INDIANA UNIVERSITY
BLOOMINGTON

Painting by Alina Böcker

Dynamical mixing of multiple populations in globular clusters

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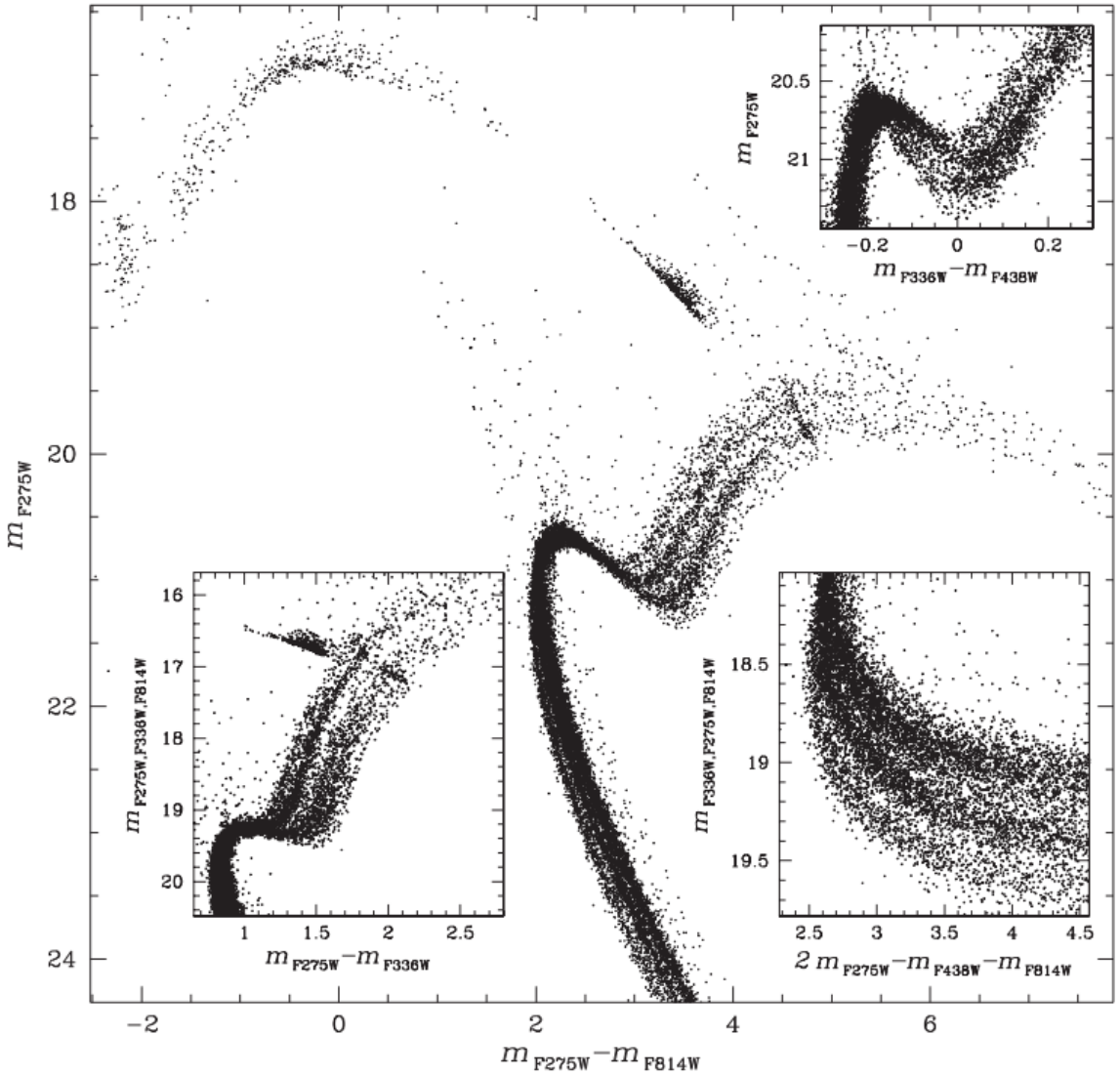
In collaboration with Enrico Vesperini, Alexander Livernois, Emanuele Dalessandro & Tuila Ziliotto

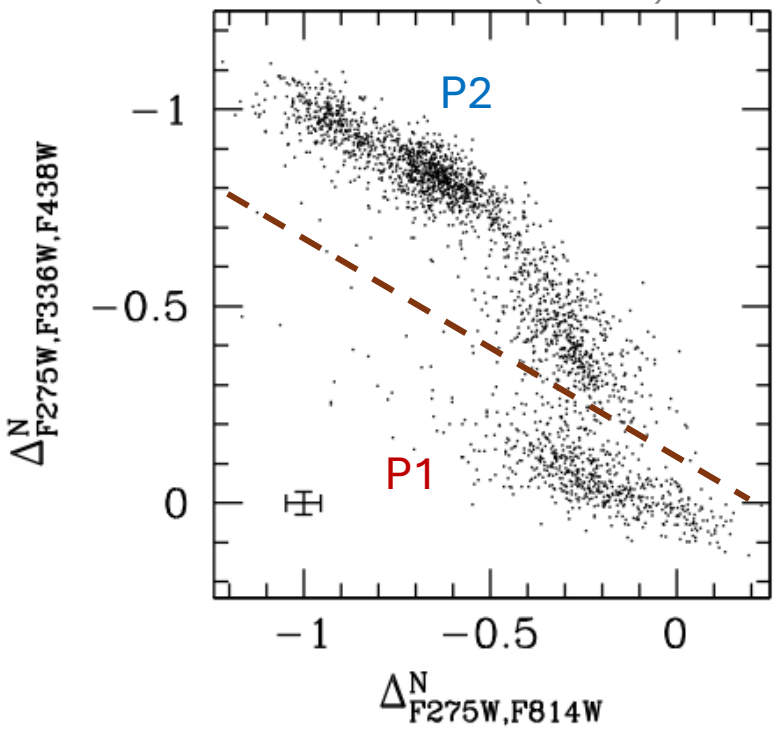
MODEST 24 – August 20 Warsaw.

Multiple populations in GCs

NGC 2808 – Milone et al. (2015)



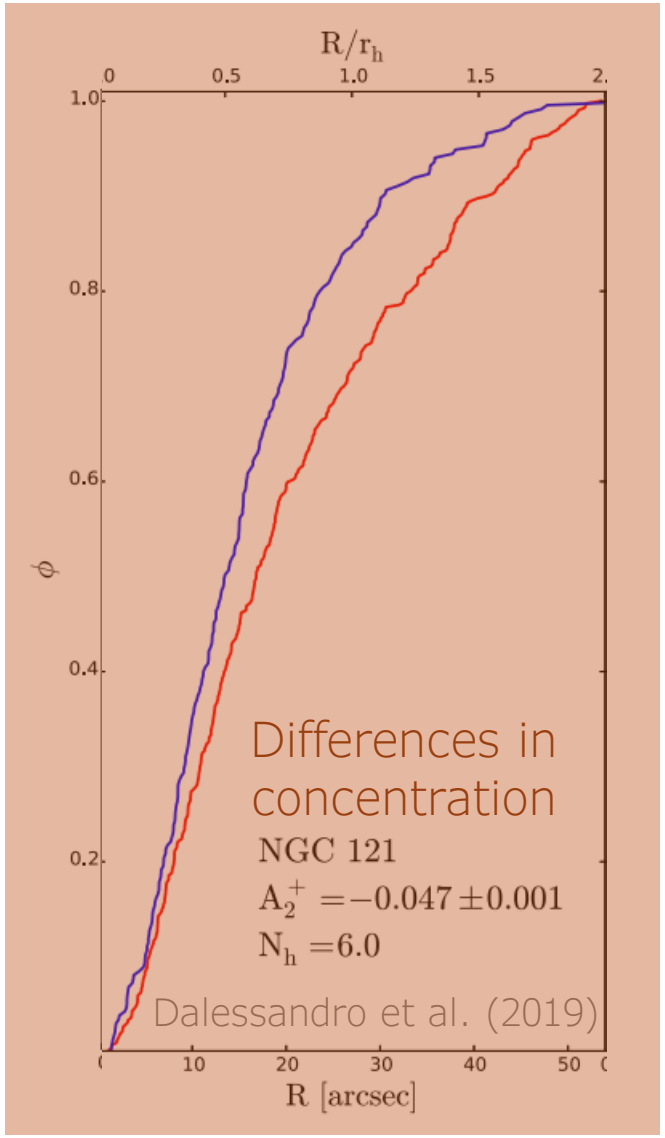
Milone et al. (2015)



