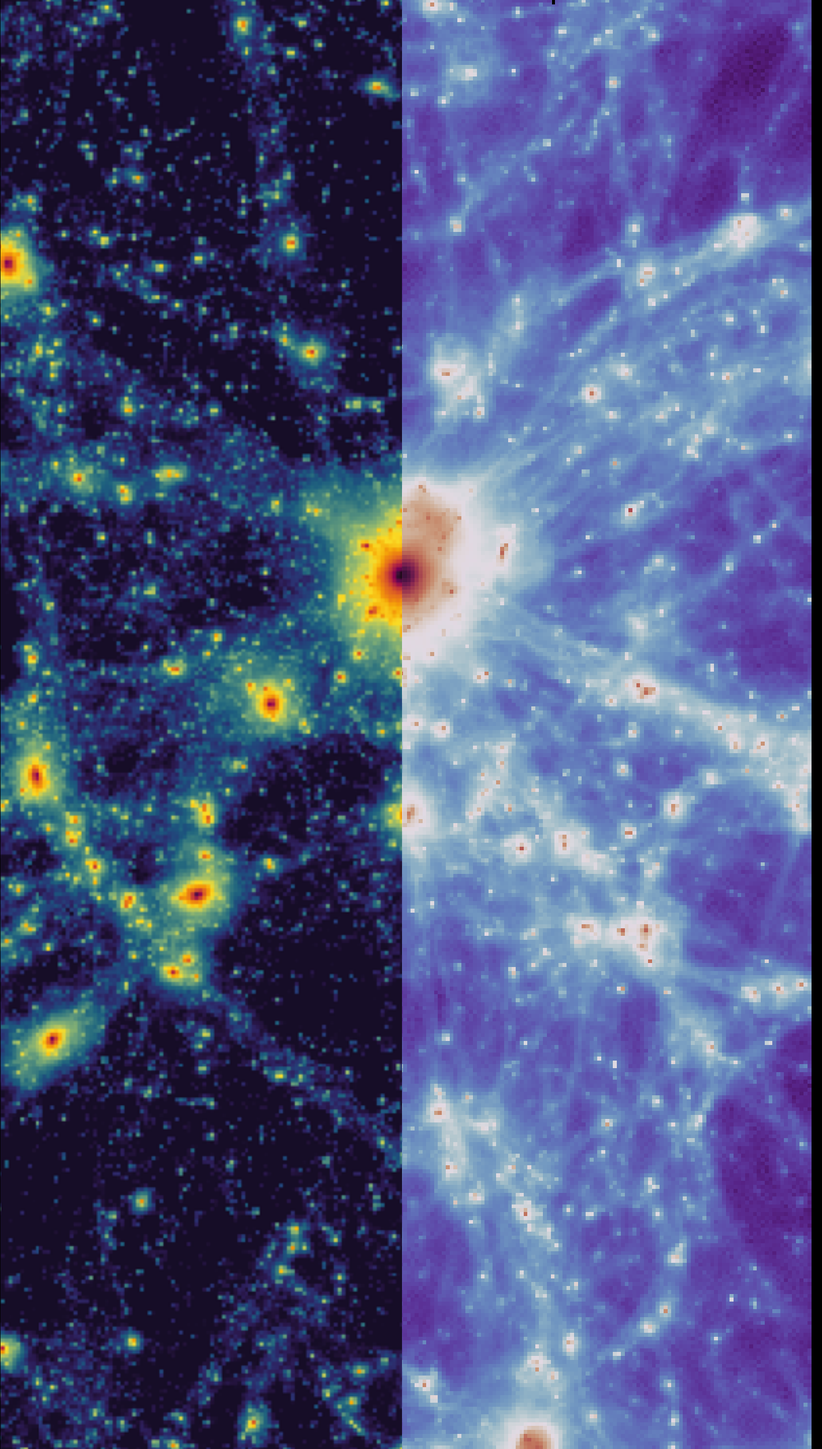


THE AIDA PROJECT: GALAXY FORMATION IN ALTERNATIVE DARK MATTER MODELS

Giulia Despali

Department of Physics and Astronomy

University of Bologna

WP3 Flagship UC

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

ICSC
Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

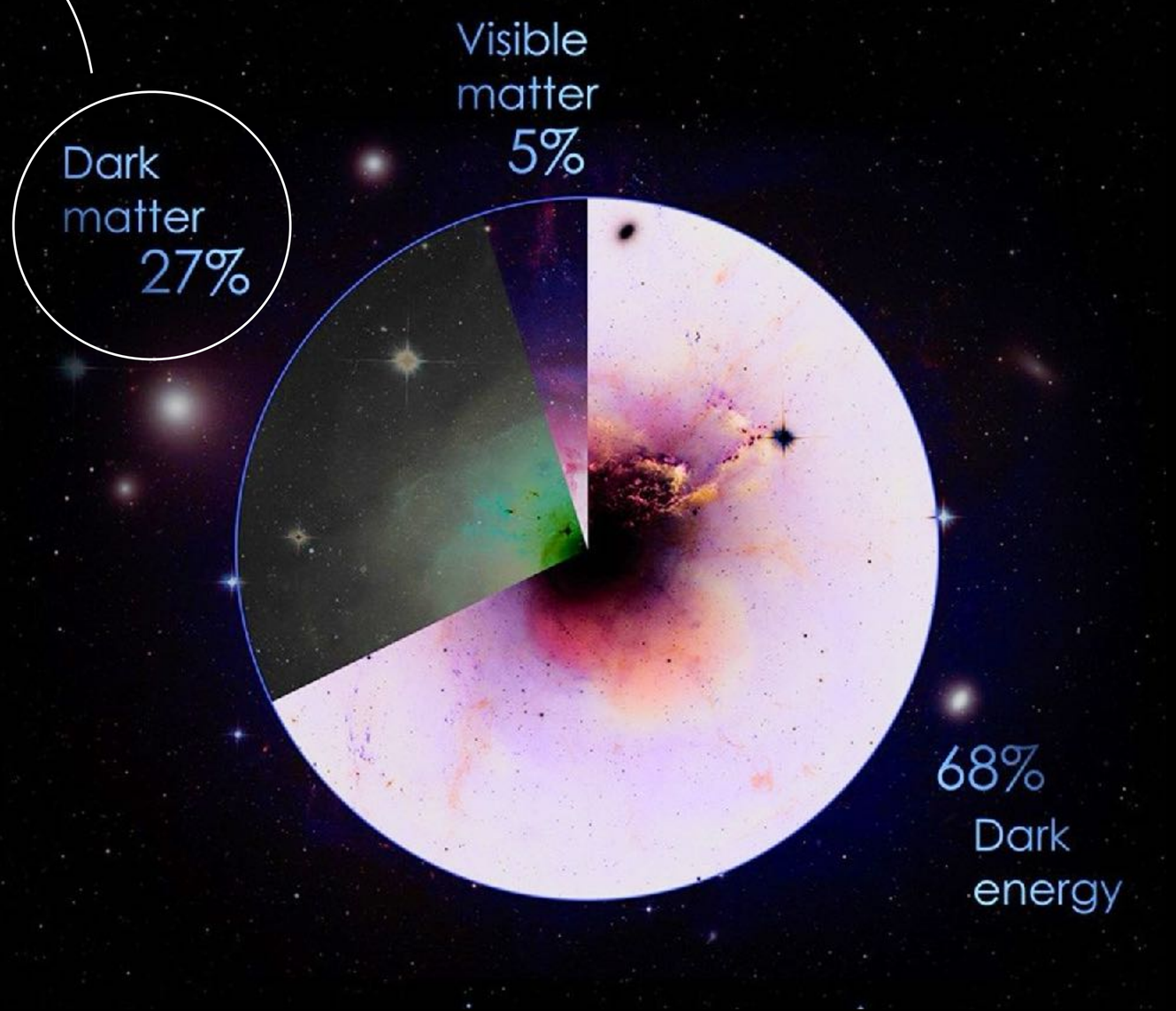
EuroHPC
Joint Undertaking

Standard model: **Cold Dark Matter**

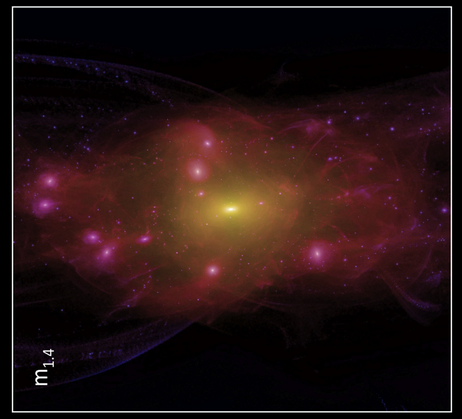
heavy particles (~GeV)
only gravitational interactions
