

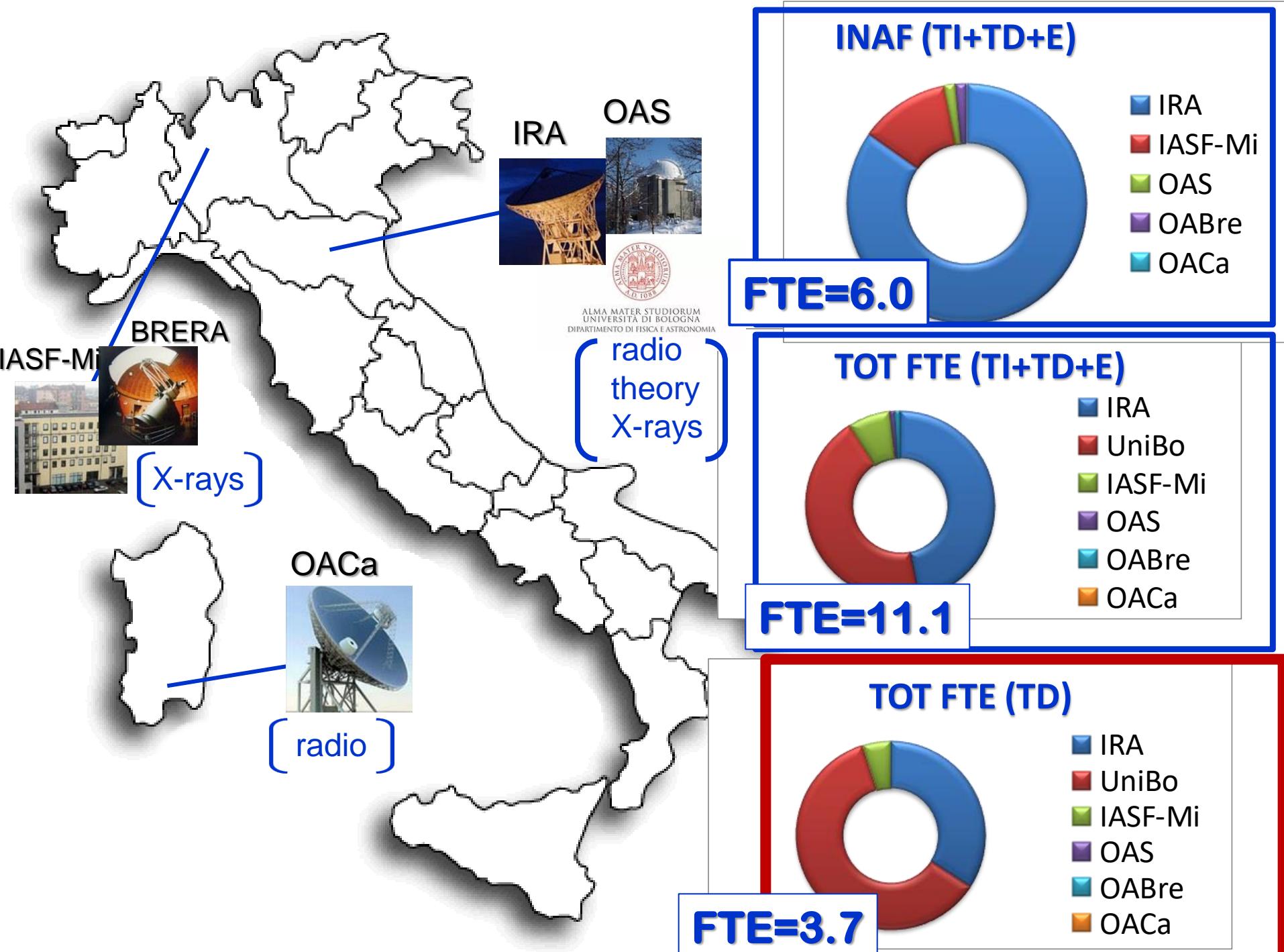
Accelerazione di particelle ed emissione non termica in ammassi di galassie e filamenti