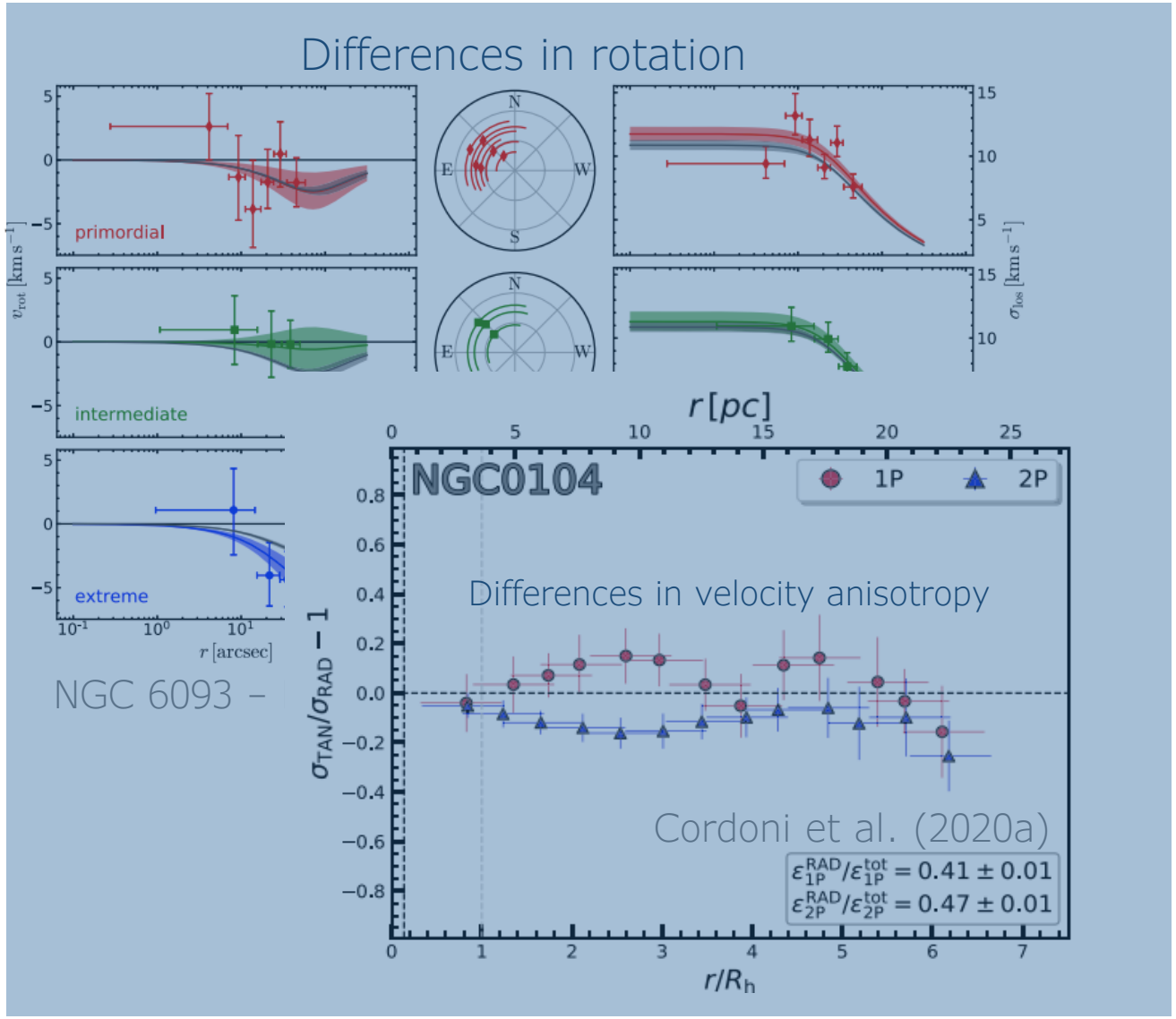
See reviews by Gratton, Sneden & Carreta (2014); Bastian & Lardo (2018). Works by Piotto et al (2015); Milone et al. (2015); Milone et al. (2017)

Structural & Kinematic differences of MPOP in GCs

SPATIAL MIXING



KINEMATIC MIXING



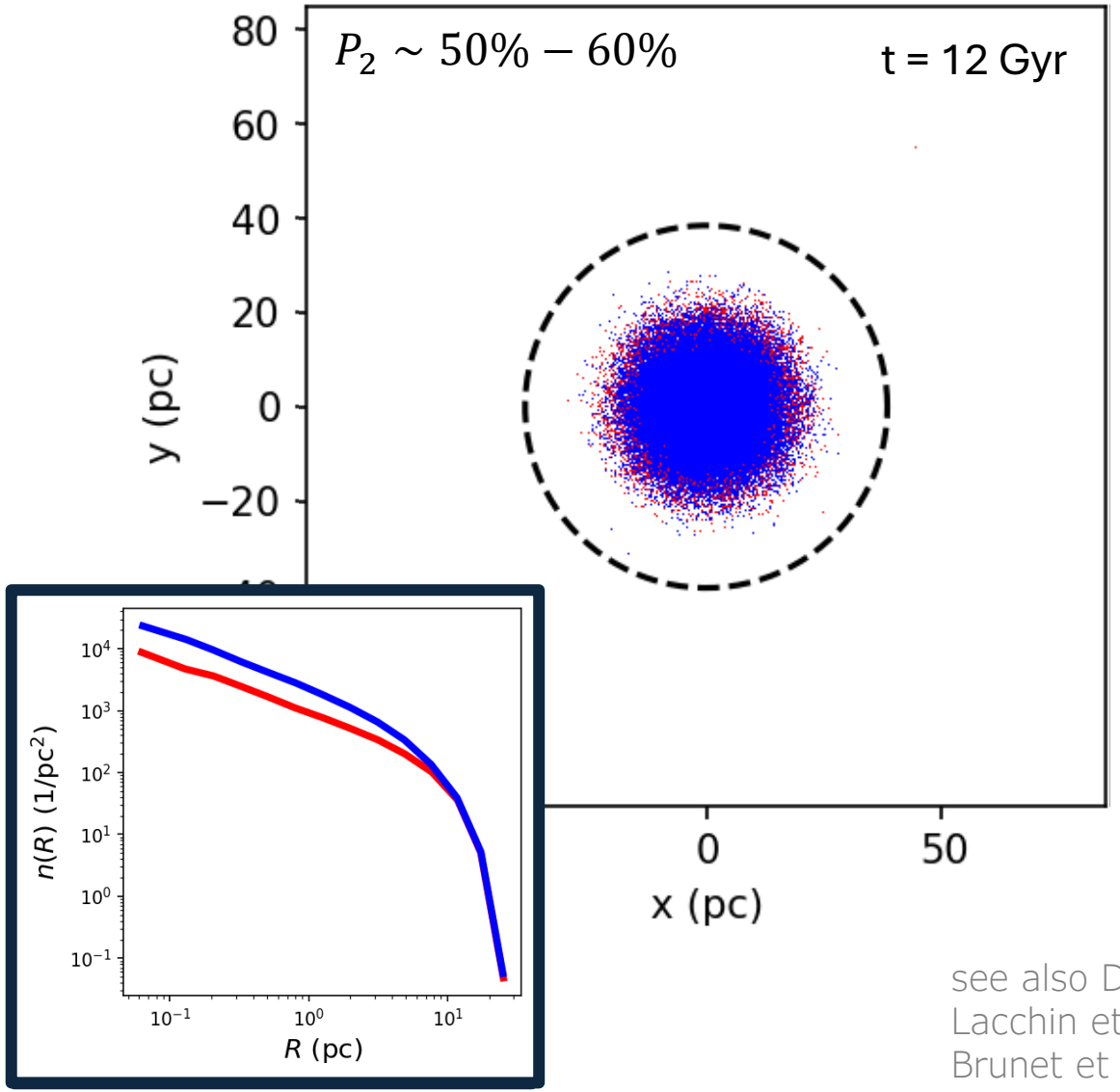
see also Richer et al. (2013); Bellini et al. (2015,2018); Cordero et al. (2017); Milone et al. (2018); Libralato et al.(2019); Cordoni et al. (2020a,b); Dalessandro et al. (2021); Leitinger et al. (2023)

