KO meeting, CN-HPC – Spoke 3, Roma 27-28 Ottobre 2022

Scuola Internazionale Superiore di Studi Avanzati

1) Astroparticle Physics (**Viel**, Ullio, Barausse, Kobayashi, Liberati)
2) Astrophysics and Cosmology (**Lapi, Spera**, Valdarnini, Bressan, Baccigalupi, Krachmalnicoff)
3) Data Science (**Trotta**)

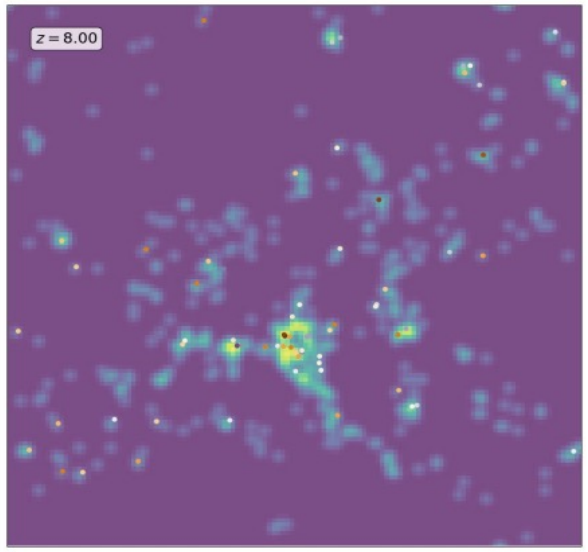
Interests: Cosmology, Dark Matter, Physics beyond Standard Models, Structure formation, Gravity, Galaxy formation, Machine learning applications

LSS and galaxy formation

Large Scale Structure Cosmology

Galaxy Formation & Evolution

Software development



ScamPy

[Ronconi, Lapi, et al. 2020](#)

Empirical modelling of galaxy occupation

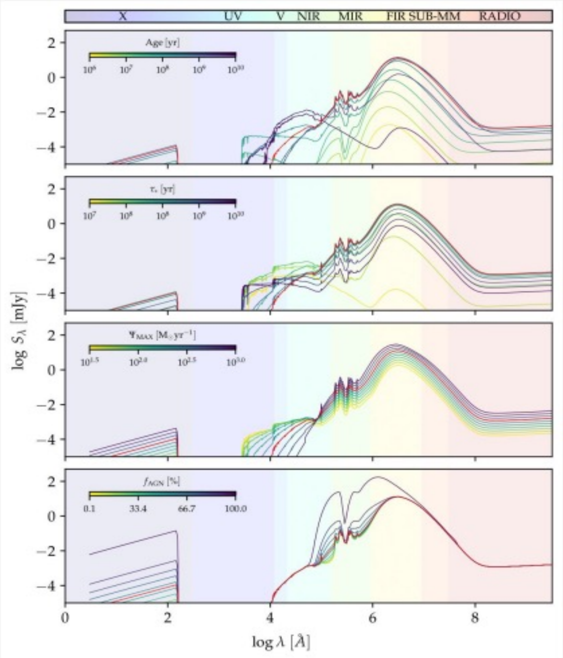
- ➔ Computational efficiency (C++ core)
- ➔ Modularity+Extensibility
- ➔ Built-in shared memory parallel + MPI-compliant
- ➔ Fast mock-catalogue generation for forward modelling

GalaPy

Ronconi, Lapi, Torsello et al. (in prep.)

Highly optimized Galactic SED-fitting tool

- ➔ Extremely flexible parameterized model
- ➔ Sampling: MCMC and/or Nested
- ➔ Energy conservation
- ➔ 2-components dust model
- ➔ likelihoods **10-100 times faster than competitors**



Artificial Intelligence assisted Empirical Galaxy-Halo connection

To overcome limitations of Mass-based methods

- ➔ No assumptions on underlying physics
- ➔ Use novel ML-methods to obtain a **blind mapping** between **DM-halo properties & Observed galaxy properties**
  - ◆ **Reinforcement Learning** (policy gradients VS Gradient-free algorithms)
  - ◆ **Unsupervised Learning** (cycle-consistency loss)

