Imprints of Evolution on the Internal Kinematics of Globular Clusters

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(theoretically) (observationally)

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

HST Proper Motion Catalogues

HST proper motions for 22 Milky Way globular clusters

Bellini+ 2014

- all archival data
- 1.4 million stars (datasets ~3k to ~300k each)
- few km/s accuracy (~35 μas/yr = ~ 1.4km/s)
- different environments
- different dynamical states
- global statistics

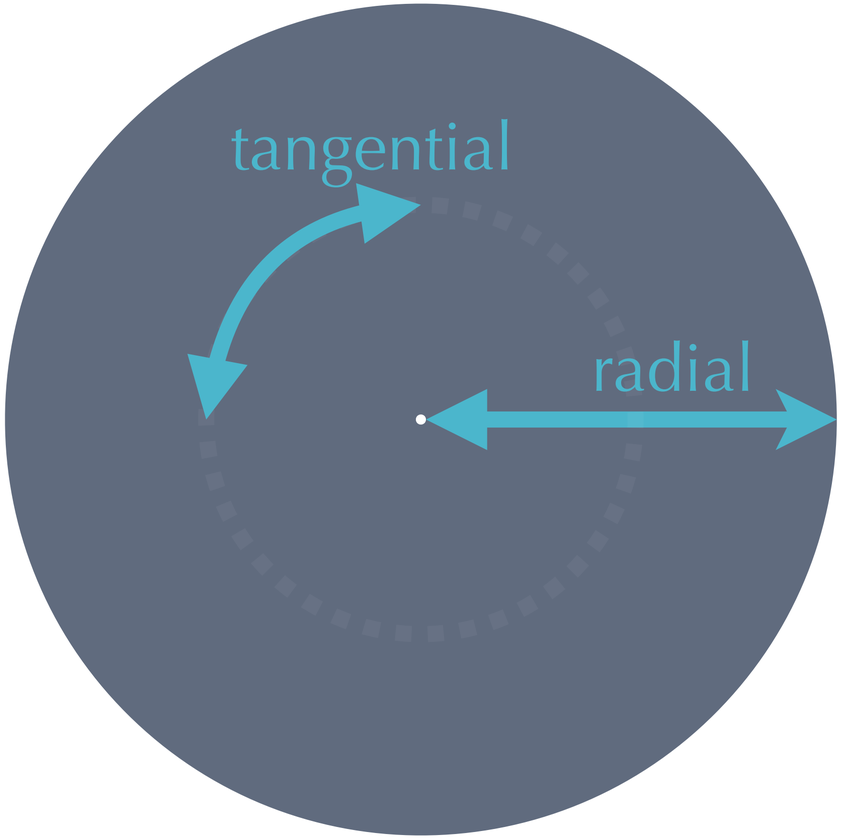
Globular clusters are dense.
stars interact

Globular clusters are old.
lots of interactions

stars exchange energy

Anisotropy

Anisotropy



$$\frac{\text{dispersion in direction A}}{\text{dispersion in direction B}}$$

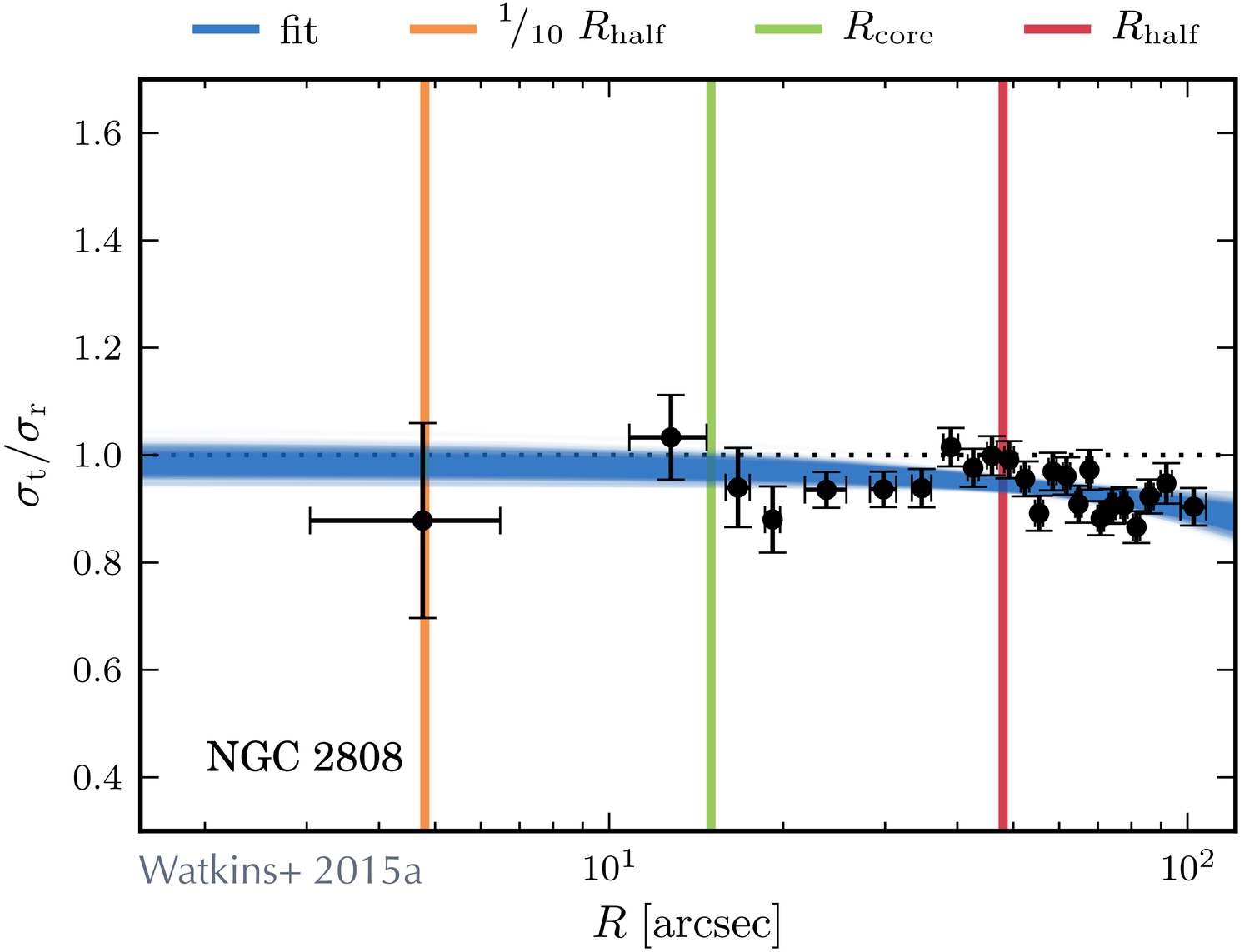
(orthogonal directions)

