Dark and luminous mass components of Omega Centauri

Addy J. Evans with Louis Strigari and Paul Zivick

Travel funded in part by the Dr. Chia-Lai Wang Memorial Scholarship

Omega Centauri: globular cluster or remnant core?

Out of known globular clusters in the Milky Way...

→ Most massive

→ Most luminous

→ Stellar stream association

→ High central velocity dispersions

Omega Centauri - NGC 5139 (credit: ESO)

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Out of known globular clusters in the Milky Way...

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Omega Centauri - NGC 5139 (credit: ESO)

Possible...

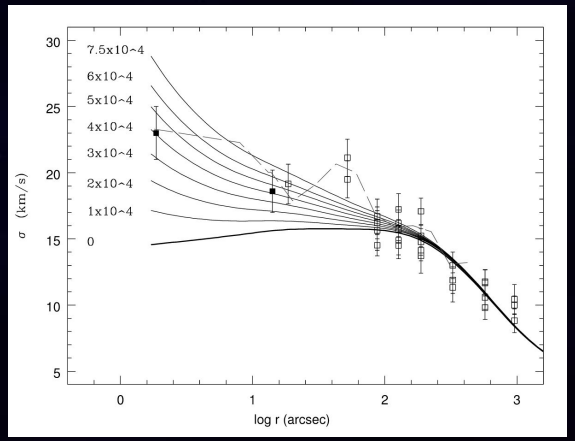
★ Intermediate mass black hole?

★ Stellar mass black holes + other stellar remnants?

★ Dark matter halo?

Mass modeling in Omega Centauri : an incomplete timeline

2008: Noyola et al.



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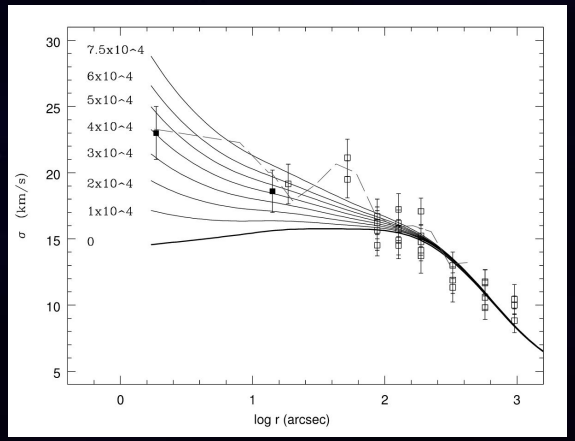

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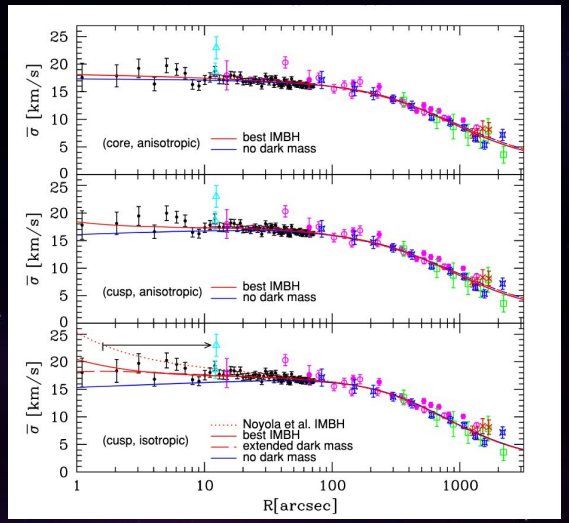

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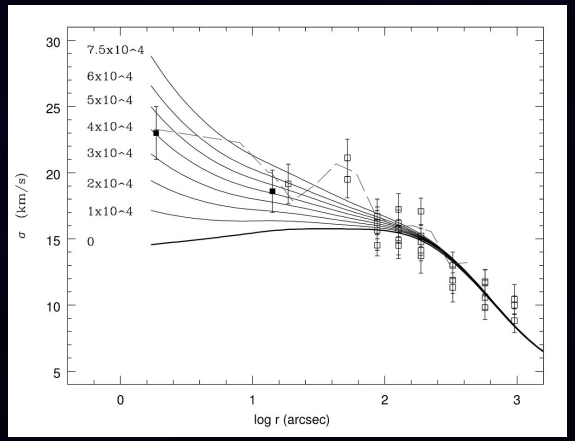

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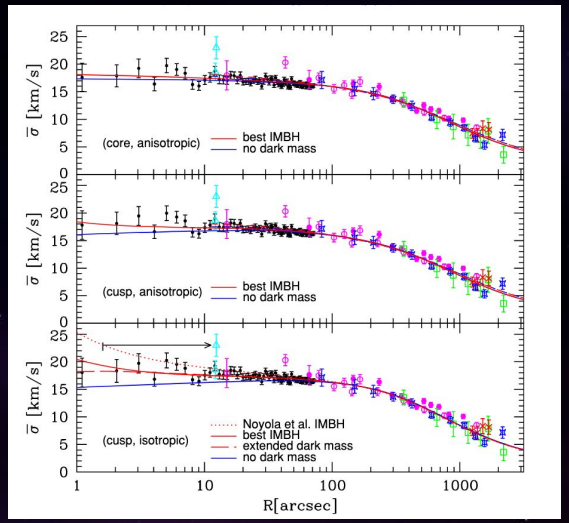

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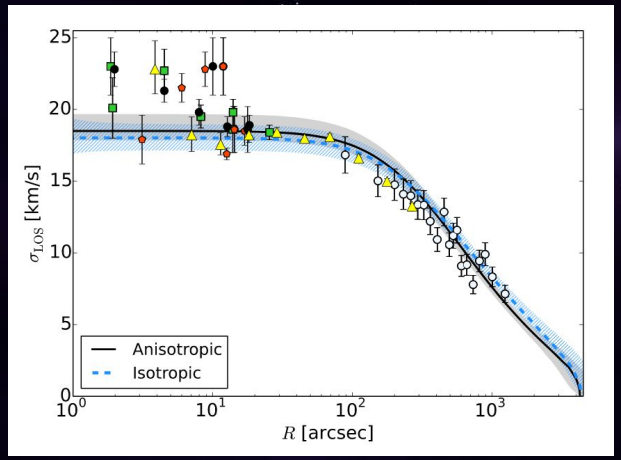

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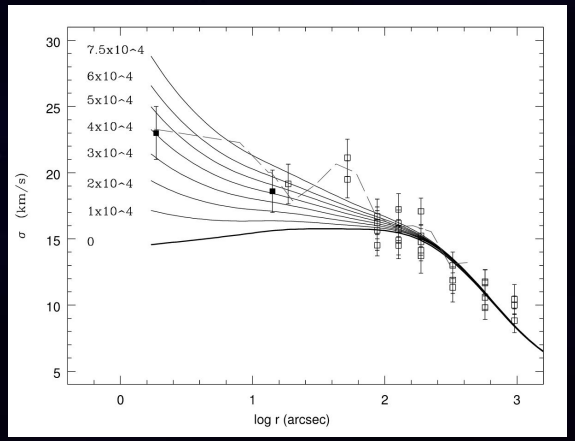

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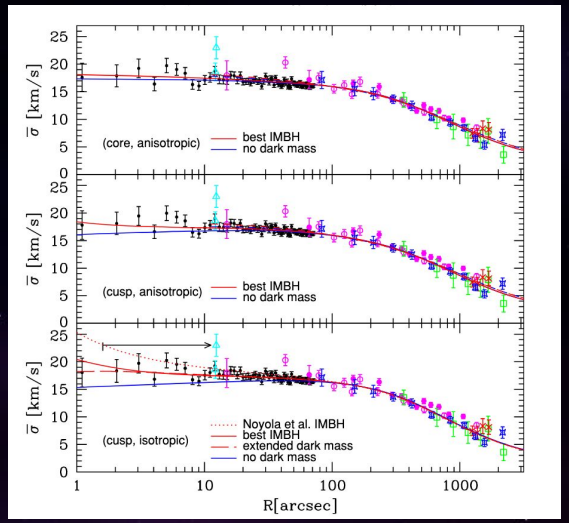