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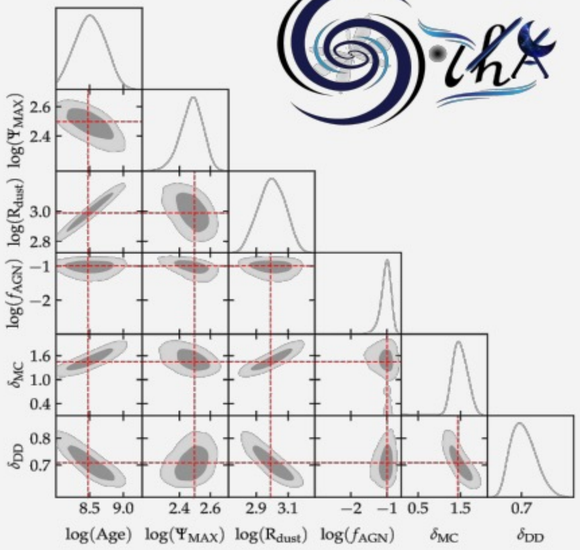
Parameters on-the-fly

Train a Neural-Network model to map observed galaxy fluxes to the model posteriors in the parameters space?



Machine Learning

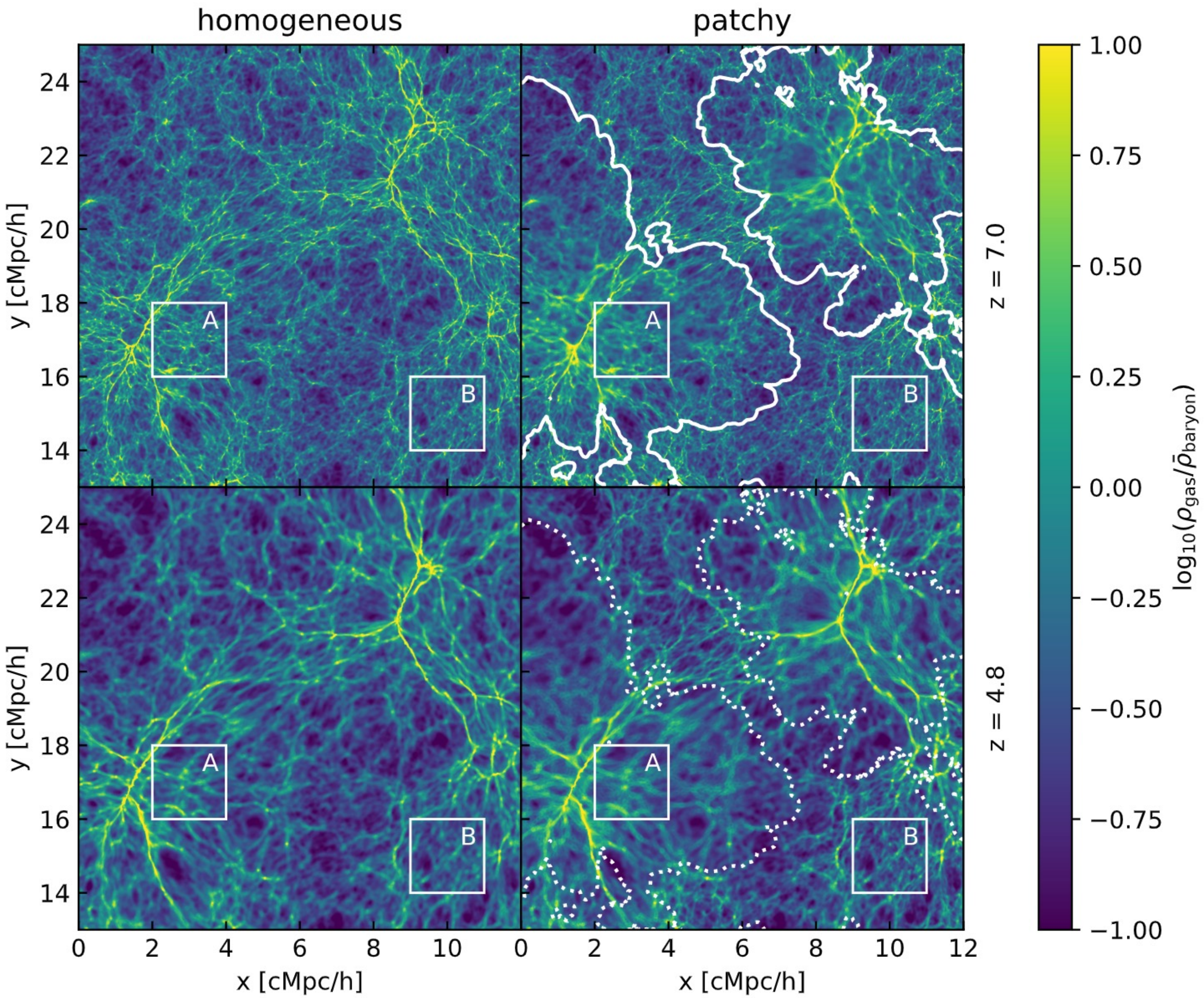
Modelling intergalactic medium from high to low redshift