=1 (isotropic)

>1 (A-biased)

<1 (B-biased)

HST Proper Motions: Projected Anisotropy Profiles



anisotropy on the plane of the sky

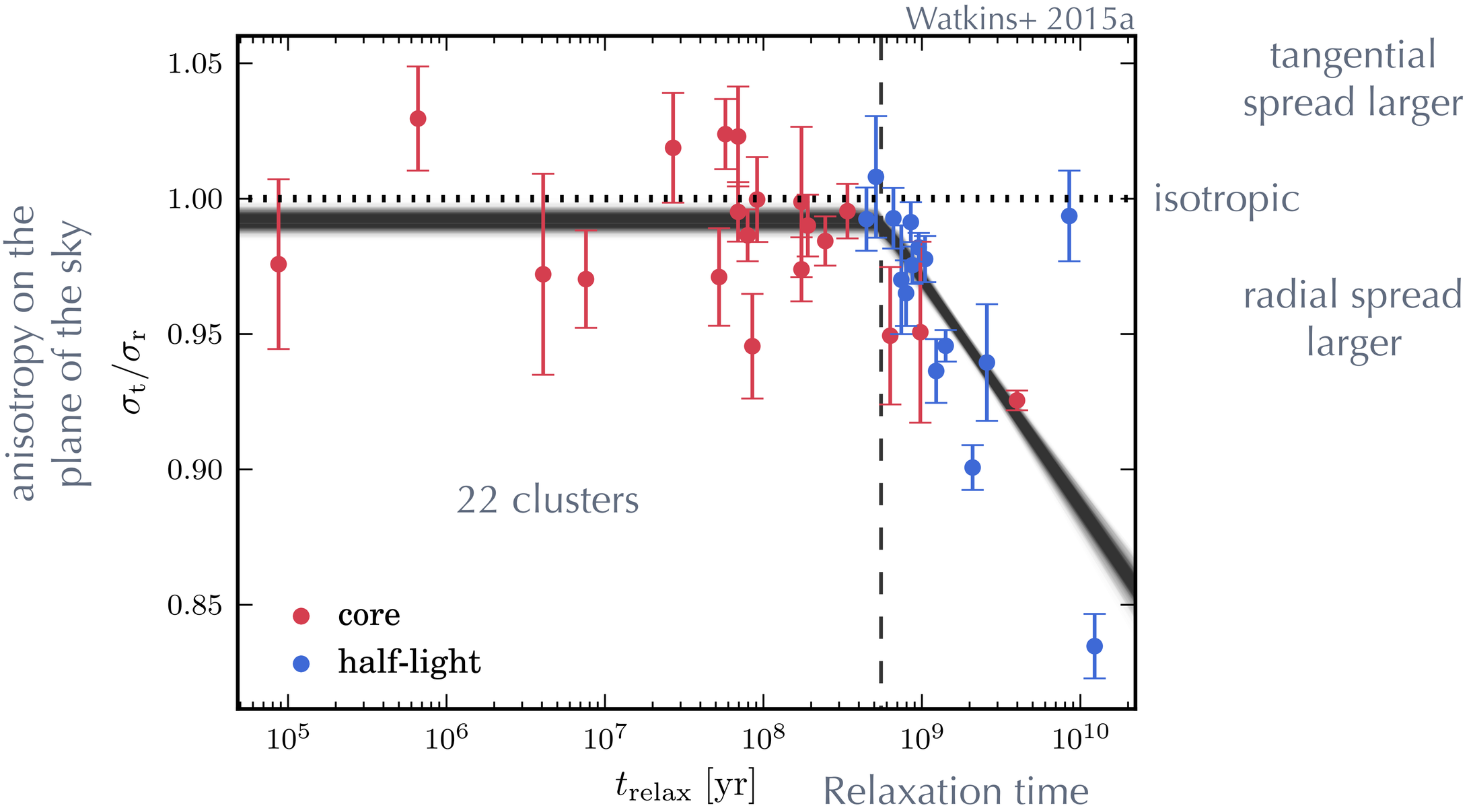
tangential spread larger

isotropic

radial spread larger

Watkins+ 2015a

HST: Anisotropy vs Relaxation Time



