

On the connection between non-thermal phenomena and cluster mergers

Seeing beyond the tip of the iceberg

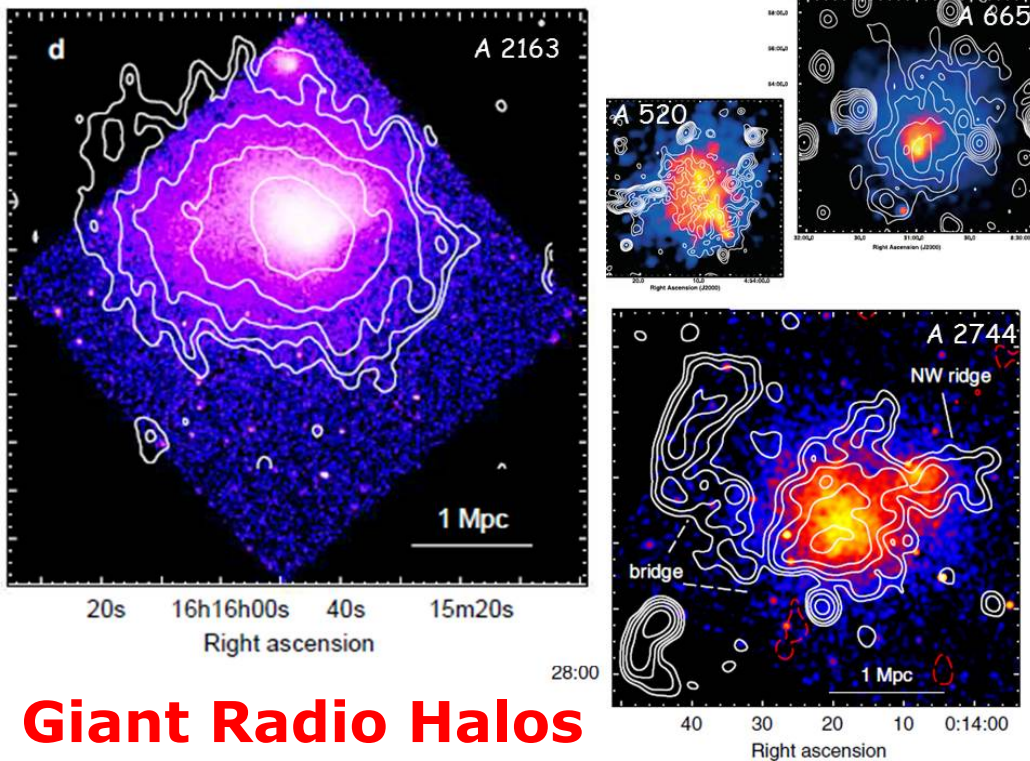
→ now



Rossella Cassano
INAF-IRA, Bologna, ITALY

“Meeting INAF-Macroarea 1”