-NonthermalWEB-

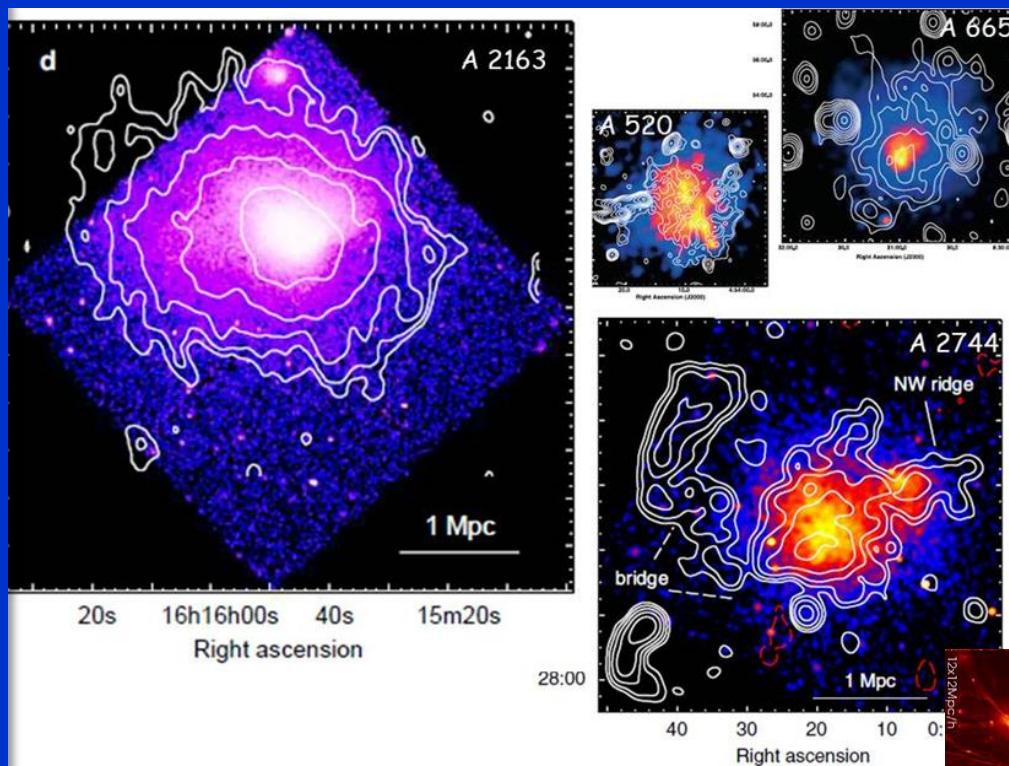
Who we are ?

G. Brunetti, I. Bartalucci, L. Bruno, G. Bernardi, R. Cassano, F. de Gasperin,
S. de Grandi, S. Ettori, F. Gastaldello, C. Gheller, S. Ghizzardi, L. Lovisari,
M. Rossetti, M. Sereno, V. Vacca, T. Venturi

A. Bonafede, M. Brienza, D. Dallacasa, M. Gitti, K. Rajpurohit, C. Risely,
C. Stuardi, F. Vazza
L. Feretti, G. Giovannini



Non-thermal phenomena in galaxy clusters & LSS



ORIGIN

- Particle acceleration in novel regimes
- Magnetic field amplification
- Emission Mechanisms

