Astrophysics at SISSA

- Mission and Strategy
- How we operate
- Highlights from Principal Investigators
- Visions of the Next Decade

Astrophysics at SISSA

- **19 PhD Students**: Paolo Campeti, Isabella Carucci, Guglielmo Costa, Chiara Di Paolo, Farida Farsian, Sebayasachi Goswami, Elias Kammoun, Francesca Lepori, Riccardo Murgia, Ikechucwu Antony Obi, Andrej Obuljen, Gor Oganesyan, Gabriele Parimbelli, Giuseppe Puglisi, Tommaso Ronconi, Anirban Roy, Jingjing Shi, Alessandro Trani, Milena Valentini,

- **5 Post-Docs**: Viviana Gammaldi, Nicoletta Krachmalnicoff, Giovanni Mirouh, Davide Poletti, Eleonora Villa

- **7 Staff**: Carlo Baccigalupi, Alessandro Bressan, Annalisa Celotti, Luigi Danese, Antonio Lanza (Director of SIS!), Andrea Lapi, Francesca Perrotta, Riccardo Valdarnini

Mission and Strategy

Mission and Strategy

- To investigate **Fundamental Physics**
- To train **Young Researchers becoming Scientists in Astrophysics and Cosmology**
- To serve **SISSA promoting Interdisciplinarity and Internationality**

Mission and Strategy: Fundamental Physics

- Astrophysical and Cosmological **experiments** are global
- Instruments probe all physical scales, **from Black Holes to the Cosmological Horizon**
- Theoretical Exploitation through Astrophysics and Cosmology directly **impact** open problems concerning **fundamental interactions and constituents**

Mission and Strategy: Fundamental Physics

- **Gravitational Waves** through Generation in the Early Universe and Astrophysical Progenitors from Stars and High Energy Astrophysics mechanisms
- **Dark Matter** through Cosmological Structure and Galaxy Formation and Evolution, Galaxy Clusters, Astrophysical Foregrounds of Galactic and Extra-Galactic origin
- **New Fundamental Interactions** through Cosmological Inflation in the Early Universe, Late Time Acceleration and Dark Energy
- **...**

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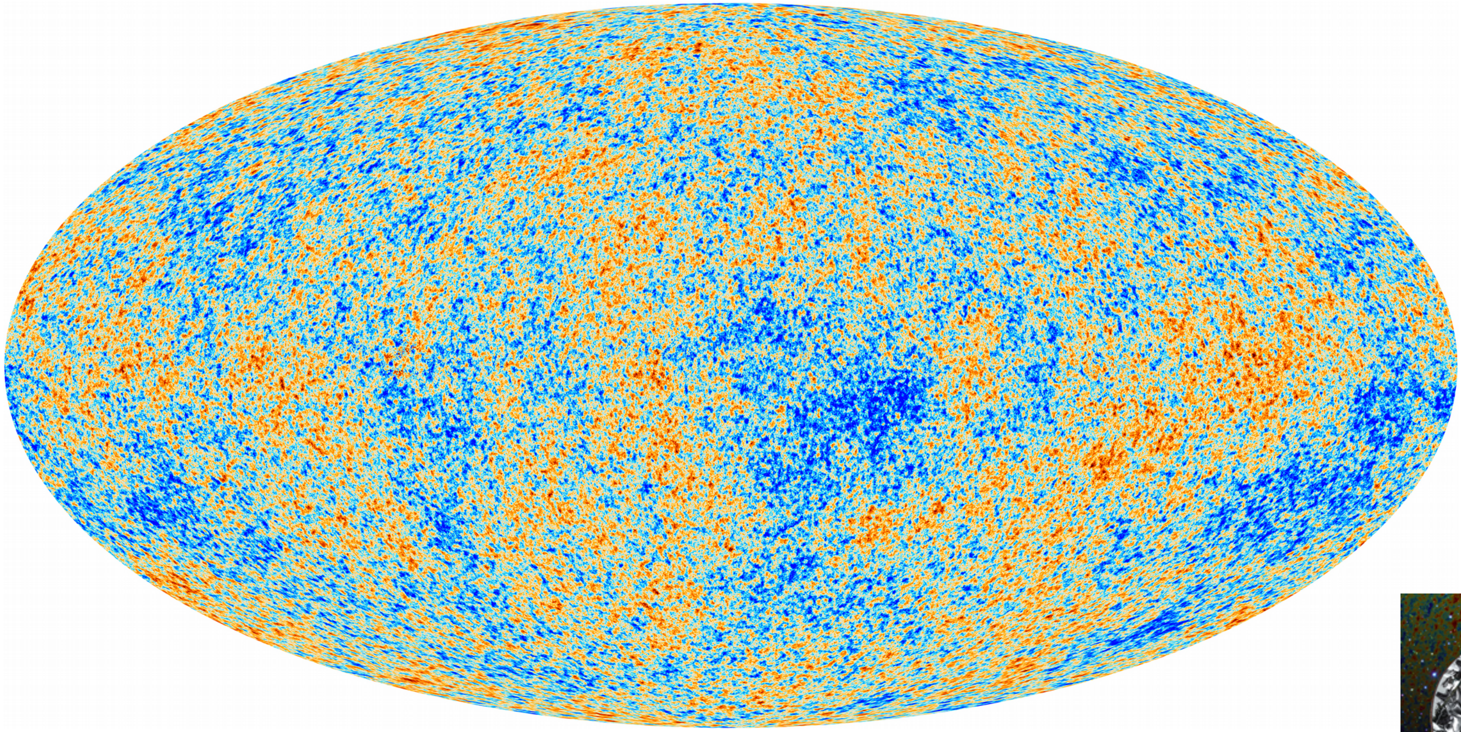
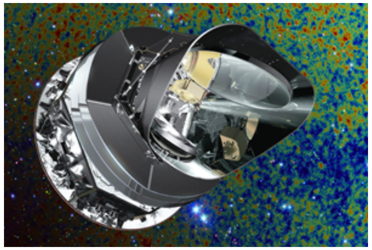
How We Operate

How We Operated...





ESA Planck

How We Operate: Principal Investigators

- Group members lead research in each system:
- **Stars: Alessandro Bressan**
- **Galaxies: Luigi Danese, Andrea Lapi**
- **Dark Matter: Paolo Salucci**
- **Clusters of Galaxies: Riccardo Valdarnini**
- **High Energy Astrophysics: Annalisa Celotti**
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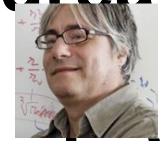


- **Clusters of Galaxies: Riccardo Valdarnini**

- **High Energy Astrophysics: Annalisa Celotti**

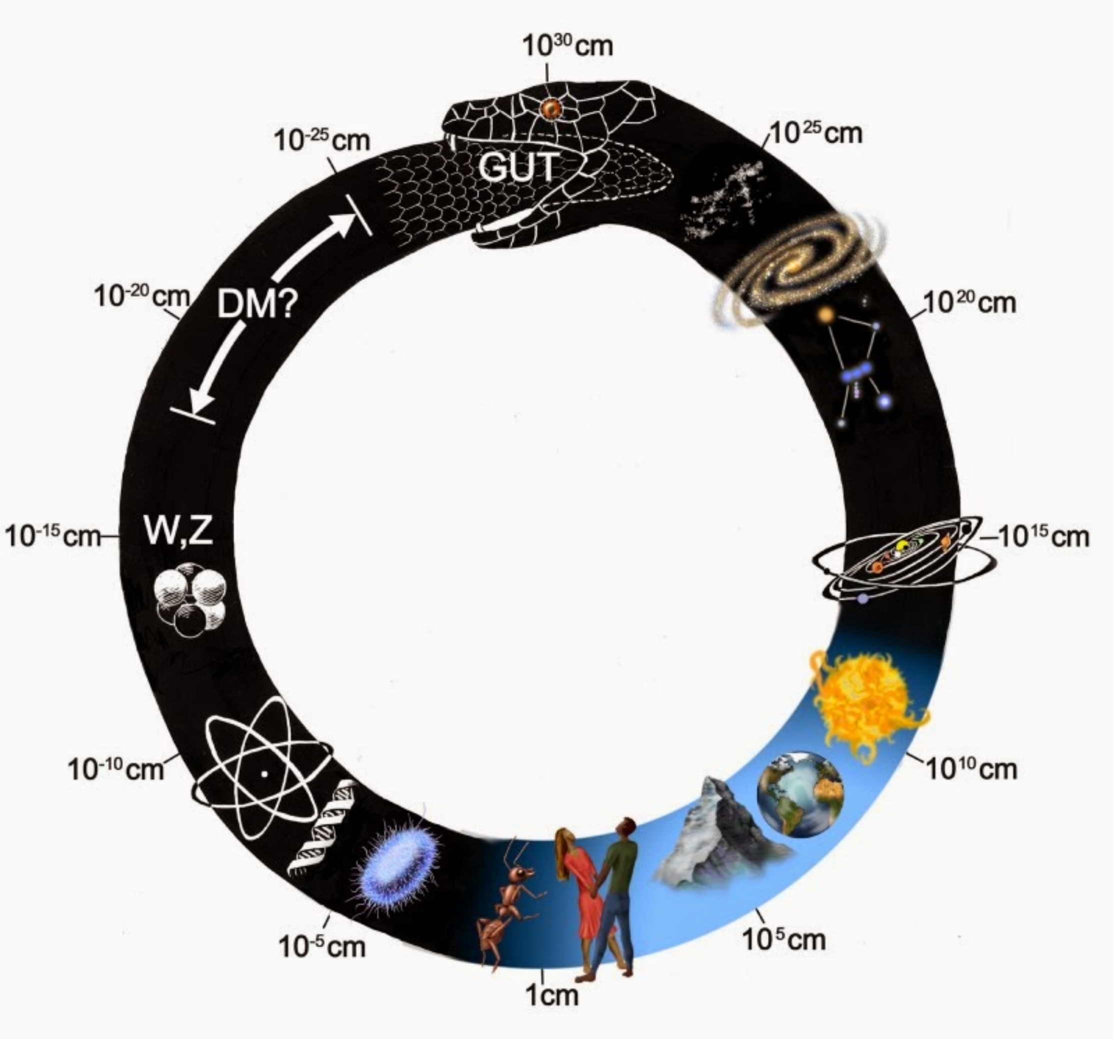
- **Astrophysical Foregrounds: Francesca Perrotta**

- **Early Universe: Carlo Baccigalupi**

How We Operate: Organization of Research

- Principal Investigators lead **teams**, composed by other staff members, **post-docs** and **PhD students**
- The teams perform **theoretical and phenomenological investigations**, do **data analysis and exploitation** of experiments in which SISSA is involved
- **Research** becomes **subject of PhD Thesis**, matter of application for **National and International Grants**
- **Research** is **linked** and **related** to **other groups** at SISSA (**Astroparticle**, **Theoretical Physics**, **...**)
- **Research** is **interfaced** with larger and international collaborations, made of **Experiments** or **Networks**

The Ouroboros Snake



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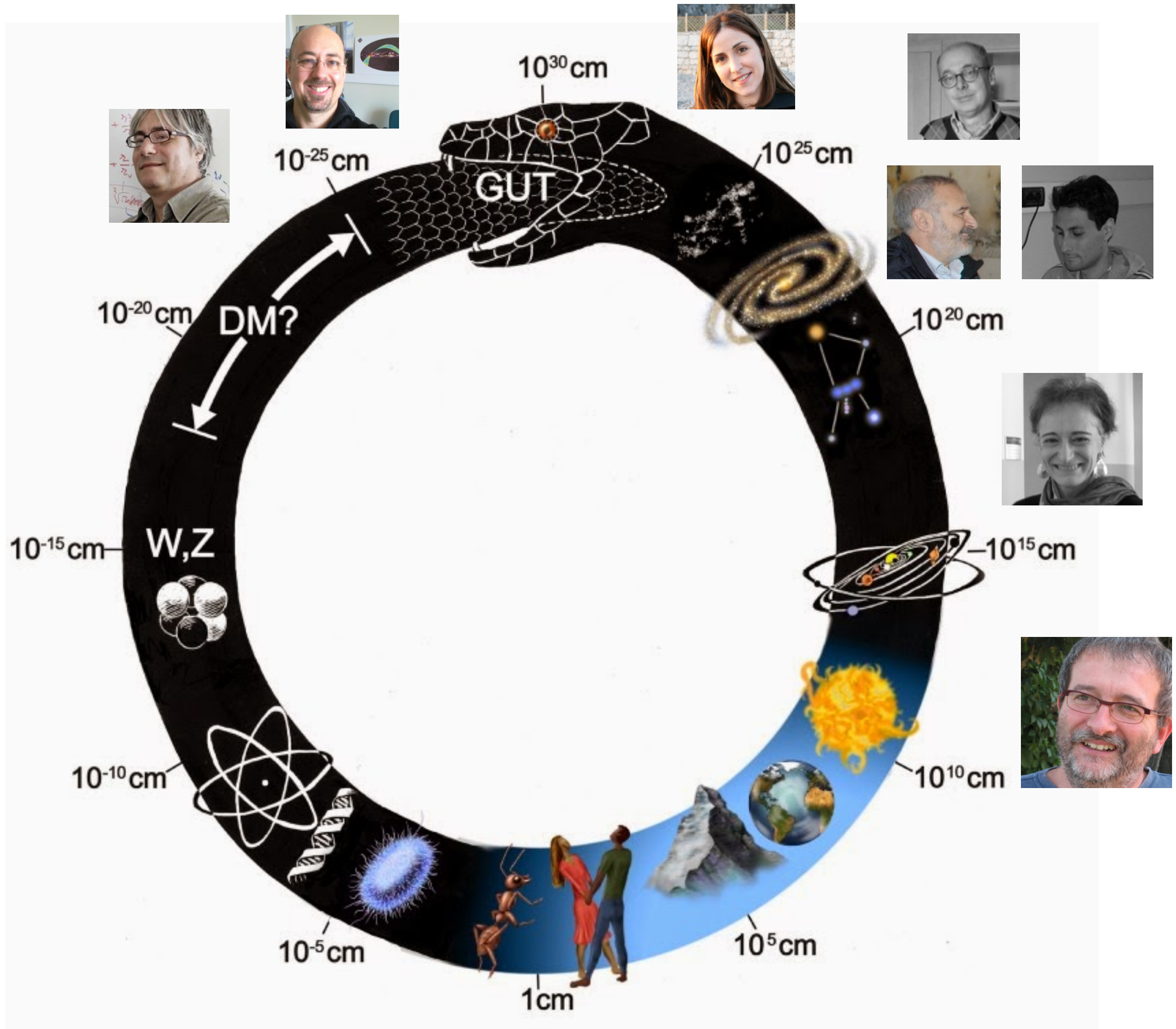

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ASTROPHYSICS

Research Highlights

Research Highlights

- **Alessandro Bressan**: **Stars**
- **Andrea Lapi**: **Galaxies**
- **Paolo Salucci**: **Dark Matter**
- **Riccardo Valdarnini**: **Clusters of Galaxies**
- **Annalisa Celotti**: **High Energy Astrophysics**
- **Francesca Perrotta**: **Astrophysical Foregrounds**
- **Carlo Baccigalupi**: **Early Universe**