Bologna, June 16-17, 2016



Giant Radio Halos

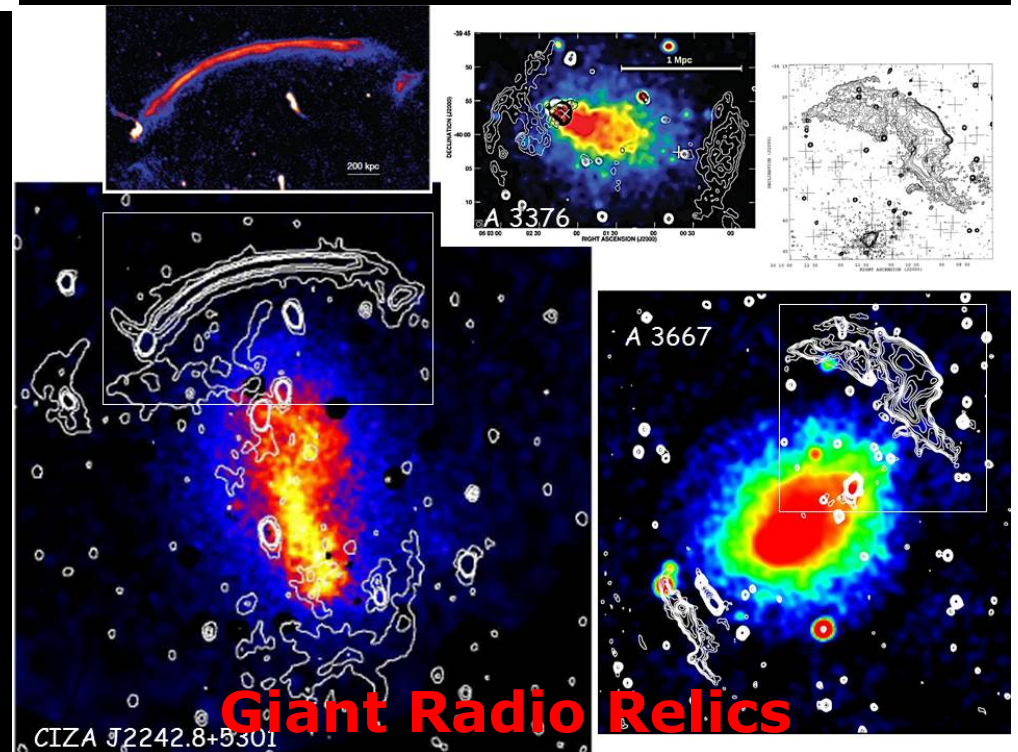
Diffuse synchrotron radiation from the ICM of **merging** clusters => GeV relativistic e^- and μG magnetic fields on Mpc-scale
(e.g.; Feretti et al. 12; Brunetti & Jones 14)

Fundamental questions...

- **ORIGIN ?**
- **IMPACT on ICM physics ?**
- **IMPACT on cluster dynamic & evolution?**

Current picture

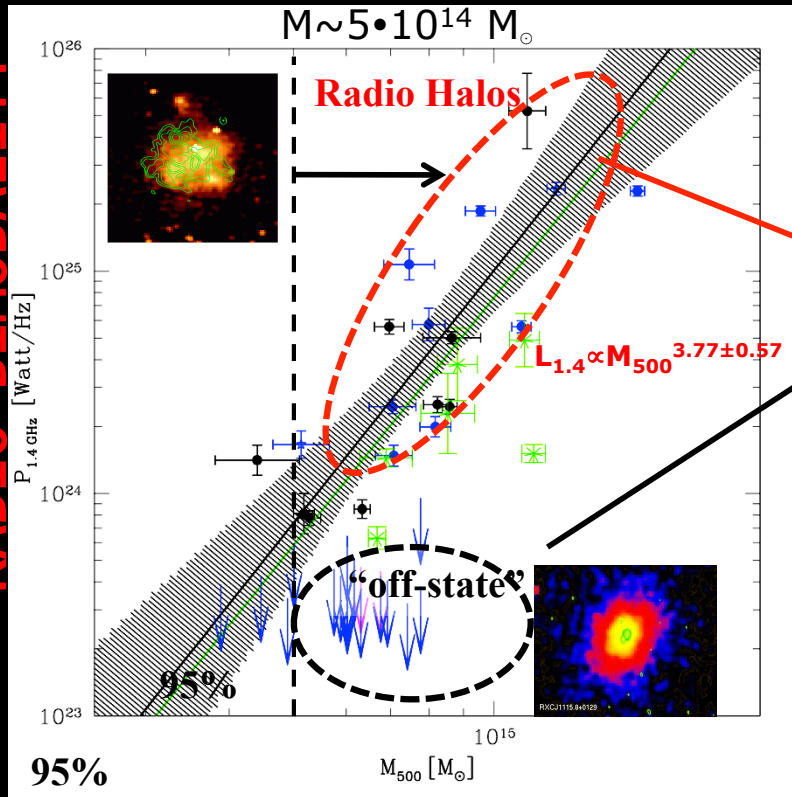
Radio Halos and Relics trace cluster regions where particles are accelerated by mechanisms related to **turbulence** and **shocks**, respectively.