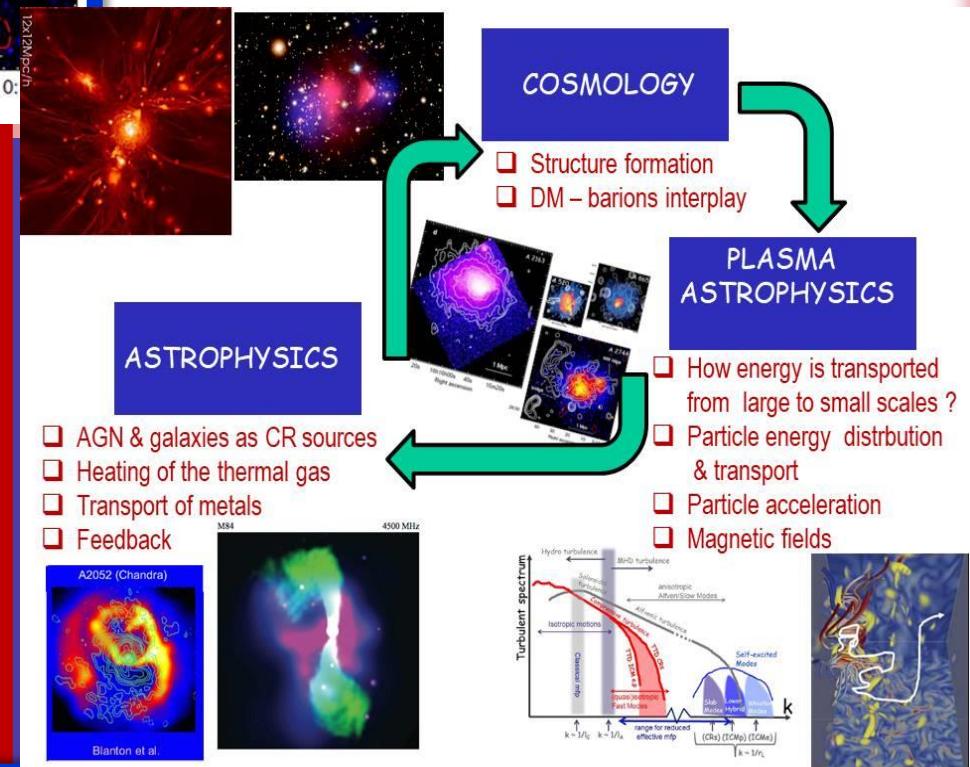
CONNECTION WITH LSS FORMATION

- How energy is transported & dissipated
- Probe of LSS dynamics

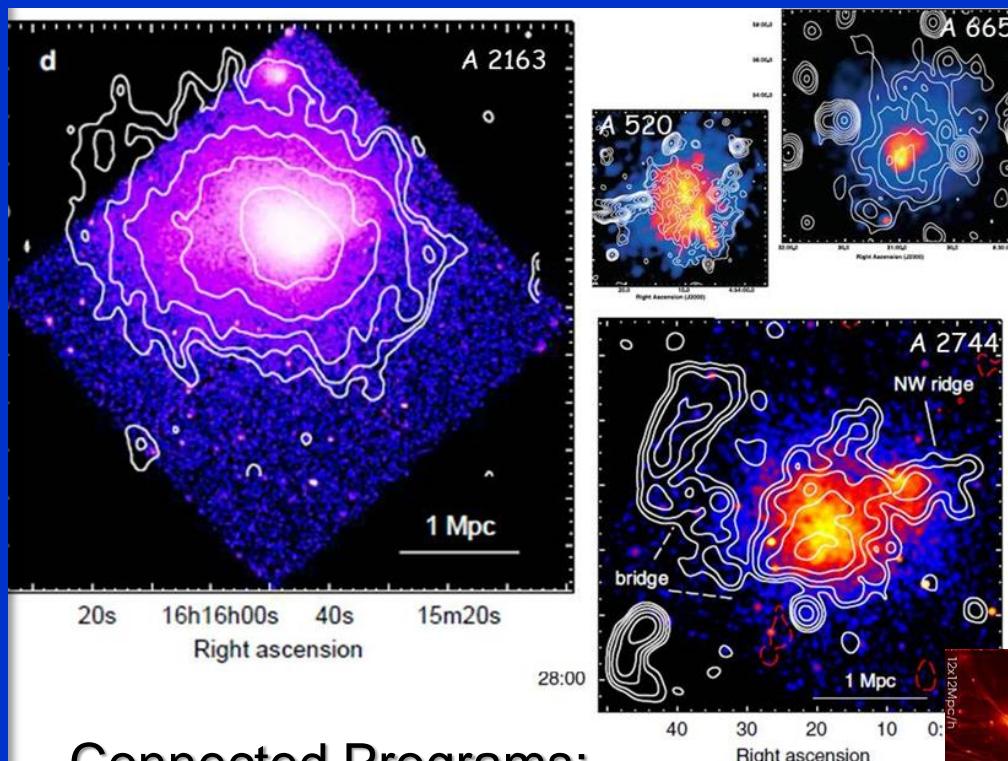
PHYSICS OF THE ICM

- Collisionless processes
- Transport & effective viscosity

These phenomena sit at the crossroad of astrophysics, cosmology & astro-plasma



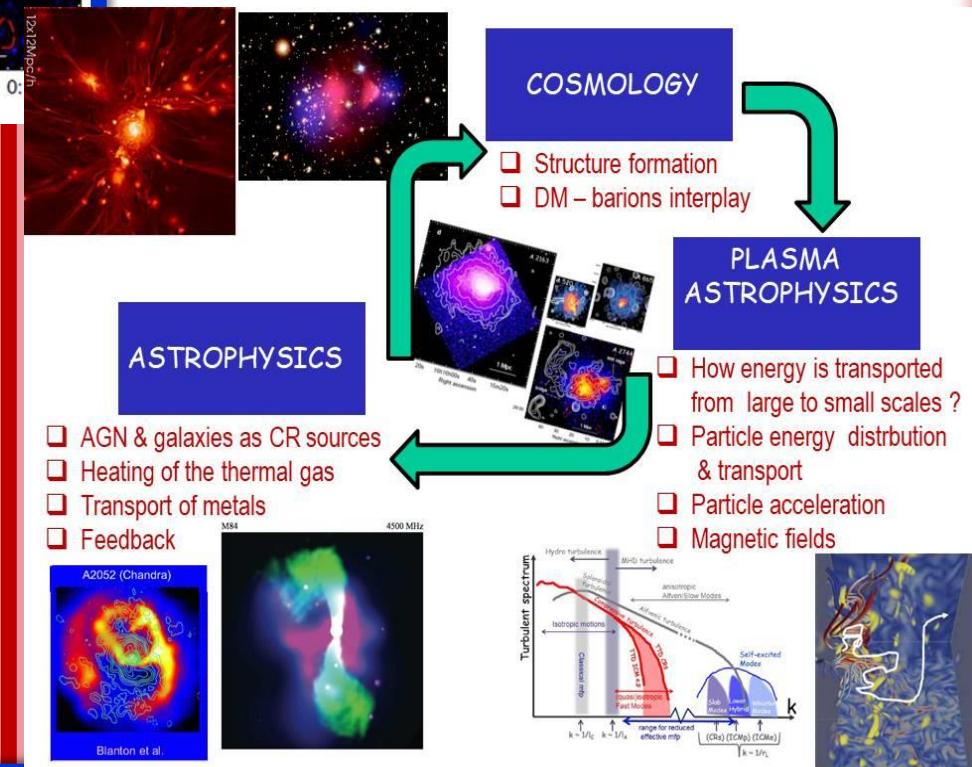
Non-thermal phenomena in galaxy clusters & LSS



Connected Programs:

- METEORA (Vacca, OACa) (Magnetic fields)
- ShapleyS (Merluzzi, OANa)
- CHEX-MATE (Ettori, OAS)
- LOFAR-It (Brunetti)
- SKA (Prandoni)
- Athena (Piro)
- PROGRESS (Antonelli)