Energy Equipartition

Energy Equipartition

equal kinetic energy

$\frac{1}{2}\ m\ v^2$

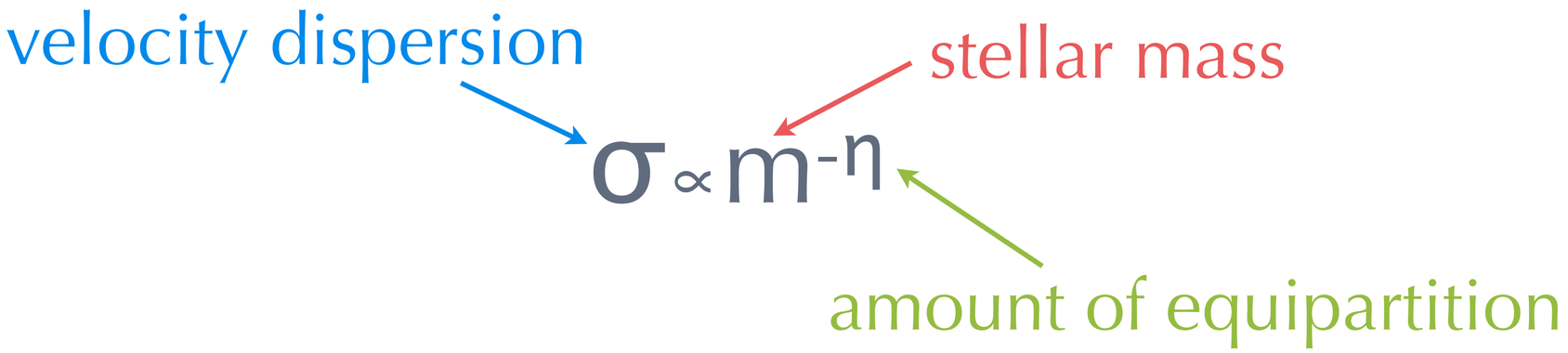
high mass : slow

low mass : fast

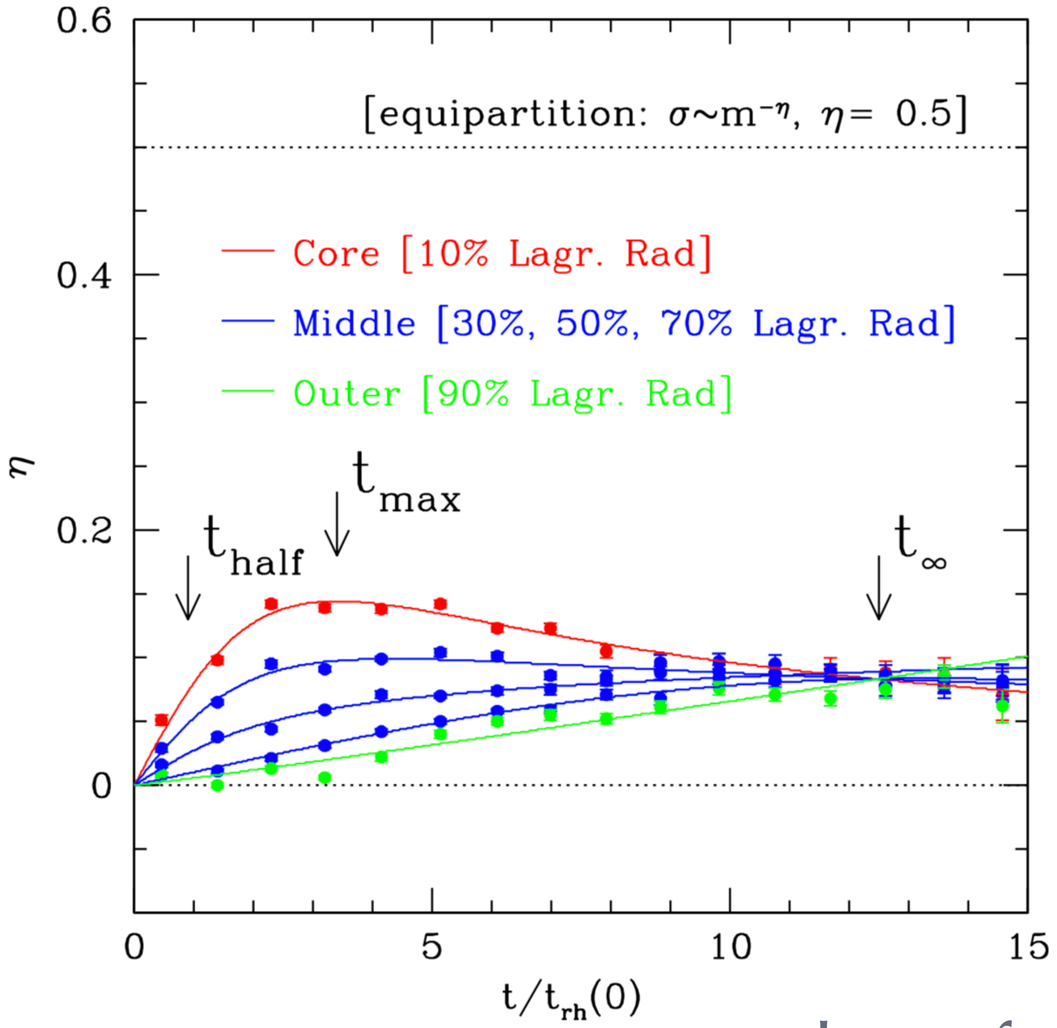
Energy Equipartition

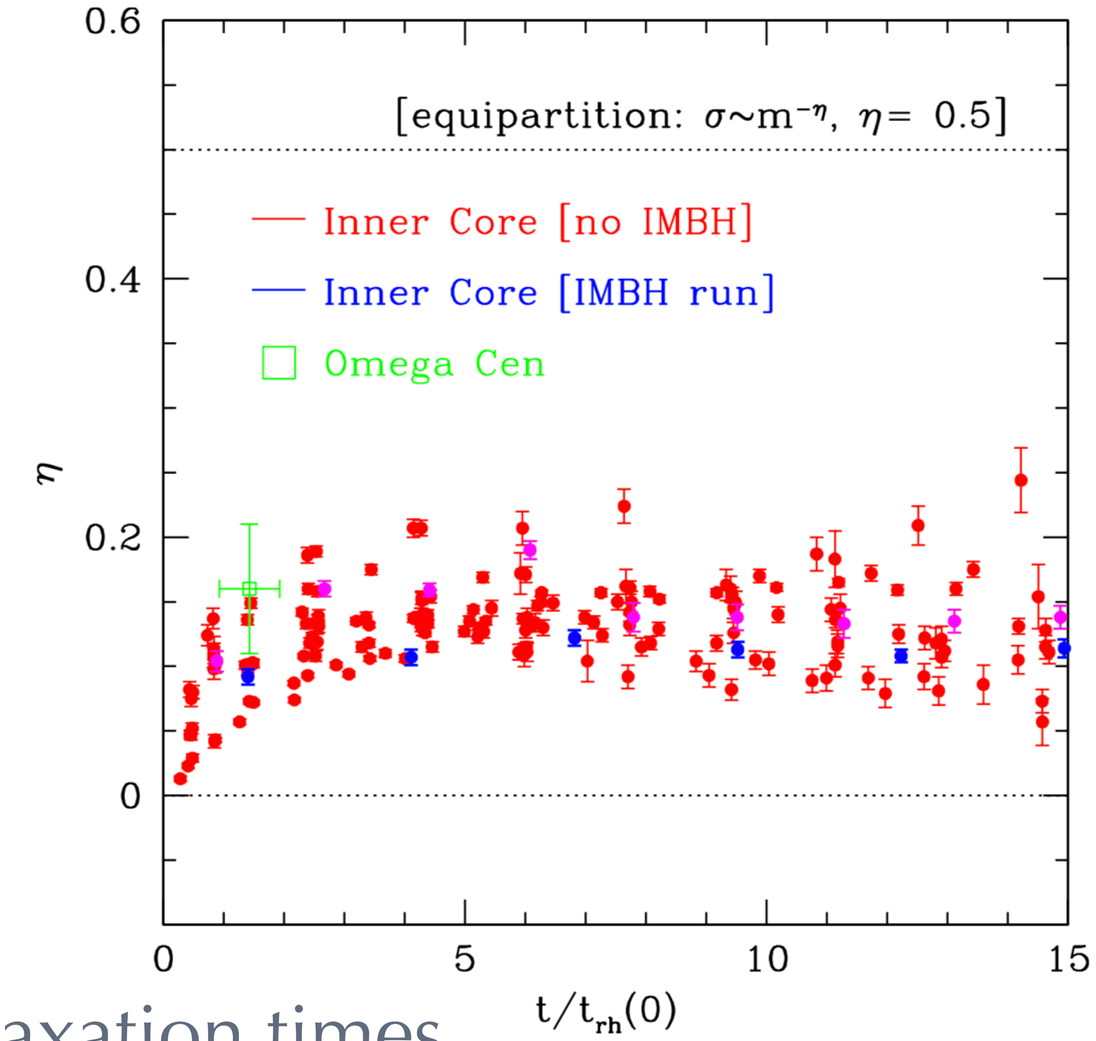
equal kinetic energy