do not emit any light

works well to explain the large scale structure
of the Universe but may fail on small scales

Stars, planets, galaxies,
everything we can observe



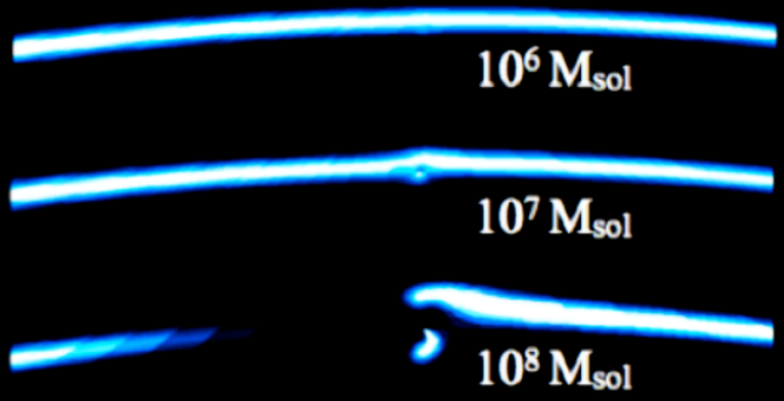
Warm Dark Matter



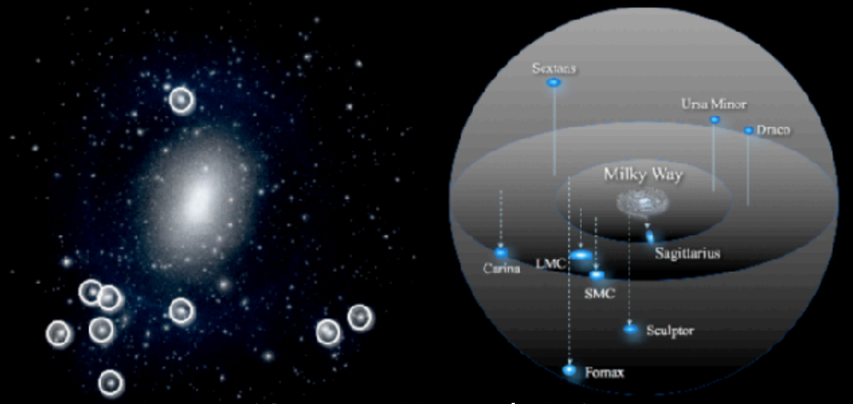
(Lovell et al. 2012)

model with less massive particles ~keV scale
still only gravitational interactions

the number of low-mass structures is reduced

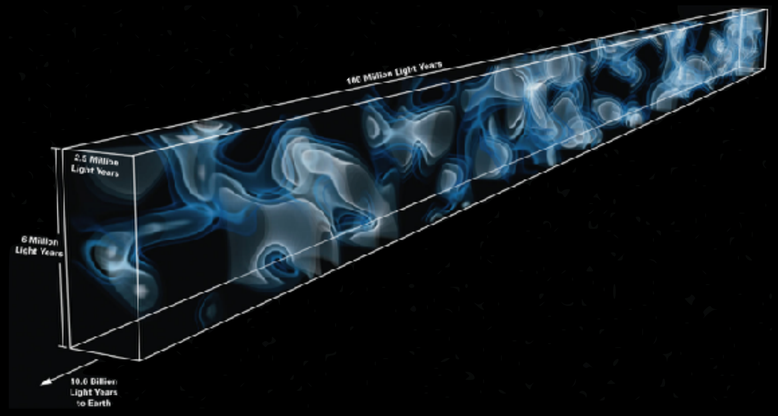


Strong lensing



(Garrison-Kimmel+14)