These phenomena sit at the crossroad of astrophysics, cosmology & astro-plasma



Science, highlights and leadership

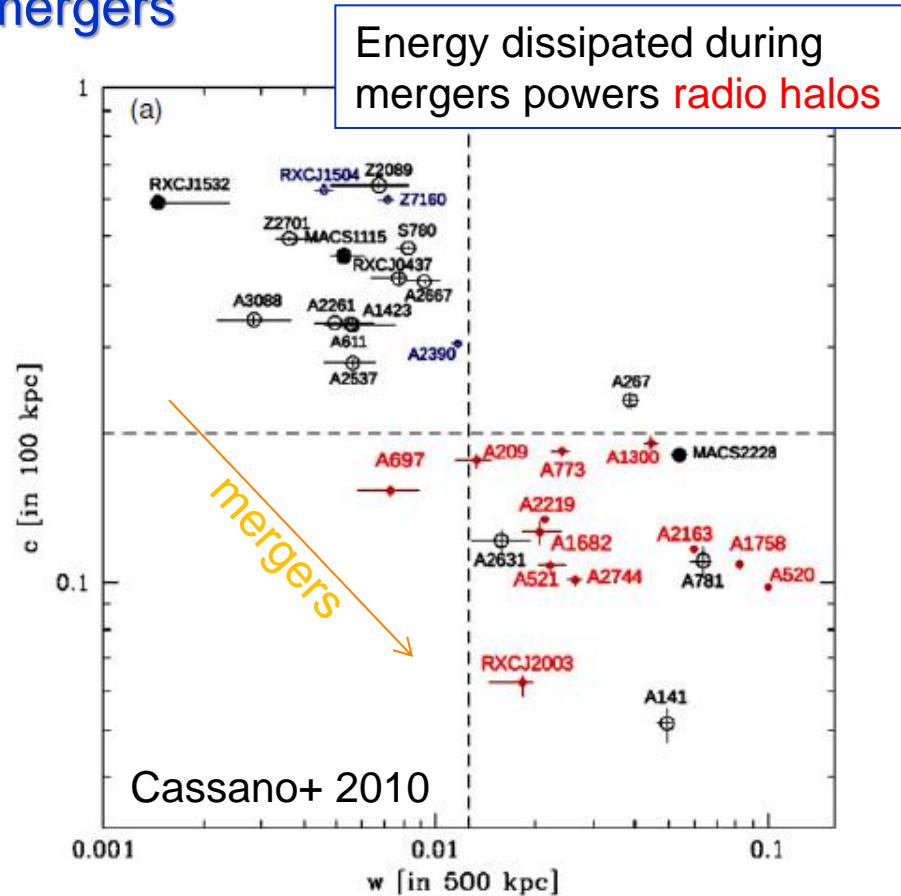
Item 1 :

Population studies & connection with mergers

- What is the occurrence of radio halos/relics in galaxy clusters ?
- How does the occurrence depend on thermal (mass,X-rays) and dynamical properties?
- How does the occurrence depend on cosmic epoch ?
- What is the connection between thermal and non-thermal properties?

INAF studies in the last decade have pioneered this area obtaining observational milestones

(Giovannini+ 1999, Feretti+ 2000,
Govoni+ 2004, Venturi+ 2007,08,
Cassano+ 2008,10,13, Kale+ 2015,
Cuciti+ 2015,21, Giovannini+ 2021,
de Gennaro+ 2021)

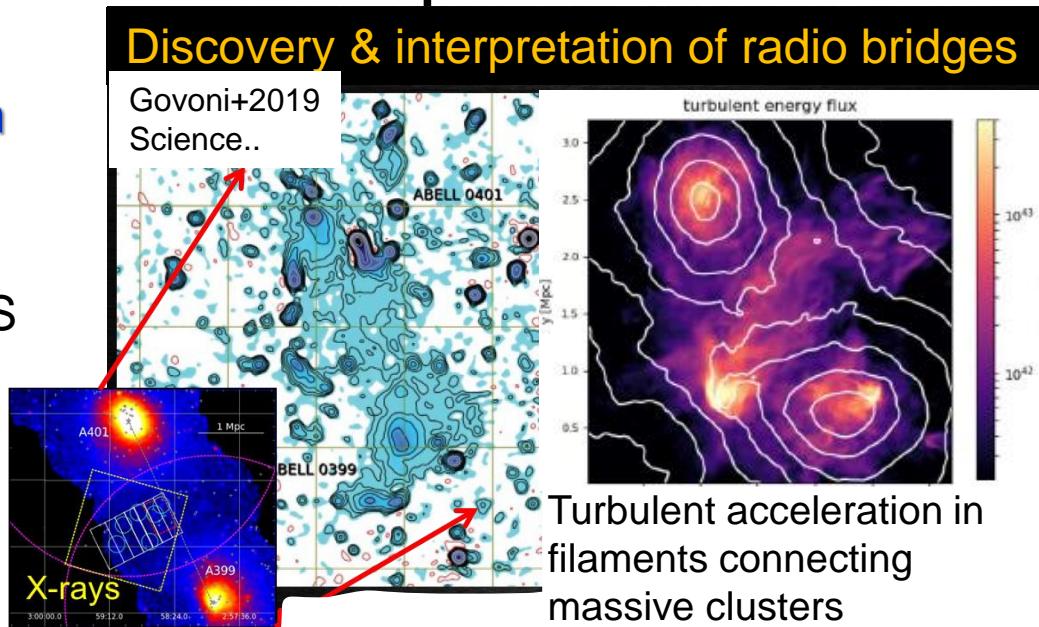


Science, highlights and leadership

Item 2 :

