)
A common mass scale? $M(<300) \sim 10^7 \, M_{\text{sun}} \rightarrow M_{\text{halo}} \sim 10^9 \, M_{\text{sun}}$

Applications: dSphs
Applications: dSphs

A common mass scale? Plotted: $M_{\text{halo}} = 3 \times 10^9 M_{\text{sun}}$
Applications: dSphs

A common mass scale? Plotted: $M_{\text{halo}} = 3 \times 10^9 M_{\odot}$

Minimum mass threshold for galaxy formation?

Notice: No trend with luminosity, as might be expected! Joe Wolf et al. 0908.2995
Applications: Global

Joe Wolf et al., 0908.2995
Much information about feedback & galaxy formation can be summarized with this plot. Also note similar trend to number abundance matching.
Much information about feedback & galaxy formation can be summarized with this plot. Also note similar trend to number abundance matching.

Ultrafaint dSphs: most DM dominated systems known!

Globulars: Offset from $L^*$ by factor of three

(Hmm…)

$L^*$: Efficient at galaxy formation

Inefficient at galaxy formation

Joe Wolf et al., 0908.2995
Applications: Global

Last plot:
Mass floor

This plot:
Luminosity ceiling

Joe Wolf et al.,
0908.2995
Fundamental Plane: Independent Observables

MLR: Intrinsic Properties

\[ \sigma \quad M_{1/2} = 3 G^{-1} r_{1/2} \langle \sigma_{\text{los}}^2 \rangle \quad M_{1/2} \]

\[ R_{\text{eff}} \quad r_{1/2} \simeq \frac{4}{3} R_{\text{eff}} \quad r_{1/2} \]

\[ I_{\text{eff}} \quad L_{1/2} = \frac{1}{2} I_{\text{eff}} \pi R_{\text{eff}}^2 \quad L_{1/2} \]

Erik Tollerud, JW, et al. in prep.
MLR Space

Erik Tollerud, JW, et al. in prep.
Erik Tollerud, JW, et al. in prep.
Despite different feedback mechanisms, all systems sitting deeply embedded in DM halos lie on this one tube, which spans 10 orders of magnitude in luminosity!

Globular clusters, which do not sit within DM halos, are offset from this tube.
Profile Matching

Erik Tollerud, JW, et al. in prep.
Profile Matching

Erik Tollerud, JW, et al. in prep.
Profile Matching

Moster et al. 0903.4682

Erik Tollerud, JW, et al. in prep.
Baryonic Tully-Fisher Relation

Red: old
Orange: new

\[ V_{\text{circ}} \geq \sqrt{3} \sigma \]

Stacy McGaugh
& JW in prep.
Baryonic Tully-Fisher Relation

Red: old
Orange: new

\[ \sqrt{3} \sigma \leq V_{\text{circ}} \]

Red: flat
Orange: rising
White: falling

Stacy McGaugh & JW in prep.
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New spectroscopic observations of M31 dSphs

The future: SIM & proper motions
Another dataset: M31

UC Irvine: James Bullock, Manoj Kaplinghat, Erik Tollerud, Basilio Yniguez

UC Santa Cruz: Raja Guhathakurta (SPLASH PI)

STScI: Jason Kalirai

Yale: Marla Geha

U. Washington: Karrie Gilbert

Caltech: Evan Kirby

And others involved in SPLASH ➔
M31 dSphs: Larger than MW dSphs

- Observed half-light radius
- Dim - Luminosity - Bright

McConnachie & Irwin 2006, MNRAS
<table>
<thead>
<tr>
<th>And</th>
<th>#</th>
<th>σ [km/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>76</td>
<td>9.1 ± 1.0</td>
</tr>
<tr>
<td>II</td>
<td>95</td>
<td>7.3 ± 0.8</td>
</tr>
<tr>
<td>III</td>
<td>43</td>
<td>4.7 ± 1.0</td>
</tr>
<tr>
<td>X</td>
<td>22</td>
<td>3.9 ± 1.2</td>
</tr>
<tr>
<td>XIV</td>
<td>38</td>
<td>5.4 ± 1.1</td>
</tr>
</tbody>
</table>

Dispersion data from Kalirai et al 2009, in prep
M31 dSphs: Bigger but less massive!