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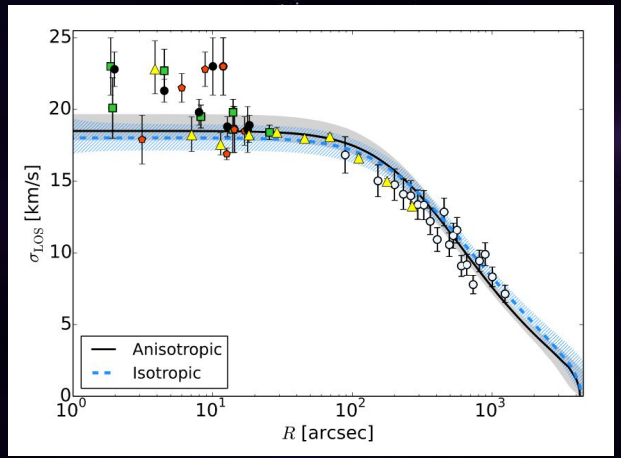

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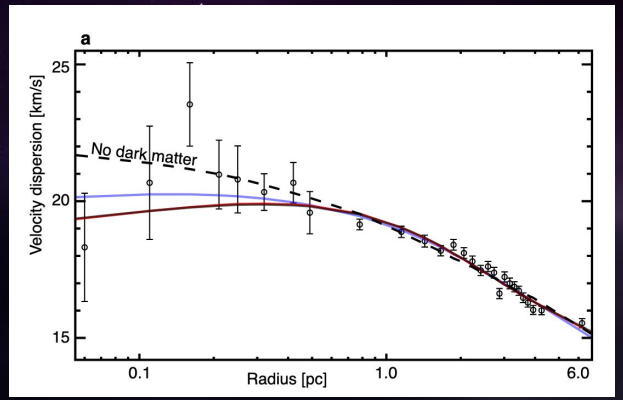
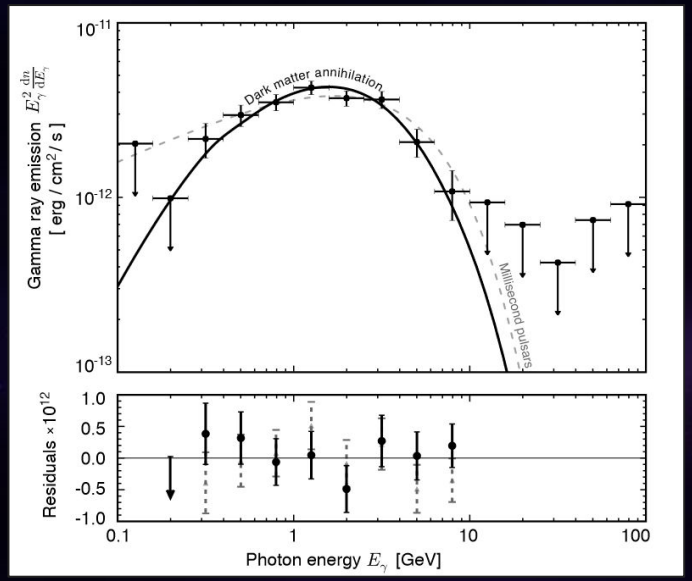


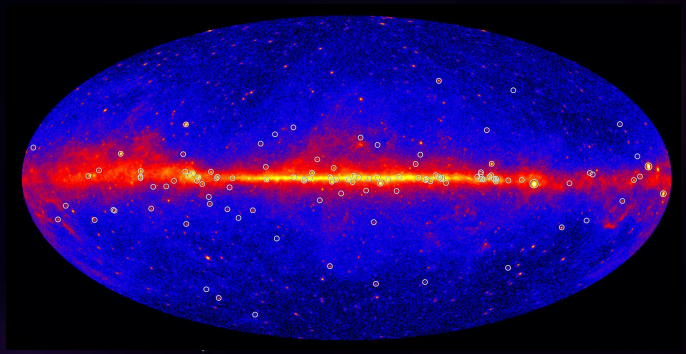
Fermi-LAT detections of Omega Centauri

→ Omega Centauri is one of the 35 Galactic globular clusters seen by the Fermi-LAT

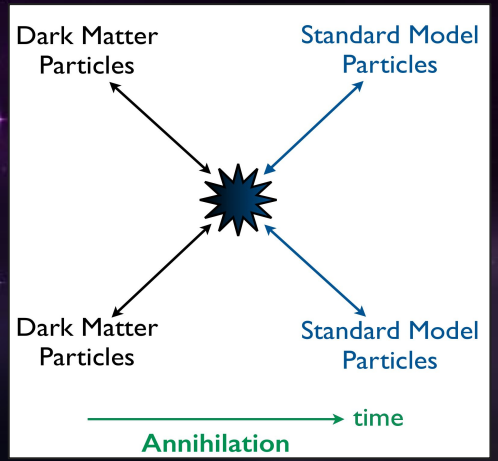
→ 5 known millisecond pulsars to date



Brown et al., 2019



NASA/Fermi-LAT Collaboration



This work

→ We test for evidence of an extended dark component in Omega Centauri's kinematics

→ This expands on previous studies by using four of the most up-to-date datasets and an axisymmetric dynamical modeling technique

→ Gamma-ray excess implications & more generally the gamma-ray emission of globular clusters is discussed

Omega Centauri - NGC 5139 (credit: ESO)

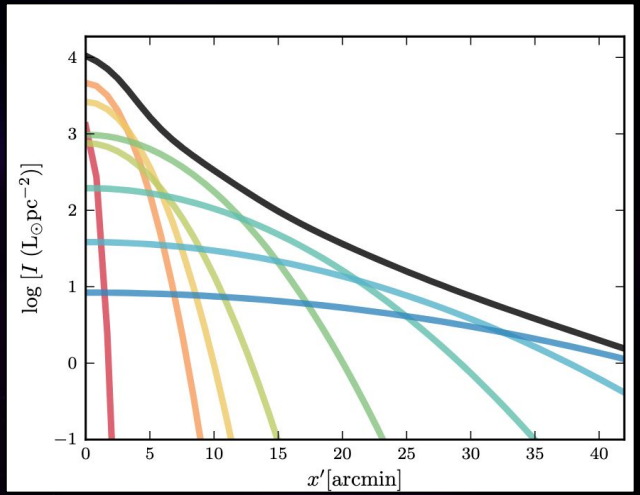
Methodology & Results

Constraining Omega Centauri's dark component: methods

CJAM - axisymmetric implementation of Jeans dynamical modeling (Watkins et al. 2013, Cappellari 2008)

→ Define gaussian components for Multi-Gaussian Expansion (MGE) description of surface brightness & mass density profiles

→ CJAM performs first and second velocity moment calculations using MGE descriptions and stellar positions



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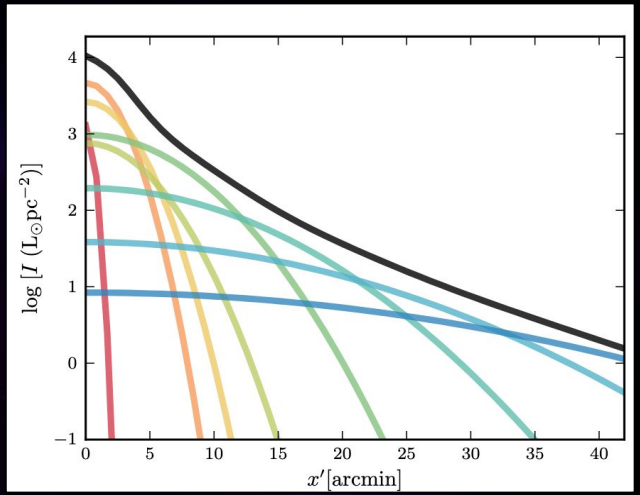
MultiNest - Bayesian inference to determine best fit parameters (Buchner 2016)

→ Provide a dataset and model to create new datasets (CJAM)