MW satellites
&
stellar streams



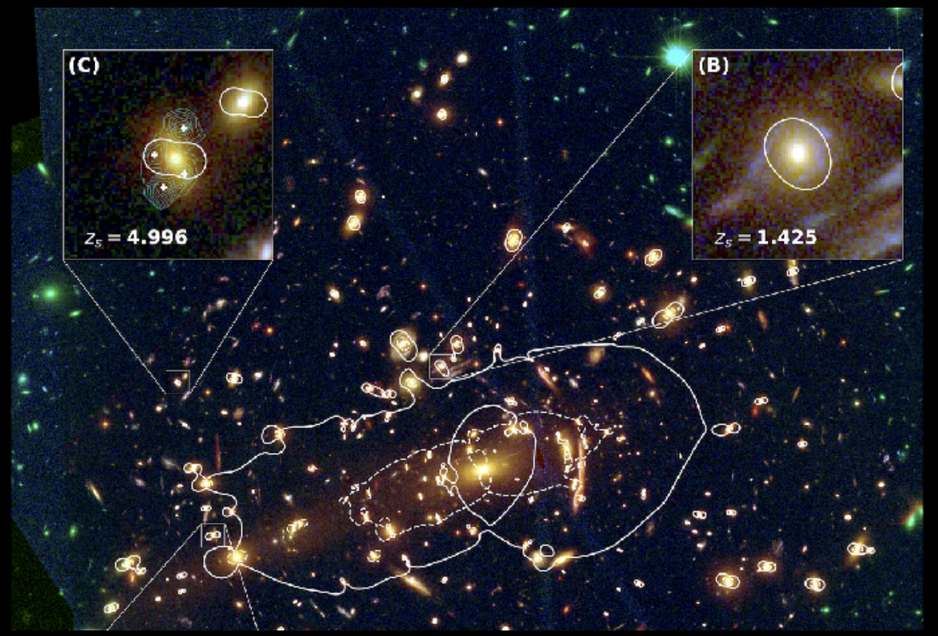
Lyman-α forest
(Lee et al. 2014)

Self-Interacting Dark Matter

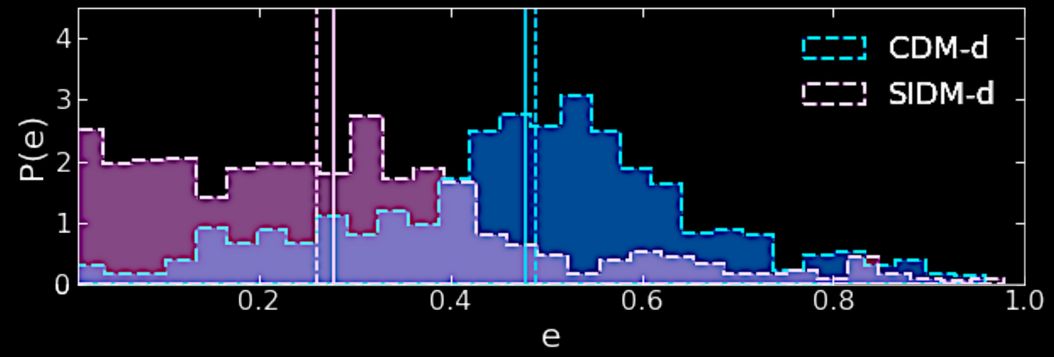
model where the dark matter particles have interactions beyond gravitation

<u>the matter distribution & density inside haloes is modified</u>

galaxy clusters

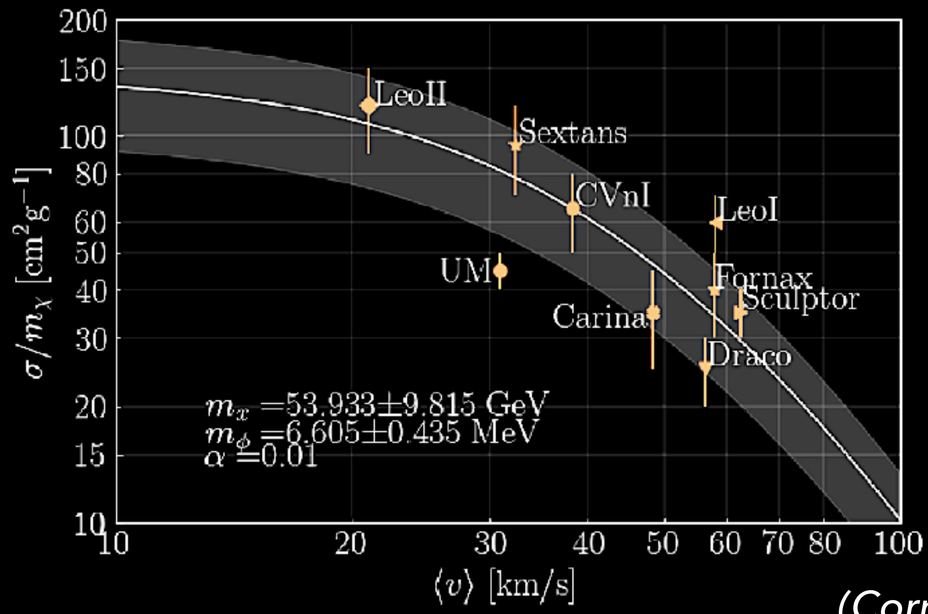


(Meneghetti+2020)