75 CPU million hrs from 2017
Through PRACE and DIRAC
competitive calls.

ATON (Radiative transfer code)
Interfaced with GADGET-3 to
perform “patchy reionization”
Models

Limited comparison with other
Codes (AREPO, NyX, etc.)

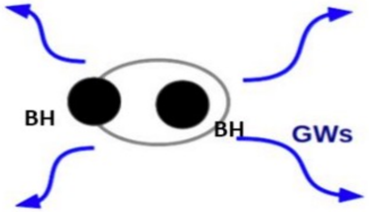
Important for SKA and
intensity mapping experiments



Puchwein+22, in prep. – Bolton+17 “Sherwood suite”

GRAVITY

Astrophyiscs of gravitational-wave sources through innovative HPC techniques



Numerical relativity simulations of binary systems in theories extending GR

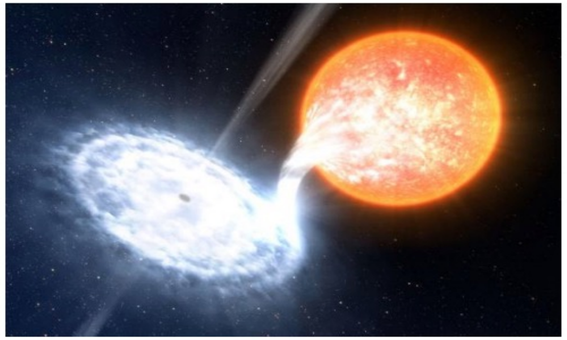
ISTEDDAS

A new GPU-accelerated N-body code to study merging binaries in dense stellar environments

C++ - CUDA - OpenMP - MPI

Mencagli, Spera et al. 2022

Mencagli, Spera et al. 2022, ApJS, in prep.