Research Highlights

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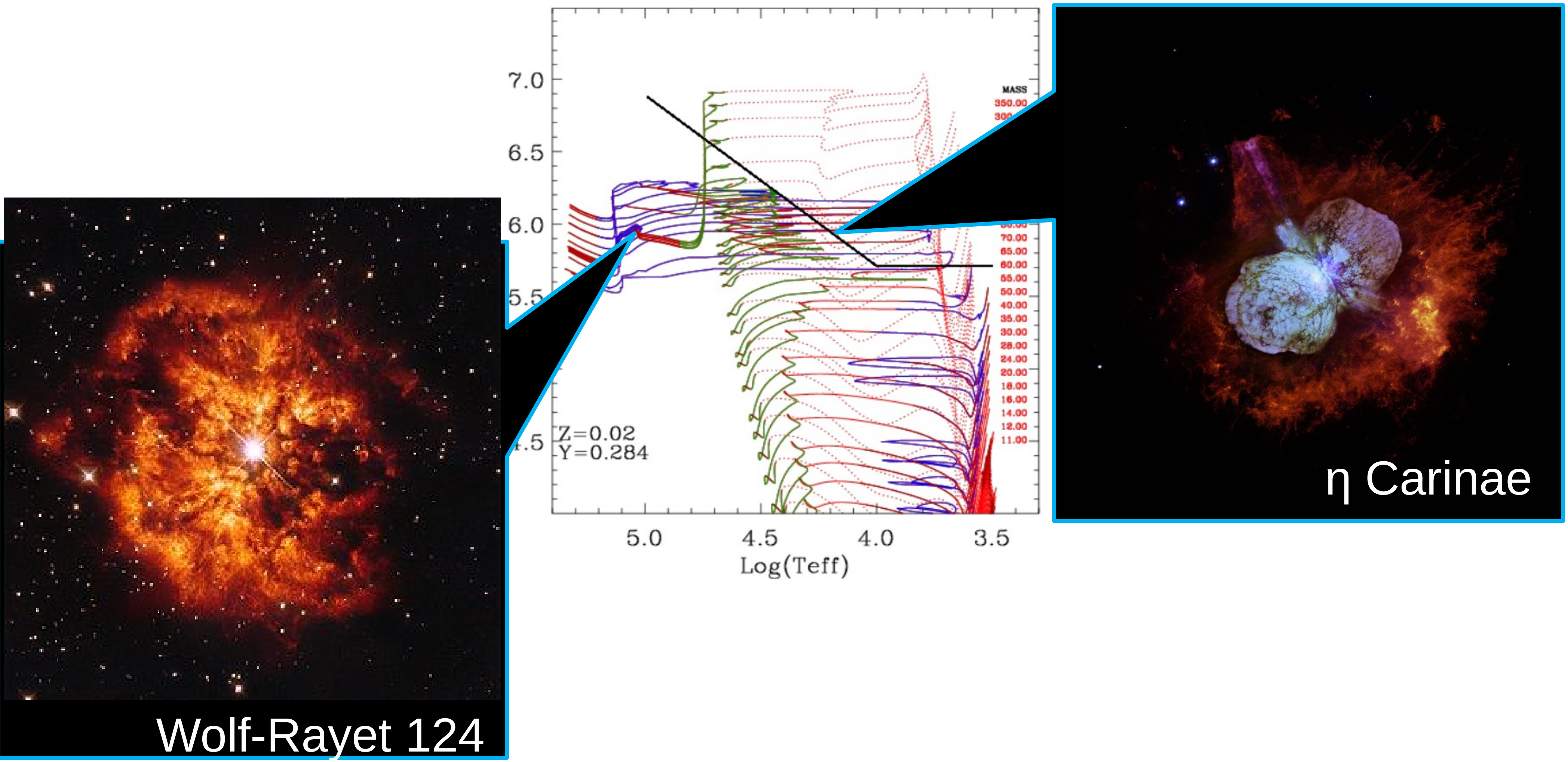
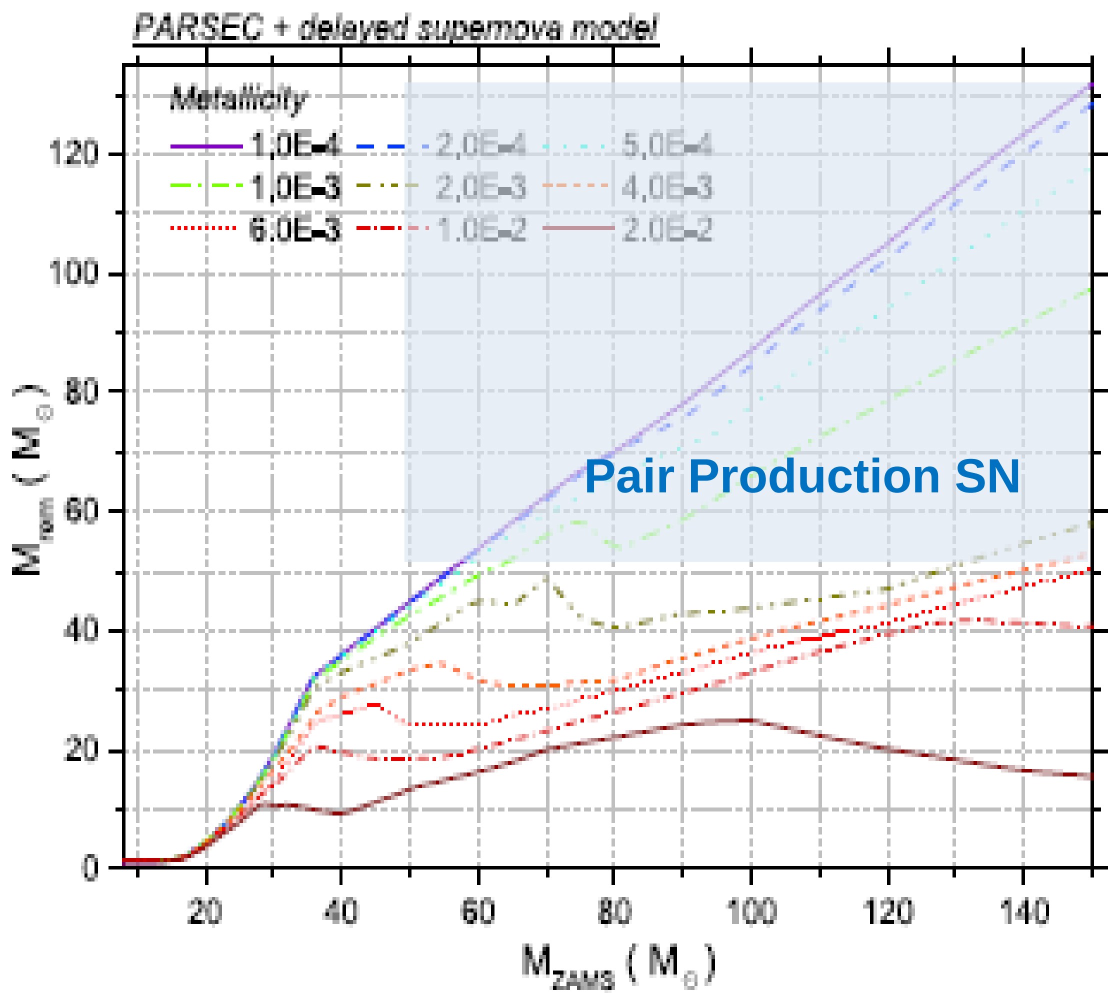
Evolution of Massive Stars



We calculate the evolution of massive stars for different metallicities with our stellar evolution code (Bressan et al 2012; Tang et al. 2014, 2015; Chen et al 2015; Costa et al 2017). We produced the largest existing database of massive stars evolutionary tracks. It is distributed to the astrophysics community for the analysis of resolved and unresolved stellar populations.

The Mass Spectrum of Stellar Black Holes



We have computed the mass spectrum of compact remnants of massive stars with a new population-synthesis code, which couples the PARSEC stellar evolution tracks with up-to-date recipes for Supernova explosion.

The Figure, from Spera, Mapelli & Bressan (2015), has been pasted into Figure 1 of "ASTROPHYSICAL IMPLICATIONS OF THE BINARY BLACK HOLE MERGER GW150914" (Abbott et al 2016) , to estimate the metallicity of the progenitors the first BH binary merger detected through gravitational waves.
Subsequent work has been focused on the Pair Instability Supernovae and on the effects of binary evolution to complete the picture presented in the first paper
(PhD student A. Trani and M. Mapelli and M. Spera, INAF OAPD)

Dust Formation in Asymptotic Giant Branch Stars

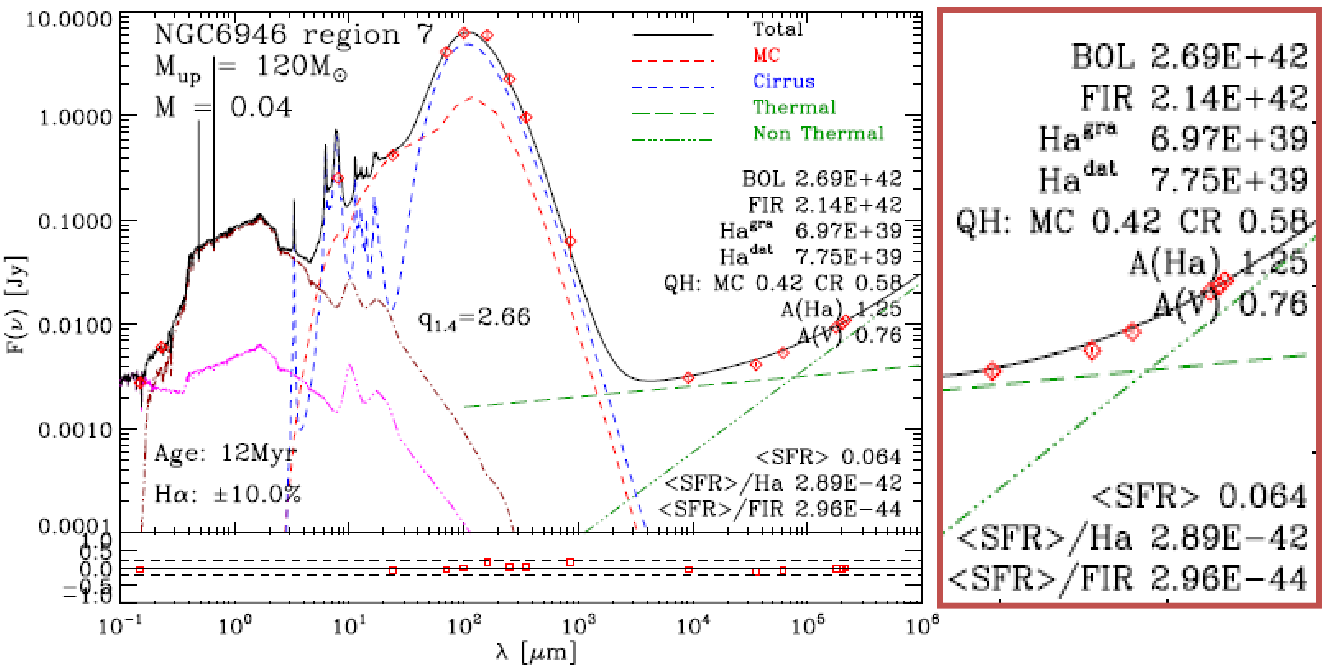
As a member of the *STARKEY* ERC grant (P.I Paola Marigo, Padova University) I’m continuing with my former PhD student Ambra Nanni our research on dust formation in AGB stars

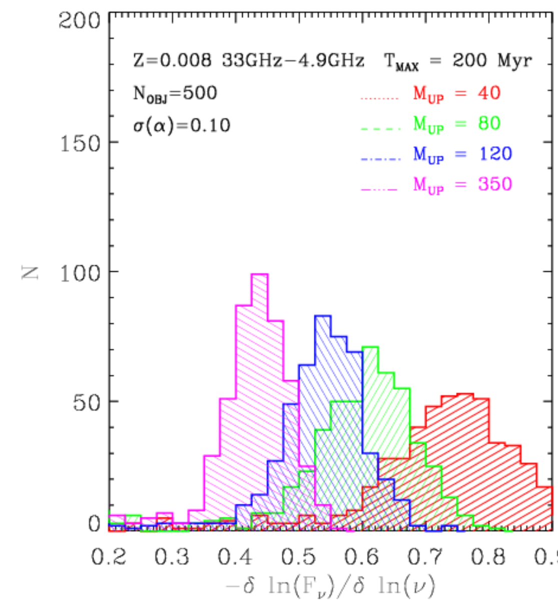
(Nanni, Bressan et al. 14;
Nanni et al. 2016;
Nanni et al. 2017)

Panchromatic Spectral Evolution of Galaxies

A deep revision of our code to predict the spectral energy distribution of dusty galaxies is underway (A. Lapi and PhD students I. Obi and S. Goswami).

NGC6946





We propose a method to probe the upper mass limit of the initial mass function (IMF) in actively star forming galaxies, based on the spectral slope of their radio emission. With this new method we will address one of the most challenging problems in stellar astrophysics.

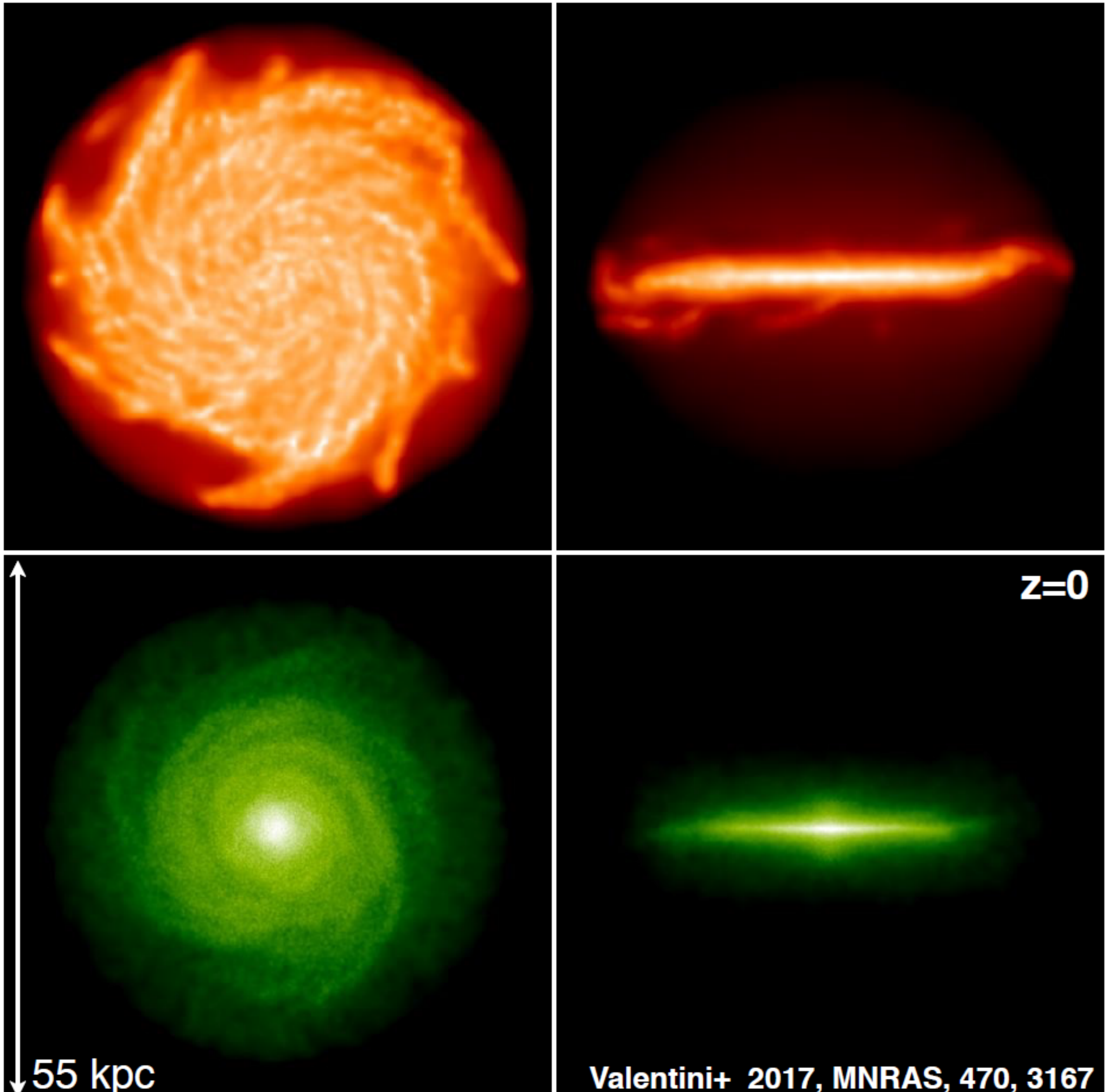


Figure: Projected gas (**top** panels) and star (**bottom**) density for the AqC5-newH (Valentini+ 2017) simulation at z=0. Left panels: face-on densities, right ones: edge-on densities. The z-axis is aligned with the angular momentum of star particles within 8 kpc from the minimum of the gravitational potential.

COSMOLOGICAL HYDRODYNAMICAL SIMULATIONS OF DISC GALAXIES

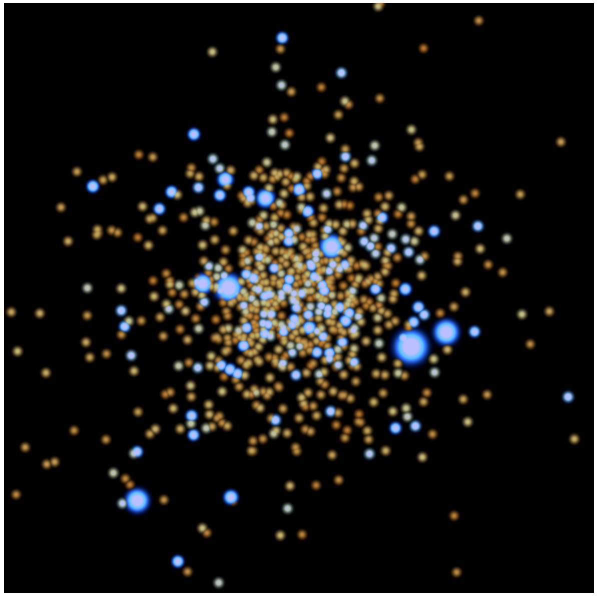
M. Valentini, A. Bressan, G. Murante, S. Borgani, A. Lapi

- **INITIAL CONDITIONS:**
  - halo of $\mathrm{M_{vir}} \simeq 2 \cdot 10^{12}\ \mathrm{M_\odot} h^{-1}$
  - box size: $100\,\mathrm{Mpc\ h^{-1}}$
- **GADGET-3 CODE:**
  - improved hydro-scheme (Beck+ 2016)
  - baryonic physics: gas cooling **+** star formation **+** chemical enrichment from stellar evolution **+** galactic outflows (Valentini+ 2017) **+** AGN feedback (Valentini+, in prep.)