$\frac{1}{2}\, m\, v^2$



Simulated Clusters

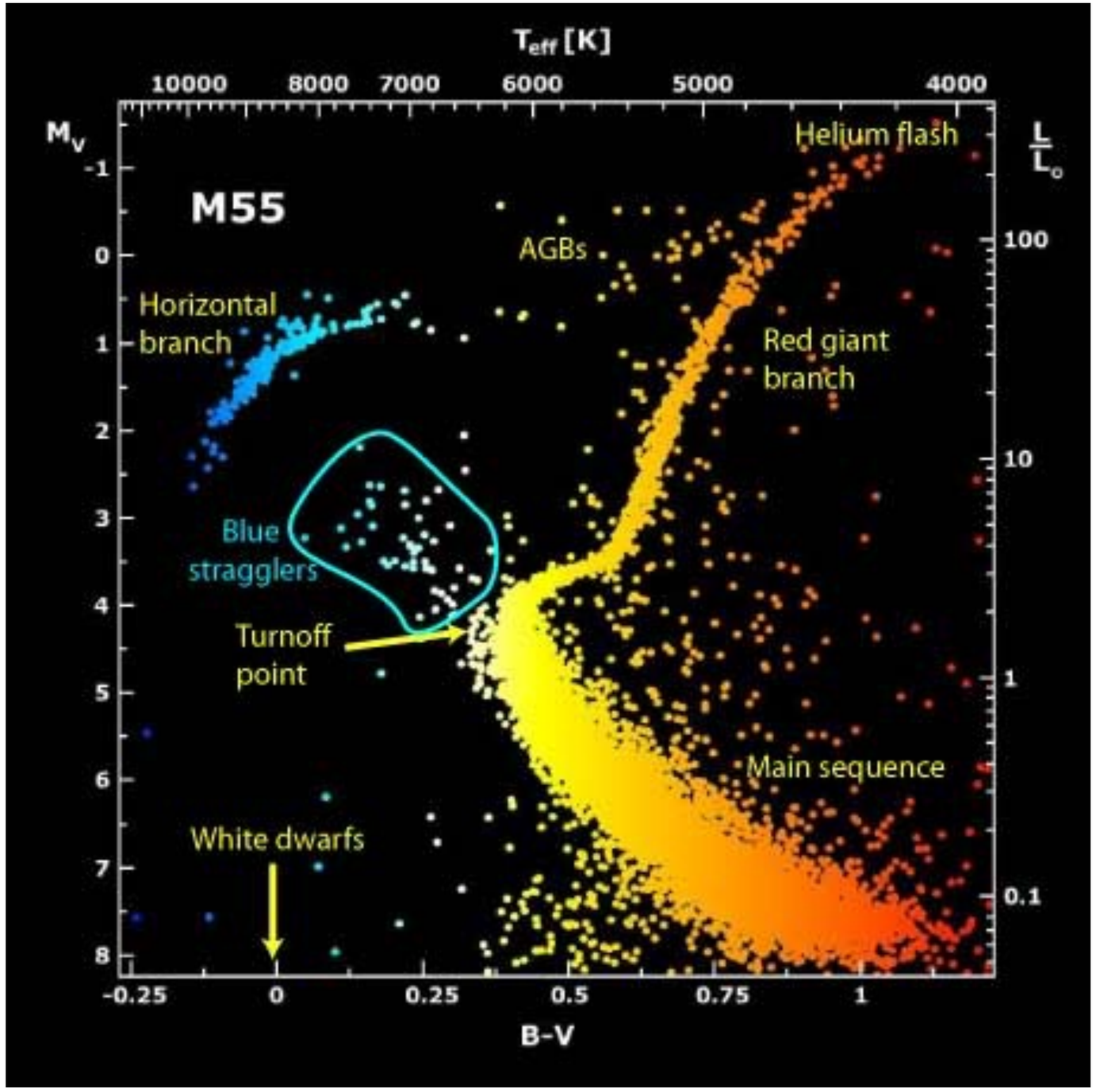




degree of equipartition

number of relaxation times

Trenti & van der Marel 2013



very small mass range

targets for kinematics

wide mass range

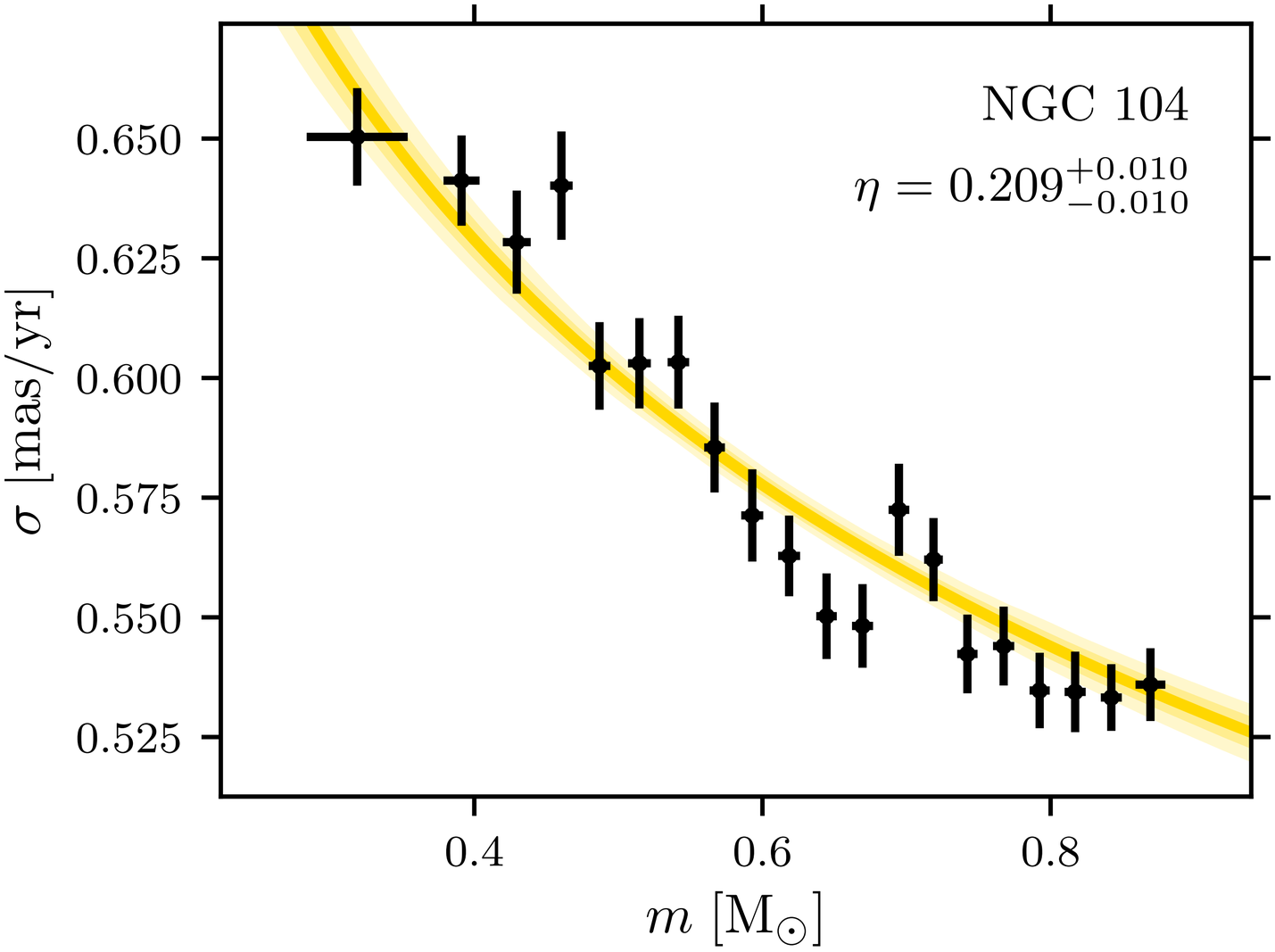
hard to get kinematics

HST