Numerical simulations

see Vesperini et al. (2021), Livernois et al. (submitted) , Aros et al. (in prep)

MOCCA

Giersz et al. (2013); Hypki et al. (2013)



Initial concentration > $r_{h,P1}/r_{h,P2}$ = 20,10

Number of stars > 2M, 1M, 500K

Tidal field > strong, weak

Primordial anisotropy > isotropic, O-M anisotropy

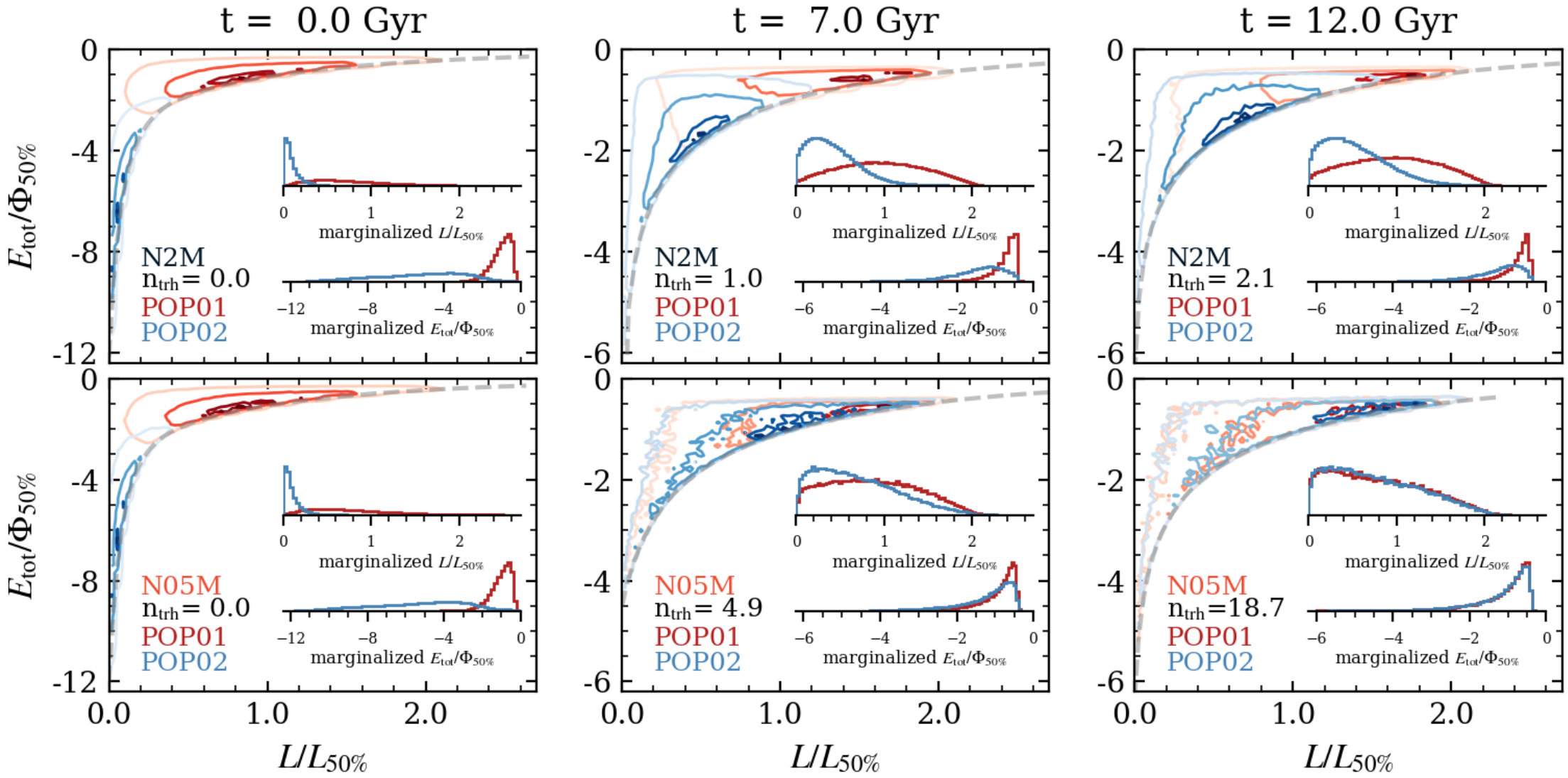
Non-rotating!

For the effects of rotation in GCs with MPOP see the virtual poster presentation by Ethan White!

see also D'Ercole et al. (2008); Bekki (2011); Bekki et al. (2017); Calura et al. (2019); Lacchin et al. (2021, 2022) and Mastrobuono-Battisti & Perets (2013, 2016); Hénault-Brunet et al. (2015); Tiongco et al. (2019); Vesperini et al. (2021); Sollima (2021).

