# Stellar Streams in the Milky Way: probes of dark matter

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## Outline

- Introduction: Developments over last decade
- Theoretical predictions: stellar streams
- Observations; what's missing
- Methods to fill in missing dimensions
- Preliminary Results
- Conclusions and Next Decade

## Last Decade: Theory

- Cosmological N-body simulations reach below Galactic scales
- Predictions: (i) hierarchy of merging dark matter halos





Latest simulations resolve close to 100,000 individual self-bound dark matter clumps within the Milky Way's virial volume

Searle & Zinn (1978); Toomre (1977)

#### Predictions (cont.): (iii) Hierarchical merging should lead to relics - stellar streams



# Last Decade:

#### Is "missing satellites problem" an observational one?

### Observations







Canes Canes Venatici I Venatici II,

> Coma Berenice

SDSS: All sky survey

kurov et al. 2008tes



#### Why stellar streams are particularly interesting:



•  $M >> M_{sat}$ :  $E_{orb} >> E_{tid} >> E_{bin}$ 

1) Good probes of the phase space structure of dark matter: "lumpiness" (e.g. Kesden & Kamionkowski 2006)



2) Shape: streams allow us to make a measurement of the shape, q, of the dark matter halo. Different dark matter models predict different q.

## How, really, do we constrain the potential of the galaxy from streams? (1) 'lumpiness'



#### Sagittarius tidal stream: shape



Fellhauer et al. 2006

#### Sagittarius tidal stream:



Law et al. 2005



- \* I arcsecond = I/3600th of a degree.
- \* Typical motions of tracers at these distances ~ I-2 milli-arcsecond per year (mas/yr).

\* Typical resolution of detectors on modern-day telescopes ~ 100 mas/ pixel.

#### Goal of current project is to measure proper motions for Sagittarius stream members.

#### **Required Proper Motion Uncertainty**



#### Our strategy: SDSS-Megacam comparison



Strategy (contd.):



Relative astrometry
SDSS gives 'true' x,y
estimate, giving
residuals:
dx = xMMT - xSDSS
dy = yMMT - ySDSS



#### • RMS of the fit = **21 mas**.

- This is a factor of 7 improvement over the best case positional accuracy in currently available proper motion catalogs (**150 mas**).
- Including the 9-year baseline gives a proper motion error per star of 2 mas/yr.

## Conclusions and the Next Decade

- We had a 3-night run in which we targeted ~3 different portions along the Sagittarius stream.
- Large-scale surveys in the next decade will probe larger volume, time domain, order of magnitude more stars, micro-arcsecond astrometry.
- Projected errors of these surveys (SIM, Gaia) at these distances ~ 1-3 mas/yr. Thus we are timely and competitive.
- Stay tuned...

## Collaborators

#### MIT: Robyn Sanderson Paul Schechter Ed Bertschinger Andrew West

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