also MUSE (Kamann+)

preliminary

HST: kinematics with stellar mass



proper motion velocity dispersion

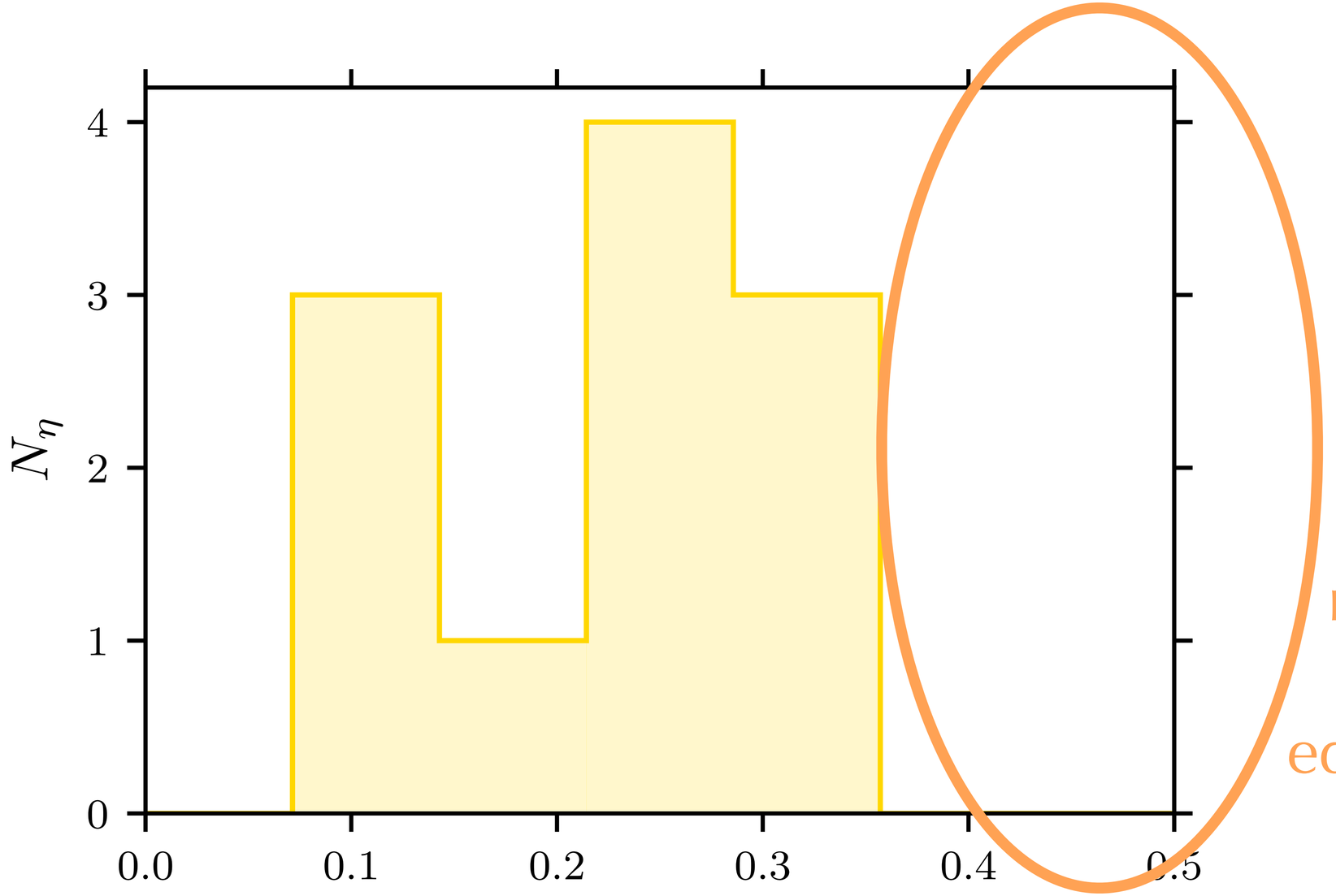
stellar mass

$\sigma \propto m^{-\eta}$

Watkins+ in prep

preliminary

HST: kinematics with stellar mass



no cluster in full equipartition (0.5)