Mixing in phase-space

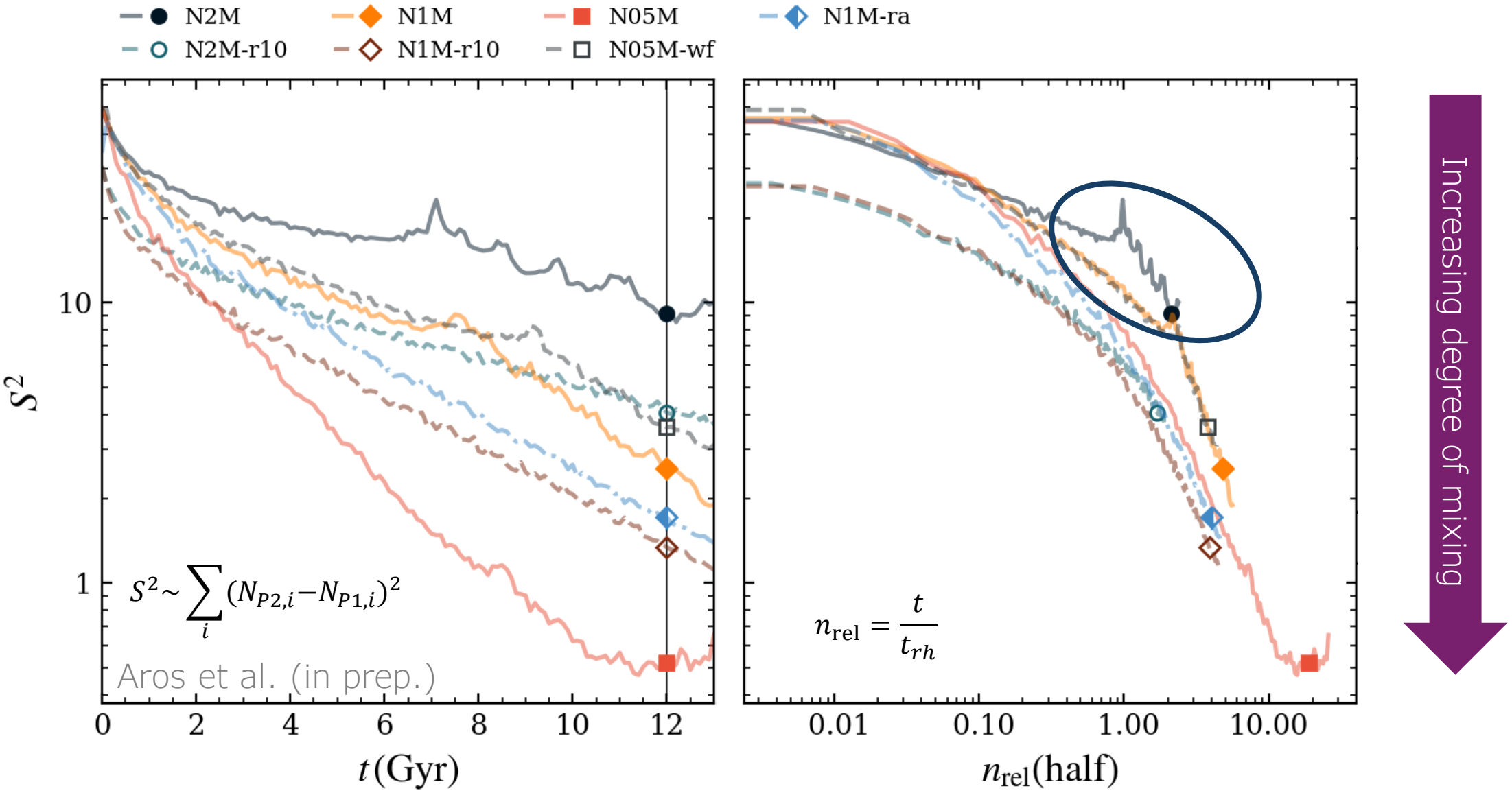
Aros et al. (in prep)



*the talk included the animated version.

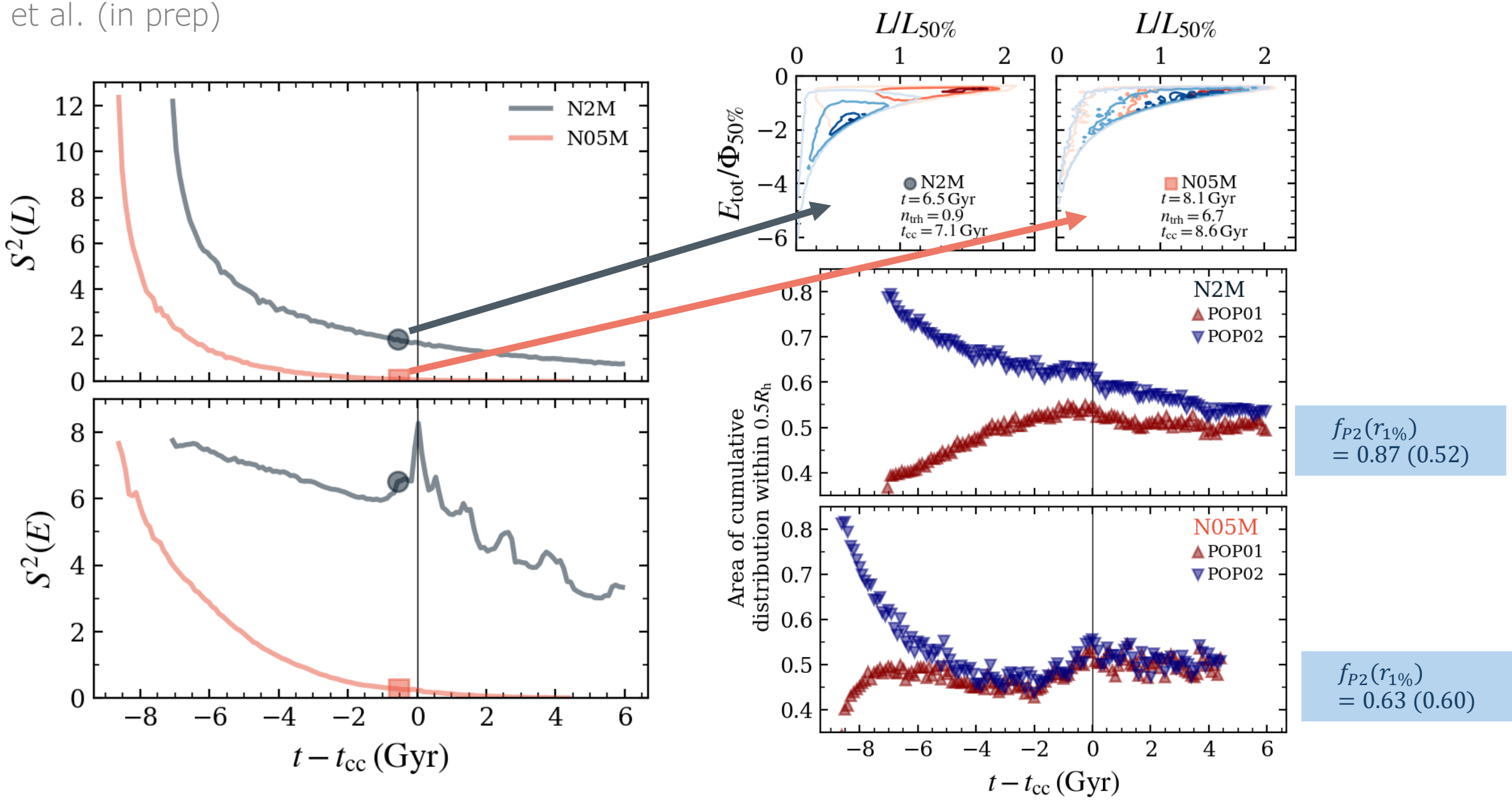
Quantifying the degree of mixing

Aros et al. (in prep)