halo shapes

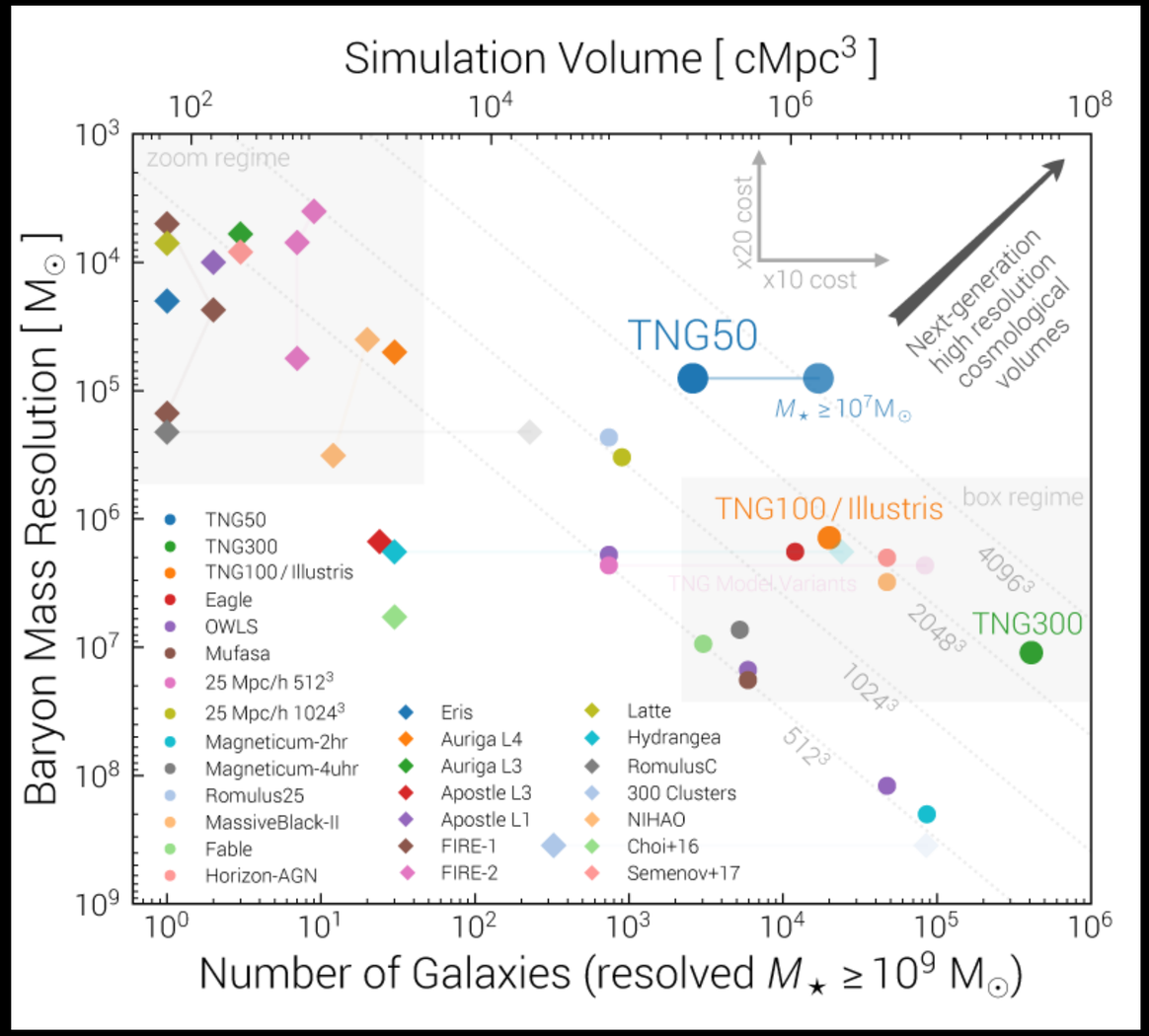
(Despali+2022)



dwarf galaxies

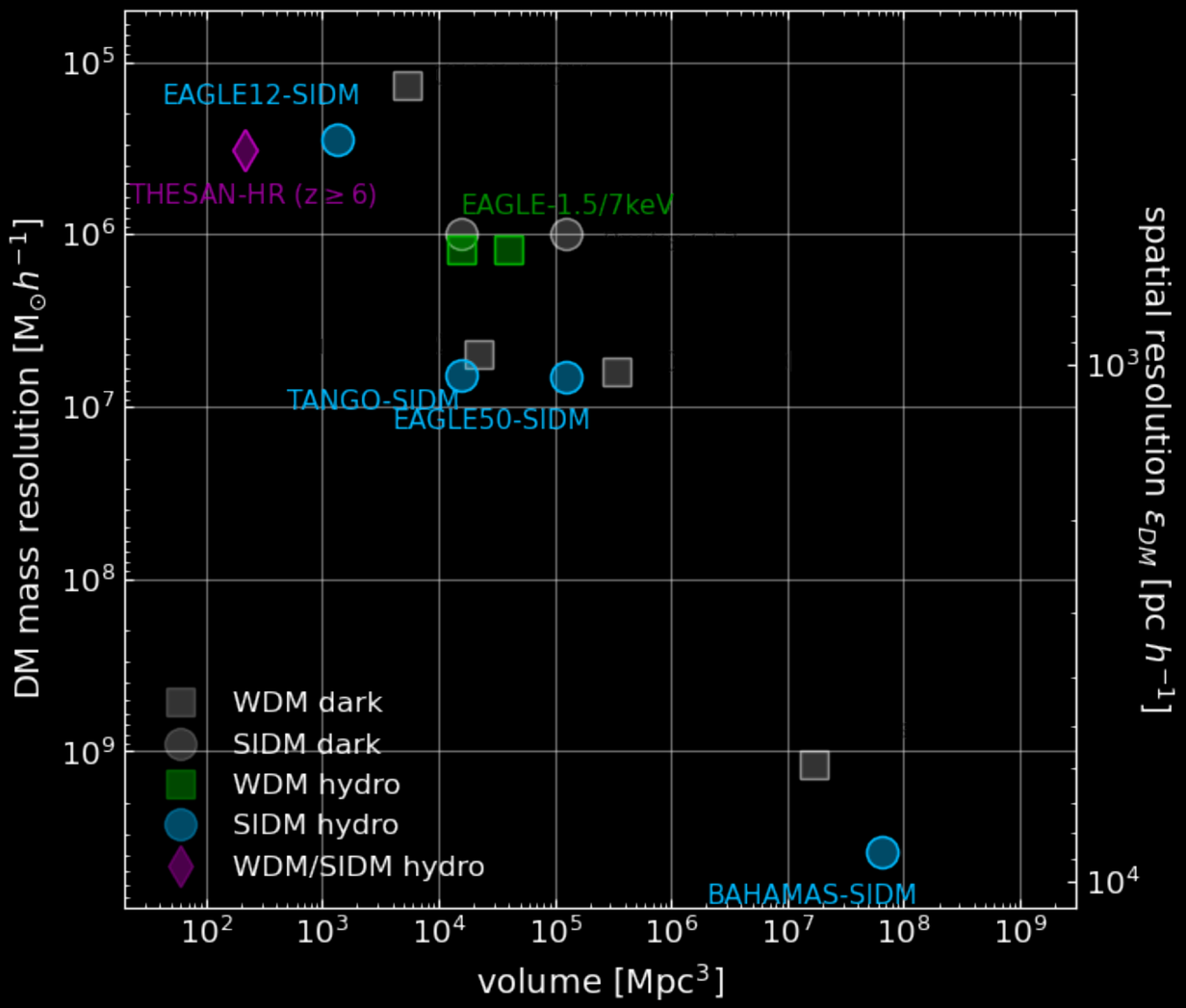
(Correa+2020)