→ Specify free parameters and max likelihood equation

→MultiNest returns best fit parameters



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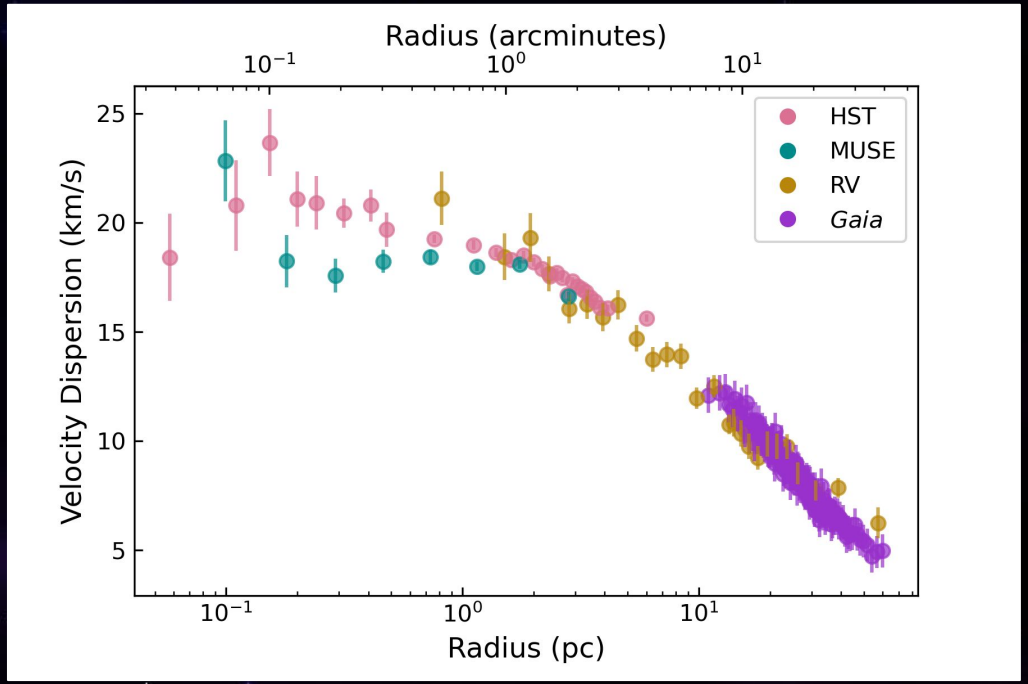
Constraining Omega Centauri's dark component: data



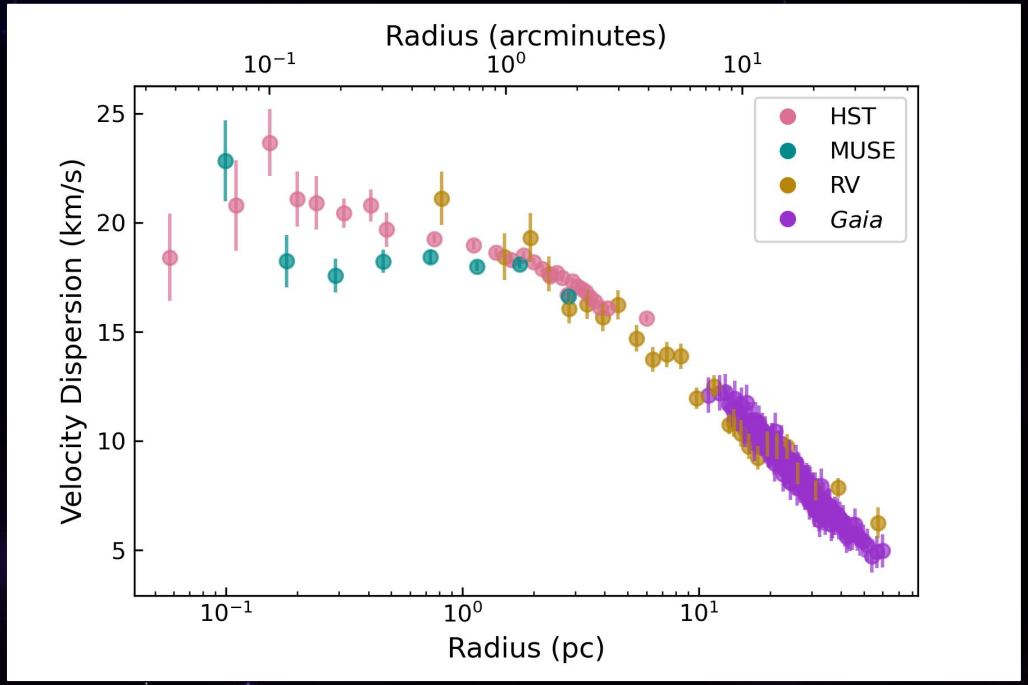
A.J. Evans et al., 2022

Constraining Omega Centauri's dark component: data

Proper motion dispersions:

→ HST (Bellini et al. 2013, Watkins et al. 2015)

→ GEDR3 (Vasiliev & Baumgardt 2021, this work)



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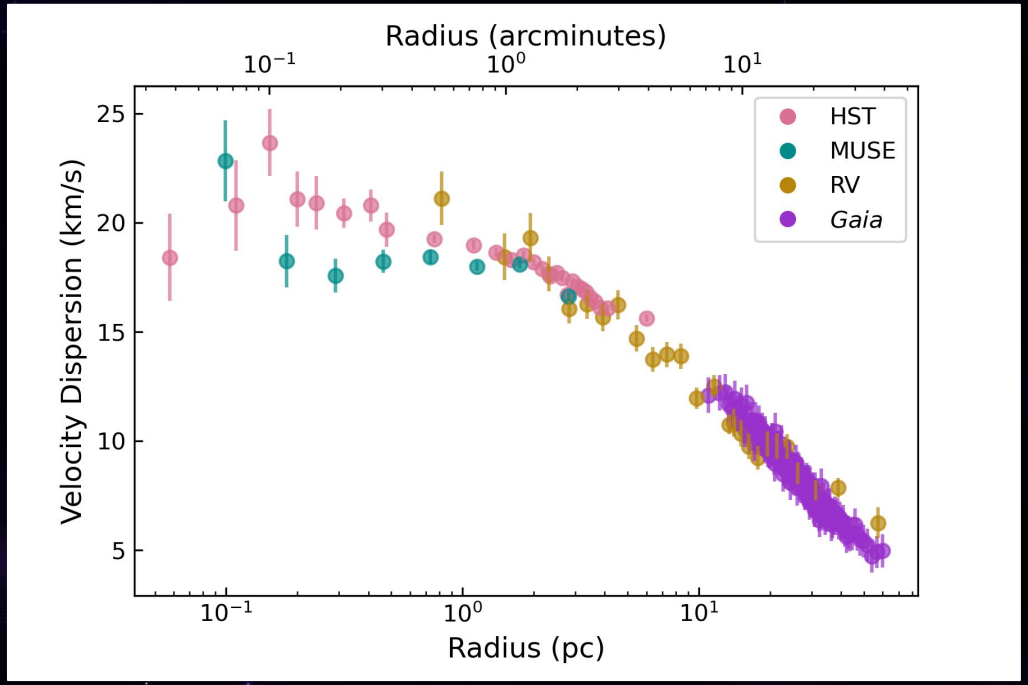
Line-of-sight dispersions:

→ MUSE (Kamann et al. 2018)

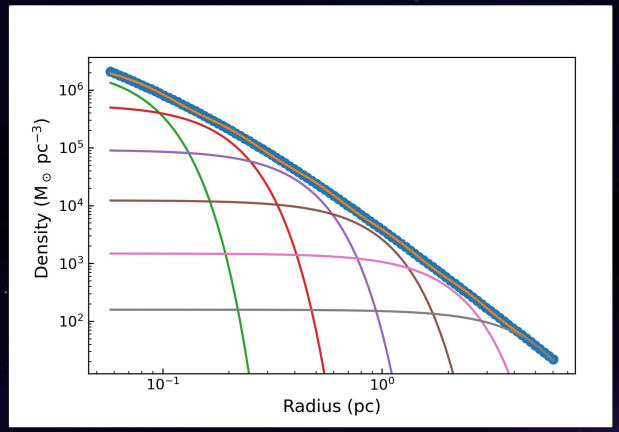
→ RV (Baumgardt 2017, Baumgardt & Hilker 2018)



A.J. Evans et al., 2022

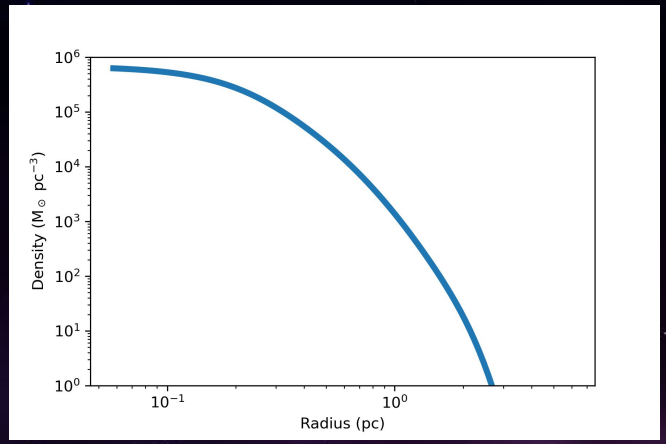
Using CJAM+MultiNest to describe a DM density profile