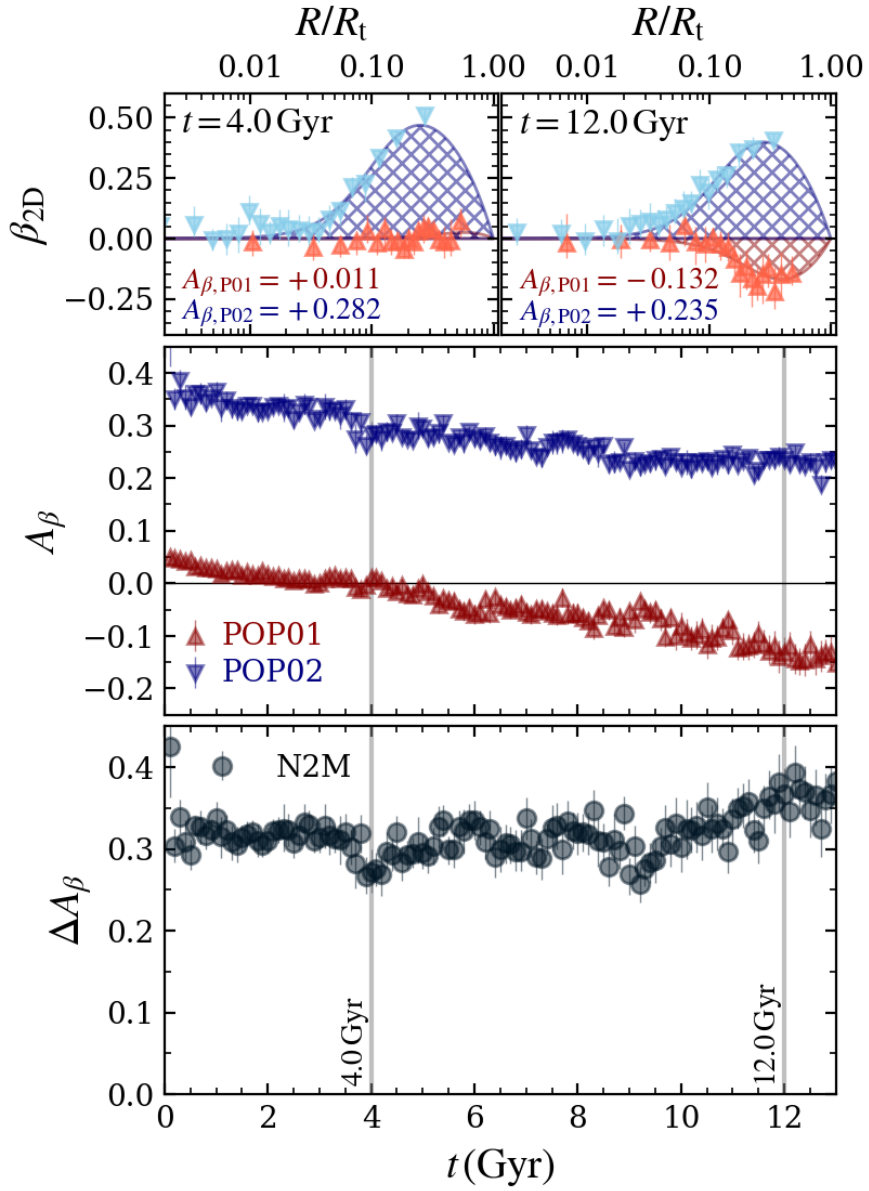
Mixing in energy-space and spatial mixing

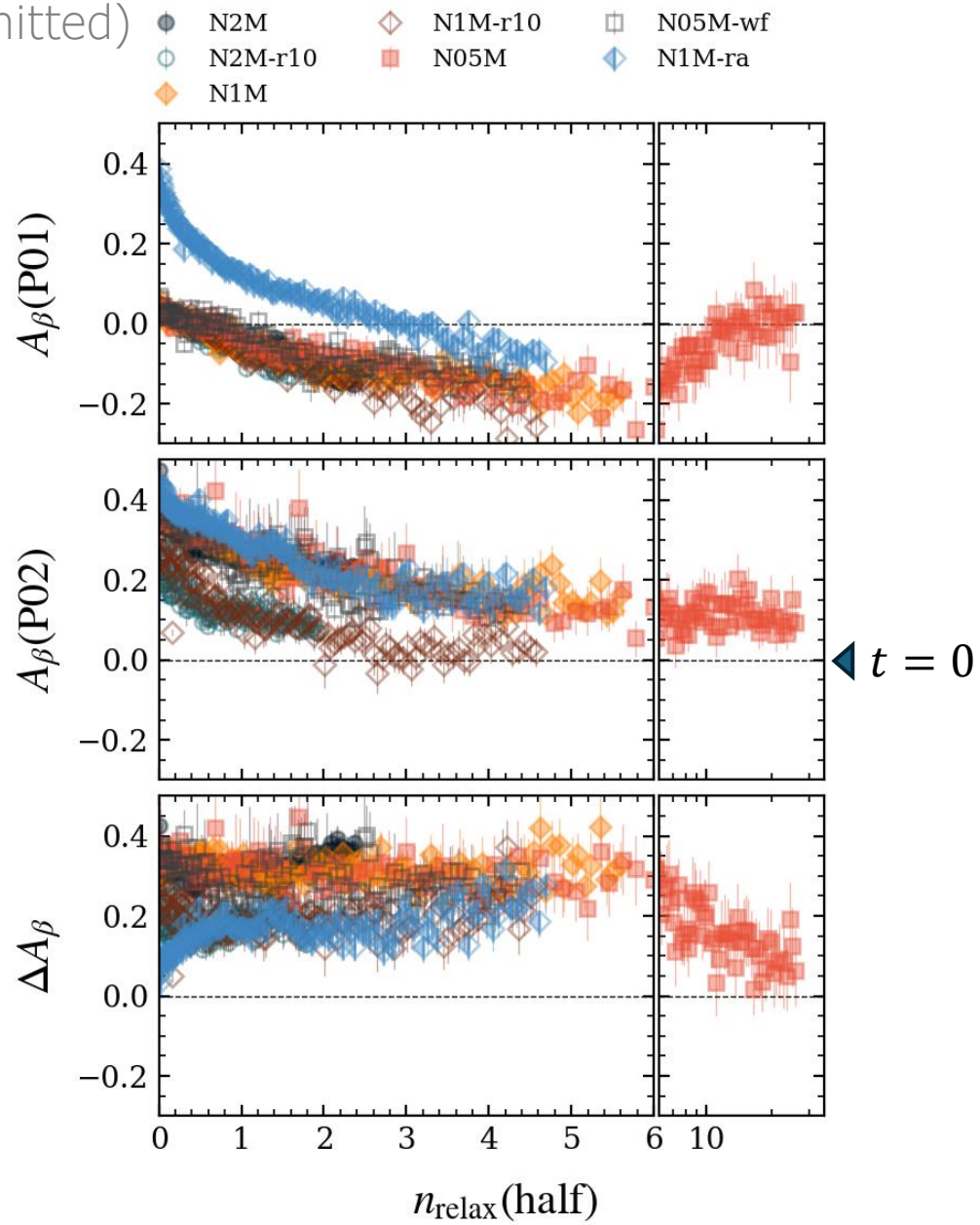
Aros et al. (in prep)



Tracing mixing with the velocity anisotropy

Aros et al. (in prep) see also Dalessandro et al. (submitted)