▸ ***COMPUTING RESOURCES:***

Millions of CPU hours at Ulysses (SISSA) and national facilities (CINECA) through HPC calls. One simulation of a disc galaxy takes ~10000-30000 CPU hours, depending on the implemented physics.

Coupled Dynamics & Stellar Evolution in Extreme Environments



DIRECT N-BODY SIMULATIONS

RESOURCES:

- 50k CPU+GPU hours on PLX (CINECA)

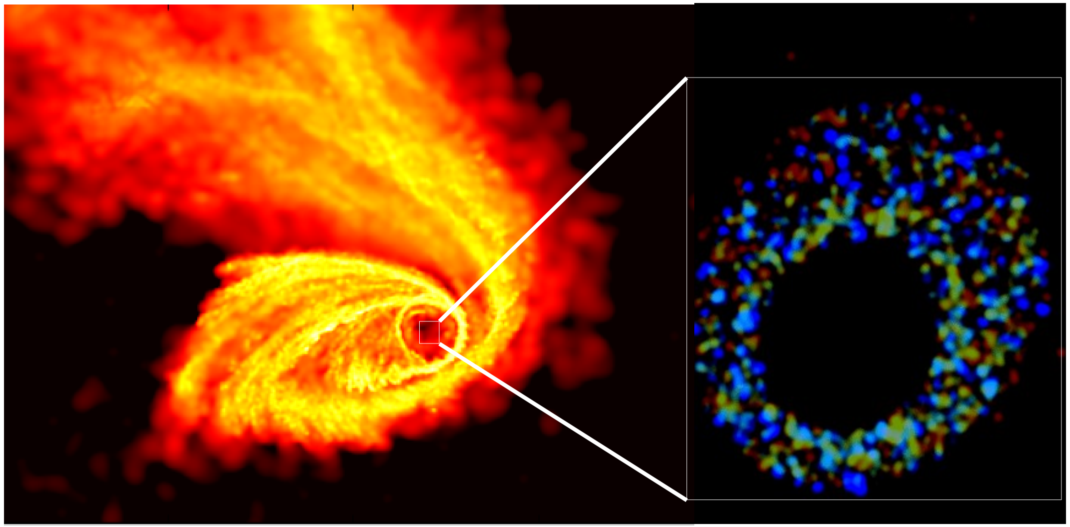
CUDA parallelization for gravity computation

Progetto CINECA: HP10CGUBV0 "FrontBH"

Publications:

- Trani, Mapelli, Bressan, 2014, MNRAS

Star Formation and Dynamical Evolution in Galactic Nuclei



DIRECT N-BODY AND HYDRODYNAMICAL SIMULATIONS

RESOURCES:

- 100k CPU+GPU hours on Ulysses
- 450k CPU hours on Fermi (CINECA)

CUDA parallelization for gravity computation

Progetto PRIN INAF2014: UA.00.FISI – Cod.
R_PRN_INAF_14_FISI_Bressan_0273
Progetto CINECA: HP10B338N6 "starSMBH"

Publications:

- Mapelli & Trani 2016, A&A
- Trani, Mapelli, Bressan et al. 2016, ApJ

Research Highlights

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Galaxy Formation and Evolution

- *Fundamental issue*: How do galaxies form and evolve in a cosmological context ?
- *Theoretical challenge*: understand complex physics of baryons within galaxies! E.g., gas condensation within dark matter potential wells, cooling, star formation, energy feedback from stars and central supermassive black holes, reprocessing of stellar light by interstellar dust grains, chemical evolution, galaxy merging, etc.
- *Observational landscape*: extremely rich datasets at different wavelengths from radio to X/γ-ray bands, both on individual targets and on statistical grounds (luminosity/mass functions, clustering, etc.), including evolution along cosmic times (>10 Gyrs !).

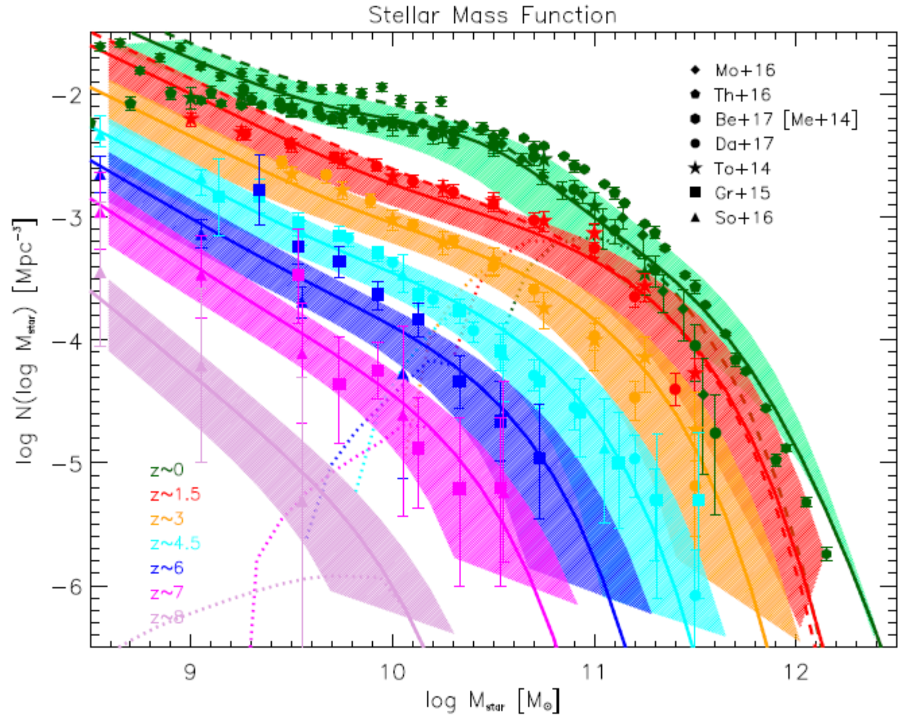
Galaxy Formation and Evolution

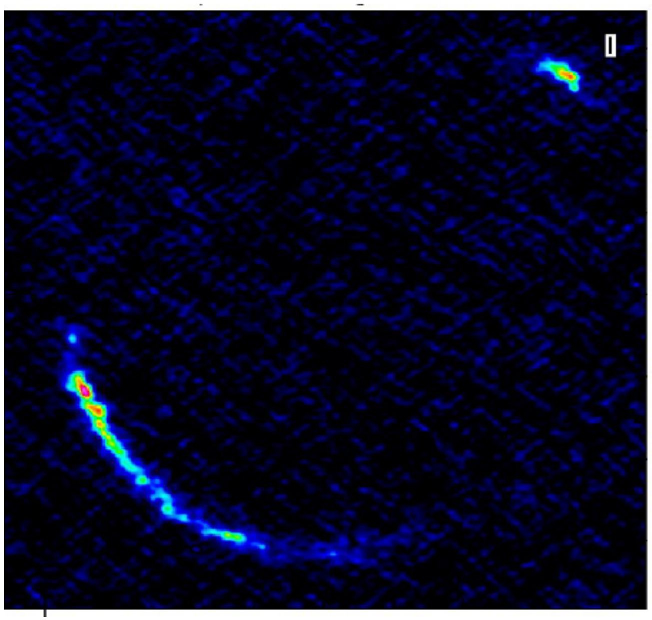
- *Team*: A. Lapi, L. Danese & Ph.D. students (average of 3-4 over 4 yrs).
- *Main collaborators in SISSA*: C. Baccigalupi & F. Perrotta (cosmology), A. Bressan (stellar evolution), A. Celotti (high-energy), P. Salucci (dark matter), M. Viel (large-scale structure).
- *International collaborations*: *Herschel* (far-IR obs.), *Planck* (CMB exp.), ATHENA (X-ray obs.), *Euclid* (dark energy via galaxy clustering and weak lensing), SKA (radio interferometer), JWST (optical/near-IR obs.).
- *Active grants*: PRIN MIUR 2015 Euclid grant, PRIN INAF 2017 SKA grant, EU H2020 RadioForeground Grant ASI-COSMOS network, INFN QGSKY and InDARK Initiatives, Spanish MINECO I+D 2015 project.

Galaxy Formation and Evolution

Spotlights on recent research activity.

1 - Understanding the buildup of massive galaxies: in-situ star formation vs. ex-situ mergers





2 - Elucidating the role of supermassive black holes in galaxy evolution via strong gravitational lensing observations.

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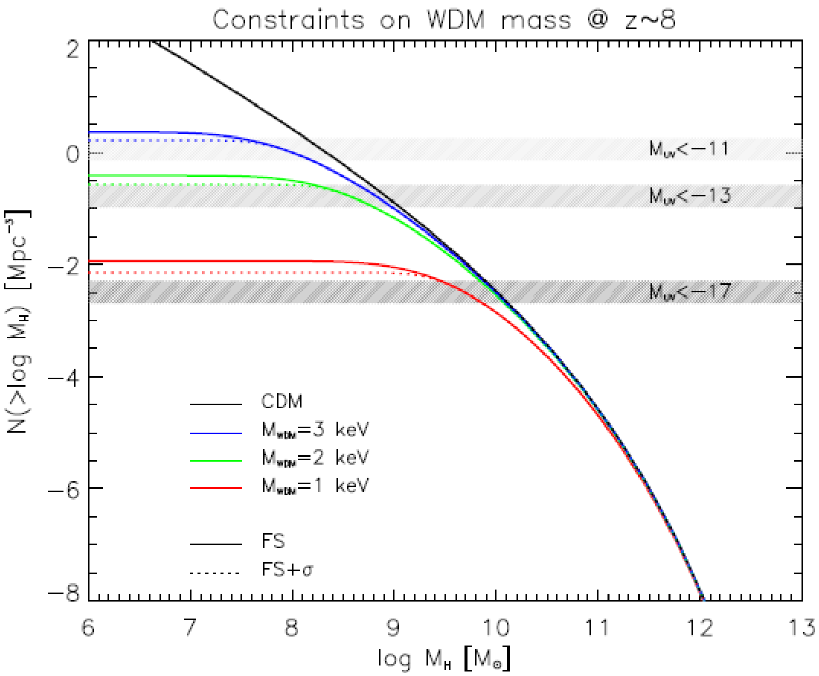
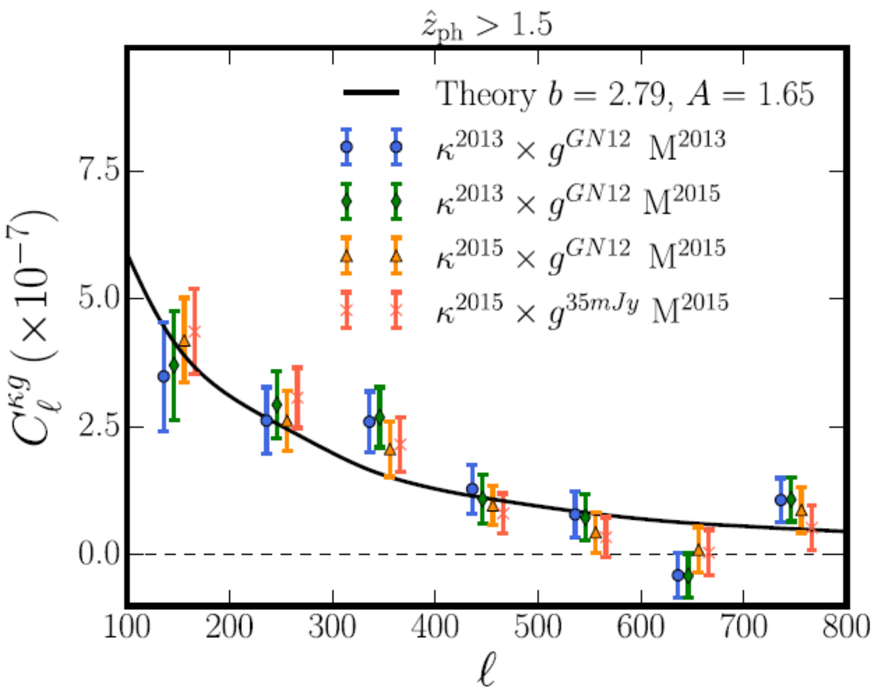
Galaxy Formation and Evolution

Spotlights on recent research activity.

3 – Abundance of high redshift galaxies as a probe for the nature of dark matter.



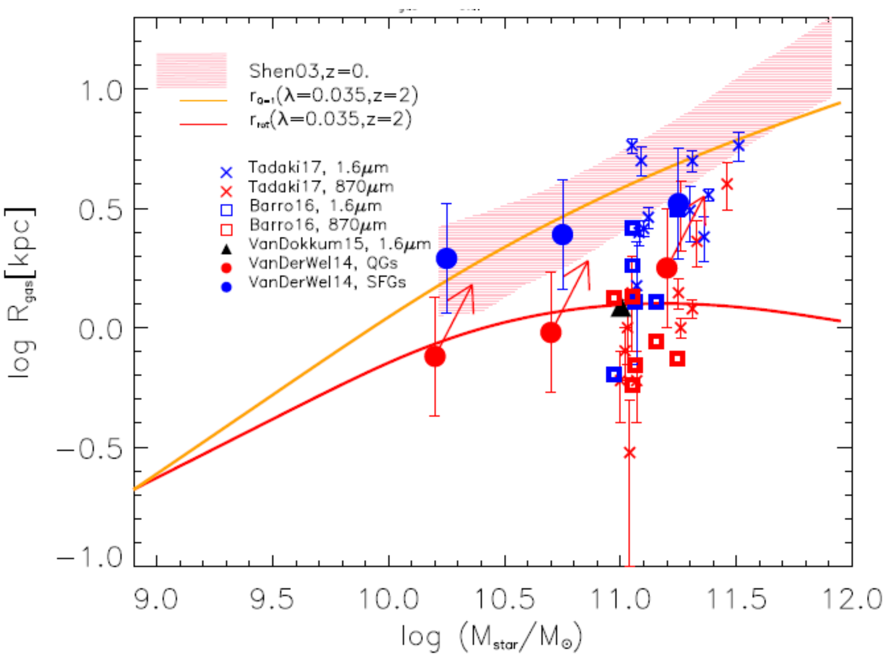


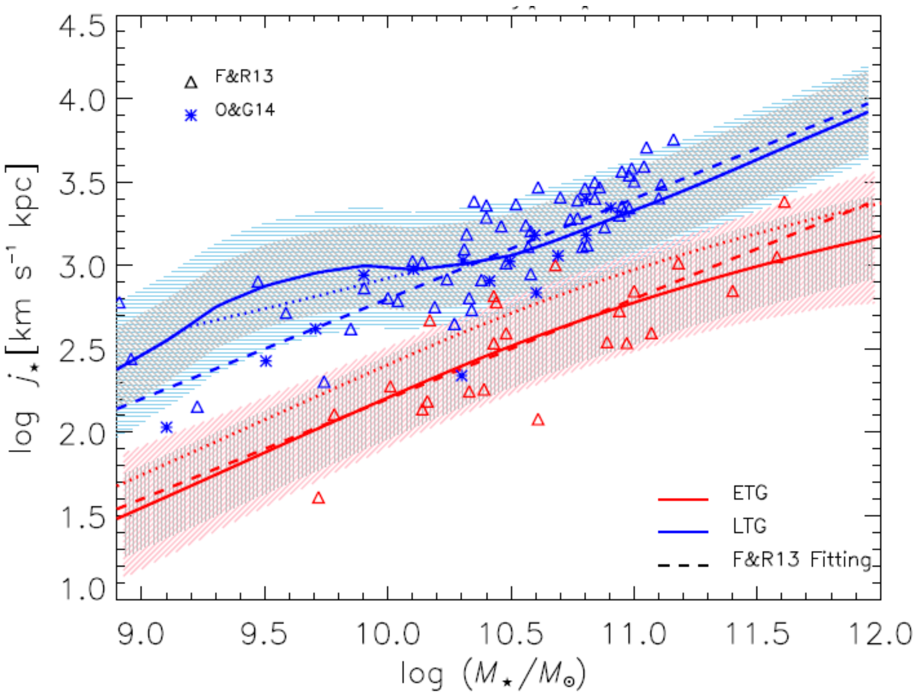
4 – Cosmology via cross-correlation of CMB lensing with wide-areas galaxy surveys.

Galaxy Formation and Evolution

What next?

1 – Looking for the origin of galaxies' angular momentum.





2 – Dissecting the size evolution of massive galaxies' progenitors.

