Discrete dynamical modelling of $\omega$ Centauri

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ω Centauri
ω Centauri is interesting

- multiple SPs
- IMBH?
HST proper motions (no black hole)  
Anderson & van der Marel (2010)

line of sight velocities (black hole)  
Noyola et al. (2008, 2010)

Proper motions
van de Ven et al. (2006)
ω Centauri is interesting

- multiple SPs
- IMBH?
- dark matter?
omega centauri dispersion profile

Sollima et al. (2009)

van de Ven et al. (2006)

Scarpa et al. (2003)

tidal effects? dark matter? (or MOND?)

mass follows light
ω Centauri is interesting

- multiple SPs
- IMBH?
- dark matter?
- lots of good data
- need dynamical models

NASA, ESA and the Hubble Heritage Team (STScI/AURA)
binning matches moments

\[ p(v) \]

\[ v \]
we don’t want to bin at all

\[ p(v) \]

\[ p(v_{\text{obs}} \mid \text{model}, \delta v_{\text{obs}}) \]
include contamination model

\[ m(x',y') \cdot p( v_{obs} \mid \text{model} ) + (1-m(x',y')) \cdot p( v_{obs} \mid \text{contaminants} ) \]
\[ m(x',y') = \frac{dN_{\text{cl}}(x',y')}{dN_{\text{cl}}(x',y') + dN_{\text{bg}}(x',y')} \]

\[ dN_{\text{cl}}(x',y') \propto I(x',y') \quad \text{surface brightness} \]

\[ dN_{\text{bg}}(x',y') = \varepsilon \, dN_0 \quad dN_0 = dN_{\text{cl}}(0,0) \]
we have 5 free parameters

- axisymmetric Jeans models
- anisotropy: \( \lambda = -\ln(<v_z^2>/<v_R^2>) \)
- shape: \( q \)
- stellar mass-to-light ratio: \( \Upsilon \)
- distance: \( d \)
- contamination fraction: \( \varepsilon \)

+ *emcee* MCMC  
Foreman-Mackey et al. (2013)
van de Ven et al. (2006)

Suntzeff & Kraft (1996)
Mayor et al. (1997)
Reijns et al. (2006)
Karl Gebhardt

intermediate & full

sigma clip outliers
& cut on error

clean
van de Ven et al. (2006)
van Leeuwen et al. (2000) full

cut on error &
cut blended stars

intermediate
cut on error &
cut blended stars
& cut outliers
clean

van Leeuwen et al. (2000) full

cut on error &
cut blended stars

intermediate
cut on error &
cut blended stars
& cut outliers
clean
results

✓ clean
(all cuts)

✓ intermediate
(cut bad PM stars)

✗ full
(no cuts)
"best" model

\[ P(\text{cluster}) = \frac{m L_{\text{cl}}}{m L_{\text{cl}} + (1-m) L_{\text{bg}}} \]
these models are fast

- < 250 stars
  - N model moments

- > 250 stars
  - 250 model moments (polar grid)
  - N moment interpolations

- N likelihoods
these models are fast

200 models on 20 CPUS = 10 models on 1 CPU

interpolation and likelihood calculations

3 minutes for 10 models of $10^5$ data points
what next?

- ω Centauri
- IMBH?
- DM halo
- chemical tagging
- better background models
- discrete Schwarzschild
- Local Group dSphs and GCs
- Milky Way
summary

- high quality and quantity data sets in the LG
- analysis usually involves binning
- we are implementing discrete modelling of discrete datasets
- initial study of ω Centauri is encouraging
- accurate data uncertainties are vital
extra slides
parameter distributions for cleaned dataset

set C

$\lambda$ (small)
$q$ ($\sim 0.91$)
$\Upsilon$ ($\sim 2.7$)
$d$ ($\sim 4.7$ kpc)
$\varepsilon$ ($\sim$ small)
"best" model
fair sampling of models