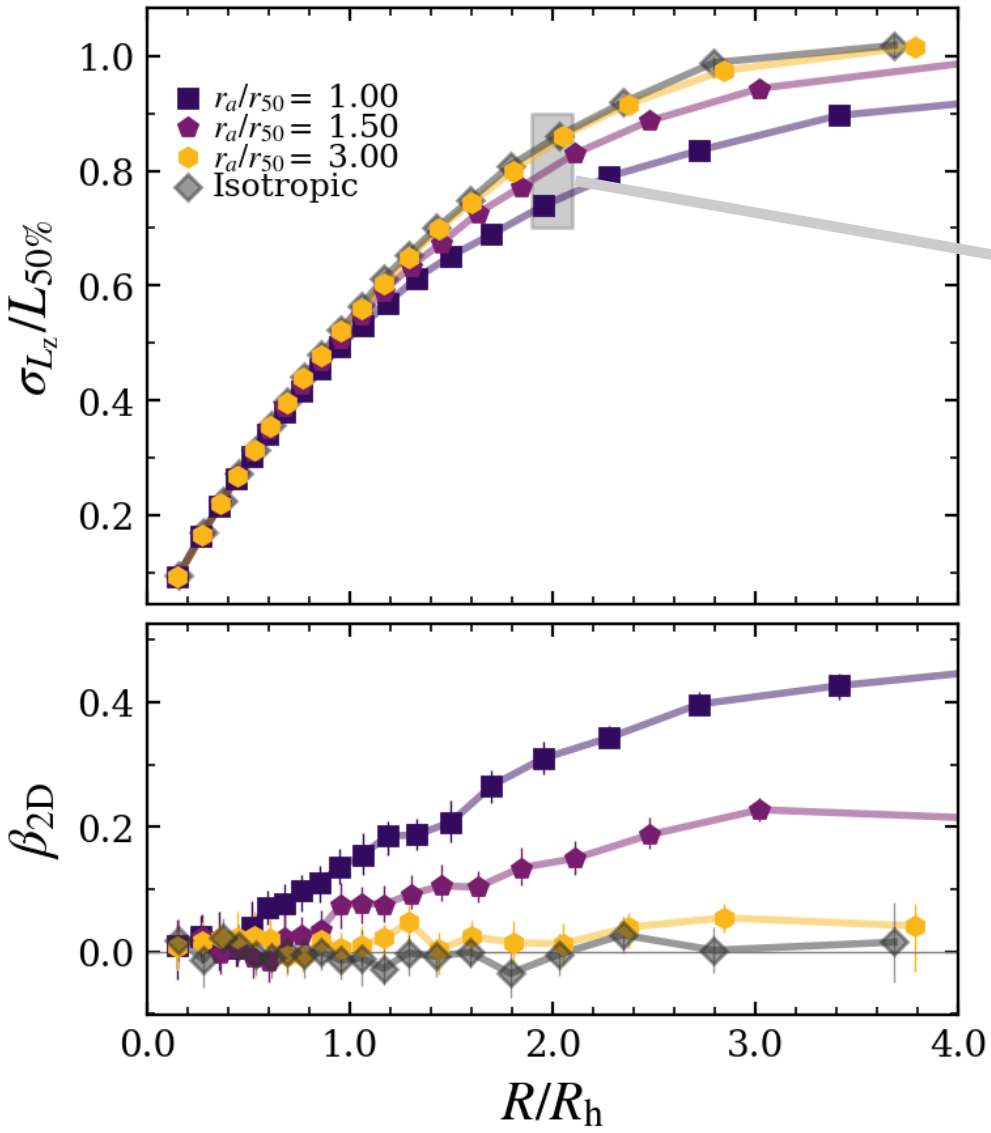


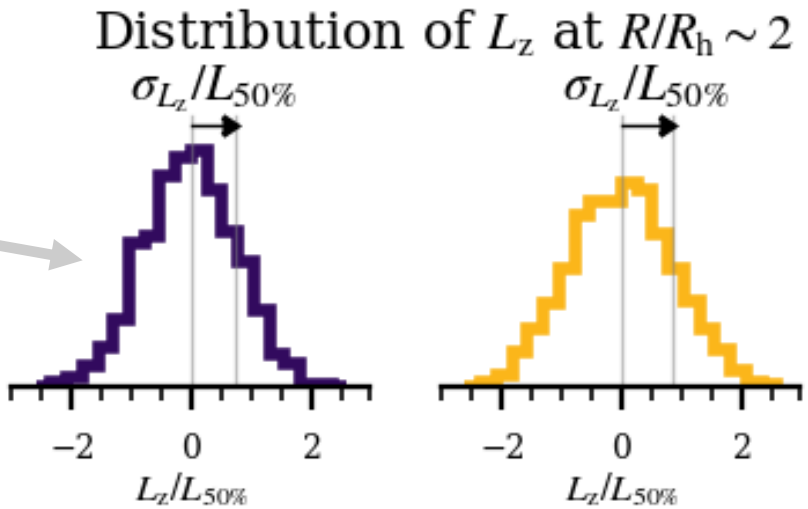


Kinematic mixing

Velocity anisotropy and angular momentum

Aros et al. (in prep)