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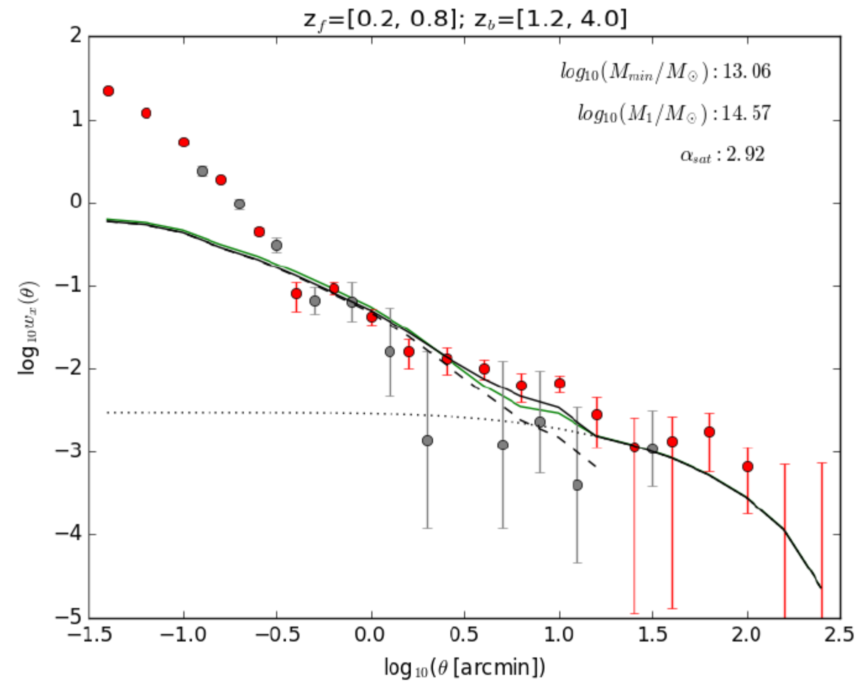
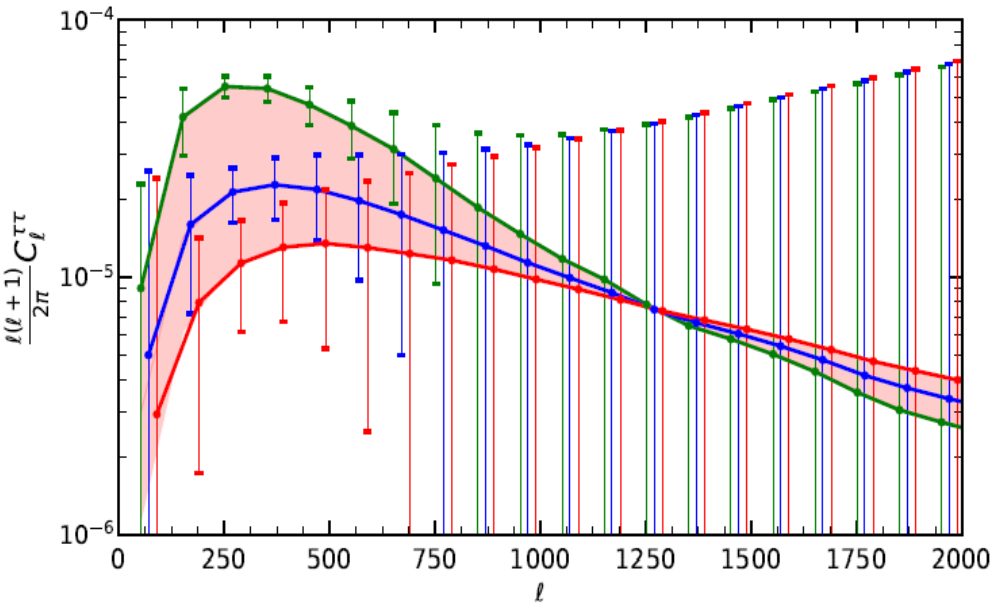
Galaxy Formation and Evolution

What next?

3 – Probing dark energy via weak-lensing magnification bias





4 – Revealing patchy-ness and spatial evolution of the cosmic reionization.

Galaxy Formation and Evolution

Long-term plans

Bottom line will be to strengthen the link between astrophysics of galaxy formation, astro-particle physics, and cosmology at large. E.g.,

- astrophysics of galaxies → control of systematics in CMB exp.

- cosmic reionization & DM microphysics → JWST + CMB exp.

- supermassive BH merging and gravitational wave emission/bkg. -> eLISA

- cross-correlation studies -> interface next-gen CMB polarization exps. with LSS surveys to probe primordial gravitational waves via delesing.

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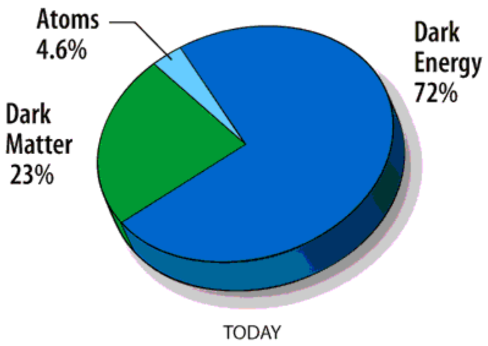
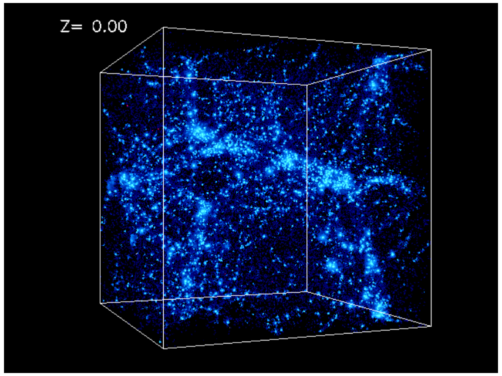
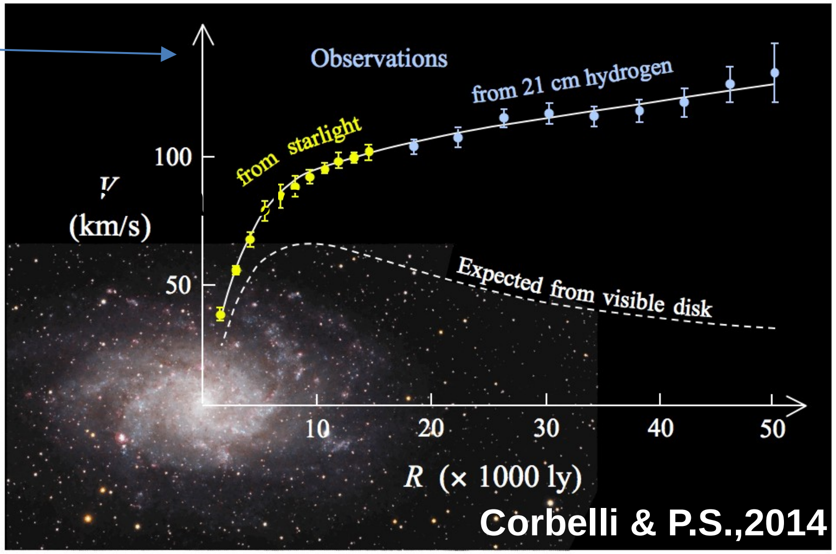
Dark matter: where it is and what it is?






Dark Matter is a main **protagonist** in the Universe

Expecially in Galaxies



Very strong links with:

Astroparticle: both looking at and same Universe

Elemen Part: both searching for physics beyond SM

To reach our goal we study the whole Universe through the 4 standard forces, Plus something else

People active in the field *Dark Matter, where it is, what it is?* at SISSA

Paolo Salucci (staff)
Viviana Gammaldi (postdoc)
Chiara di Paolo (stud)
Abhishek Subaranian (stud GSSI)
J.Philippe Fontaine (stud GSSI)
Gauri Sharma (stud)
Andrea Lapi (staff)
Gigi Danese (staff)
Stefano Liberati (staff) just started

In SISSA others also work in different, but related, aspects of Dark Matter among them: Sandro Bressan, C. Baccigalupi, P. Ullio, M. Viel , A De Simone, A. Takahashi and several students : there will likely be future collaborations .

Long term collaborations in this research field outside SISSA

- **Nicola Turini (CERN), Norma Sanchez (Observ. de Paris), Gerry Gilmore (Cambridge). Andrea Cattaneo (LAM Marseille), Gianfranco Gentile (Univ of Gent), Ruben Alfaro (UNAM, Mexico), Fabrizio Nesti (Rudjer Boskovic Inst., Zagabria), Edvige Corbelli (INAF-Firenze-Arcetri), Maria Felicia de Laurentis (Univ. Francoforte) , Andy Burkert (Munich), Ekaterina Karukes (Sao Paolo)**

GRANTS for this Research Field

-Twinnings Rudjer Boskovic Institute, **H2020,EU**
-CANTATA, **COST H2020,EU**
-Iniziativa speciale QGSKY**, INFN**

Open lines of research inside the field: DM…

Distribution of Dark Matter in all different types of galaxies
Distribution of Dark Matter in galaxies at high redshift
Angular Momentum, Galaxy Formation and Dark Matter
Collisional Dark Matter
The fundamental nature of the “dark Particle”
New Physics..

In the past year 2 thesis defended on these argument (Karukes and Lopez Fune)

Highlights on recent Results

Universal Rotation Curve in Dwarf Disks

Karukes and P.S., 2016

Dwarf disks range 2 order of magnitude in Luminosity but they

-obey to the same URC of much bigger Spirals,
-are mostly dark matter dominated .
-have a cored DM distribution (and not a NFW)
-show an intriguing relation between the concentrations of Dark and Luminous matter.

The URC of dwarf disc galaxies

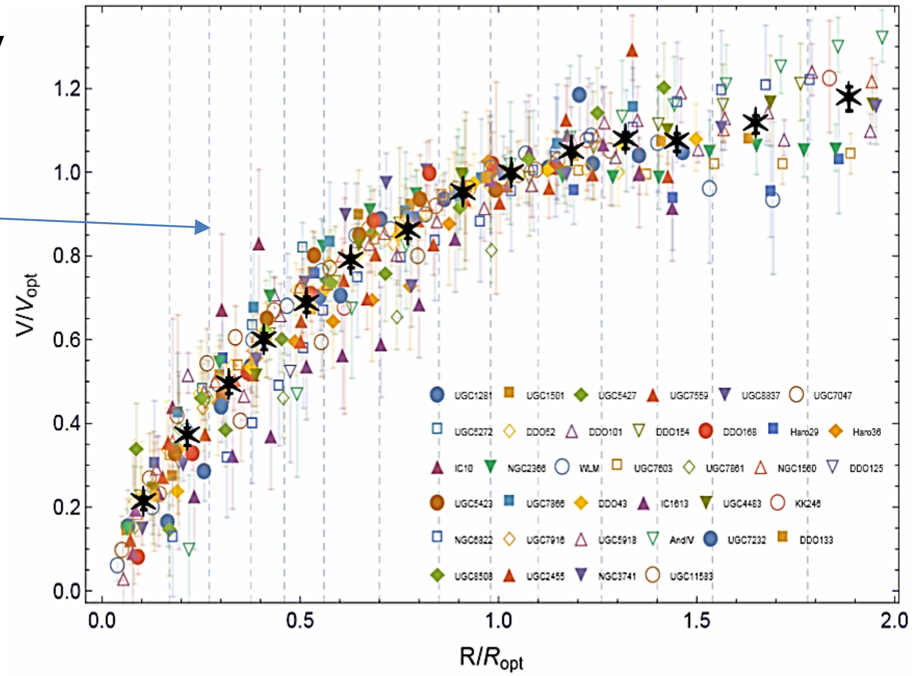


Figure 3. Individual RCs normalized to R_{opt}, V_{opt}. Black stars indicate the synthetic RC. Bins are shown as vertical dashed grey l

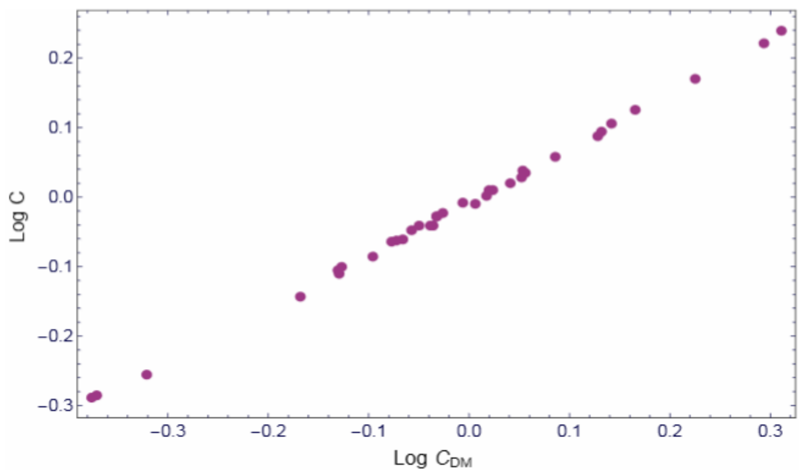
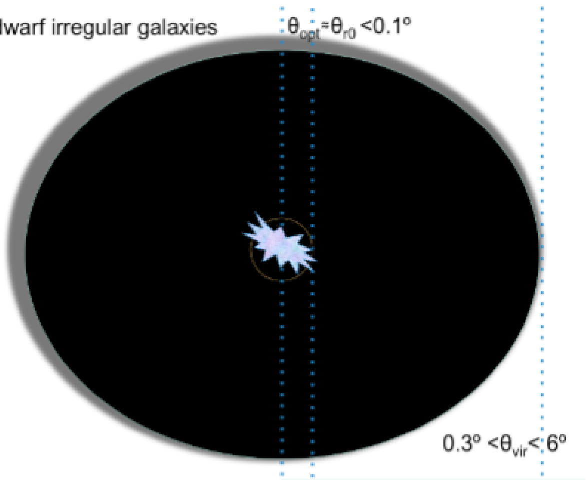


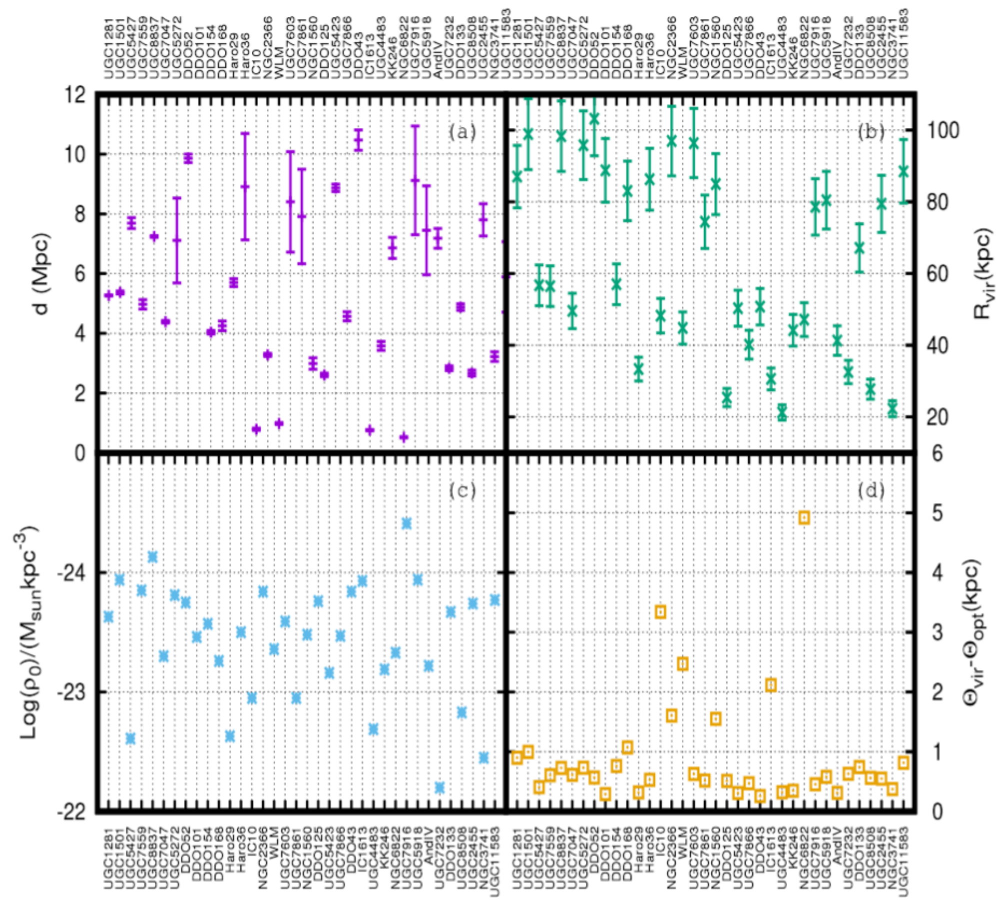
Figure 15. The compactness of the stellar disc versus the compactness of the dark matter halo.