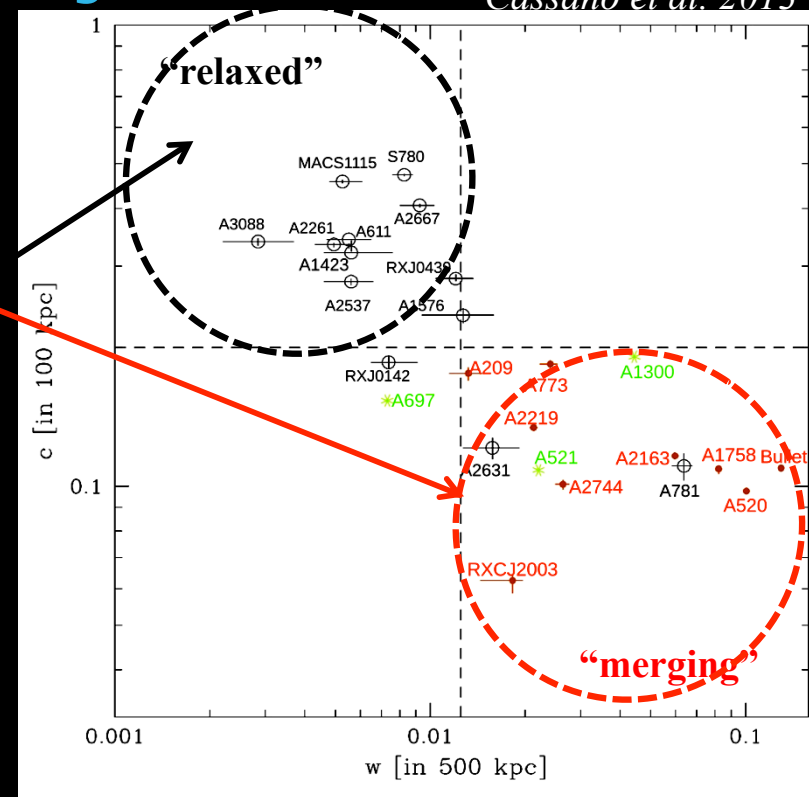
Giant Radio Relics

INAF researchers established fundamental results: RH & cluster mergers

RADIO BIMODALITY



Cassano et al. 2013



Radio Halo-merger

✓ RH are not ubiquitous in clusters (e.g. Giovannini et al. 99; Brunetti et al.07, Venturi et al.07,08, Cassano et al.08) and **are always found in merging clusters** (e.g. Govoni et al. 04; Boschini et al. 04, 06; Venturi et al. 07; Cassano et al. 10, 13; Rossetti et al. 11; Girardi et al. 11, 16; Cuciti et al.15)

✓ RH probe the dissipation of kinetic energy in the DM-driven merger events into CRs and B

INAF researchers proposed the most popular models in the field

Brunetti + 01; Brunetti+04, Cassano & Brunetti 05; Brunetti & Blasi 05; Cassano + 06; Brunetti & Lazarian 07,11,16

merger-driven turbulence in the ICM re-accelerates stochastically CRe (fossil and secondaries) via Fermi II-type mechanisms

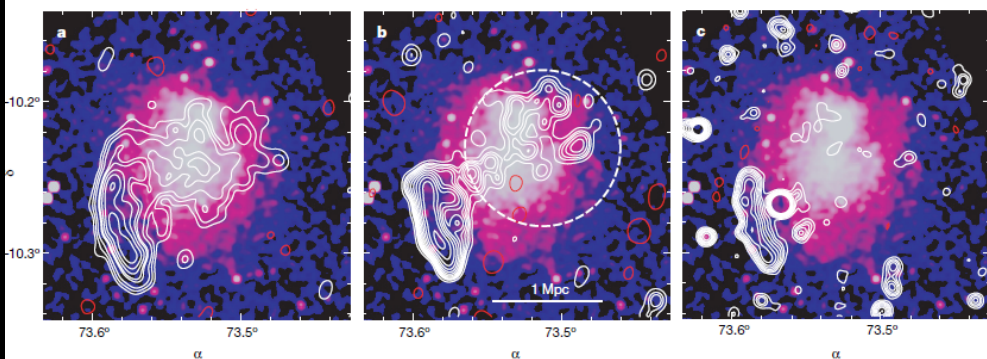
This inspired the LOFAR cluster science case