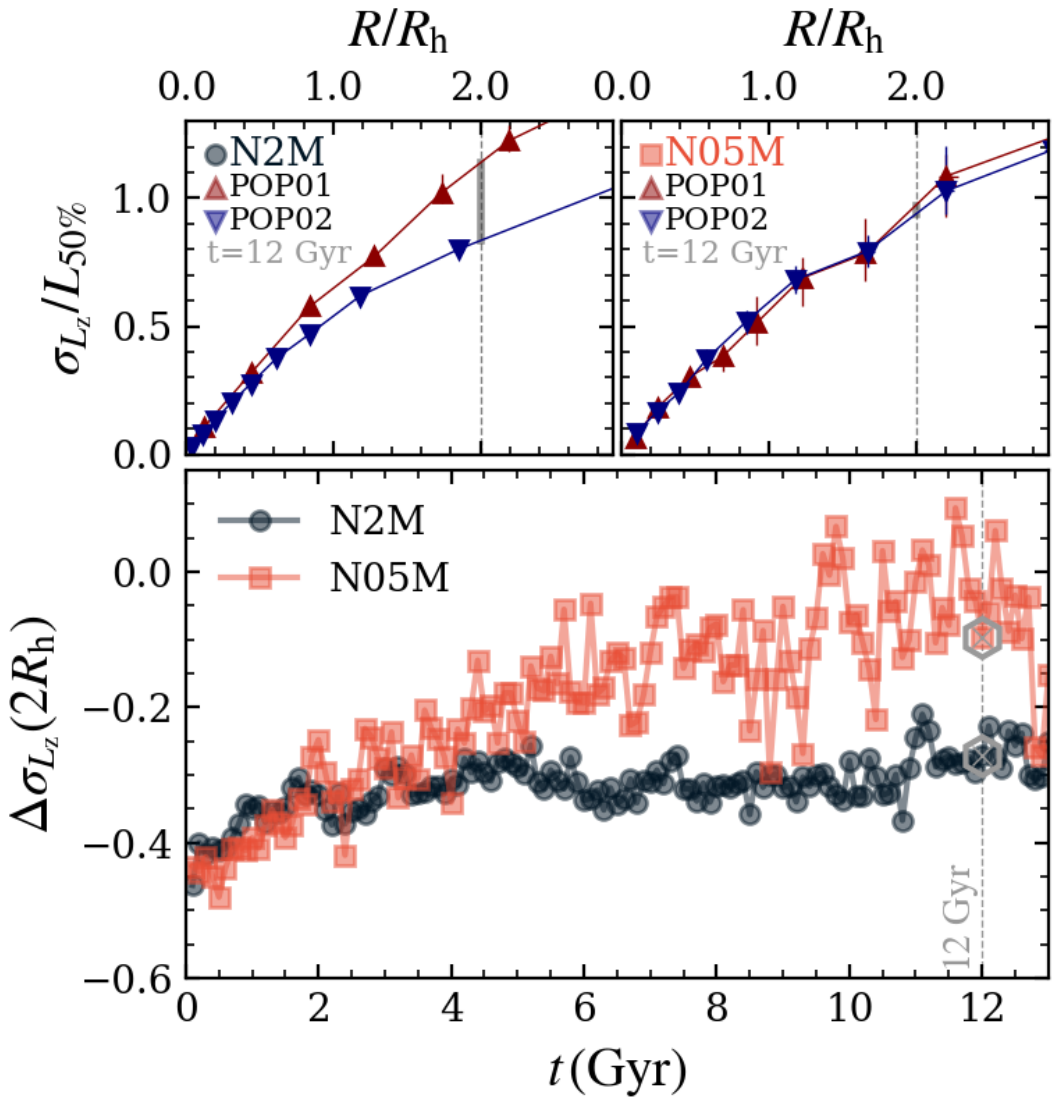
radially anisotropic

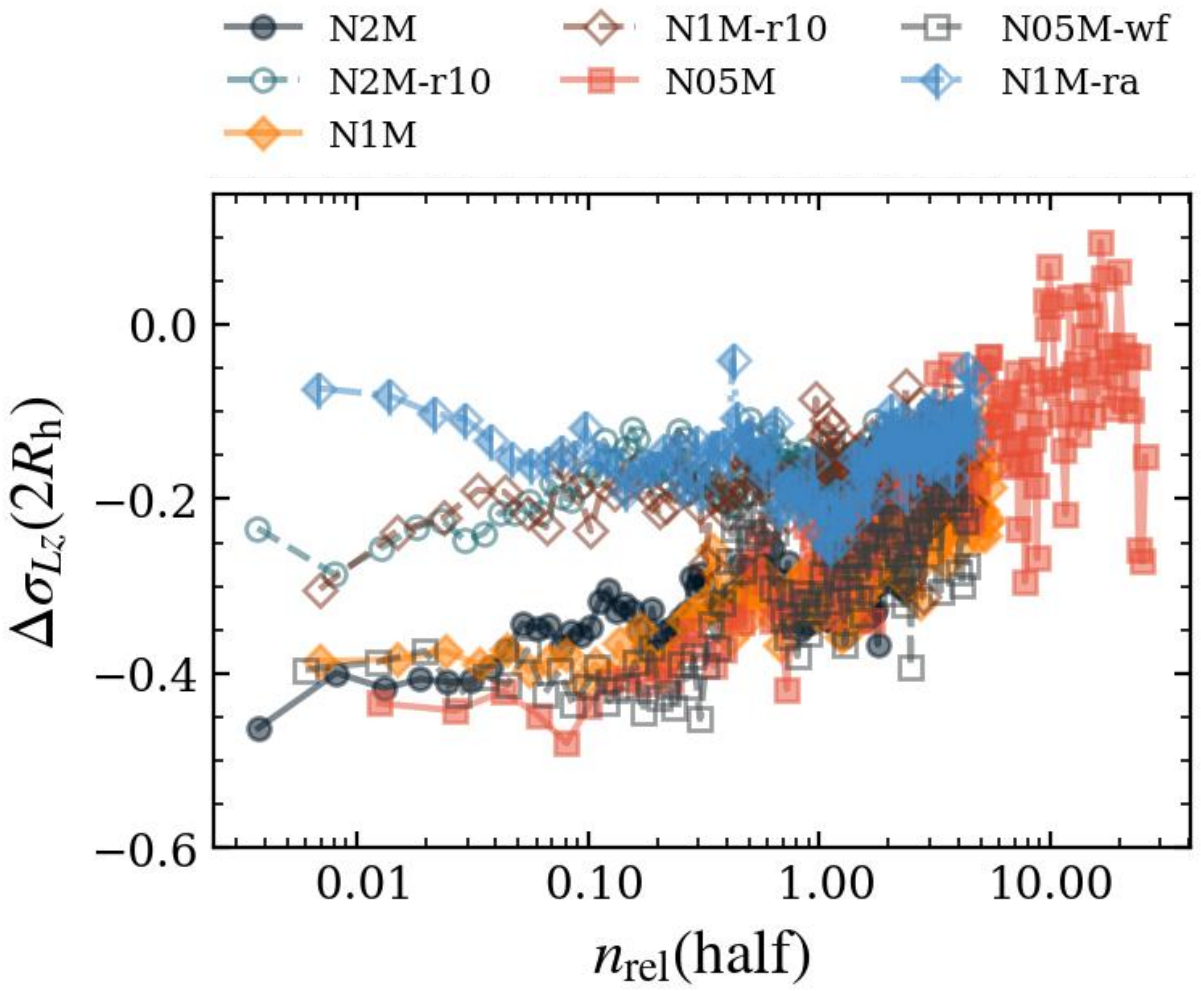
close to isotropic

Isotropic and radially anisotropic King models built with **limepy**; see Gieles & Zocchi (2015)

Tracing mixing with angular momentum

Aros et al. (in prep)





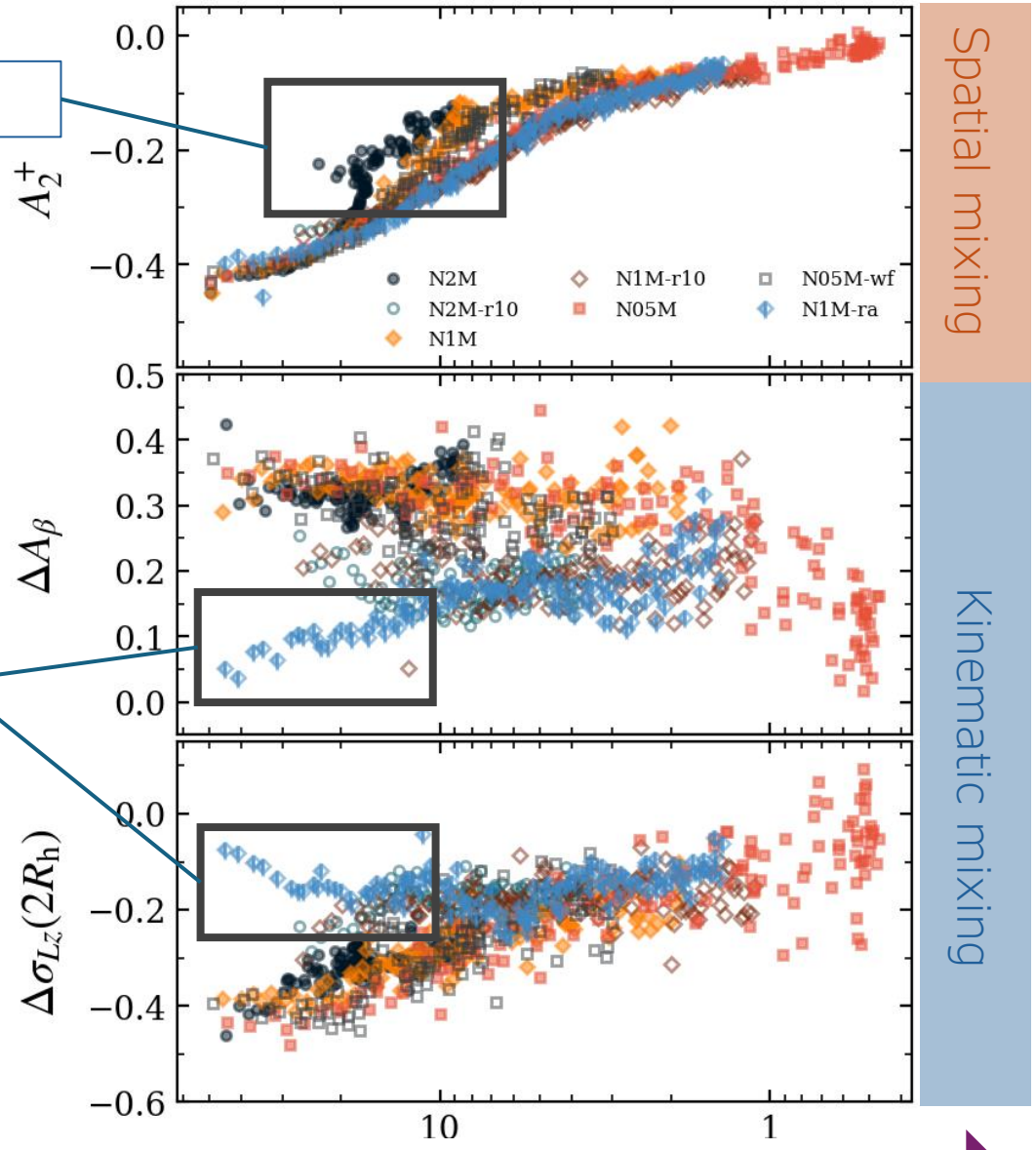
Kinematic mixing

Phase-space mixing and projected quantities

Aros et al. (in prep)

Core-collapse

Primordial anisotropy



Summary

>We have a general view of population mixing by looking at the energy-angular momentum space.

>Differences in velocity anisotropy follow the same overall evolution, but they might conserve differences in initial conditions.