Cold Dark Matter + Hydrodynamics simulations



(Nelson+2019)

Hydro simulations with other dark matter models

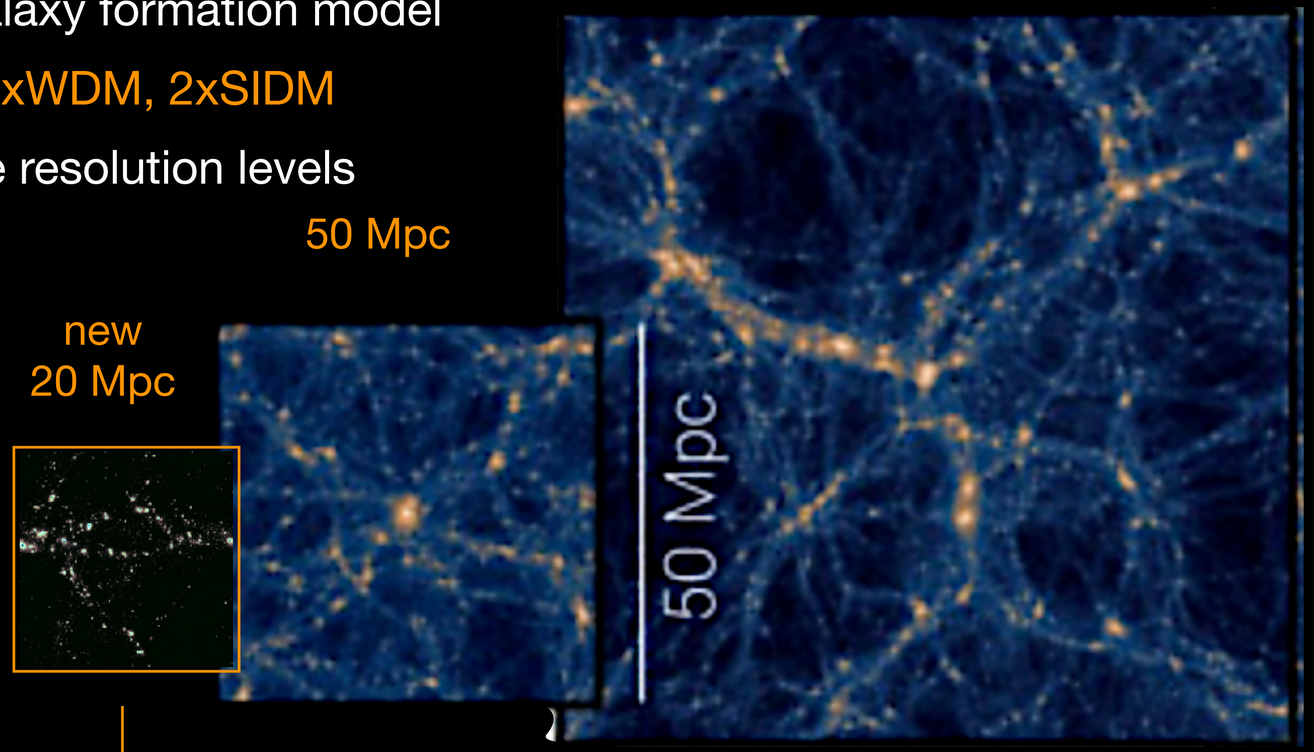


AIDA-TNG SIMULATIONS

- ✓ three cosmological boxes
- ✓ AREPO - moving mesh
- ✓ TNG galaxy formation model
- ✓ CDM, 3xWDM, 2xSIDM
- ✓ multiple resolution levels

100 Mpc

50 Mpc



new
20 Mpc

max resolutuion:
4 x 10^5 M⊙
280 pc

LAURO MOSCARDINI
DYLAN NELSON
ANNALISA PILLEPICH
MARK VOGELSBERGER
VOLKER SPRINGEL

AIDA(-TNG) SIMULATIONS

Arepo

(Springel et al. 2008)

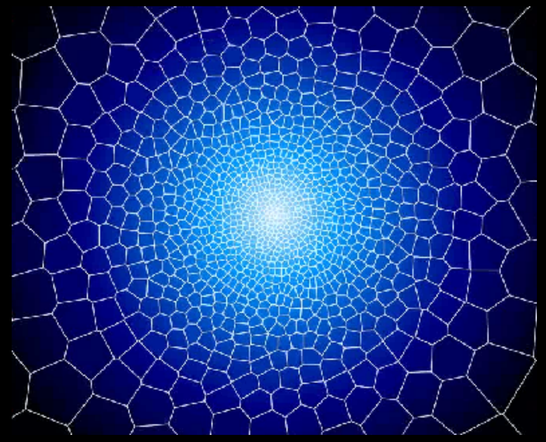
- Gravity with a Tree-PM approach, MPI paralell

- Hydrodynamics on a moving Voronoi tessellation, where the mesh adapts over time

- domin decomposition on a Peano-Hilbert curve that splits the workload into the required number of MPI tasks

- Sophisticated on-the-fly analsysis that already produces post-processing catalogues

- highly portable: written in C, with dependences only to gsl, gmo, fftw and hdf5 libraries



Simulation set-up

- improved routines for alternative DM models
- 8 runs with $(2x910)^3$ resolution elements
- 10 runs with $(2x1080)^3$ resolution elements
- additional lower resolution versions