1) NFW profile



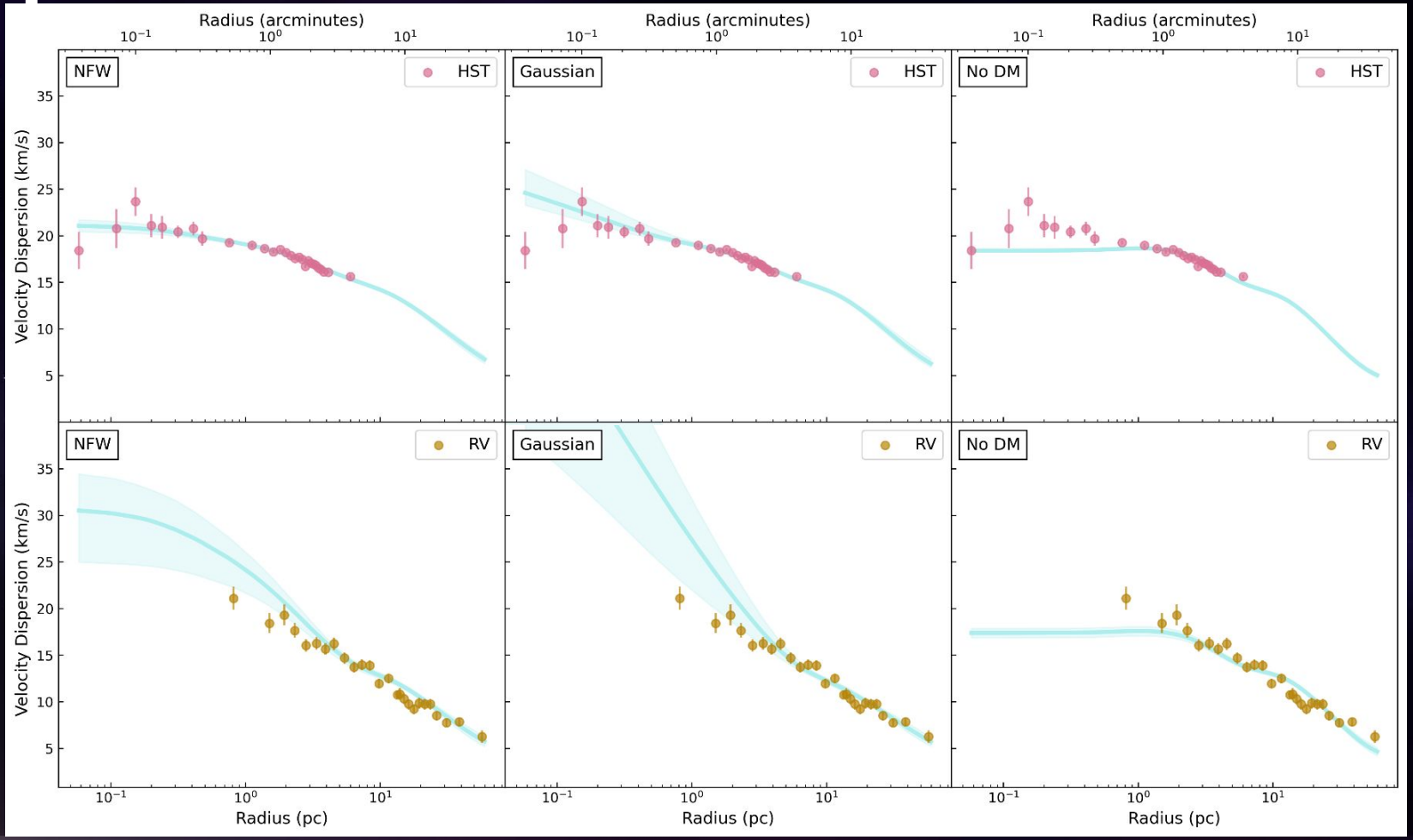
A.J. Evans et al., 2022

2) Gaussian profile



Using these density profiles, we compare models with a dark component versus models with no dark component

Dispersion fit results



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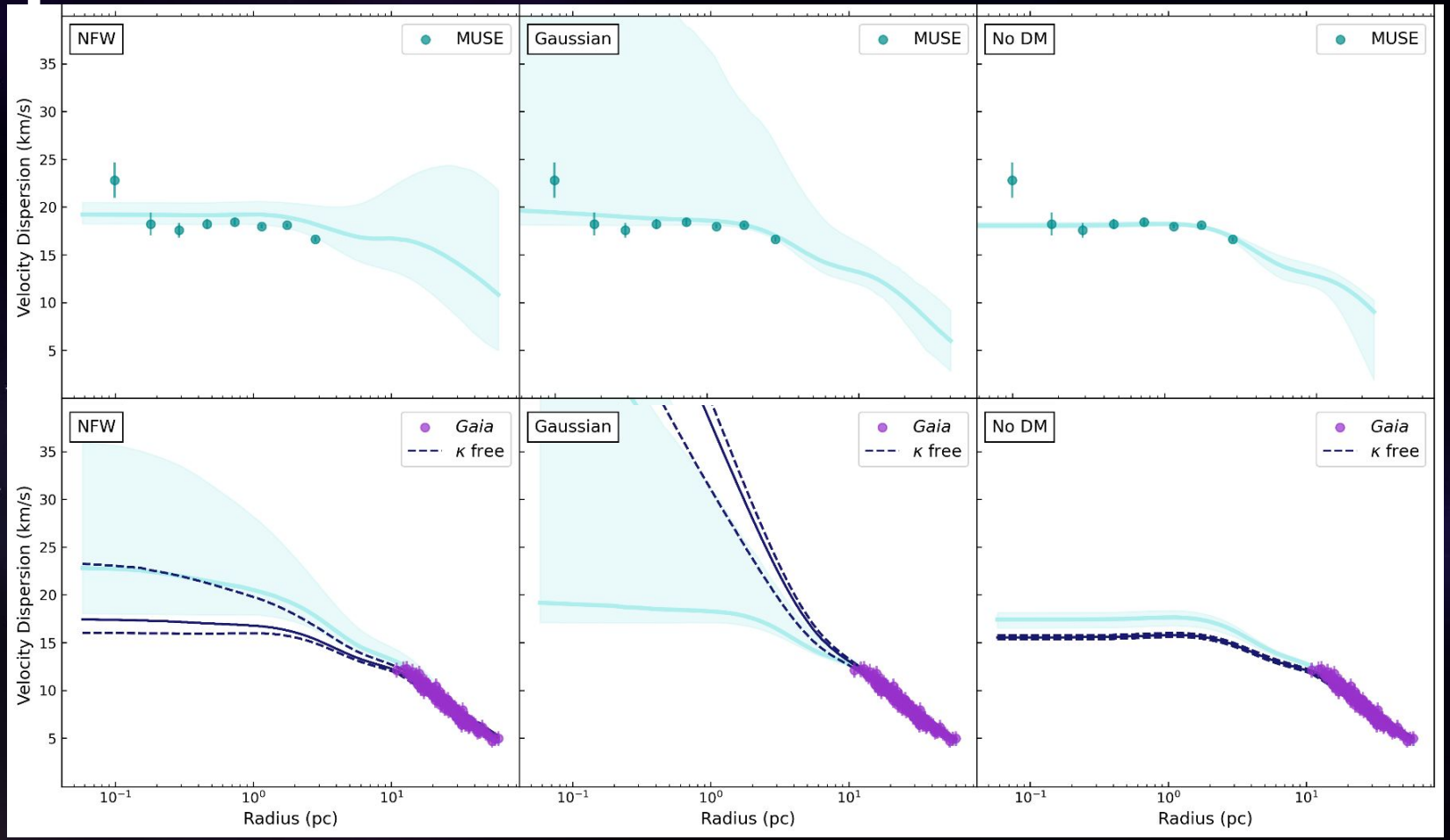