Prospect for dark matter detection in the extended halos of dwarf disks through their gamma emission *(Gammaldi, P.S. et al 2017)*

36 *new* nearby dwarf disks



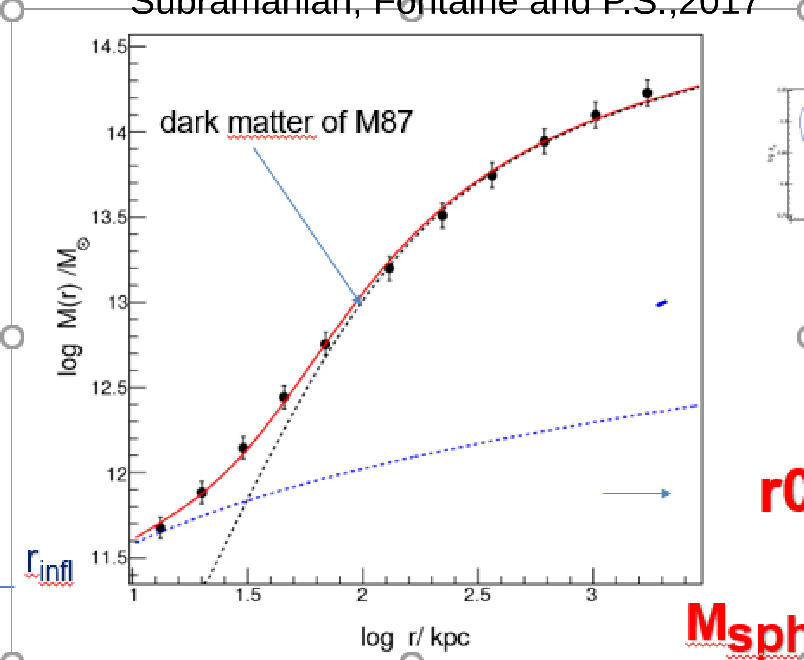
Observed and Derived galaxy properties

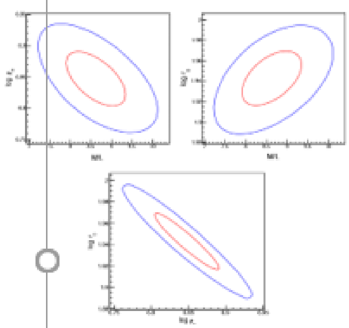


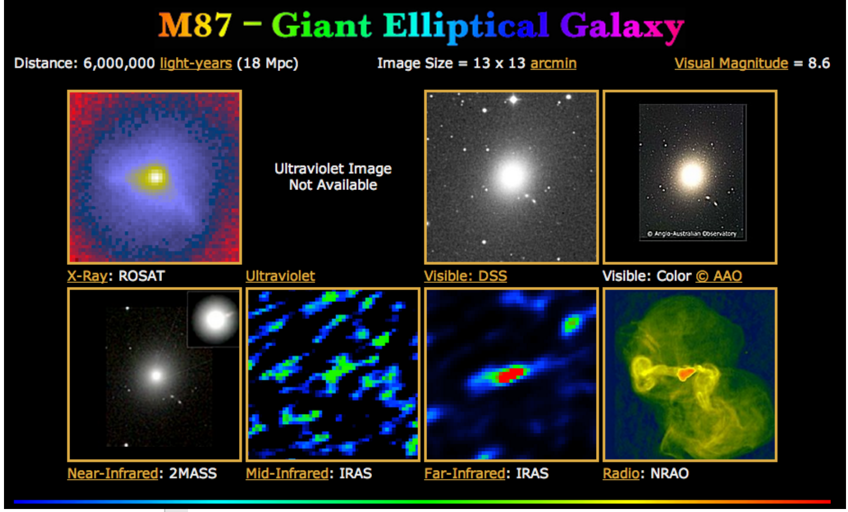
New data, accurate mass models.
Gamma emission free from astrophysical contamination,

The Mass Model of M87

Subramanian, Fontaine and P.S.,2017







$r_0 = (91.2 \pm 9.0)$ kpc

$M_{sph} = (1.3 \pm 0.1) \times 10^{12} M_\odot$

$M/L_V = (8.6 \pm 1.2) M_\odot L_\odot^{-1}$

log Mvir/Msun=14.0

$rho_0 = (6.9 \pm 1.4) \times 10^6 M_\odot / kpc^3.$

The biggest galaxy of the Local Universe

It has a giant DM core of 100 kpc, that could not be created by SN Explosions.

Self-Interacting/Collisional/Fuzzy dark matter particles ?

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Future developments and plans

The aim is always: The full understanding of the Dark Matter Phenomenon (that it is likely to require New Physics)

5-year strategy: to gather always more specific information on the distribution of dark matter in galaxies, in order to definitely rule out, barring surprises, the WIMP paradigm
10-year strategy: to build, guided by the properties of dark and luminous matter of all kind of galaxies at all redshifts, the new paradigm: Modified Gravity, WDM, Collisional DM, Fuzzy DM , Other Dark Matter.

GAIA, ALMA, SKA, JWO are some of the experiments that will provide crucial Data

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Numerical hydrodynamic with Cluster of Galaxies (R. Valdarnini)

- Galaxy clusters are very important in cosmology
- They are very massive
- Their properties strongly depend on cosmological parameters
- Therefore an accurate knowledge of their structure allows to exploit these objects as cosmological probes
- In perspective, this is necessary since upcoming surveys (Euclid etc…) will pave the way to the so-called ‘precision cosmology’

- However, the formation of evolution of a galaxy cluster is a strong non-linear process leading to the gravitational collapse of baryons and dark matter (DM)

- It is then necessary to resort to N-body/hydrodynamical codes to properly model the collapse of a galaxy cluster

In the scientific community there are two schools of thoughts about which numerical scheme to use to model the hydro : Eulerian (Adaptative Mesh Refinement, AMR) and Lagrangian (Smoothed Particle Hydrodynamic, SPH) . Both approaches present merits and shortcomings, I am an SPH follower.

The past years have been dedicated to the development of a state-of-the-art N-body/SPH code with which to simulate galaxy clusters. In particular the code is aimed at studying

TURBULENCE IN GALAXY CLUSTERS

Turbulence is very important because it is a source of pressure and heating, thus affecting several processes:

- ✓ Pressure profile : non-thermal (impact on Sunyaev-Zel'dovich (SZ) effect
- ✓ Mass estimates of galaxy clusters (X-ray estimates based on hydrostatic equilibrium, missed
- ✓ Cooling flow problem : fraction of cold gas in cluster cores, unknown source of heating

- A technical detail : basically the parallelization of an SPH code is a problem of DSDE (Dynamic Sparse Data Exchange)
- The latest library MPI3.0 has been implemented paying attention to this sort of problems.
- A parallel version of the code based on these new features greatly increases its scalability properties (benchmark tests under way). This is good because in simulations of turbulence the BIGGER the BETTER: one needs a number of particles as large as possible to probe the spectral inertial range down to the smallest scales

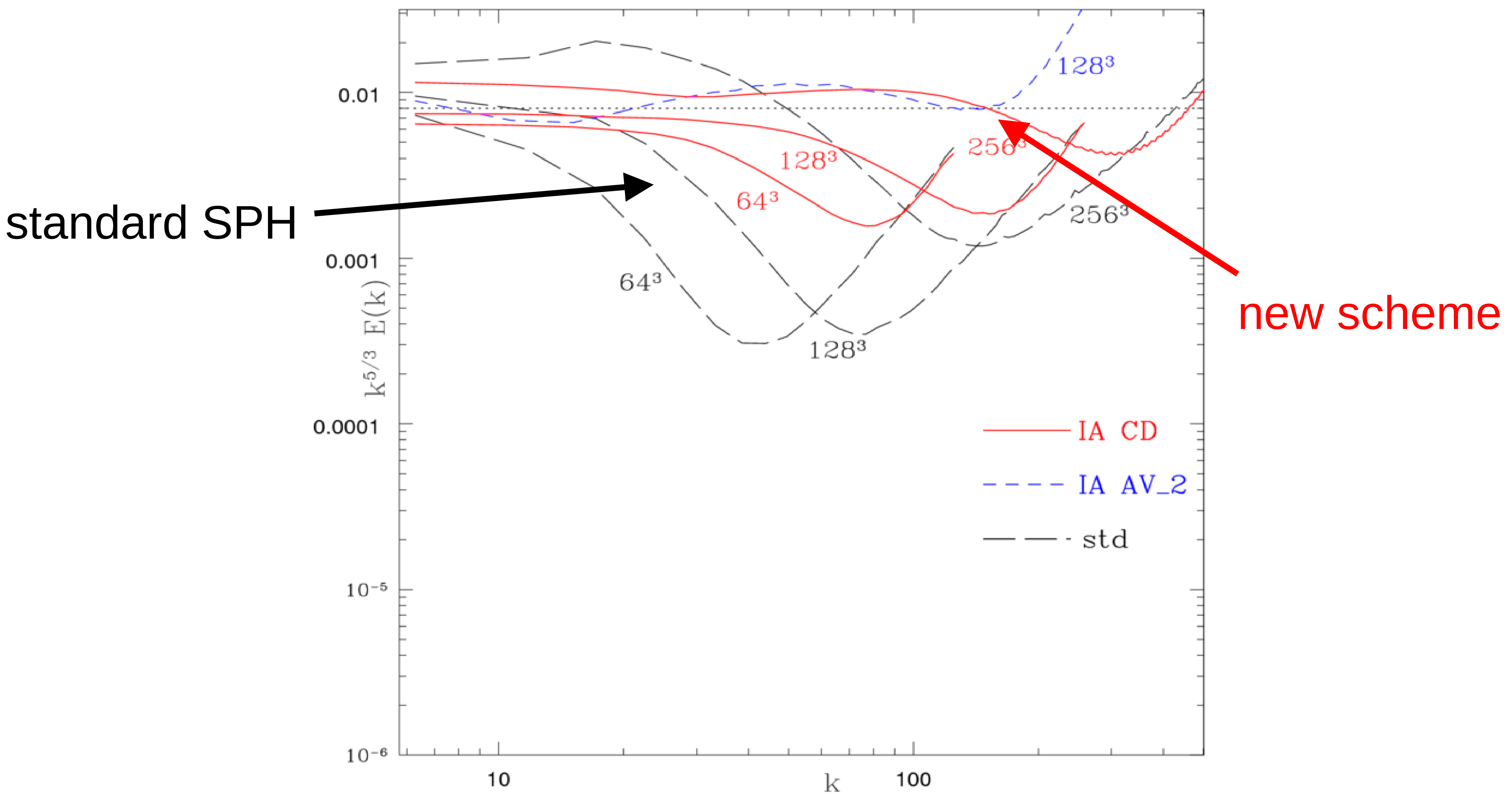
Highlights on Results

- In the past years a thermal diffusion model has been incorporated into the SPH equations with the aim of mimicking sub-resolution turbulence (RV2012). A striking result has been the solution to the long-standing problem of the discrepancies found between the level of core entropies in AMR and SPH simulations of galaxy clusters

- The code has been applied to study the thermal structure of baryons in a large numerical sample of galaxy clusters (V. Biffi and RV , 2015) finding significant differences with respect previous results

- Recently (RV , 2016), an high order gradient scheme has been implemented with the aim of reducing sampling errors in the SPH momentum equation. Results from a variety of hydrodynamical tests show that the code is competitive (or even better) with other numerical schemes recently proposed .

The figure shows the spectral velocity behaviour in simulations of driving subsonic turbulence , the dashed line indicates the Kolgomorov spectrum



The results indicate that the code can be profitably used in many astrophysical contexts where an accurate modeling of the hydrodynamic is necessary (for example subsonic turbulence)

Collaborations: V. Biffi, Trieste, Astronomical Observatory
S. Ettori Bologna INAF

Future perspectives:

- The code will be used to study turbulence in galaxy clusters, paying particular attention to the SZ effect
- Other topics where code performances are an asset:

- Collisions between galaxy clusters: very energetic events, useful to test alternative DM models
- Collapse of a dwarf galaxy(dW): there is a deficit of baryons in dW, simulations helpful to study the cusp/core problem

Research Highlights

- Alessandro Bressan: Starts
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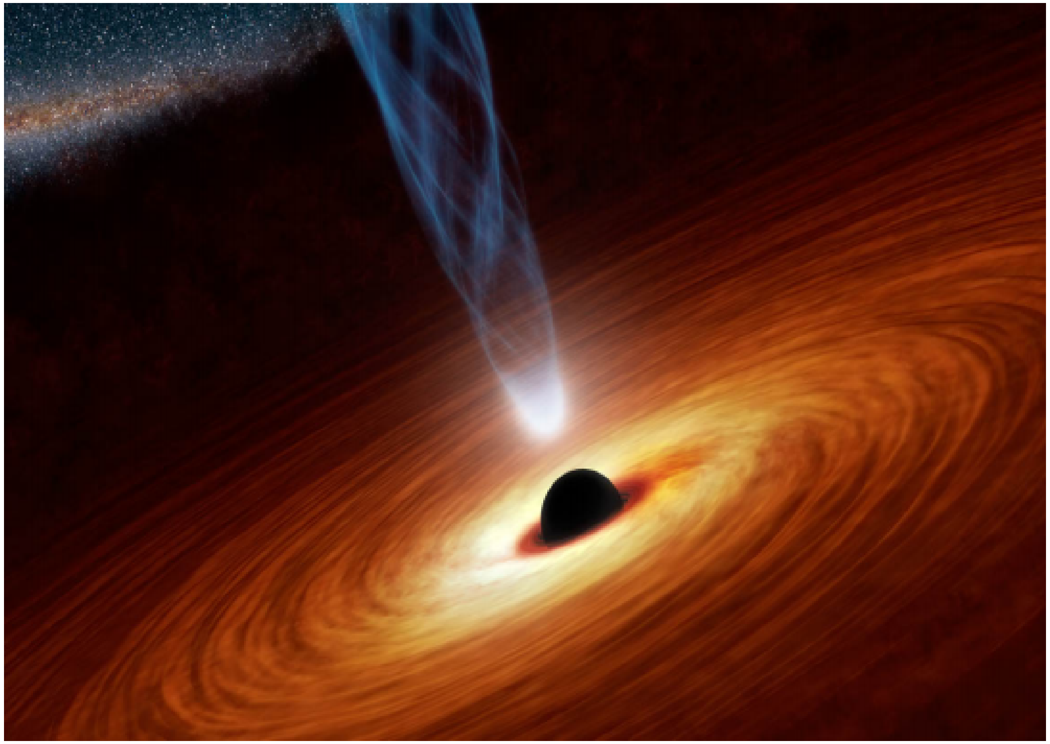
- Francesca Perrotta: Astrophysical Foregrounds
- Carlo Baccigalupi: Early Universe

Research Context and Description

- Study of the most extreme and distant sources in the Universe: *Gamma-Ray Bursts (GRB)* and *Active Galactic Nuclei (AGN)*. Focus on: identify the nature of processes responsible for the observed radiation, understand acceleration of particles to high energies, role of magnetic fields, jet formation and composition)



- Connections to other fields: these sources are laboratories for astroparticle physics, cosmology, plasma physics, quantum gravity,…

Ongoing activities

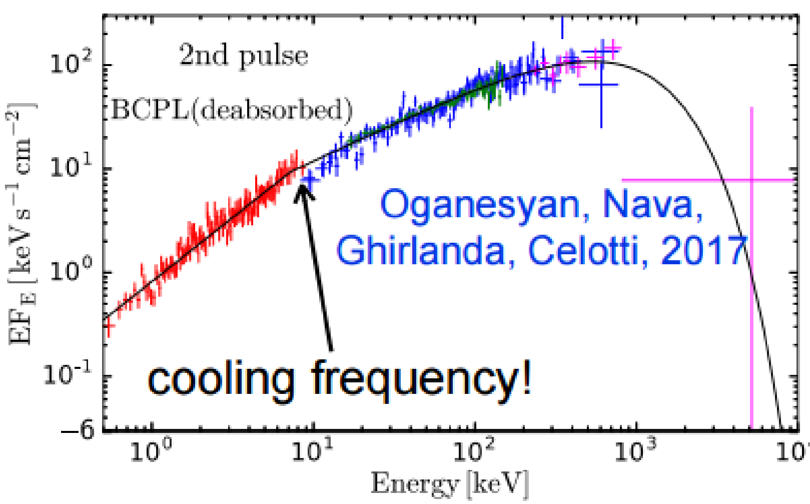
- **People:** Prof. Annalisa Celotti, Dr. Lara Nava (INAF), Gor Oganesyan (PhD student) and Elias Kammoun (PhD student)
- **Ongoing research:**
  - Gamma-Ray Bursts: what is the physical mechanism producing the observed gamma-ray radiation? Recent breakthrough discovery points to synchrotron radiation (Oganesyan et al. 2017)
  - AGNs: study of X-ray emission: variability and coronal properties (Kammoun et al. 2015, 2017a, 2017b)
- **Collaborators:** UniTs/INFN Trieste (Dr. Longo + PhD students and postdocs), INAF-Brera (Dr.s. Ghirlanda and Ghisellini), University of Zagreb (Dr. Zeljka Bosnjak), University of Nova Gorica (Prof. Andreja Gomboc)
- **Membership** in large collaborations: Fermi-LAT and CTA

Highlights on Results

GRBs — Origin of keV-MeV radiation

- Characterisation of gamma-ray burst spectra down to 0.5 keV: first time that this analysis was performed. Found consistency with synchrotron shape and identified the location of the cooling frequency (*Oganesyan, Nava, Ghirlanda, Celotti, 2017a*).