~100 Terabytes of data

~ 60 million CPU hours for the entire sample

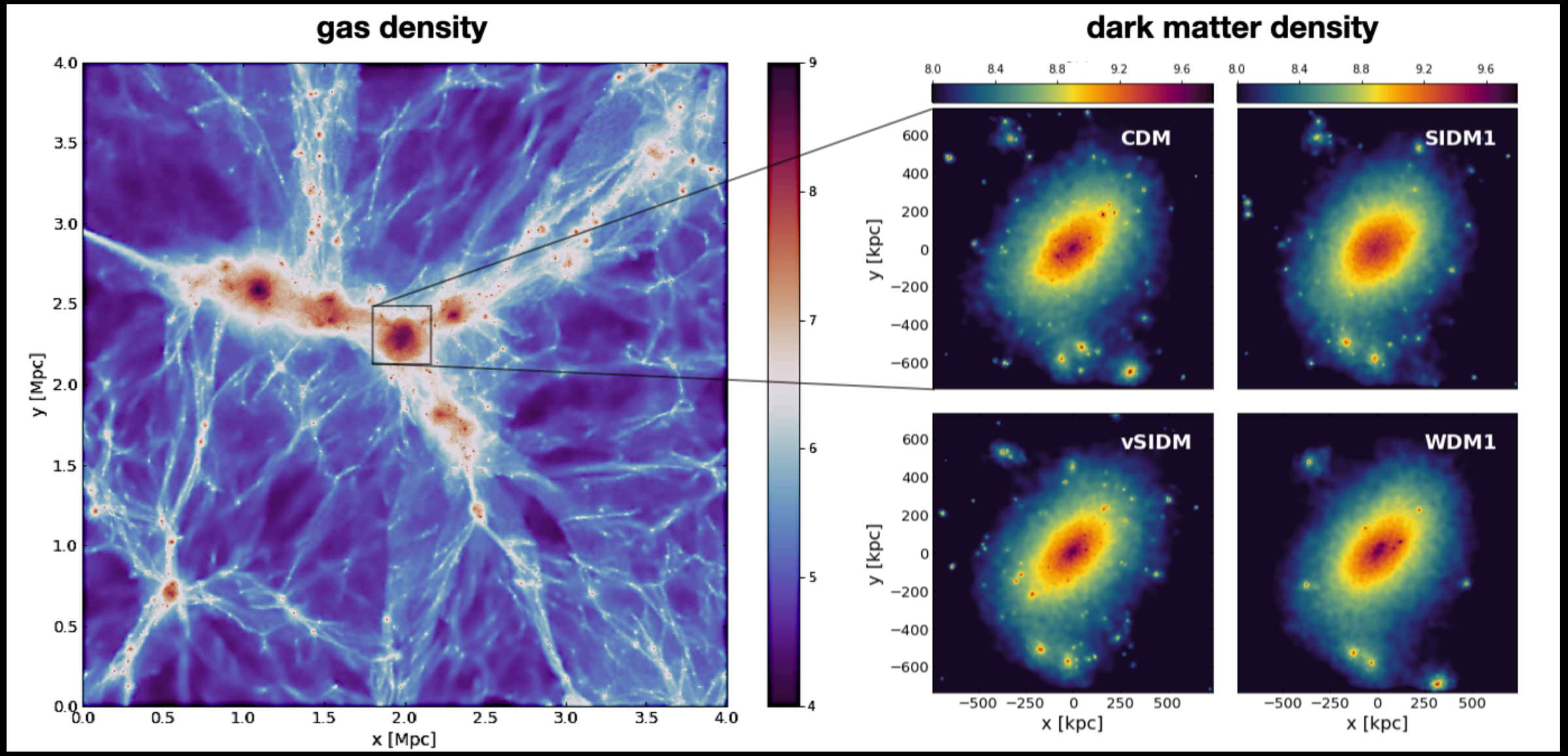
Processing pipeline

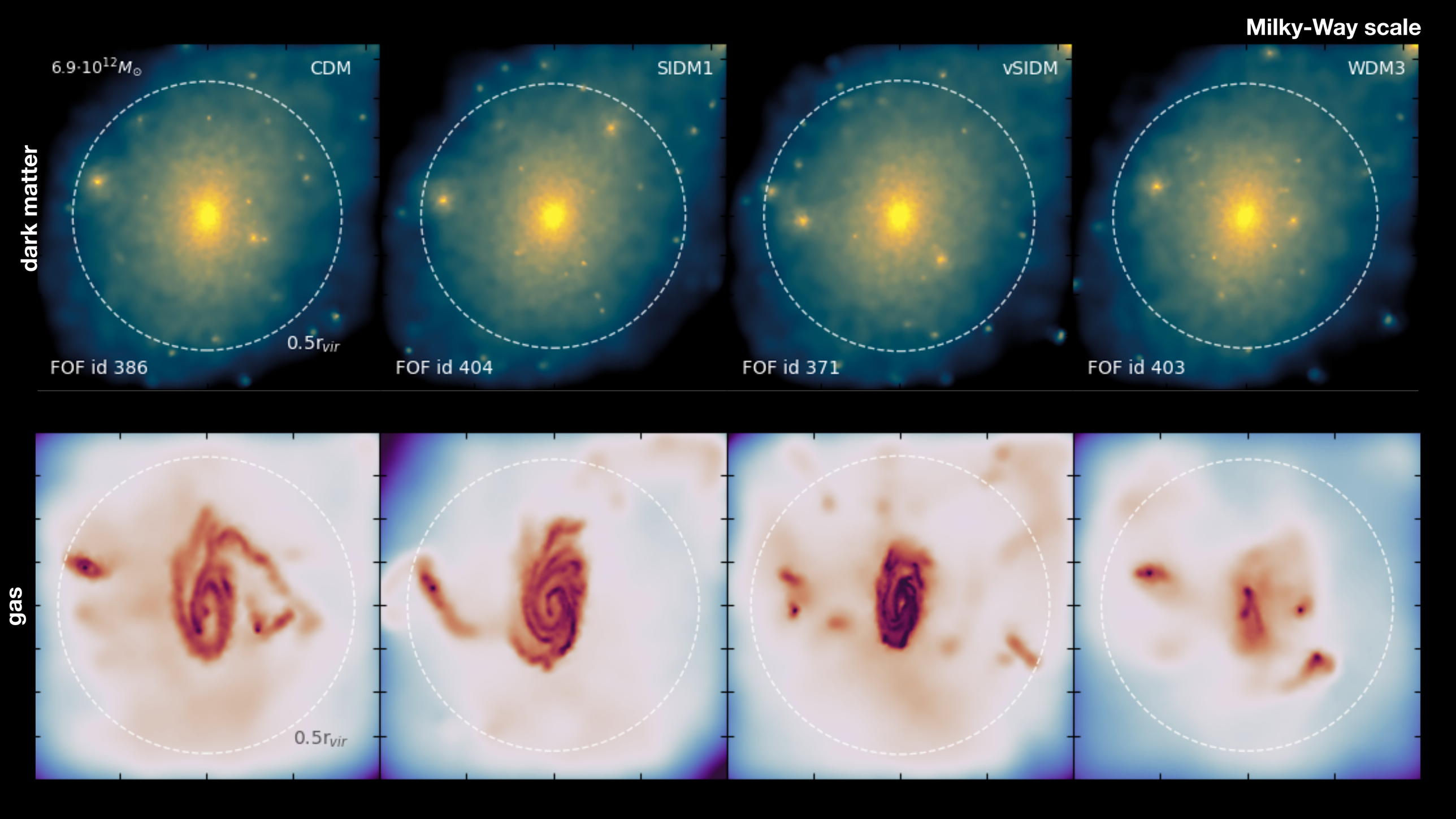
- creation of mock observations from the simulations
- acceleration on GPUs (in progress)