nature Vol 455|16 October 2008|doi:10.1038/nature07379

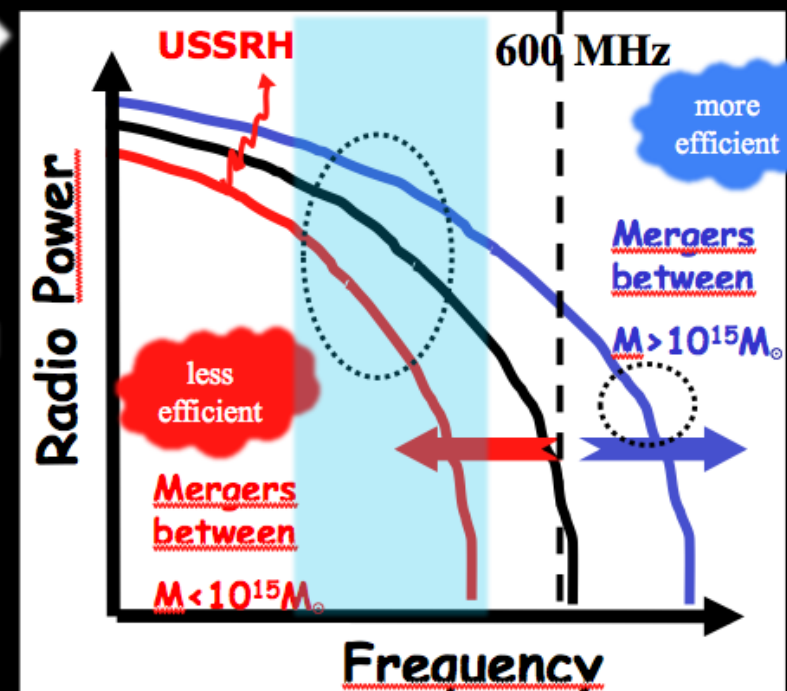
LETTERS
Brunetti + 08

A low-frequency radio halo associated with a cluster of galaxies

G. Brunetti¹, S. Giacintucci^{1,2}, R. Cassano¹, W. Lane³, D. Dallacasa⁴, T. Venturi¹, N. E. Kassim³, G. Setti^{1,4}, W. D. Cotton⁵ & M. Markevitch²



240 MHz — frequency —> 1400 MHz



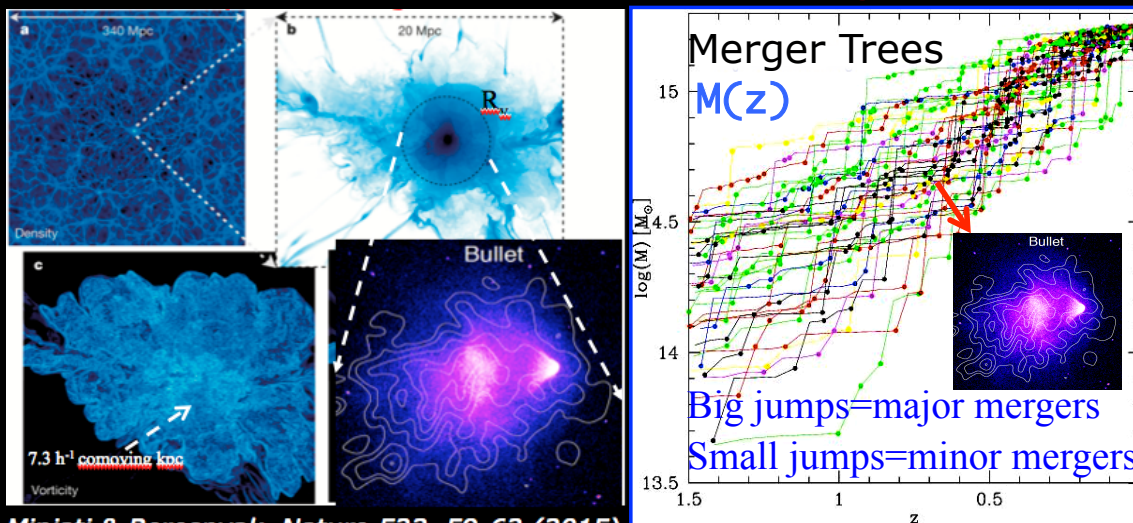
Models predict that the majority of cluster-scale radio emission should glow-up at low frequencies (*Cassano et al. 06,12,15*)