Spectroscopic data from Keck/DEIMOS: 10 times more than existed before!

DM halo mass offset by ~10. M(<300 pc) offset by ~2.

Joe Wolf et al., in prep
M31 dSphs: Bigger but less massive!

CDM Prior on masses
(preliminary)

Joe Wolf et al., in prep
M31 dSphs: Bigger but less massive!

CDM Prior on masses
(preliminary)

Joe Wolf et al., in prep
If M31’s DM halo collapsed later $\rightarrow$ Less dense substructure & later forming star formation.

Interesting:
Brown et al. 2008 find that portion of investigated M31 stellar halo is younger (on average) than MW’s.
Itemized Outline

• Motivation
• Describe our mass modeling technique
• Derive a new mass estimator that is independent of anisotropy
• Apply the new mass estimator
• New spectroscopic observations of M31 dSphs
• The future: SIM & proper motions
From Earth-Like Planets to Dark Matter...

SIM Lite
Astrometric Observatory:
Late 2015
THE ASTRONOMICAL PYRAMID

ILLUSTRATING THE INTERDEPENDENCE OF THE VARIOUS AREAS OF STUDY

COSMOLOGISTS, GENERAL RELATIVISTS, CRANKS,
OTHER FUZZY-BRAINED PENCIL-PUSHERS,

ATMOSPHERES, INTERIORS, INTERSTELLAR MED.
THEORISTS

SPECTROSCOPISTS PHOTOGRAPHERS

ASTROMETRISTS

GET BACK TO BASICS -- SUPPORT ASTROMETRY

by Ron Probst, ~1978
While a grad student at UVa
All remaining observing time on SIM Lite will be competed through a General Observer (GO) Call. About 31% of 5 years. This is about half of the total science time.

GO Program call will be issued 2-3 years before launch.

GO call will be completely open with respect to science topics. Peer review will determine the most promising science.
SIM Lite

SIM Lite discovery space

Gaia discovery space

Internal proper motions of dSphs
Internal dSph proper motions

Mean PM error
O: 10 km/s
B: 7 km/s
R: 5 km/s
G: 3 km/s
Need 1,500 hours of SIM integration time to retrieve 200 PMs of Draco RGBs with a mean uncertainty of 5 km/s.
Knowing $M_{1/2}$ accurately without knowledge of anisotropy gives new constraints for galaxy formation theories to match. Future simulations must be able to reproduce these results.

- Something weird is going on with the M31 dSphs.

- Inner slopes of dSphs cannot be determined with only LOS kinematics. Need internal proper motions to solve cusp-core issue.

- Real conclusion: Job security for astronomers. 😊
A word on binaries

Best fit dispersion (4 km/s) with 200 stars

Quinn Minor, Greg Martinez, et al. in prep
A word on binaries

Best fit dispersion (10 km/s) with 500 stars

![Image of a graph]

- 2-epoch P(B)
- flat P(B)
- biweight

Quinn Minor, Greg Martinez, et al. in prep
A word on binaries

How many multi-epoch stellar velocities needed to constrain binary fraction (which will provide an additional constraint for detailed galaxy formation theories)?

![Graph showing the number of stars versus 95% confidence interval in B with lines for B=0.3, B=0.5, and B=0.7.](Image)
“Can the observed or potentially measurable velocity dispersions tell apart a cusp vs. a core in their centers?” – Extreme Star Formation in Dwarf Galaxies Conference Website, Ann Arbor, Michigan, July 2009

No. (At least not with LOS kinematics alone.)
Beta prior #1: Constant beta that is flat from -10 to 0.91. Gamma = Log slope of Carina at 0 pc
Beta prior #2: Constant beta that is as likely to be negative as positive (ranging from -10 to 0.91).
In Bayesian analysis, a prior is always present.

If changing your prior affects your posterior, then you are getting out what you put in.

That is, your data is not constraining your posterior.
G. Gilmore 2007: “Cores always preferred”
Forcing isotropy: 4 of the 8 classical dSphs show no preference for either cores or cusps, and Sculptor strongly prefers a cusp.

Joe Wolf et al., in prep