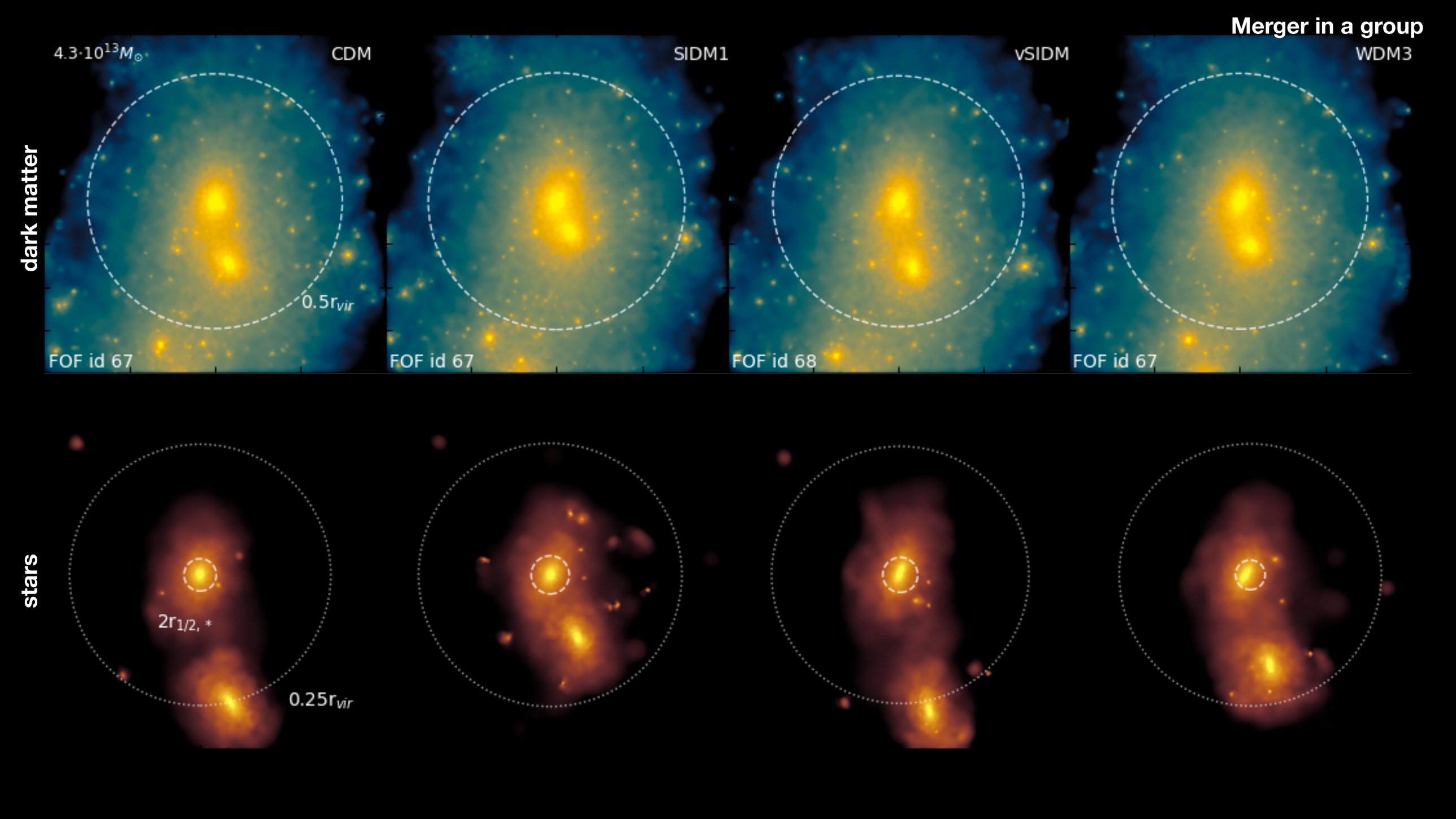
Resources

- computing time (5 Million CPU hours) and storage space (100 TB) on **Leonardo** via CN HPC
- computing time on **Lumi** via EuroHPC application