INAF researchers proposed the most popular models in the field

Brunetti + 01; Brunetti+04, Cassano & Brunetti 05; Brunetti & Blasi 05; Cassano + 06; Brunetti & Lazarian 07,11,16

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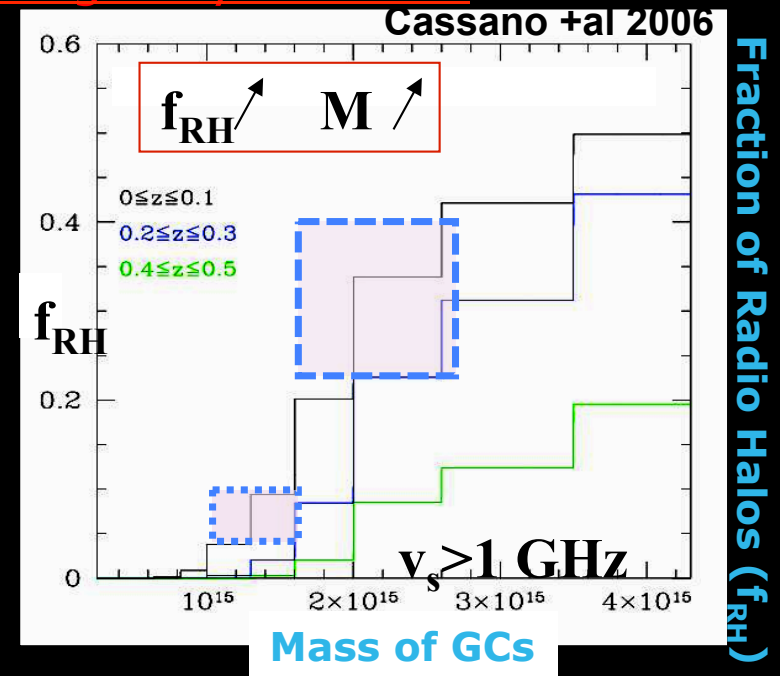
The connection with the cosmological evolution of galaxy clusters



Miniati & Beresnyak, Nature 523, 59-62 (2015)

✓ the formation history of RH depends on the interplay between the GC merging rate throughout cosmic epochs and the process of particles acceleration

✓ diffuse radio emission in GCs can be used to probe the **cluster merging rate** with cosmic time => **large numbers** (e.g. LOFAR...SKA)



INAF researchers proposed the most popular models in the field

Brunetti + 01; Brunetti+04, Cassano & Brunetti 05; Brunetti & Blasi 05; Cassano + 06; Brunetti & Lazarian 07,11,16

merger-driven turbulence in the ICM re-accelerates stochastically CRe (fossil and secondaries) via Fermi II-type mechanisms

The connection with the cosmological evolution of galaxy clusters

Can giant radio halos probe the merging rate of galaxy clusters?
Cassano +al 2006

R. Cassano¹, G. Brunetti¹, C. Giocoli², and S. Etori^{3,4}

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Received ...; accepted ...