New regimes of article acceleration physics

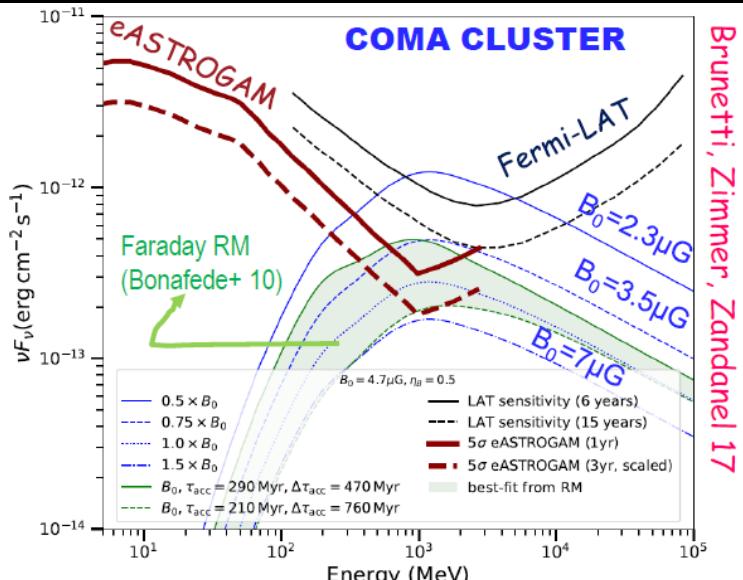
- Turbulence, turbulent acceleration (Fermi 2nd) in galaxy clusters & LSS
- CR transport and confinement in galaxy clusters
- Shocks and shock acceleration in galaxy clusters & LSS
- Collisionless ICM physics & impact on transport and acceleration



INAF studies provided fundamental contributions to set the current theoretical paradigm and inspired the science cases of radio (LOFAR, MeerKAT, etc) and high-energy (CTA, etc) facilities

(Brunetti+ 2001, 04, Cassano+ 2005,06, Brunetti+Blasi 2005, Brunetti+Lazarian 2007,11,16, Donnert+ 2013, Vazza+2011,14 Brunetti+Vazza 2021)