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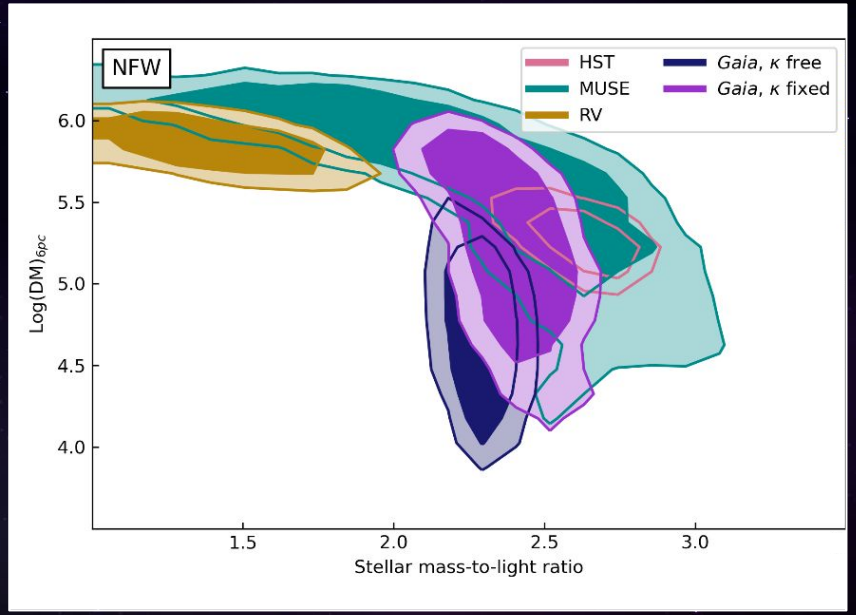
Dark mass results



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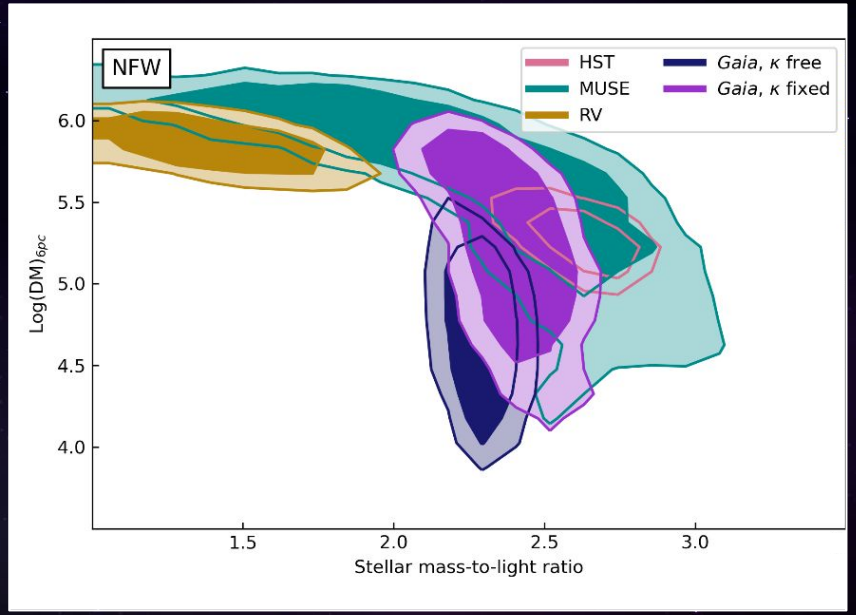
Our analysis shows that the kinematics are consistent with the existence of a centrally concentrated dark mass component with a mass up to 10^6 solar masses.

Dark mass results



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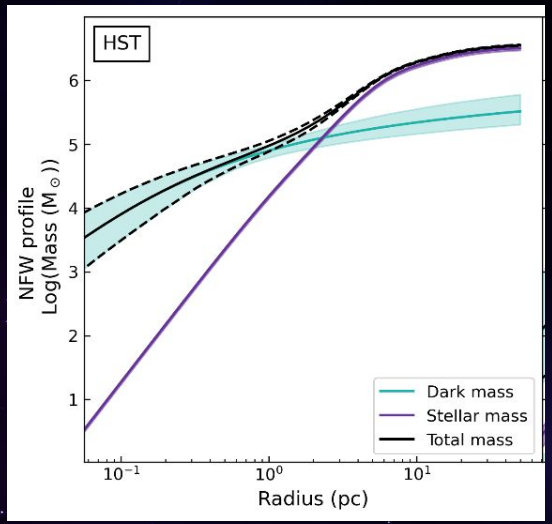

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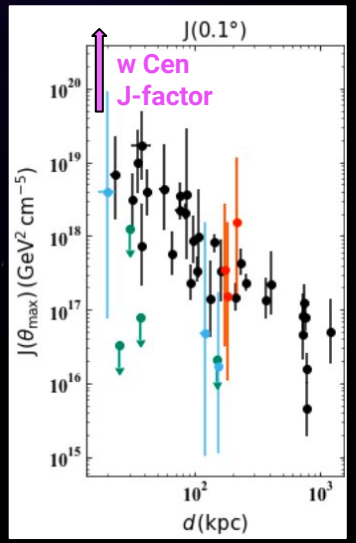
J-factor results & implications

→ The J-factor is a way to estimate the strength of signal of annihilating DM, which is dependent on the distance to the source and the density of the DM halo.

→ Depending on the dataset, for an NFW profile we calculate a J-factor of ~ 10^{22} - 10^{24} GeV^2 / cm^5, which is larger than any known dwarf galaxy.



Pace & Strigari, 2019

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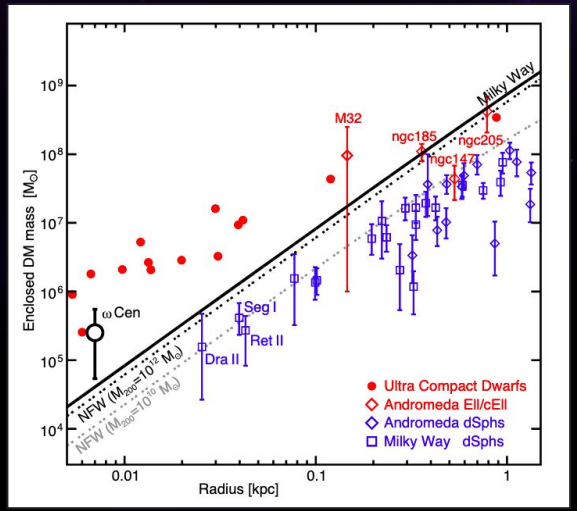
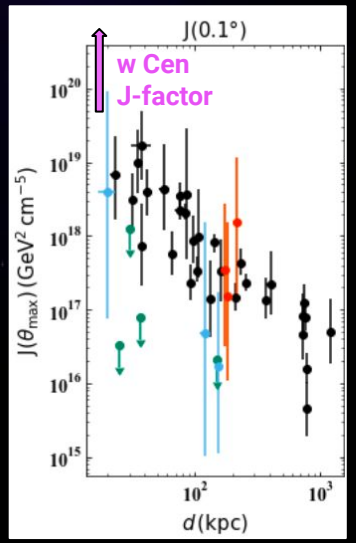
→ Based on Omega Centauri's estimated dark mass and its half-light radius, Omega Centauri most closely resembles an ultra compact dwarf galaxy



Brown et al., 2019



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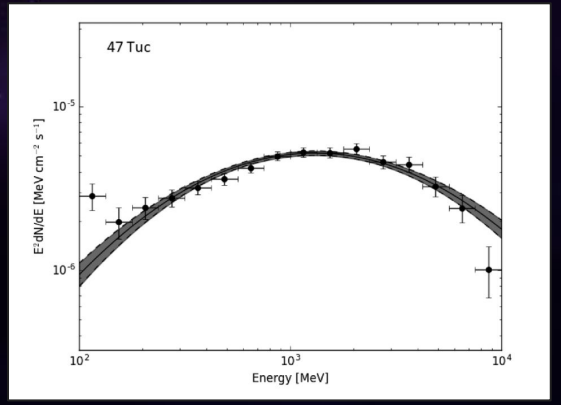
Current work

Understanding the gamma-ray emission of globular clusters

→ The gamma-ray emission of globular clusters is often attributed to millisecond pulsars

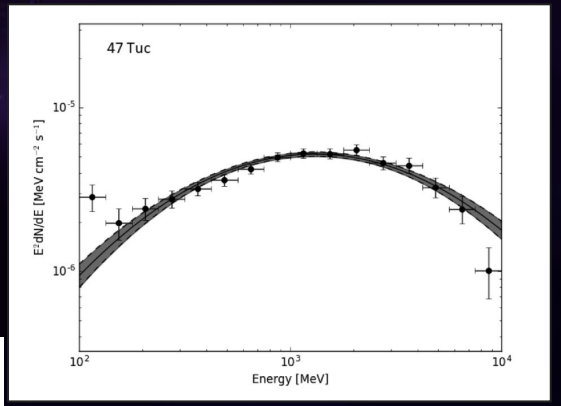


Lloyd et al., 2018

Understanding the gamma-ray emission of globular clusters

→ The gamma-ray emission of globular clusters is often attributed to millisecond pulsars

→ Are millisecond pulsar populations the sole source of gamma-ray emission in globular clusters?