- This new feature identified in the spectra brings information on magnetic fields at the source, distance from the Black Hole where the radiation was produced, fluid Lorentz factor (*Oganesyan et al 2017b* and *Nava et al 2017, in preparation*).

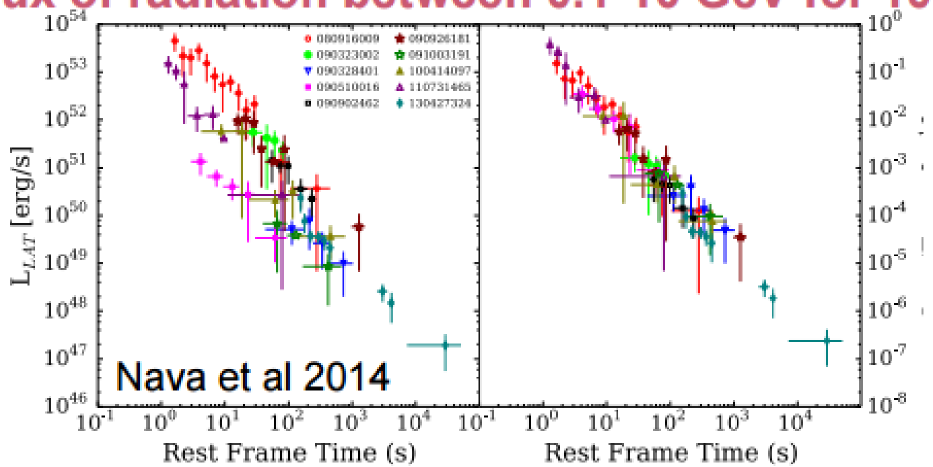


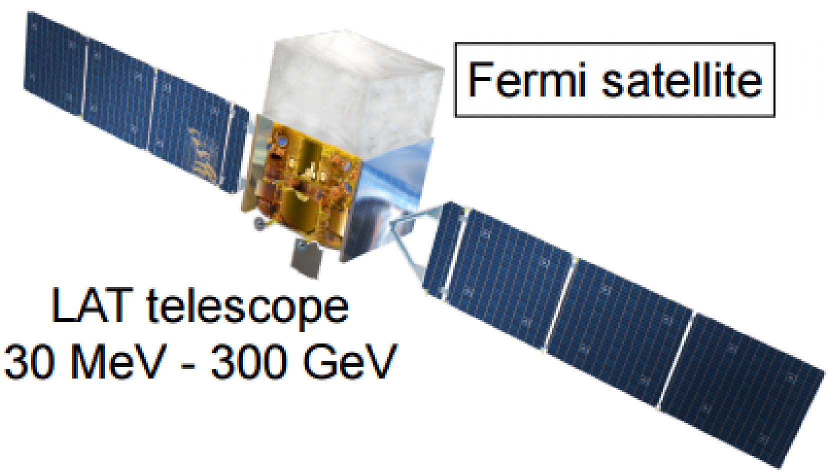
Highlights on Results

GRBs — Origin of GeV radiation

- Proposed interpretation: leptonic emission from electrons accelerated in the relativistic shocks between the jet and the external ambient medium (*Ghisellini, Ghirlanda, Nava, Celotti 2010*). Now is the most accepted scenario

Flux of radiation between 0.1-10 GeV for 10 GRBs



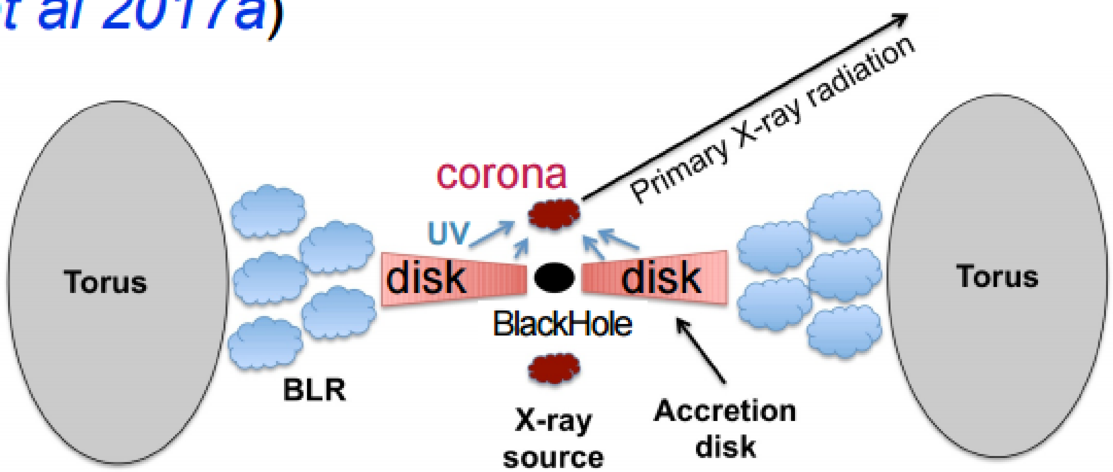


- Follow up studies to use GeV radiation to derive constraints on: Lorentz factor of the jet (*Nava, Desiante, Longo, Celotti et al, 2014*), magnetic field strength and configuration in relativistic shocks, efficiency of particle acceleration mechanisms,…

Highlights on Results

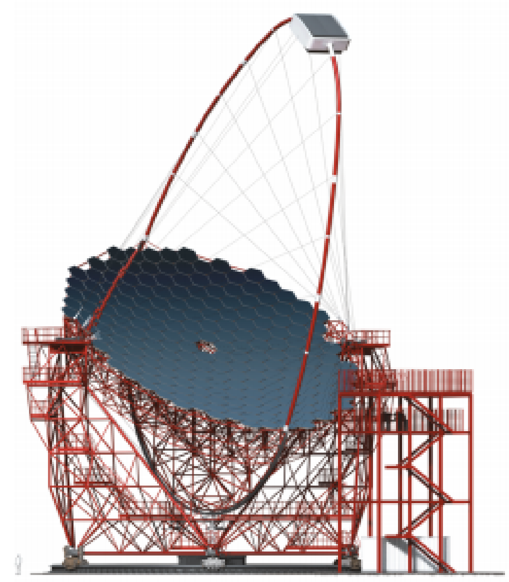
Active Galactic Nuclei

- Coronal properties of distant and luminous quasars: X-ray corona (= hot trans-relativistic medium) up-scatters UV/soft-Xray photons coming from the disc and produces a hard X-ray continuum emission (*Kammoun et al 2017a*)



- X-ray variability: X–ray spectral and timing studies can provide important clues regarding the physical processes that operate in the innermost region of AGN (*Kammoun et al 2015 and 2017b*)

Future developments and plans



- HE Astrophysics will soon experience a major boost, thanks to the upcoming facility CTA (Cherenkov Telescope Array), that will have unprecedented sensitivity to photons from 20 GeV to 300 TeV. It will be revolutionary both for AGN and GRB studies
- We are actively involved in the CTA collaboration: we will provide the theoretical modeling for GeV-TeV emission from GRBs

- Main aim: this is new window of observations for GRBs. If coupled with theoretical models, observations will provide new information on nature of radiation mechanisms, study of Extragalactic background light, insights on quantum gravity models,…

Future developments and plans

- Renovated interest for High-energy astrophysics. We are living in an exciting era, thanks to newly available non-electromagnetic channels for observing the high-energy Universe:
  - ***gravitational waves*** (recent detection in connection with a GRB?)
  - ***neutrinos*** (extragalactic PeV neutrinos of unknown origin recently detected)
  - ***cosmic-rays*** (what are the sources of extragalactic cosmic-rays? Where and how these particles are accelerated?)

- Team strategy: build a high-energy astrophysics team lead by SISSA, by further strengthening collaborations with researchers from the Trieste area. The team already comprises researchers with complementary expertise, theoretical (SISSA and Univ of Zagreb) and observational (UniTs, INFN-Ts and Univ of Nova Gorica), involved in all the major present and future facilities for the study of the high-energy Universe.

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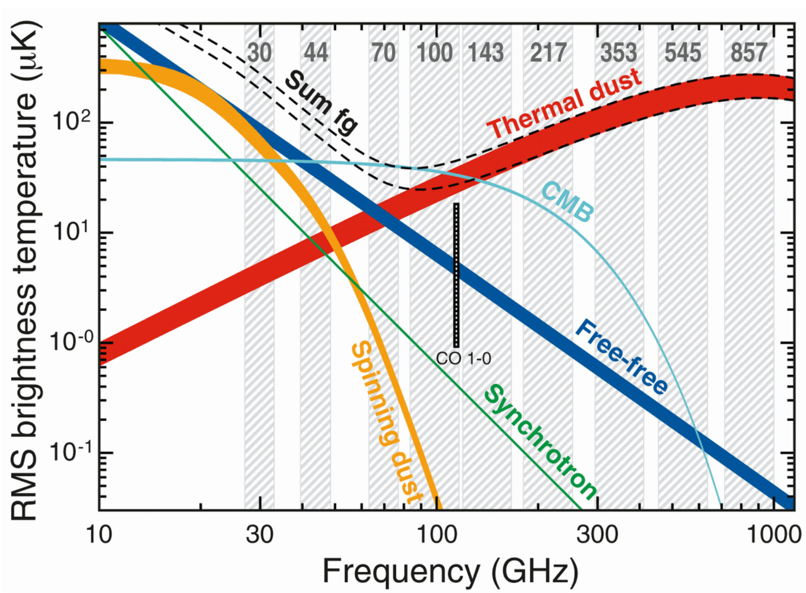
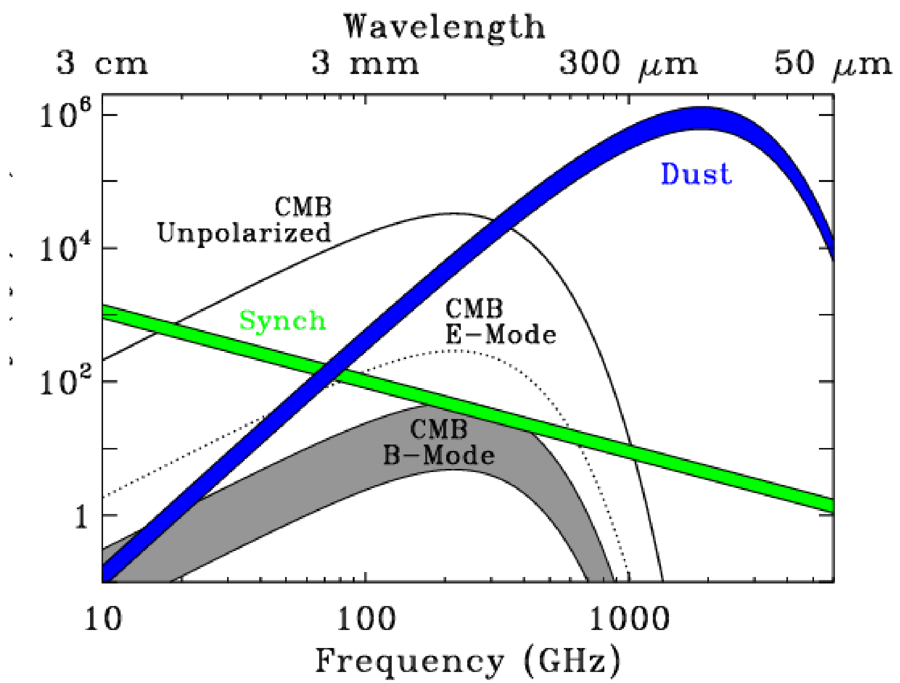
- Francesca Perrotta: Astrophysical Foregrounds
- Carlo Baccigalupi: Early Universe

Astrophysical Foregrounds

- Study of the CMB contaminations (galactic and extragalactic emissions): galactic synchrotron, dust, radio galaxies….
- Especially focused on **polarized** signals.





Astrophysical Foregrounds

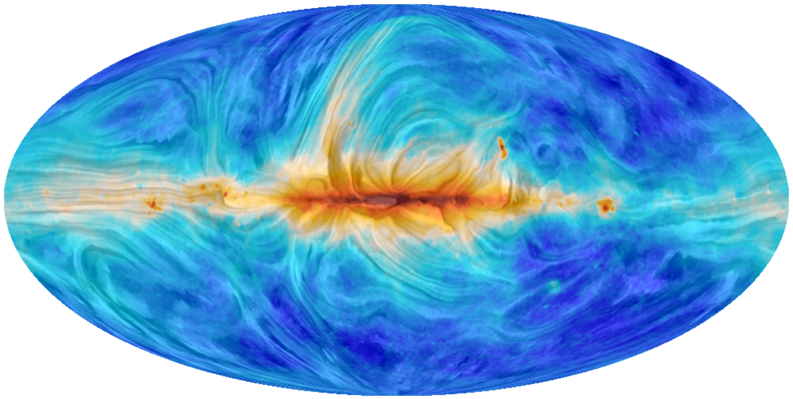
International collaborations and experiments: Planck (CMB), PolarBear (CMB), SKA (radio telescope), ALMA (Acatama Large Millimeter Array, radio telescope), SPASS, QUIJOTE (radio telescope)

Active grants : EU H2020 grant «RADIOFOREGROUNDS», ASI-COSMOS

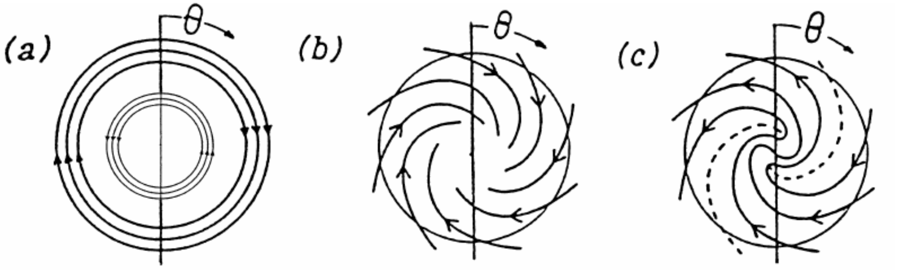
Galactic Synchrotron

- Characterization /modeling of the Galactic magnetic field properties. The magnetic field triggers Cosmic Rays leptons to emit synchrotron radiation.
- How can observations of synchrotron radio emission put constraints on the Cosmic Rays propagation parameters? How do synchrotron models compare to data?

Magnetic field lines traced by synchrotron Emission at 30 GHz



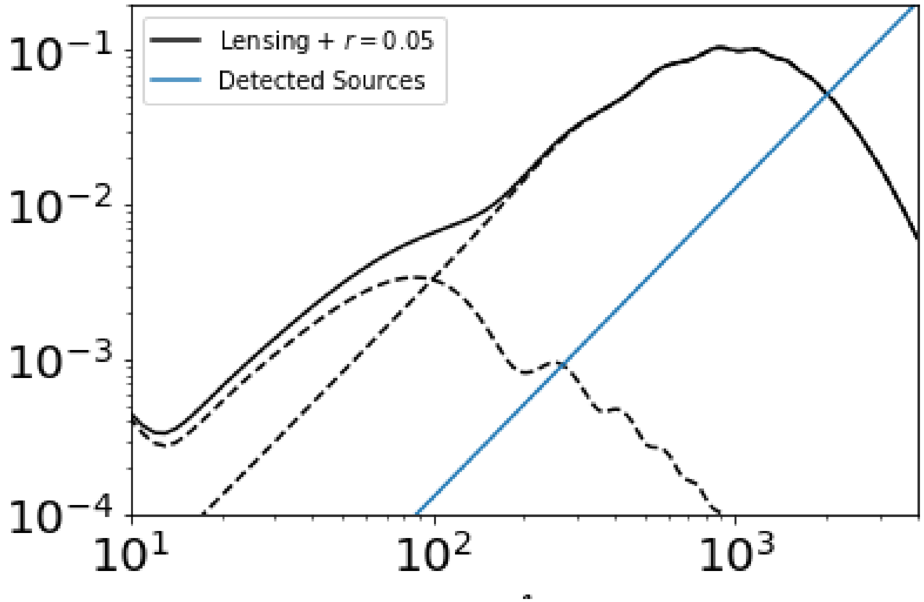
Sketch of simple models for the galactic field: concentric rings, axysimmetric spiral model and bisymmetric spiral model



- People active in this research at SISSA: N. Krachmalnicoff, D. Poletti, Jiaxin Wang (APP), P. Ullio (APP), C. Baccigalupi, F. Perrotta

Extragalactic (polarized) sources

- We are using available data at several frequencies to forecast the number of sources (and their polarization fraction) that will be detected in the next radio surveys (eg. Polarbear @150 GHz). These predictions make use of a model (developed in SISSA by Mancuso et al.) for the black hole duty cycle in radio galaxies.



This will not just be a tool for cleaning CMB maps , but will help to shed light on the inner engine of radiogalaxies.