Cassano et al. 16, A&A in press

ABSTRACT

Observations of galaxy clusters both in the radio and X-ray bands probe a direct link between cluster mergers and giant radio halos, suggesting that these sources can be used as probes of the cluster merging rate with cosmic time. However, while all giant radio halos are found in merging clusters not every merging cluster host a giant radio halo. In this paper we carry out an *explorative* study that combines the observed fractions of merging clusters and radio halos with the merging rate predicted by cosmological simulations and attempt to infer constraints on merger properties of clusters that appear disturbed in X-rays and of clusters that host radio halos. We use

Fraction of Radio Halos (f_{RH})

GHz

10¹⁵ 4x10¹⁵

Cs

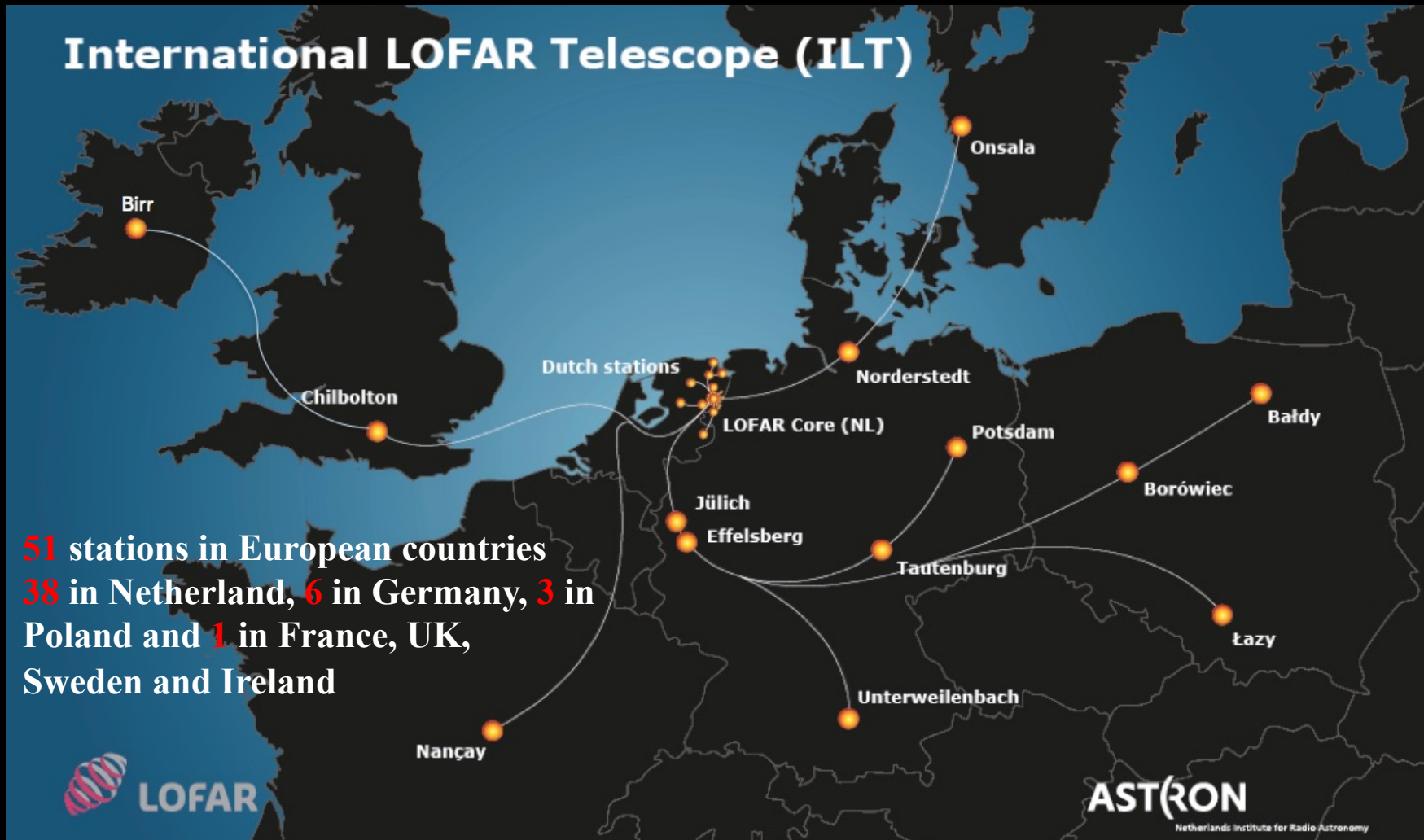
✓ the inter cosmic epochs and the process of particles acceleration