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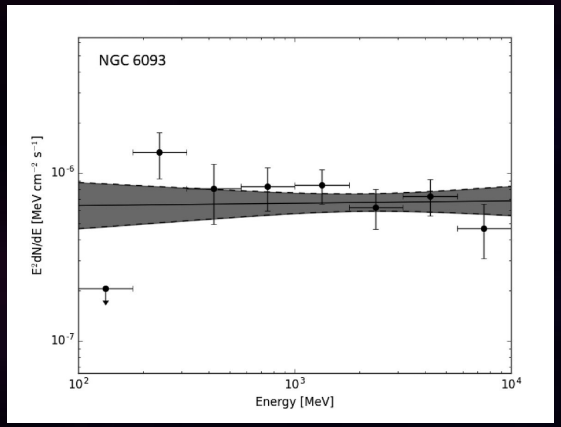
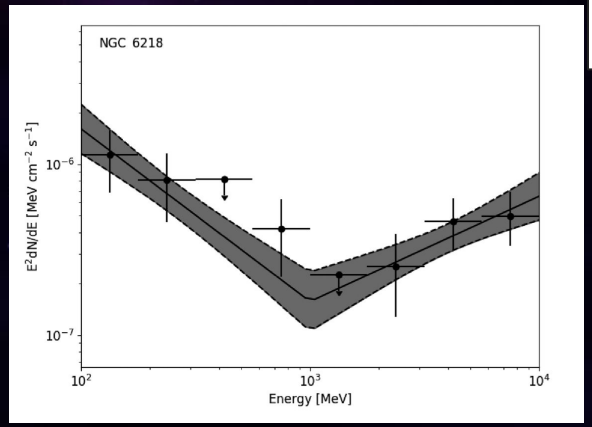
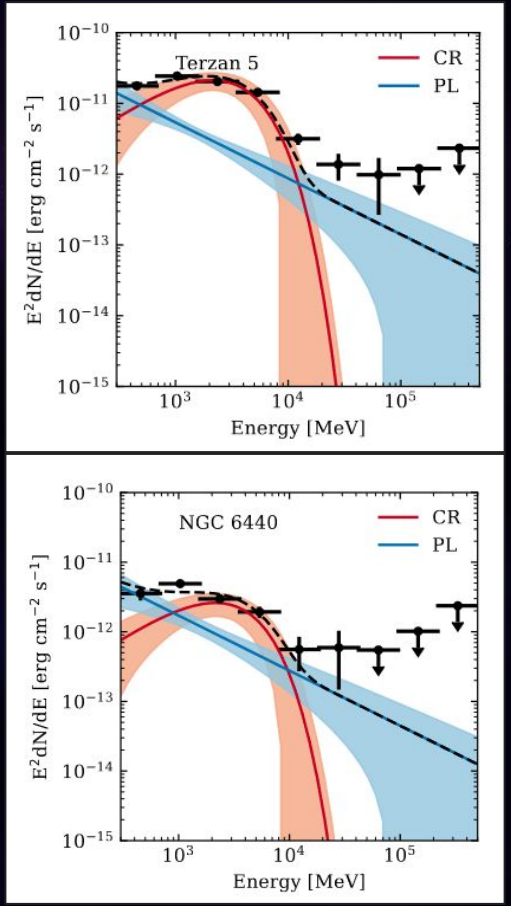




Understanding the gamma-ray emission of globular clusters by going to higher energies

→ We can learn more about possible sources of gamma-ray emission by looking in different energy regimes



Song et al., 2021

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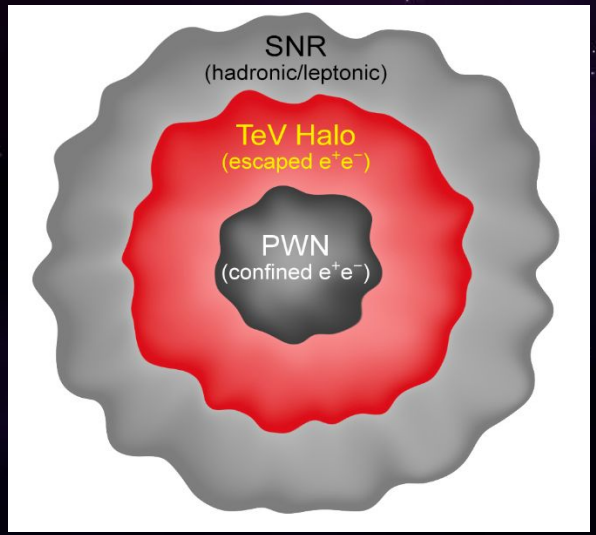
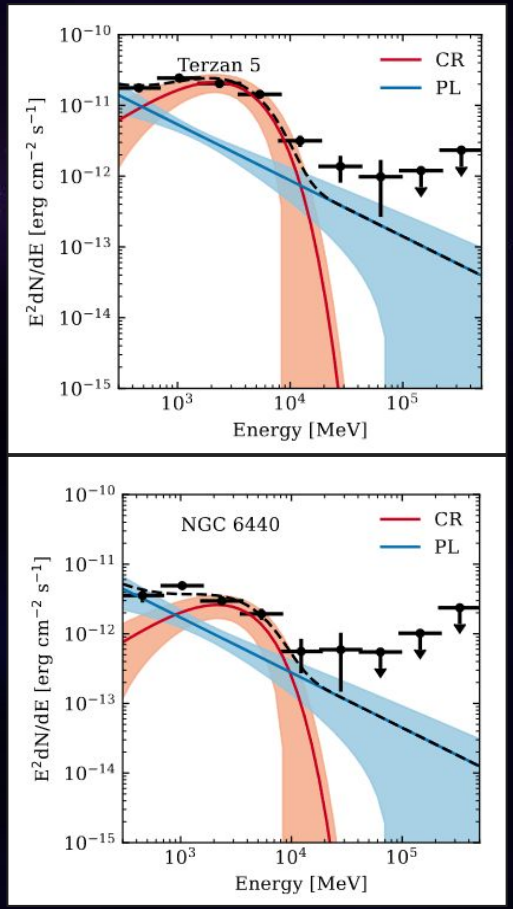


Sudoh, Linden, and Beacom 2019



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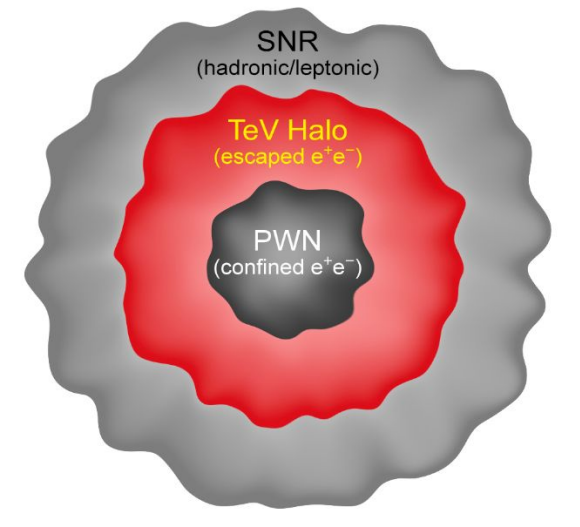

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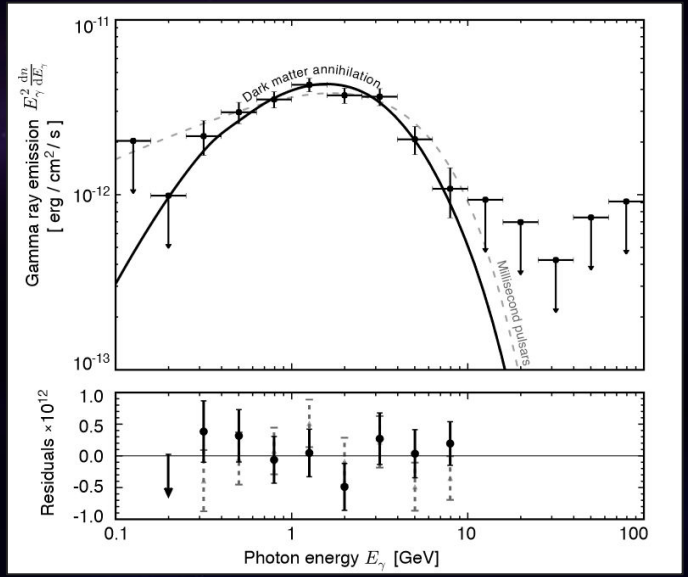