People involved in SISSA:
G. Puglisi, A. Lapi, C. Baccigalupi, A. Celotti, L. Danese, F. Perrotta

Future developments and plans

- To determine the statistical properties of polarized radio sources, updating the existing source count models in total intensity and in polarization

- To investigate the relationships polarized vs. total emission as a function of frequency and flux density, and, if z available, also of luminosity and redshift.

- To determine analytical or numerical probability density functions for the polarization fraction of the sources

- To refine existing simulation tools of the spatial distribution of polarized sources at all the relevant frequencies

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- Modelling the diffuse Galactic synchrotron emission.

- Investigate the capabilities to get Cosmic Rays information from current and future synchrotron observations.

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Early Universe

- Two main physical quantities to investigate:
- **The Tensor to Scalar Ratio, r**
- **The Properties of the Dark Energy**

- Two main observables:
- **Cosmic Microwave Background (CMB) Polarization**
- **Large Scale Structure (LSS)**
- **Their Cross-Correlation (XC)**

- Main Roles, including data analysis responsabilities, in Ongoing and Future Experiments:
- **PolarBear/Simons Array**
- **Simons Observatory**
- **Euclid**

PolarBear/Simons Array

- SISSA contributes to:
- Management
- Analysis and Removal of Foreground Contaminants
- Map-Making and Power Spectrum Estimation
- Weak lensing Analysis

- Support:
- RadioForegrounds H2020
- ASI-COSMOS
- INFN InDark

The Simons Observatory

- 8 Countries
- 35+ Institutions
- 160+ Researchers

United States

- Carnegie Mellon University
- Columbia University
- Cornell University
- Florida State
- Haverford College
- Johns Hopkins University
- Lawrence Berkeley National Laboratory
- NASA/GSFC
- NIST
- Princeton University
- Rutgers University
- Stanford University/SLAC
- Stony Brook
- University of California - Berkeley
- University of California – San Diego
- University of Colorado
- University of Illinois at Urbana-Champaign
- University of Michigan
- University of Pennsylvania
- University of Pittsburgh
- West Chester University

Canada

- CITA/Toronto
- Dalhousie University
- Dunlap Institute/Toronto
- McGill University
- University of British Columbia

Chile

- Pontificia Universidad Catolica
- University of Chile

Europe

- APC - France
- Cardiff University
- Imperial College
- Manchester University
- Oxford University
- SISSA – Italy

Japan

- KEK
- IPMU

South Africa

- Kwazulu-Natal, SA

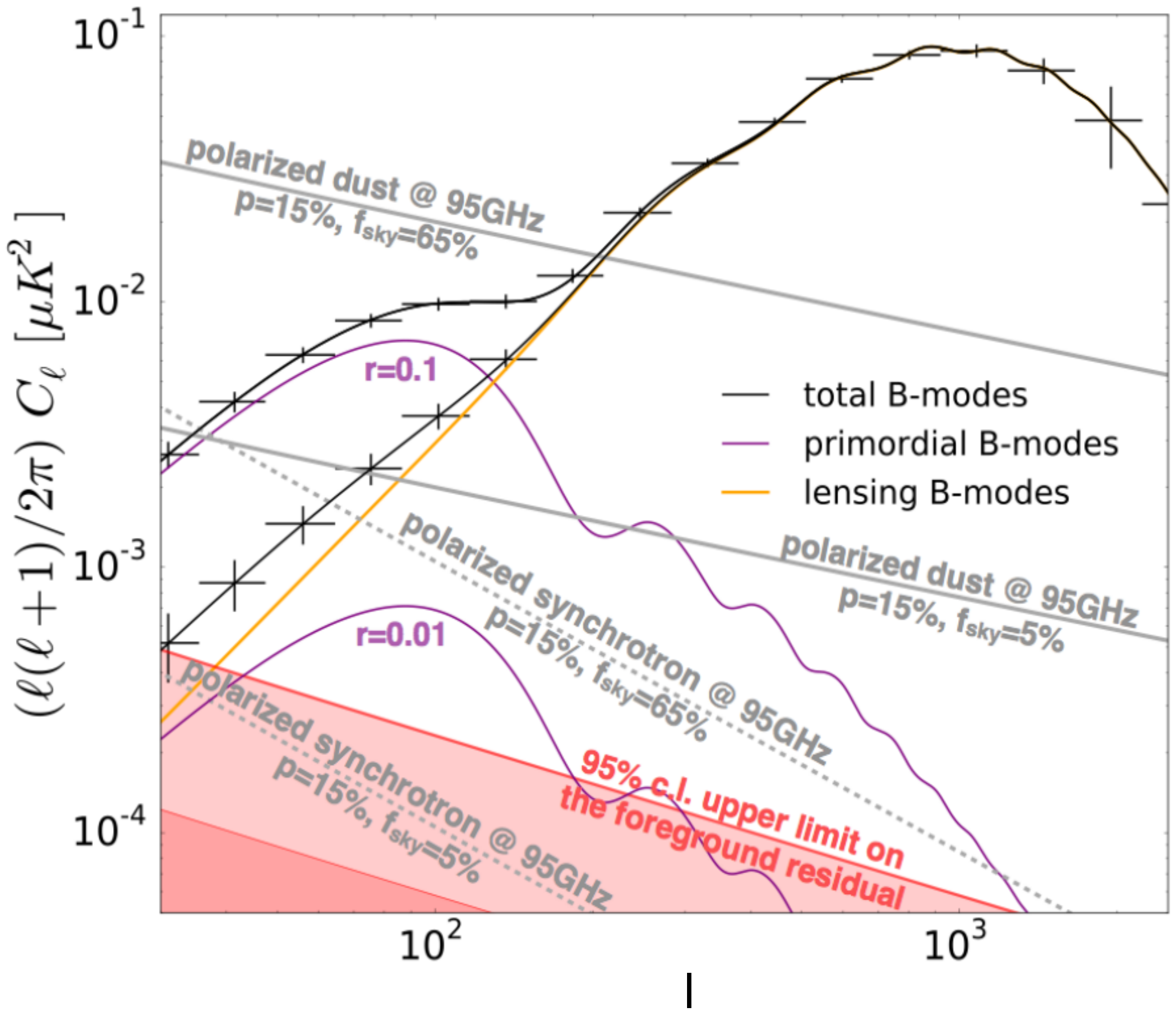
Expectations

Simons array
projected sensitivity

Multi-frequency
90, 150, 220 GHz setup
Forecasts including
Foreground removal

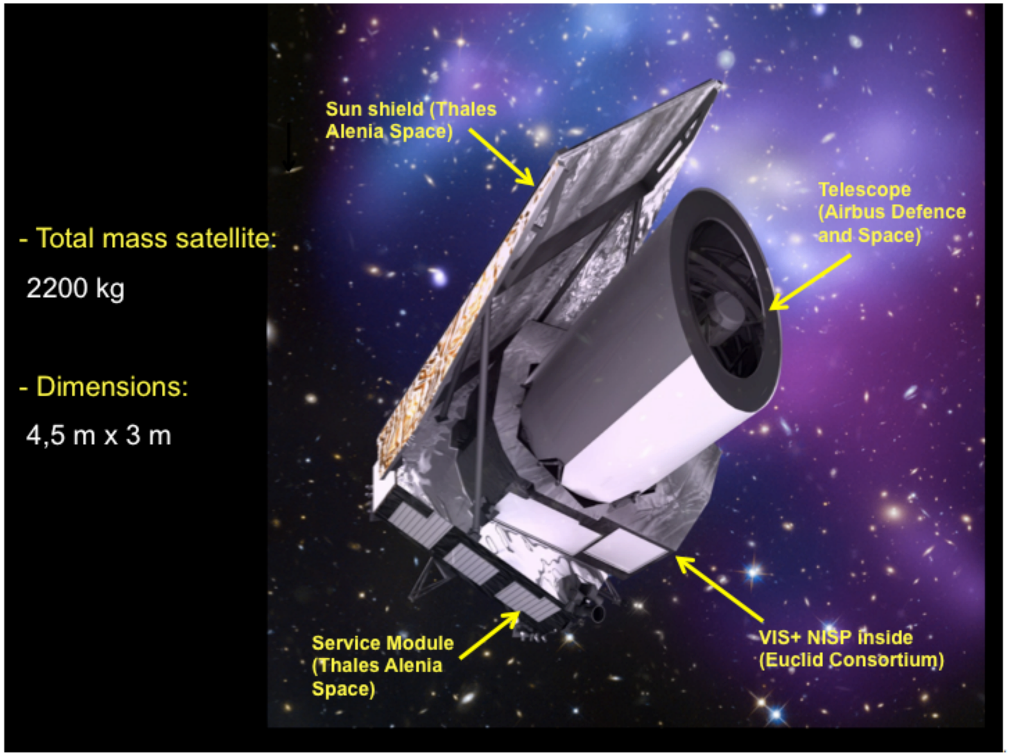
$\sigma(r=0.1)=6\times10^{-3}$ (4×10^{-3} stat.)

$\sigma(\Sigma_\nu m_\nu)$=40 meV (19 meV stat.)



Plots by Josquin Errard

Euclid

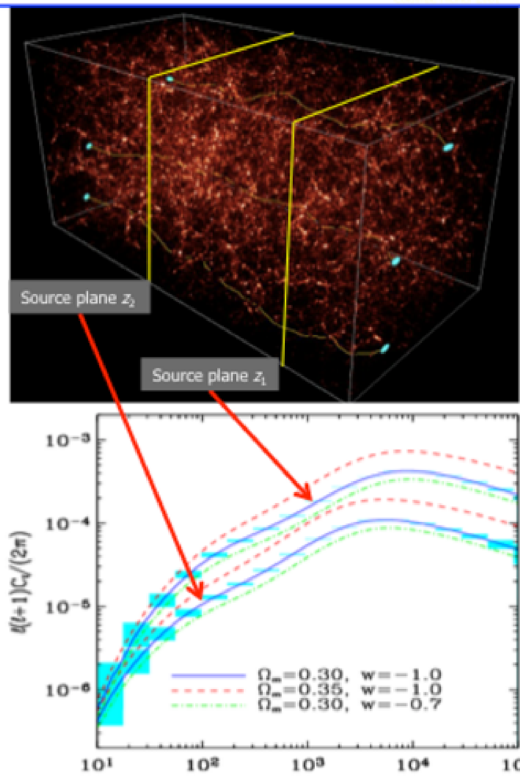


Launch in 2020,
Impacting Fundamental Physics through Astrophysics and Cosmology
Coordination responsibility for SISSA, concerning XC with CMB,
Strongly Connected with the Astroparticle Group, see also Viel's Talk

Expectations

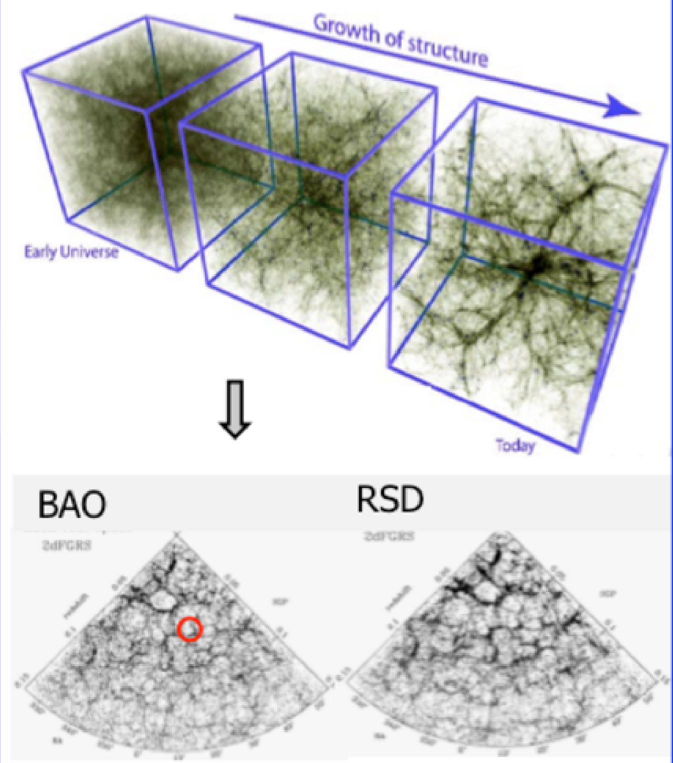
WL probe: Cosmic shear over 0<z<2 :

1.5 billion galaxies shapes, gravitational shear and photometric redshifts (u,g,r,i,z,Y,J,H) with 0.05 (1+z) accuracy over 15,000 deg^2



GC; BAO, RSD probes: 3-D positions of galaxies over 0.7<z<1.8 :

35 million spectroscopic redshifts with 0.001 (1+z) accuracy over 15,000 deg^2



Ongoing activities

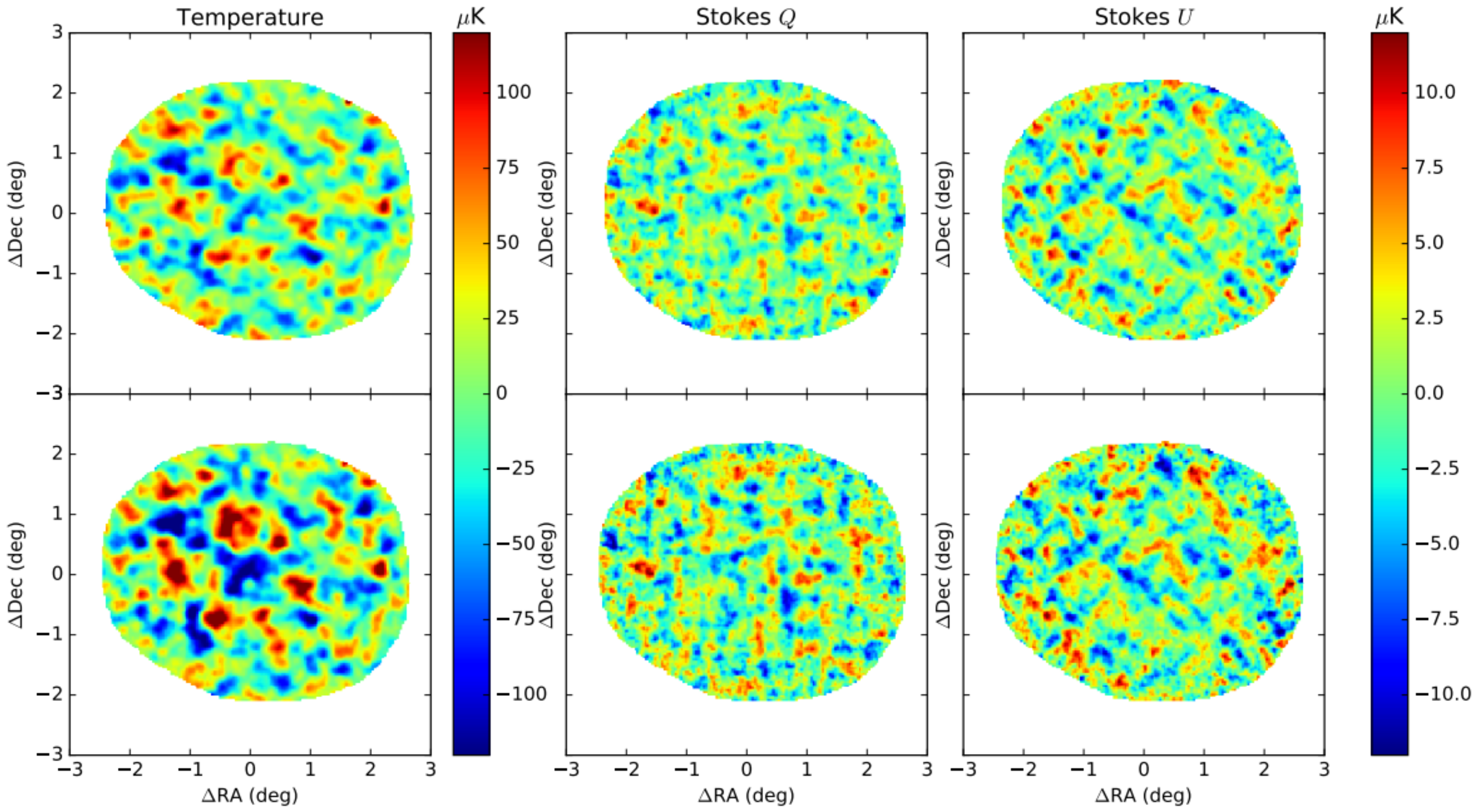
- **Nicoletta Krachmalnicoff**: leading the efforts concerning the study of Astrophysical Foregrounds throught Data Analysis
- **Davide Poletti**: leading the creation of Map-Making and Component Separation Algorithms for Operating and Future Experiments
- **Giuseppe Puglisi**: Completing his PhD Course on Modeling on Contaminants, and Advanced Map-Making techniques for PolarBear, about to leave for Stanford!
- **Anirban Roy**: Carrying a PhD Course on the Interplay between B-mode, Large Scale CMB Experiments and Astrophysics