Most advanced gamma-ray emission models



Science, highlights and leadership

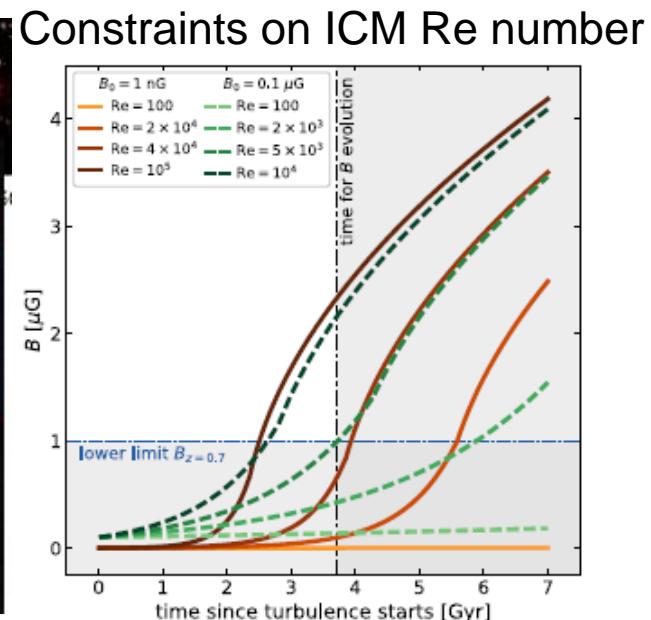
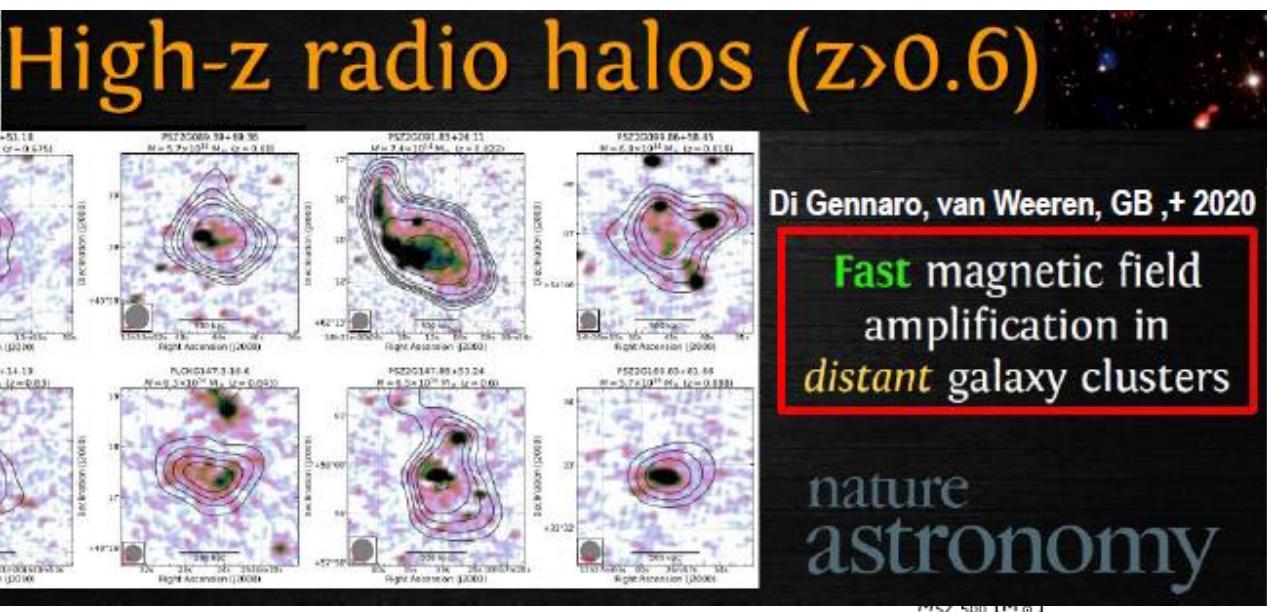
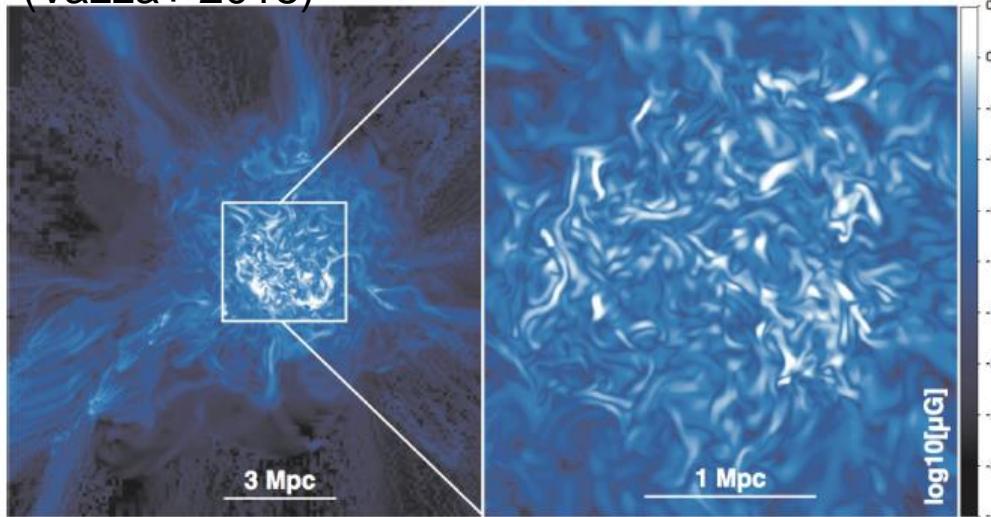
Item 3 :  METEORA

Magnetic field amplification in LSS

- What is the origin of magnetic fields ?
How fast ??
- Amplification mechanisms
& connection with turbulence
- Constraints on ICM physics

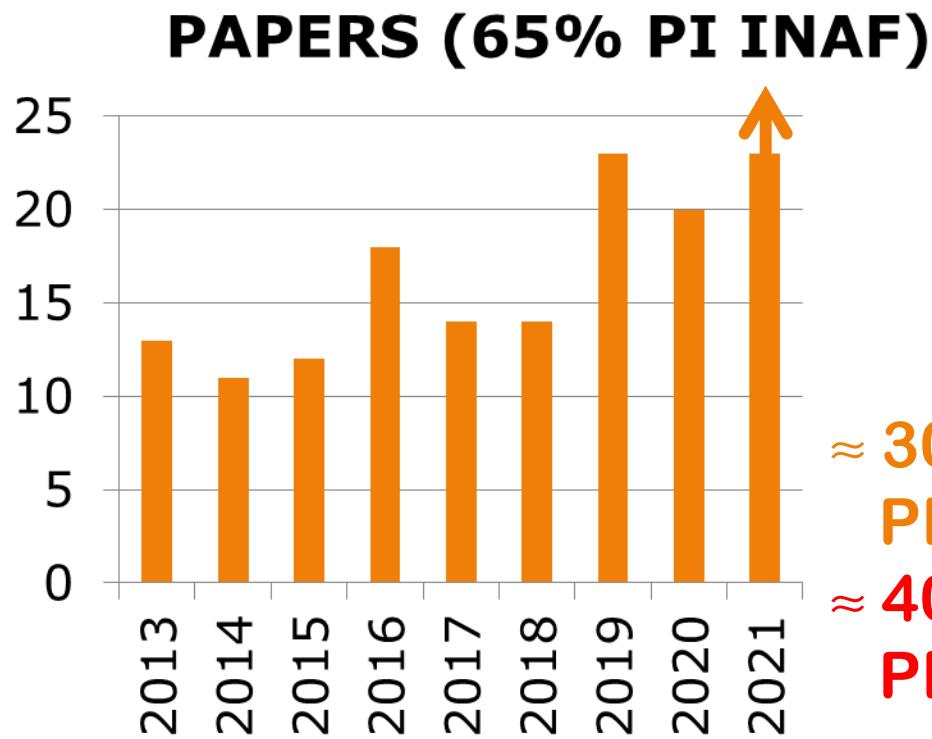
INAF studies are strongly recognised
(Vazza+ 2014,15,18, Dominguez-Fernandez+ 2021)