AIDA-TNG SIMULATIONS



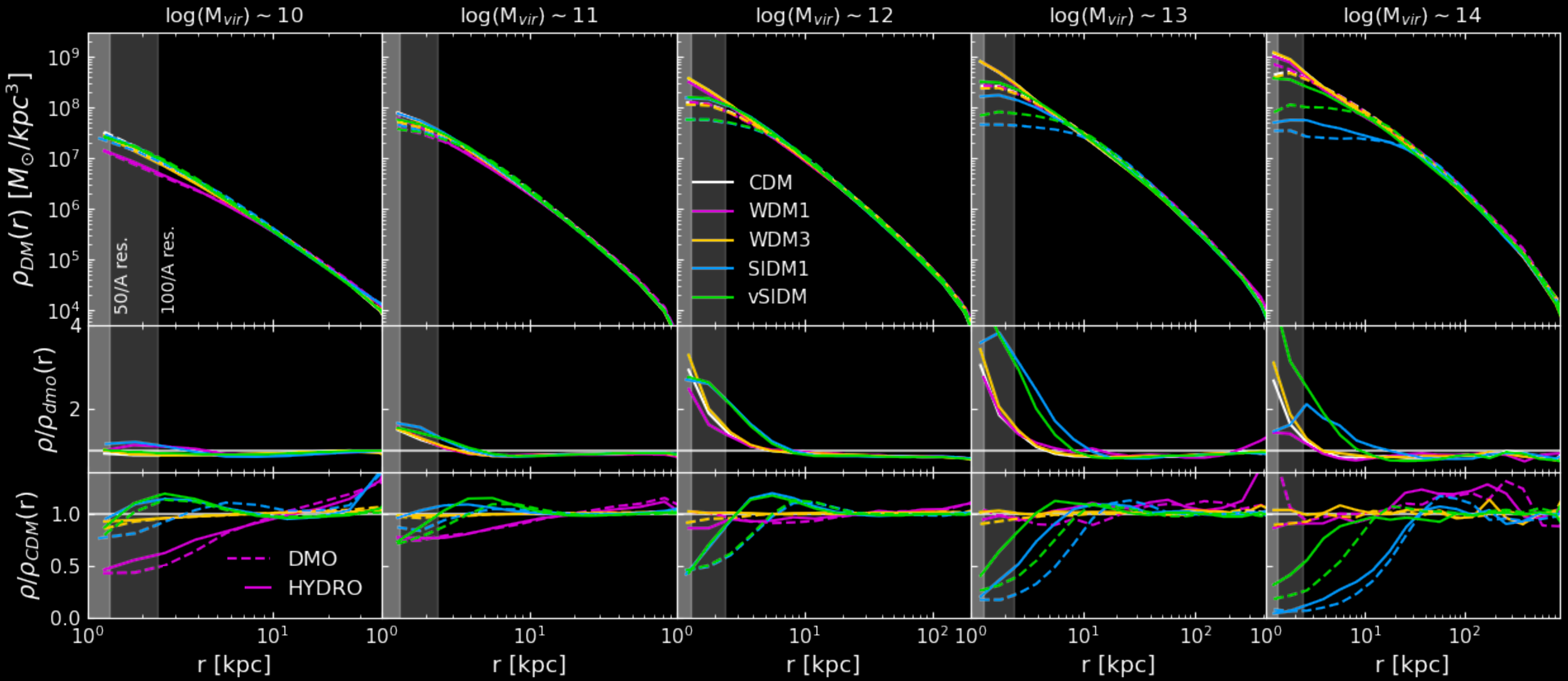

Milky-Way scale
dark matter
gas
$6.9{\cdot}10^{12}M_\odot$
CDM
SIDM1
vSIDM
WDM3
$0.5r_{vir}$
FOF id 386
FOF id 404
FOF id 371
FOF id 403
$0.5r_{vir}$


Merger in a group
dark matter
stars
4.3·10^13 M⊙
CDM
SIDM1
vSIDM
WDM3
0.5r_vir
FOF id 67
FOF id 67
FOF id 68
FOF id 67
2r_1/2, *
0.25r_vir

SIDM and WDM have opposite trends with mass

HALO PROFILES

not only the DM profile is affected, but also the total density



AIDA(-TNG) SIMULATIONS

presentation paper to be submitted this month

Astronomy & Astrophysics manuscript no. output
December 10, 2024
©ESO 2024

Introducing the AIDA-TNG project: galaxy formation in alternative dark matter models

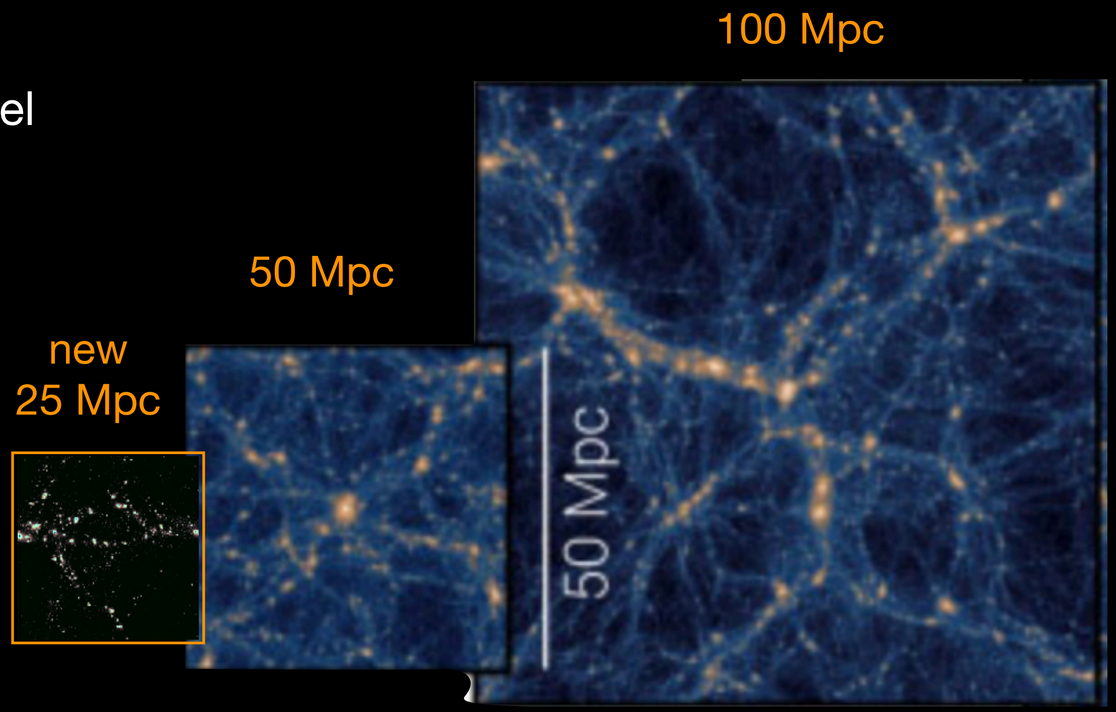
Giulia Despali[1,2,3,⋆] and ...[4] Lauro Moscardini[1], Dylan Nelson[5], Annalisa Pillepich[6], Mark Vogelsberger[7], Volker Springel[8]

[1] Dipartimento di Fisica e Astronomia "Augusto Righi", Alma Mater Studiorum Università di Bologna, via Gobetti 93/2, I-40129 Bologna, Italy
[2] INAF-Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, Via Piero Gobetti 93/3, I-40129 Bologna, Italy
[3] INFN-Sezione di Bologna, Viale Berti Pichat 6/2, I-40127 Bologna, Italy
[4] ...
[5] Universität Heidelberg, Zentrum für Astronomie, ITA, Albert-Ueberle-Str. 2, 69120 Heidelberg, Germany
[6] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany
[7] Department of Physics, Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
[8] Max-Planck-Institut für Astrophysik, , Karl-Schwarzschild-Straße 1, D-85740, Garching bei München, Germany

SUMMARY

new AIDA-TNG simulations

- ✓ three cosmological boxes
- ✓ AREPO - moving mesh
- ✓ TNG galaxy formation model
- ✓ CDM, WDM, SIDM
- ✓ multiple resolution levels
- ✓ large statistics of galaxies



…more results & public release coming!

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

ICSC
Centro Nazionale di Ricerca in HPC,
Big Data and Quantum Computing