- **New Members! Paolo Campeti** beginning a PhD Course on Theoretical Exploitations and Implications of B-mode Experiments, **Farida Farsian** beginning a PhD Course on Cross-Correlation of Cosmic Fields, CMB and LSS

- **Strong Connection** with Other Researches in **Astrophysics, Astroparticle, Particle Physics, Science of Data Analysis**

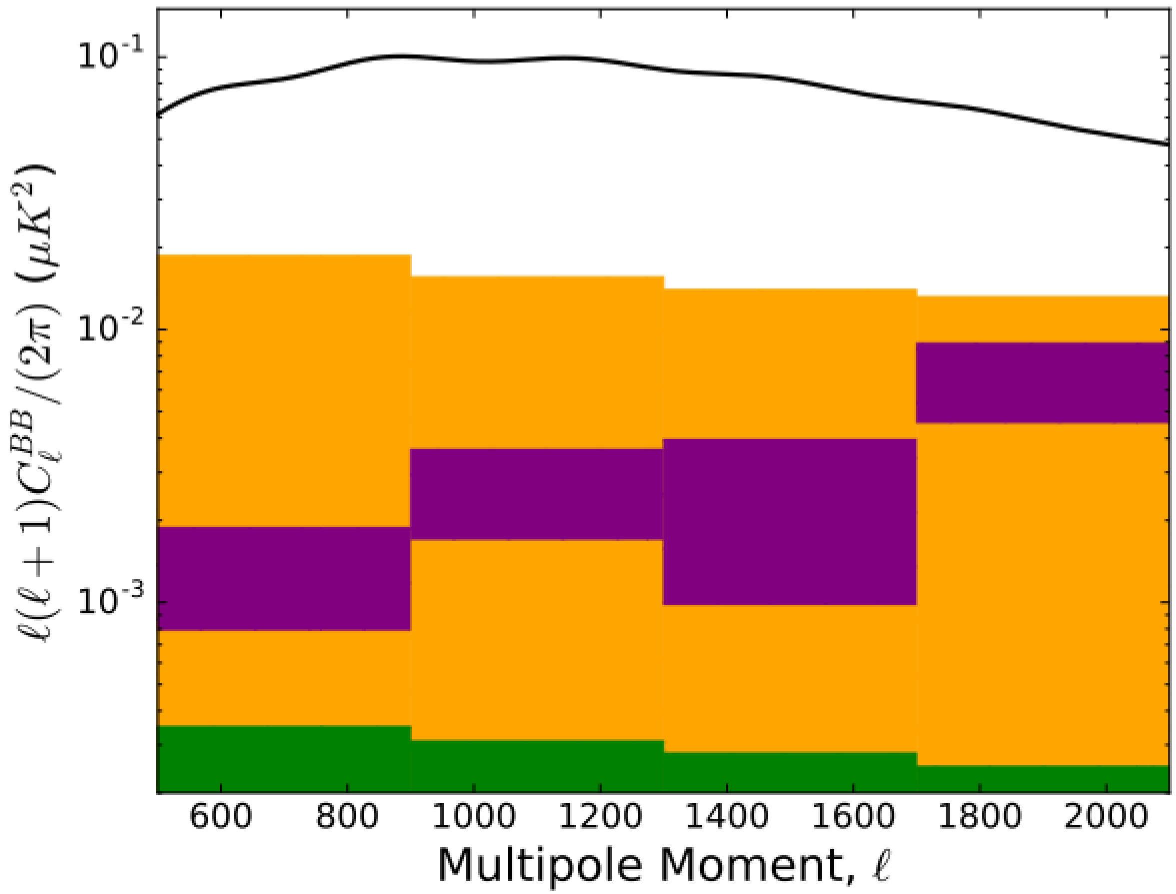
- **Support!** Ongoing Grants and Support from **RadioForegrounds, ASI-COSMOS (hiring in progress), PRIN 2016 (hiring in progress), INDARK INFN, ...**

Highlights on Results



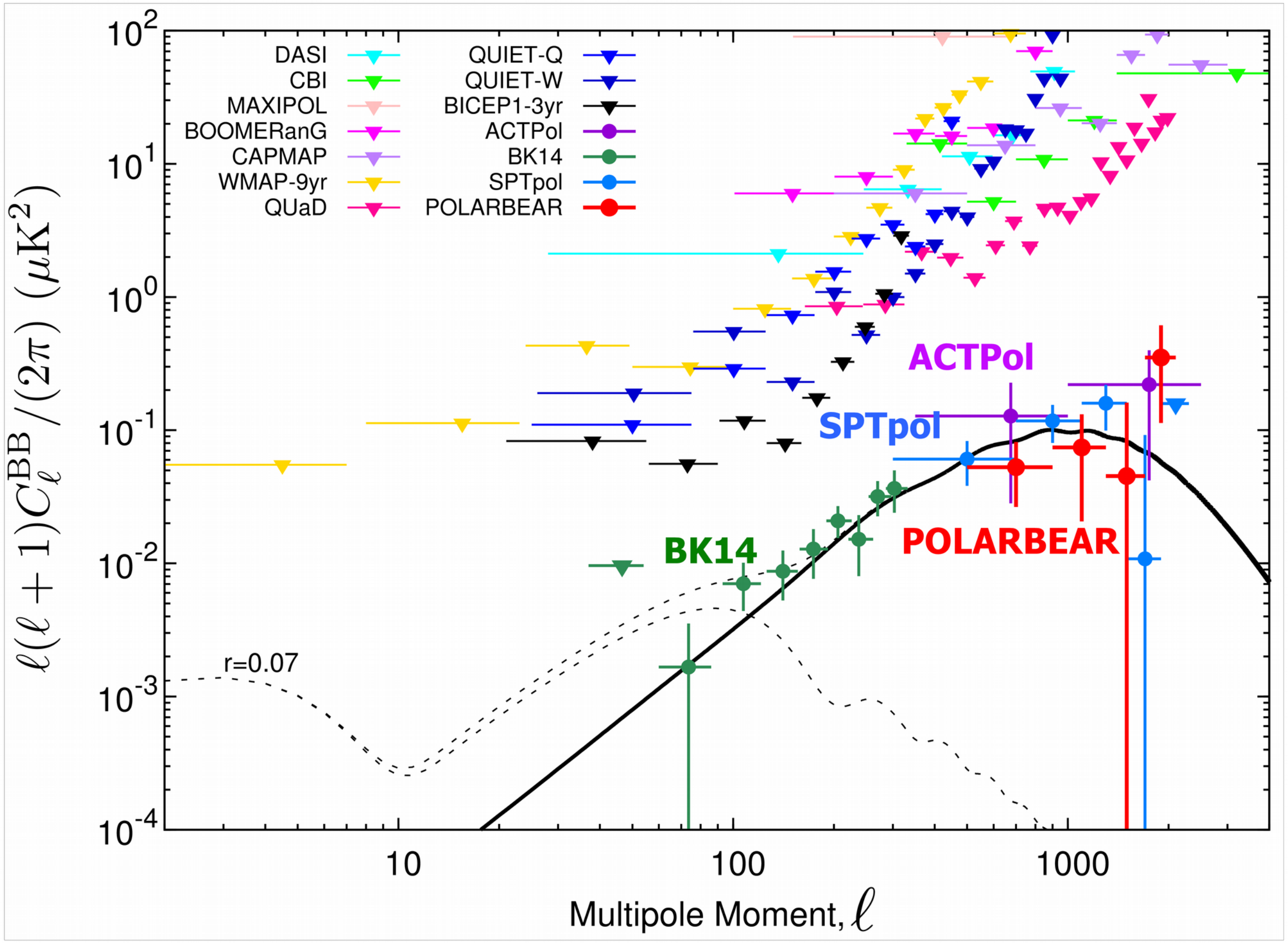
Results By Davide Poletti

Highlights on Results

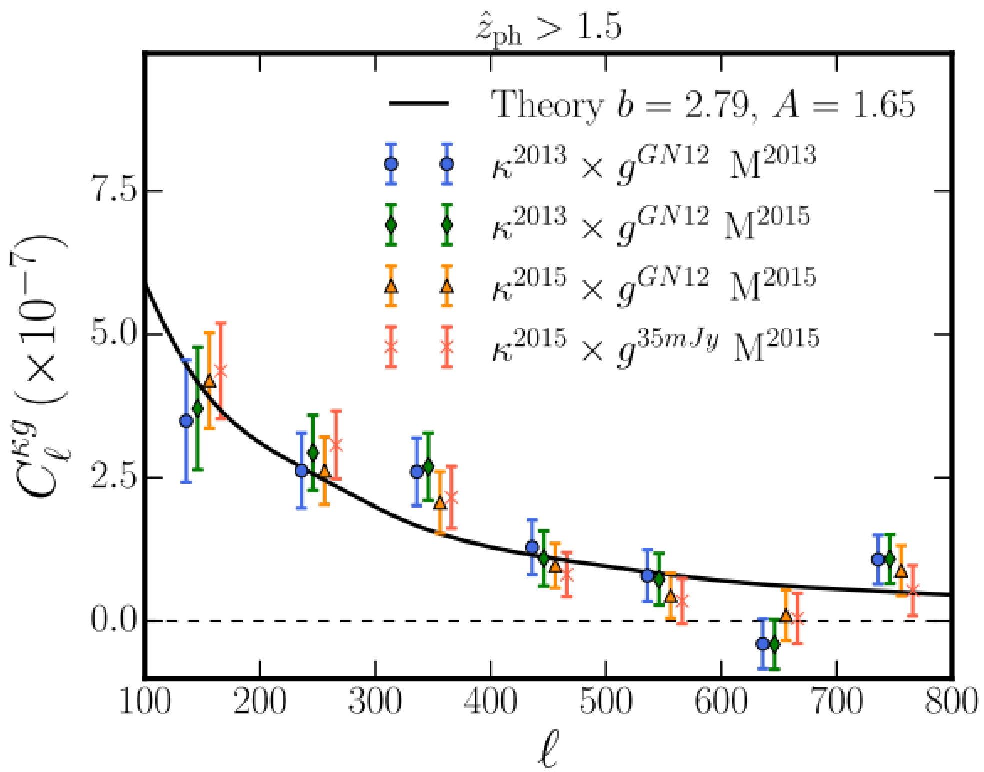


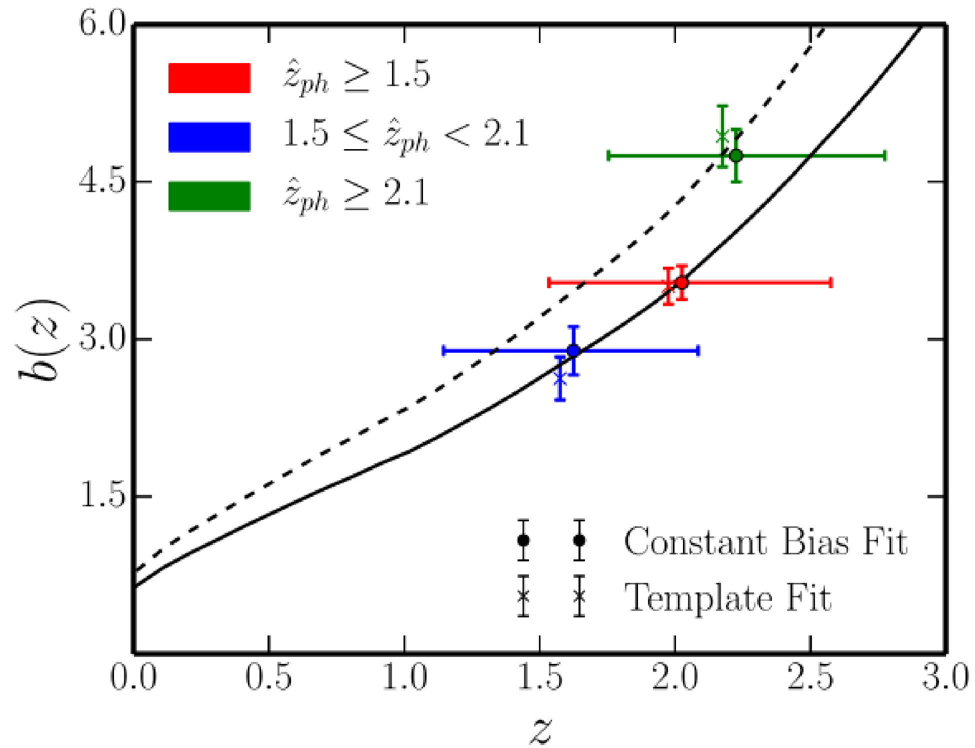
Results by Nicoletta Krachmalnicoff

Highlights on Results



Highlights on Results





From Bianchini et al. 2016, example of Joint Study of Galaxies and Cosmology

Future developments and plans

- **Completion** of Quoted Experiments will take till the end of the **next decade**, in terms of **Data Analysis, Theoretical Exploitation**
- **SISSA has leading roles in Crucial Areas** of those
- We wish to **Consolidate** those, and **Maximize** the **Impact and Return for SISSA**, concerning the fundamental observables which will be measures
- **Challenges** are represented by **Strong Competition**, **Coordination** with main **Research Centers** (at this moment EU, US, Japan, China, ...), **Training of Young Researchers to Leading Scientists, Support,** ...

Visions of the Next Decade

Visions of the Next Decade

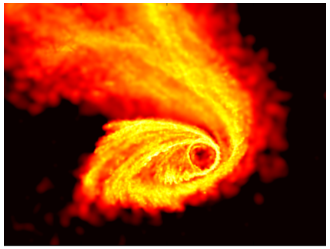
- **Global** scale **experiments, data analysis, theoretical exploitation,**
- **Astronomy** goes **electromagnetic and gravitational**
- **SISSA** gets to this scenario as a **main** and **internationally recognized actor**
- We wish to **Capitalize**, **Consolidate**, and **Expand** the capabilities of SISSA to face new challenges in **fundamental physics, through Astrophysics and Cosmology**

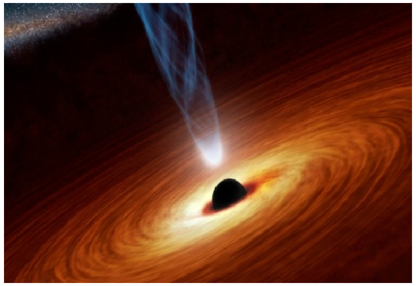
Visions of the Next Decade

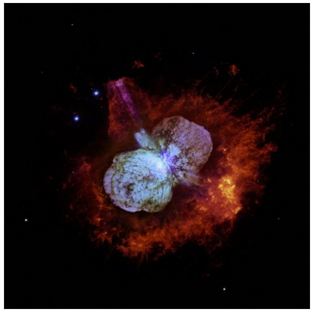
- **@SISSA**: **Connect** and **Expand** (and **Communicate**) **links** to other **Expertises** and **Groups (Astroparticle, Theoretical Physics)**, throught the promotion of **Interdisciplinary, Innovative Research connecting Science, Theory** and **Data**
- **@SISSA**: undertake Strategic and Synergic Actions
- @world: consolidate impact seeking **top training**, **top team work**, capitalize on existing r**esponsibility roles in big experiments**,

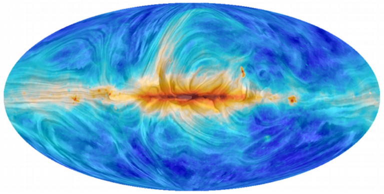
Ongoing Actions towards the Next Decade

- Institute for Fundamental Physics of the Universe: old SISSA Building, hosting **Workshops** and **Collaboration Meetings, long term visits, post-docs**, across the academic year, **Joint Effort with the Astroparticle Group** and the **other Institutions in our area involved with Fundamental Physics, Astrophysics, Astroparticle, Cosmology**, see Ullio's presentation,
- Increase Robustness of the **Interface** with **new Gravitational Wave Astronomy** through coordinated **hirings of Young Researchers as Principal Investigators** capable of top research in **Gravitational Waves, dealing with the physics of Plasmas in Emitters**
- Increase **Robustness** versus our capability of implementing **scientific analysis and exploitation** on forthcoming **Big Datasets**,
- ...

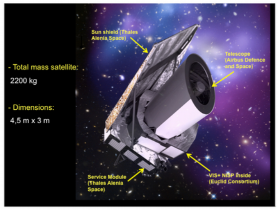


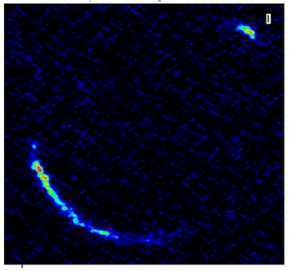


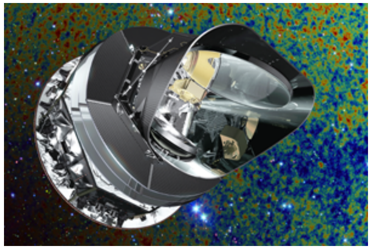




THANK YOU







ASTROPHYSICS

SISSA

ma per seguir virtute e canoscenza