Brown et al., 2019

Summary

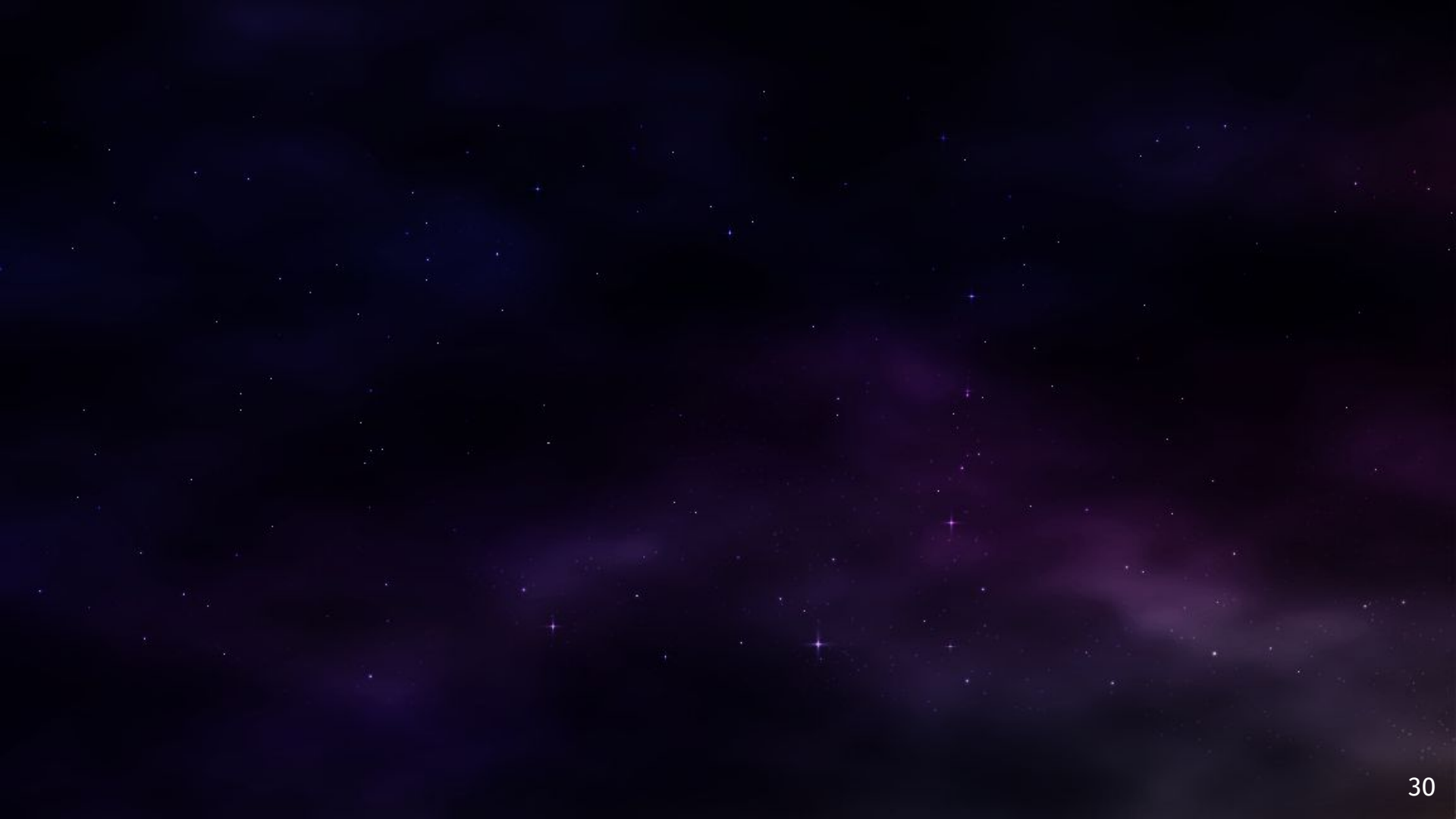
→ We use four up-to-date datasets combined with axisymmetric & anisotropic dynamical Jeans modeling to constrain the properties of Omega Centauri's dark, massive component

→ We find evidence for an extended dark component of up to 10^6 solar masses

→ Using our derived density profiles, we estimate the possible strength of signal due to annihilating dark matter and find a J-factor 2-4 orders of magnitude higher than for any known dwarf galaxy

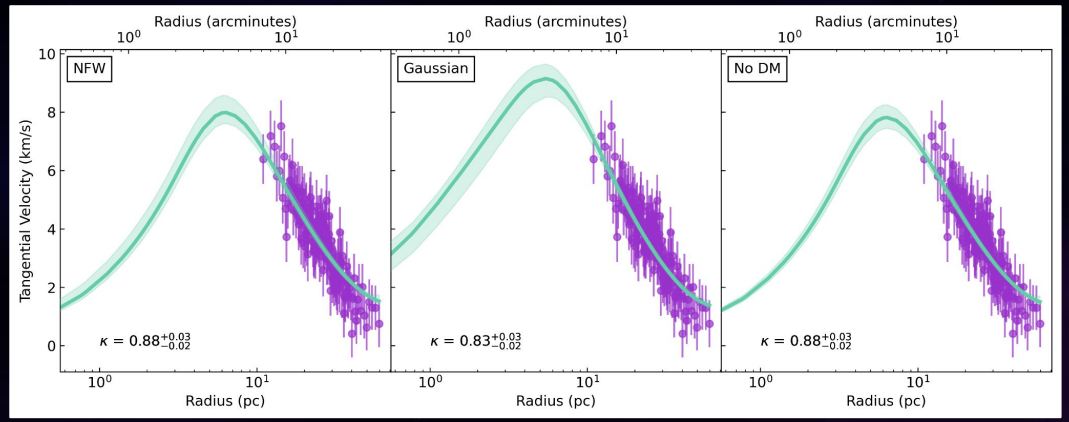
→ The high-energy emission of globular clusters holds information on the physics of millisecond pulsars and other possible gamma-ray sources – stay tuned!