SEVN

A new fast population-synthesis code to study merging binaries in isolation

C++ - OpenMP - MPI

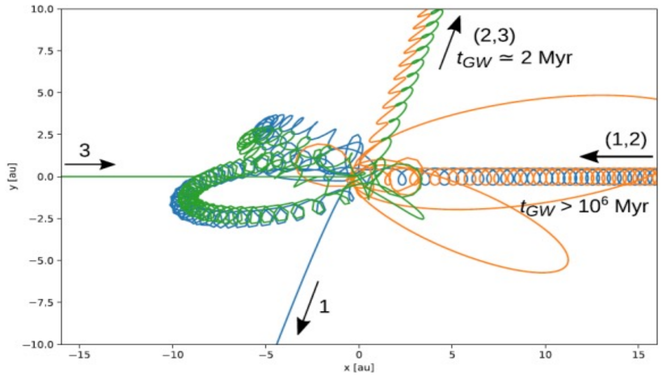
Spera et al. 2015, 2017, 2019

TSUNAMI

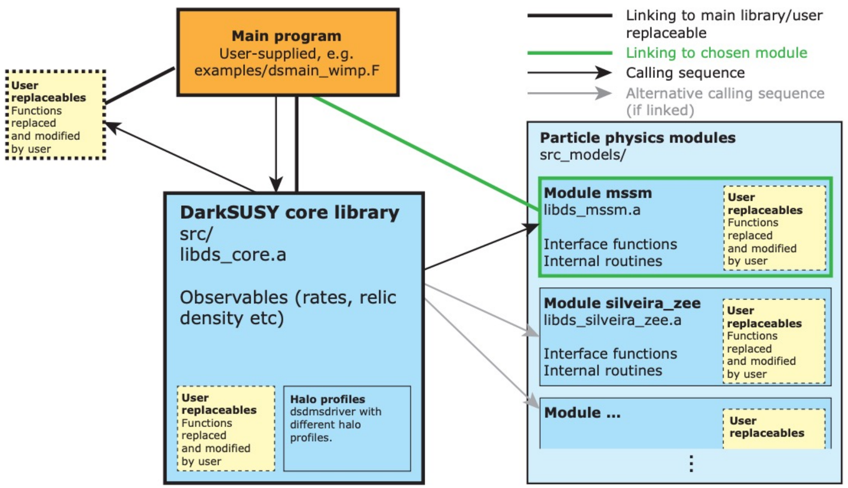
A new few-body code for accurate simulations of tight hierarchical stellar systems

C++ - OpenMP - MPI

Trani, Spera, et al., 2022, in prep,



Dark Matter properties



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DarkSUSY

DarkSUSY is a flexible and modular Fortran package to calculate observables for a variety of dark matter candidates. It is written by Joakim Edsjö, Torsten Bringmann, Paolo Gondolo, Piero Ullio and Lars Bergström, with further significant code contributions by (in alphabetical order) Ted Baltz, Francesca Calore, Gintaras Duda, Mia Schelke and Pat Scott. On these pages you will find general information about DarkSUSY and you can also download the package.

The present version, DarkSUSY 6, comes with a completely new structure compared to previous versions of the code, including the possibility to add new particle physics modules.

If you use DarkSUSY, please refer to the following publication describing DarkSUSY:

> **T. Bringmann, J. Edsjö, P. Gondolo, P. Ullio and L. Bergström,**
> **JCAP 1807 (2018) 033** [arXiv:1802.03399]

+ Hammurabi X code (simulating galaxy synchrotron emission)
+ Dragon2 code (for cosmic ray propagation)

AstroMachine Learning in data Science

SISSA DATASCIENCE
Machine Learning for the Natural Sciences

datascience.sissa.it

Research directions:

Machine learning and data science for high-dimensional and complex cosmological data
Interpretable AI via inference in the space of DAGs and automated model discovery, incl. HPC code optimization
Supervised learning under covariate shift in general setting
Simulation-based and likelihood-free inference (HPC-based)
Dimensionality reduction in high-dimensions
Bayesian hierarchical models: numerical methods for efficient sampling
Hybrid Frequentist-Bayesian methods with informative priors for higher-power source detection

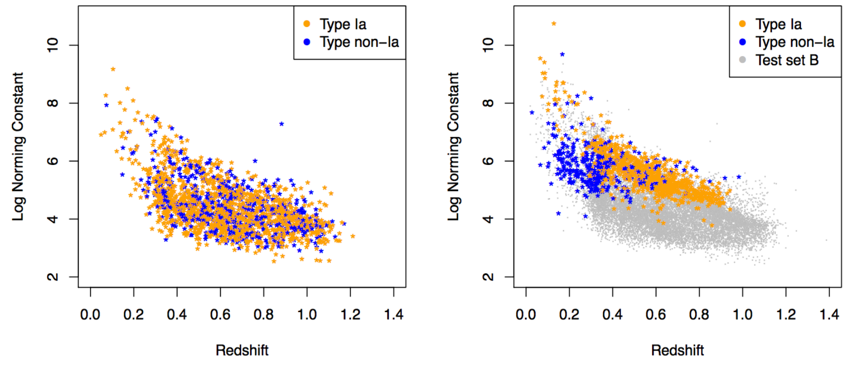
Applications in cosmology and astrophysics:

Supernova Type Ia cosmology for dark energy properties recostruction with ~10^5 objects
Dark matter searches with multi-wavelengths probes
Feature extractions from high-dimensional galaxy surveys data

Applications in the public and private sector:

Collaboration with Agenzia LavoroSviluppo Impresa on automated Neural Language Processing recommender system

Collaboration (PhD student on borsa Innovazione/Green) with RACHAEL/SWG on enrichment of heterogeneous, non-representative population data



Supervised learning under covariate shift: representative training set (left; not available in reality), vs biased training set (right). Source