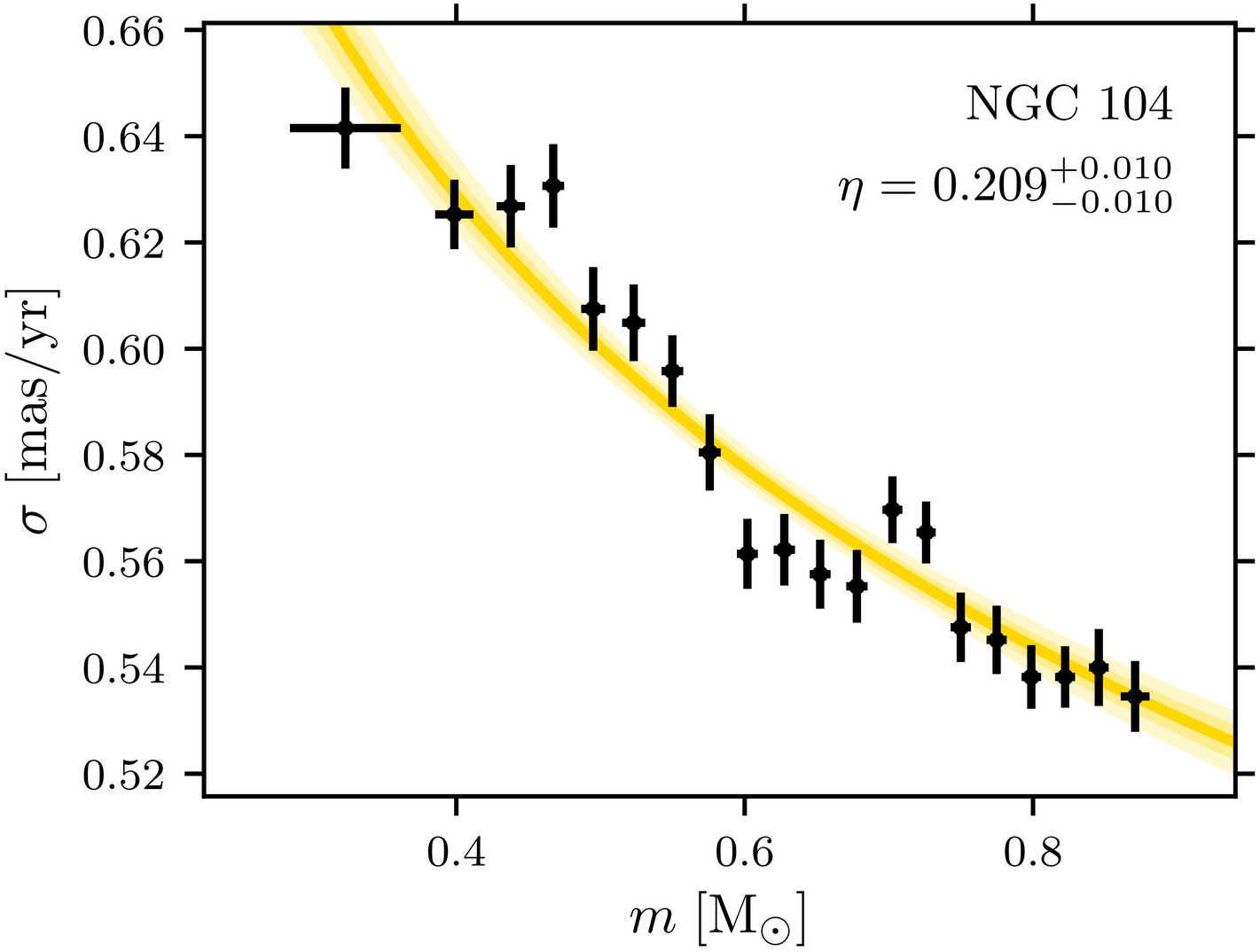
no equipartition

full equipartition

Watkins+ in prep

preliminary

HST: kinematics with stellar mass



proper motion velocity dispersion

stellar mass

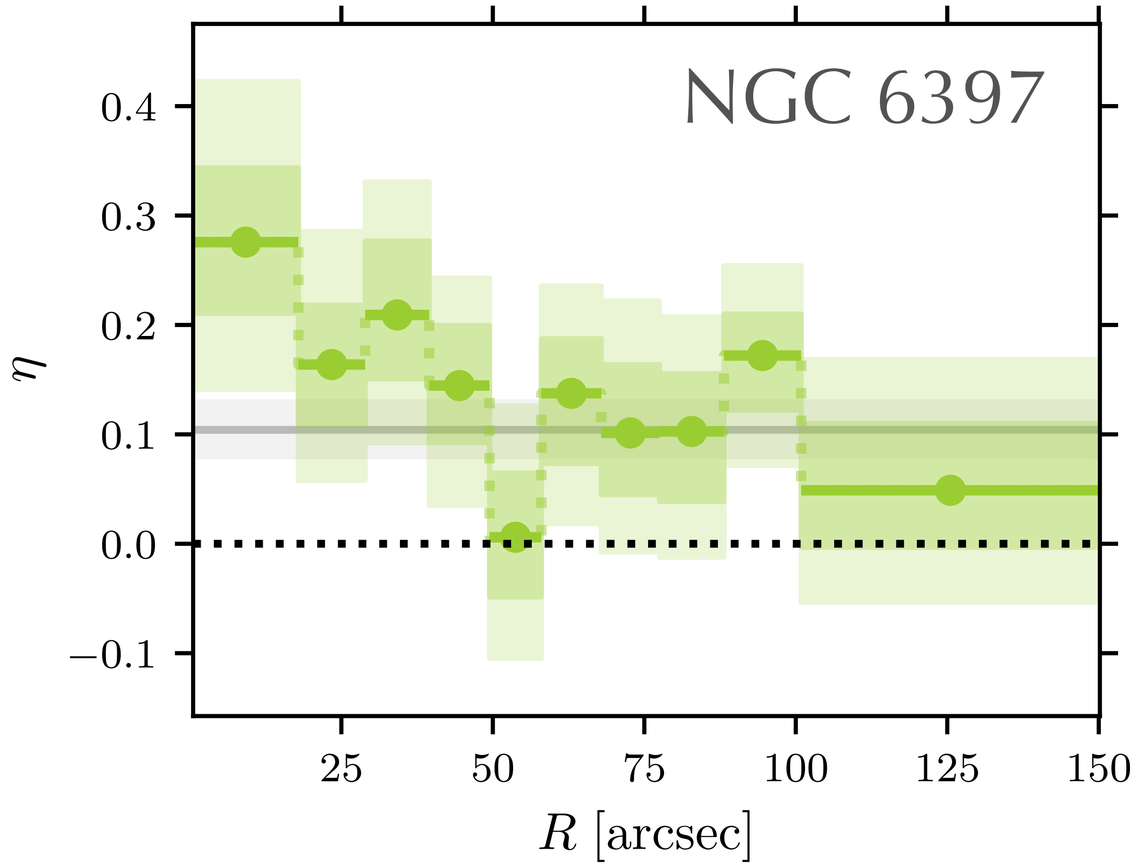
$\sigma \propto m^{-\eta}$

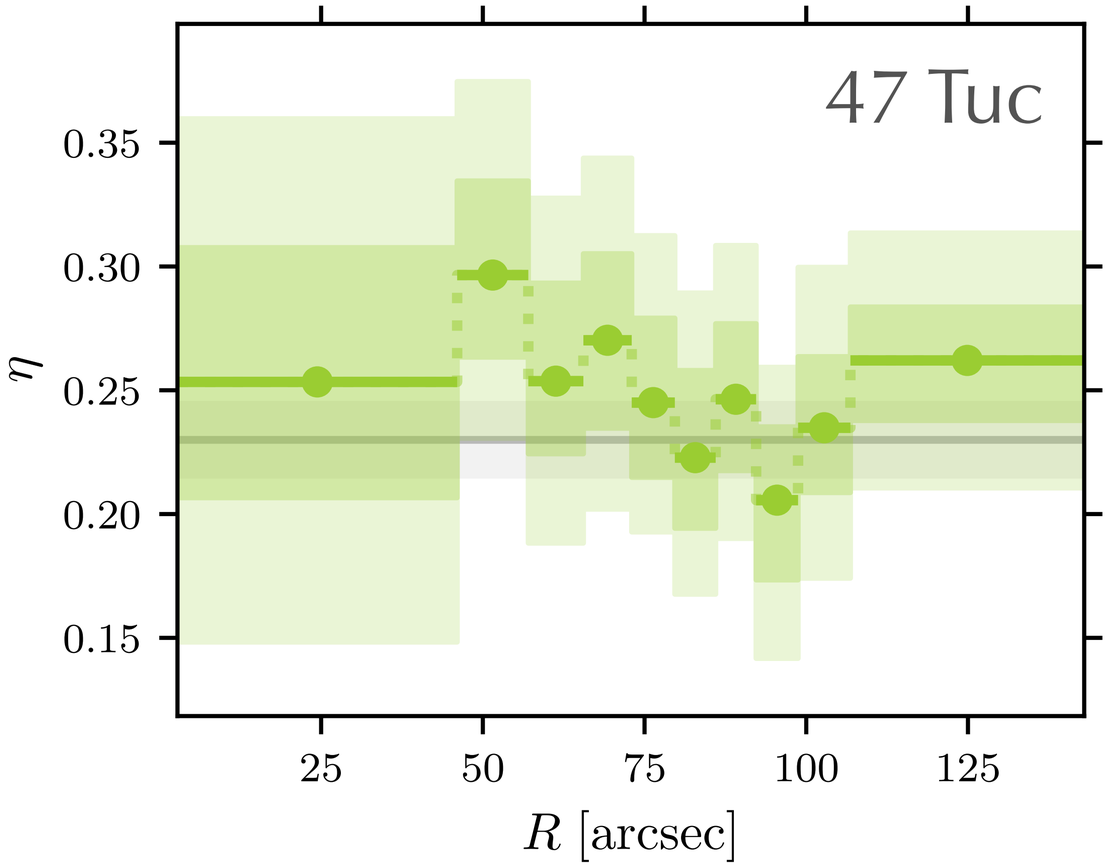
Watkins+ in prep