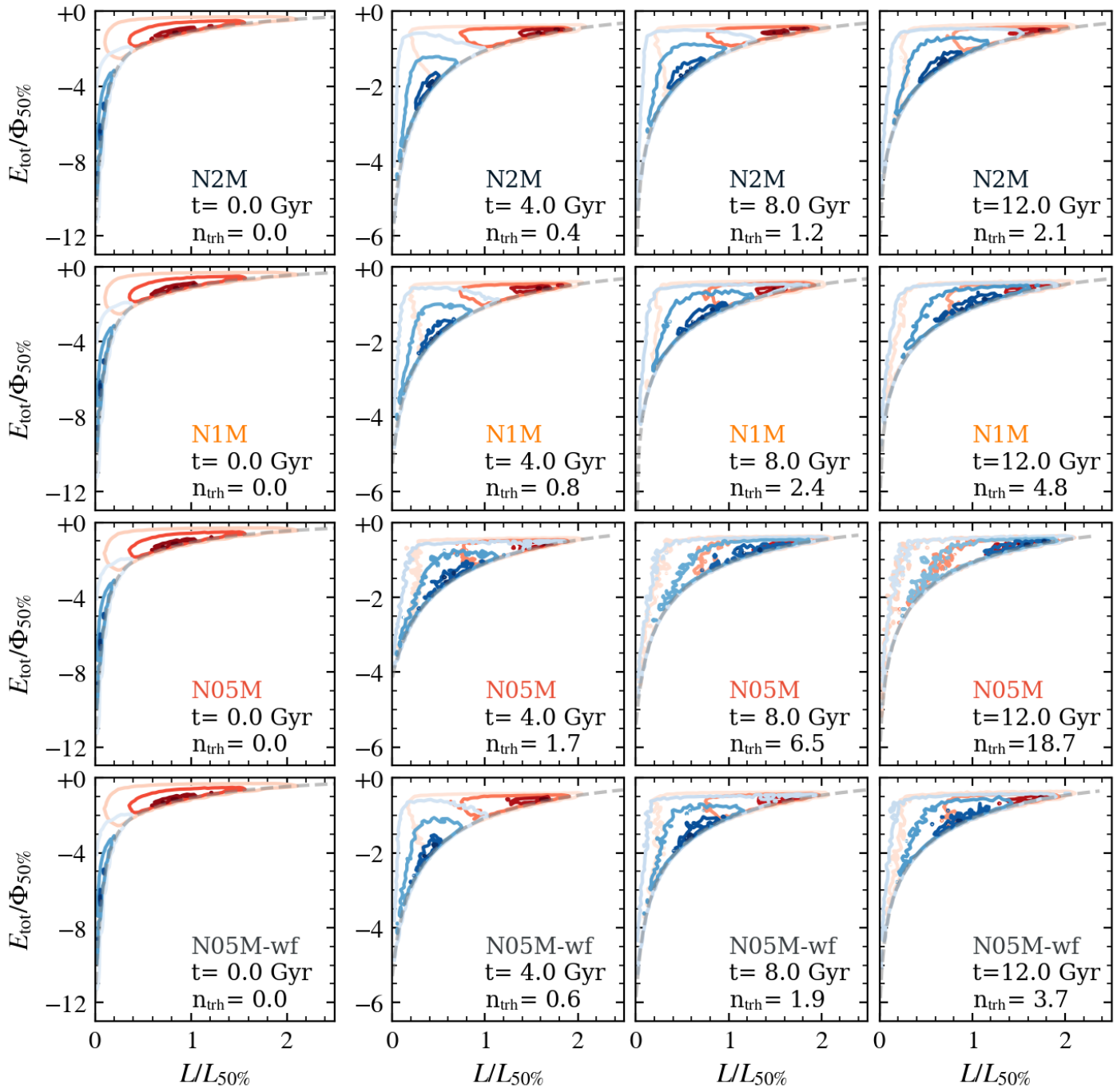
>These differences are less apparent on the projected angular momentum distribution (effects of rotation in follow-up work).

>Spatial and kinematic mixing happens at different rates. We do not see any clear signature of the initial POP02 concentration in the A_2^+ parameter after one relaxation time. Kinematic differences persist for a longer time.

Extra slides

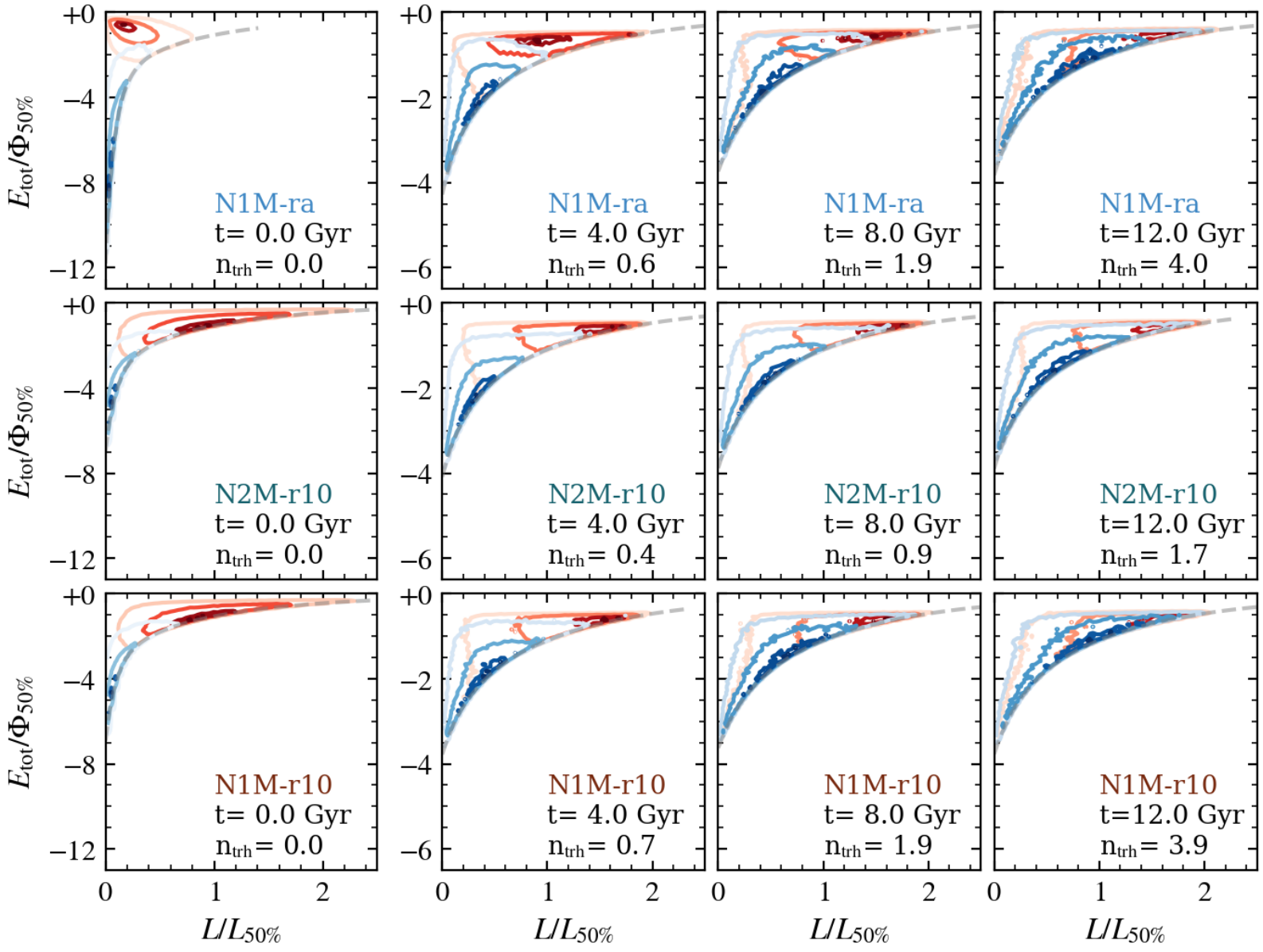
Phase-space distributions: N2M, N1M, N05M and N05M-wf

Aros et al. (in prep)



Phase-space distributions: N1M-ra ,N2M-r10, N1M-r10

Aros et al. (in prep)



Evolution of A_2^+ Parameter

Aros et al. (in prep)