First resolved dynamo in cosmological simulation
(Vazza+ 2018)

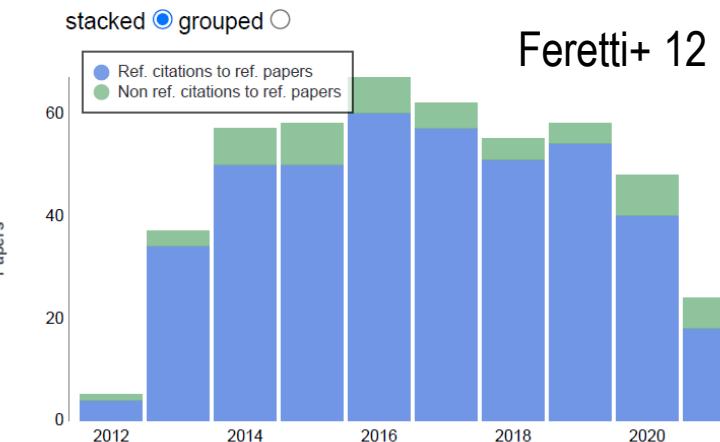


PUBLICATIONS

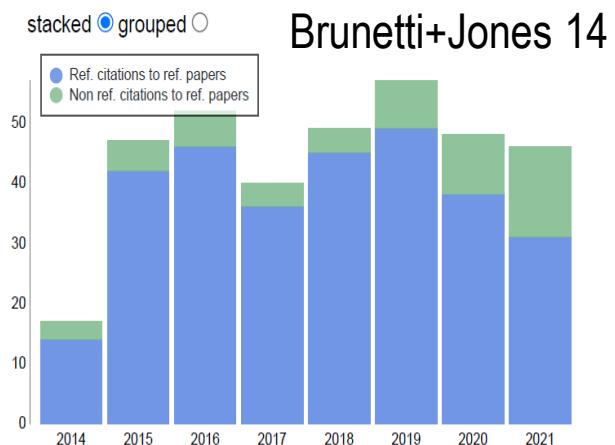
About 20 papers/yr (NonthermalWEB)
including Nature, Nat Astronomy,
Science, Science Adv, PRL, etc....



REVIEWS



Feretti+ 12



Brunetti+Jones 14

≈ 3000 cit 2014+
PI INAF/ass
≈ 400 cit/yr
PI INAF/ass

LOFAR



FACILITIES
radio....high-energy
Super-computers

MeerKAT



JVLA



CHANDRA



FERMI



LOFAR-It



INAF NEW FACILITIES

MeerKAT+





INAF
NEW +
FUTURE
FACILITIES



PROGRESS



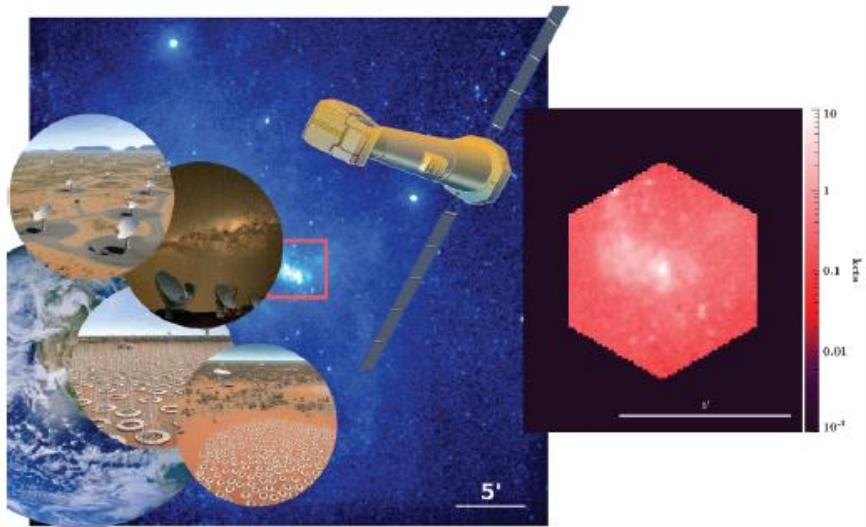


ATHENA:

- Rossella Cassano (INAF-Istituto di Radioastronomia, Italy).
- Rob Fender (University of Oxford, United Kingdom).
- Chiara Ferrari (Observatoire de la Côte d'Azur, France).
- Andrea Merloni (Max-Planck Institute for Extraterrestrial Physics, Germany).