preliminary

HST: kinematics with stellar mass

$$\sigma \sim m^{-\eta}$$

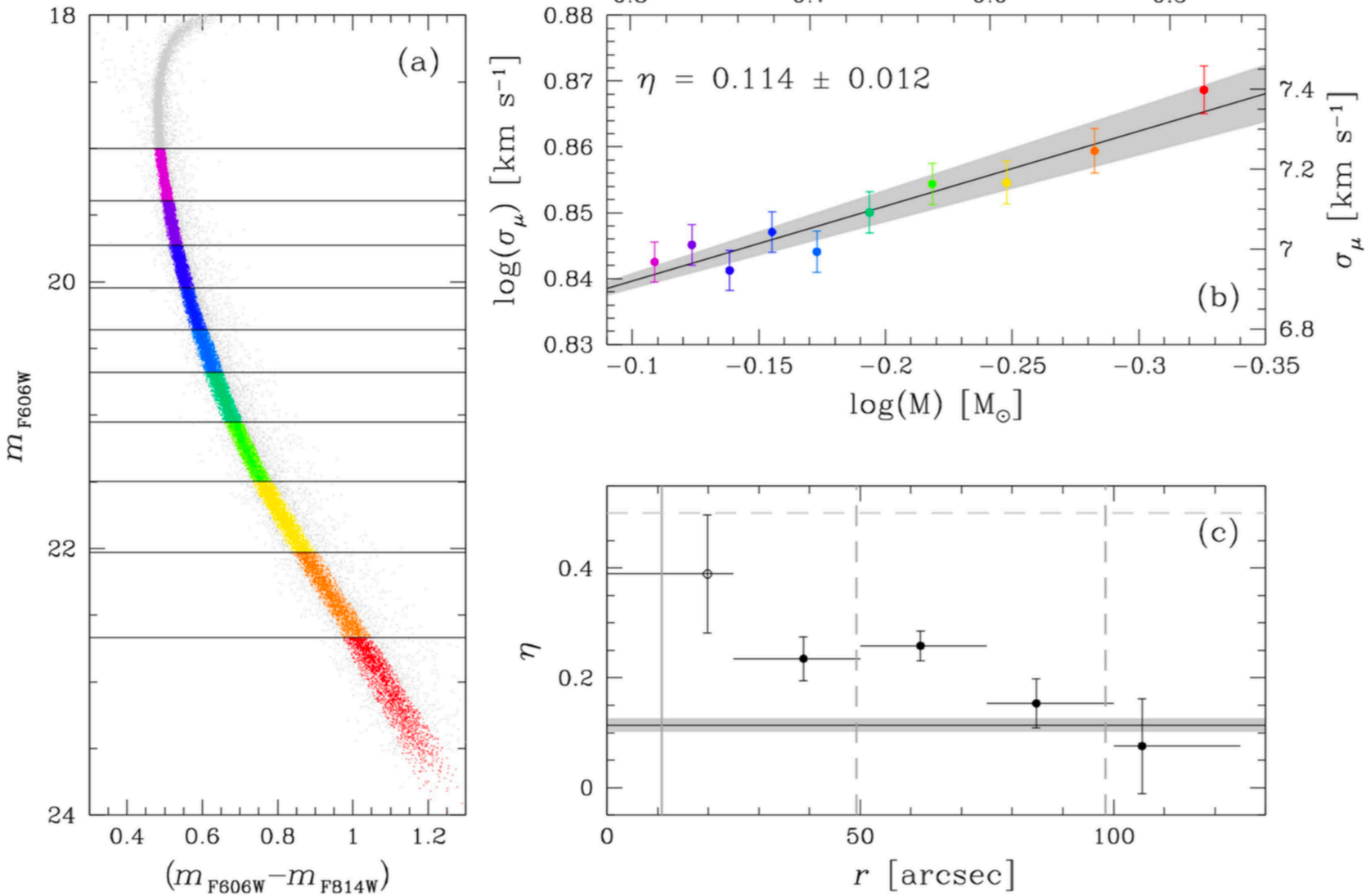




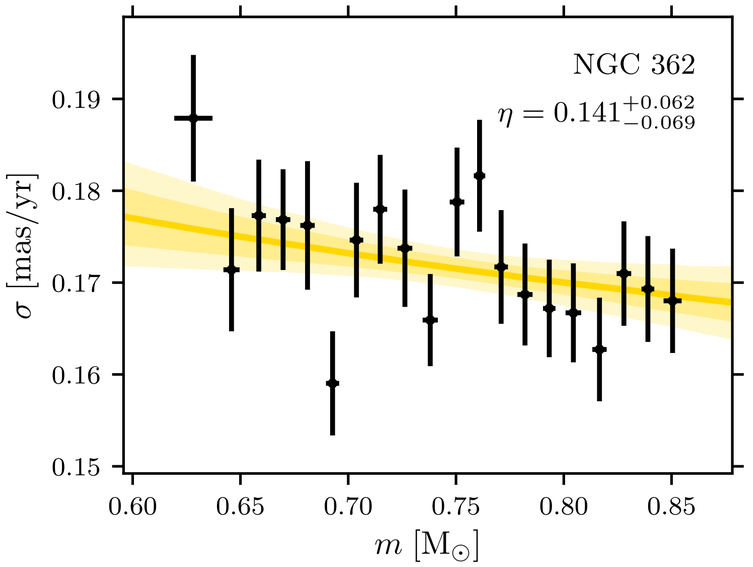
Watkins+ in prep

NGC 362

Libralato+ 2018

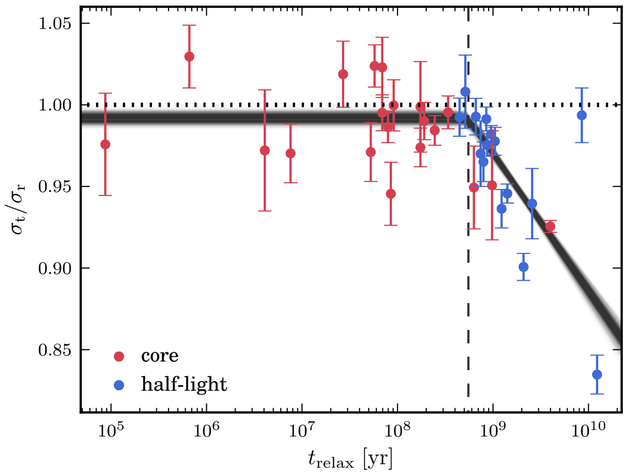


improved catalogue

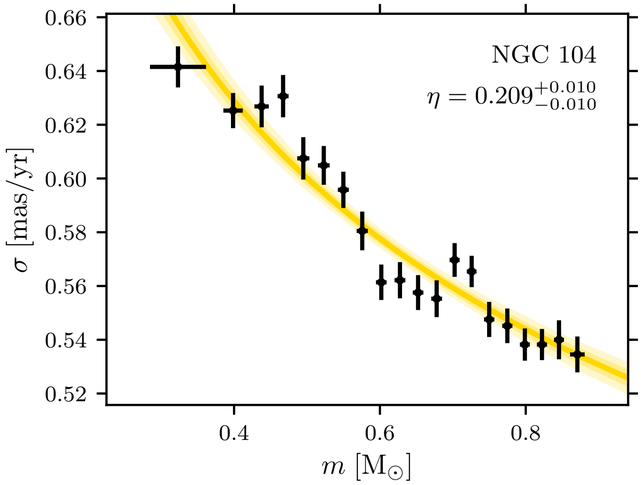


Watkins+ in prep