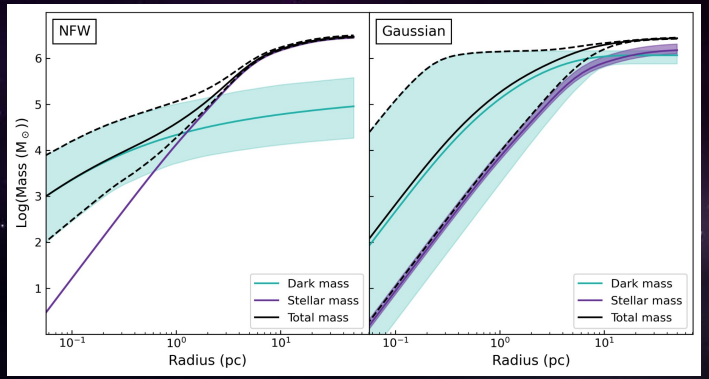
Stay in touch :)
addyevans@tamu.edu

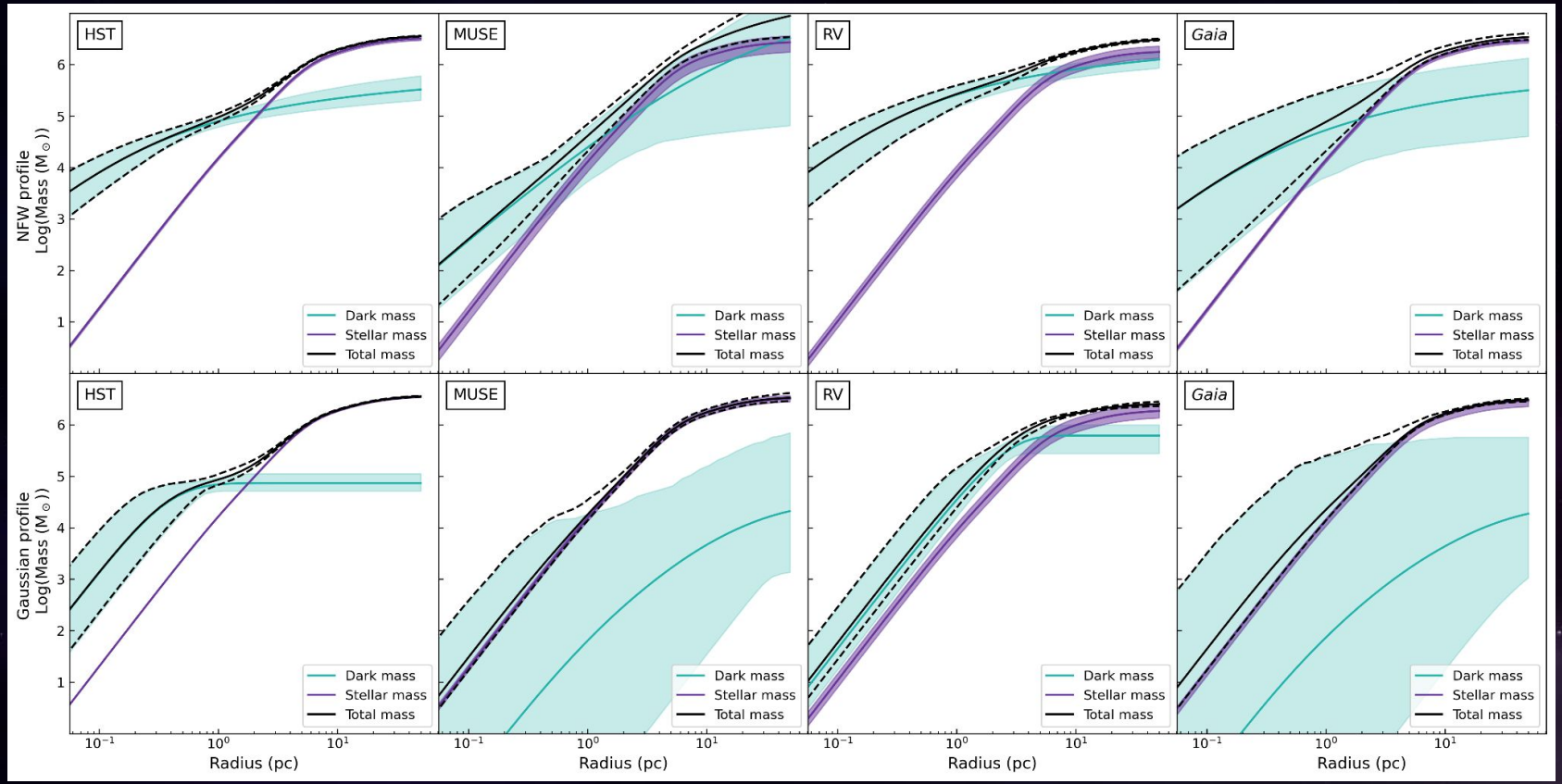


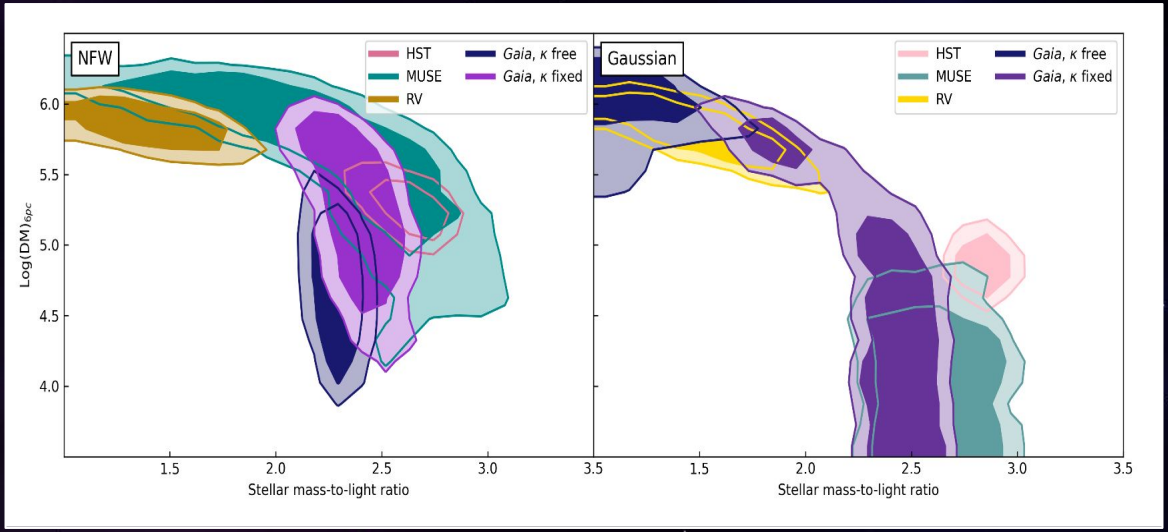
Extras

Tangential velocity fit results






HST
MUSE
RV
Gaia
NFW profile
Log(Mass (M⊙))
Gaussian profile
Log(Mass (M⊙))
Dark mass
Stellar mass
Total mass
Radius (pc)


NFW
HST
MUSE
RV
Gaia, κ free
Gaia, κ fixed
Gaussian
HST
MUSE
RV
Gaia, κ free
Gaia, κ fixed
Log(DM)$_{6pc}$
6.0
5.5
5.0
4.5
4.0
1.5
2.0
2.5
3.0
3.5
Stellar mass-to-light ratio
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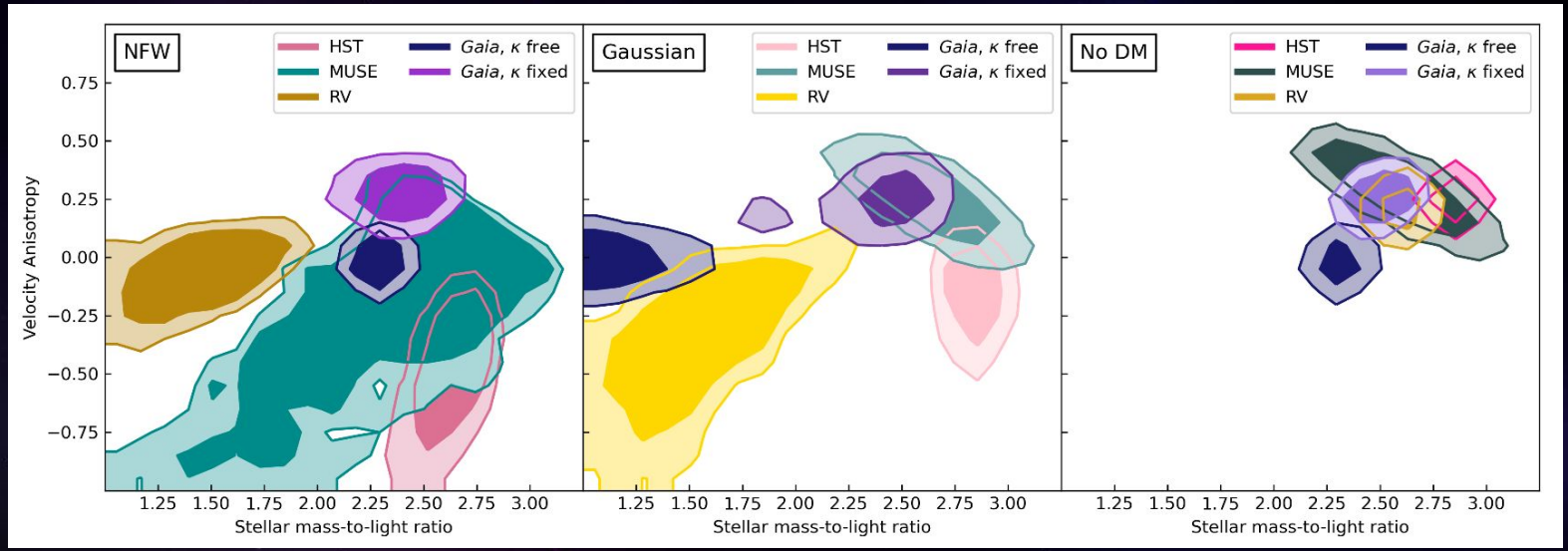
NFW
HST
MUSE
RV
Gaia, κ free
Gaia, κ fixed
Gaussian
HST
MUSE
RV
Gaia, κ free
Gaia, κ fixed
No DM
HST
MUSE
RV
Gaia, κ free
Gaia, κ fixed
Velocity Anisotropy
0.75
0.50
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1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00
Stellar mass-to-light ratio
1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00
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