SKA-Athena Synergy White Paper

SKA-Athena Synergy Team



Clusters of Galaxies and the Cosmic Web with Square Kilometre Array

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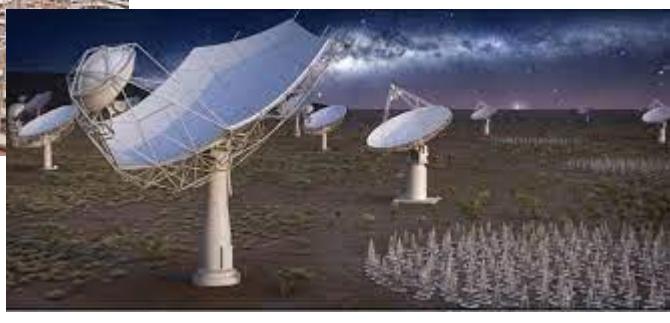
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~35% citations to IT-PI (~18% to Indian-PI)

FUNDS & TRAINING

~720 kEuro obtained in the last 10 years (PRIN,ASI,Fellowships),
2x ERC Starting programs,
IT-SAfrica bilateral program

- PRIN INAF 2009 (2012-15) (UdR G.Brunetti)
- ASI INAF NuSTAR (2015) (F.Gastaldello)
- ASI INAF NuSTAR (2016) (F.Gastaldello)
- PRIN INAF 2014 (2015-17) (G.Brunetti)
- ASI INAF NuSTAR (2018) (F.Gastaldello)
- PRIN Mainstream (2019-xx) (G.Brunetti)
- Marie Curie IEF G.Donnert 2012-14 (G.Brunetti)
- Marie Curie GF G.Donnert 2015-18 (G.Brunetti/T.Jones)
- ASTROFIT F.Vazza 2016-17 (G.Brunetti)
- RADIOSKY2020 (2018-xx) (T.Venturi)
- ERC Starting DRANOEL 2017-22 (A.Bonafede) UniBo(IRA)
- ERC Starting MAGCOW 2017-22 (F.Vazza) UniBo

PhD : last 5 years record

- 35 (2020-23)
 - L. Bruno (G.Brunetti/D.Dallacasa) - INAF
- 34 (2019-22)
 - N. Biava (A.Bonafede) - ERC
 - S. Banfi (F.Vazza) - ERC
- 33 (2018-21)
 - N. Locatelli (F.Vazza) - ERC
 - A.Ignesti (M.Gitti/G.Brunetti)
 - C. Stuardi (A.Bonafede) -ERC
- 32 (2017-20)
 - B.Terni de Gregori (T.Venturi/M.Nonino) - INAF
- 31 (2016-19)
 - A.Botteon (D.Dallacasa/G.Brunetti/F.Gastaldello)
 - M. Cau (G.Giovannini)

Submitted

- PRIN-MIUR (G.Brunetti)
- 2x ERC Consolidator

CRITICAL ASPECTS

OBSERVATIONAL SIDE :

Our research activity is based on the exploitation of the new generation of radio interferometers (SKA precursors/pathfinders), including LOFAR and MeerKAT+ where INAF is investing M+Euro : roadmap for LOFAR2 & SKA. Critical : support critical mass & advanced competences in INAF.

1. In less than 10 years the radio data we use has grown in size by about two orders of magnitude requiring dedicated computing infrastructures. A similar trend in data-size will be observed in other bands in the next 5+ years (see Euclid, Rubin-LSST, etc).

Action : INAF computing infrastructure and support??

2. Calibration of radio data and analysis techniques have also changed completely. All this requires the training (and stabilization over time according to a sustainable & planned roadmap) of scientific and technological personnel (competitive INAF PhD/postdoc program?). Exchange programs/Attract scientists from abroad are also important (“named” fellowship program? bi-lateral exchange programs?).

CRITICAL ASPECTS

THEORETICAL SIDE :

Non-thermal phenomena in clusters and LSS are central in the science cases of future radio (LOFAR2,SKA), X-rays (Athena: turbulence), and high-energy (CTA: clustersKP).

Critical: support critical mass, new skills and synergies

1. Understanding kinetic/plasma mechanisms in the ICM is the new frontier

- **On the science**, as highlighted in our Manifesto at CLUSTER1 (2017), we invite INAF to allocate resources to explore new areas related to *plasma physics* & their observables (in X, radio, micron bands), and to the *high-res X-ray spectroscopy*

Step: Kinetic/PIC simulations necessary to complement theory.

Solid experience on simulations in other groups in IT (UniCal, Firenze ... but very different fields) and abroad (Princeton, Chicago, Columbia, Korea, JP).

Action: Support personnel/networking + computing (also scientists).

2. Critical mass for theory (CR, acceleration, plasma) is necessary but difficult to establish : tendency of INAF funding system to support large programs and infrastructures

Actions: establish multi-disciplinary (RSNs) networks in INAF (GSSI, INFN,...) through dedicated programs to support theoretical activities??