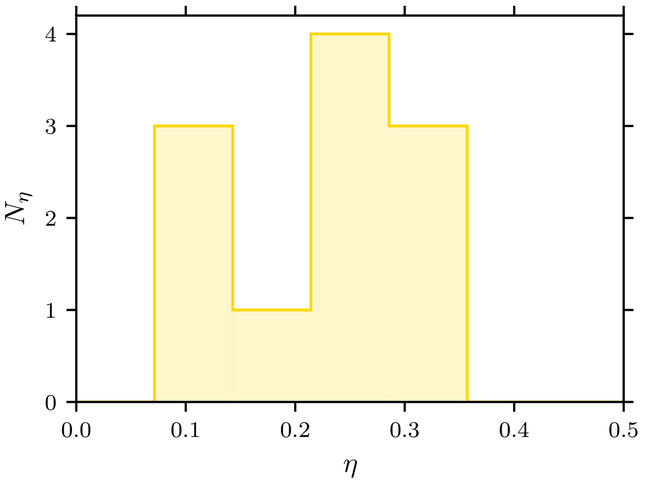
Anisotropy and energy equipartition in Milky Way GCs with HST proper motions.



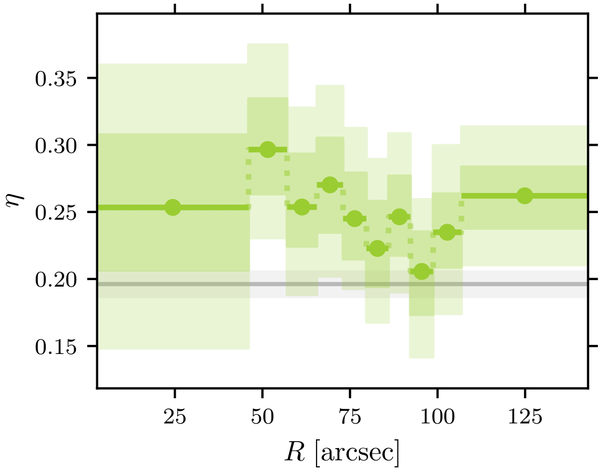
anisotropy with relaxation time



equipartition on main sequence



no full equipartition



equipartition with radius

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