✓ diffuse radio emission in GCs can be used to probe the **cluster merging rate** with cosmic time => *large numbers* (e.g. LOFAR...SKA)

First attempts recently published in Cassano et al. 16, A&A (soon on arXiv)

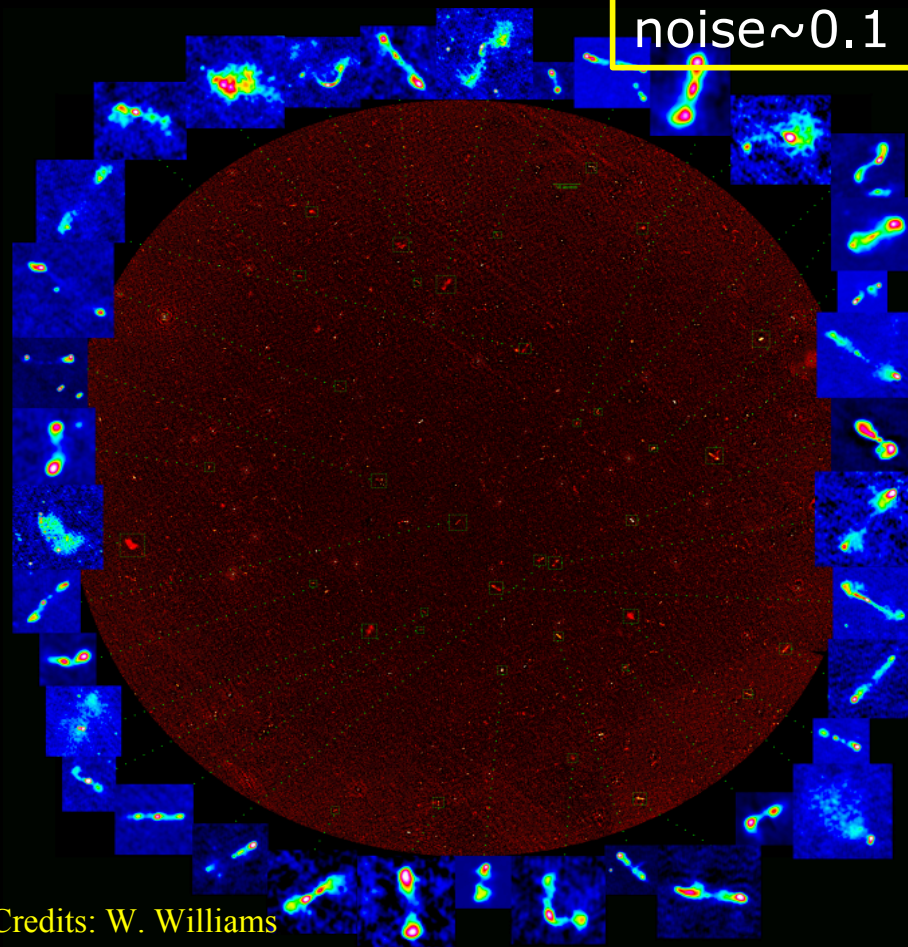
Future: short term...**LOFAR** (LOW Frequency Array)

- World's largest radio telescope
- unprecedented resolution and sensitivity at low frequency (15-250 MHz)
- wide field of view => excellent for surveys



LOFAR (Low Frequency Array): First Results

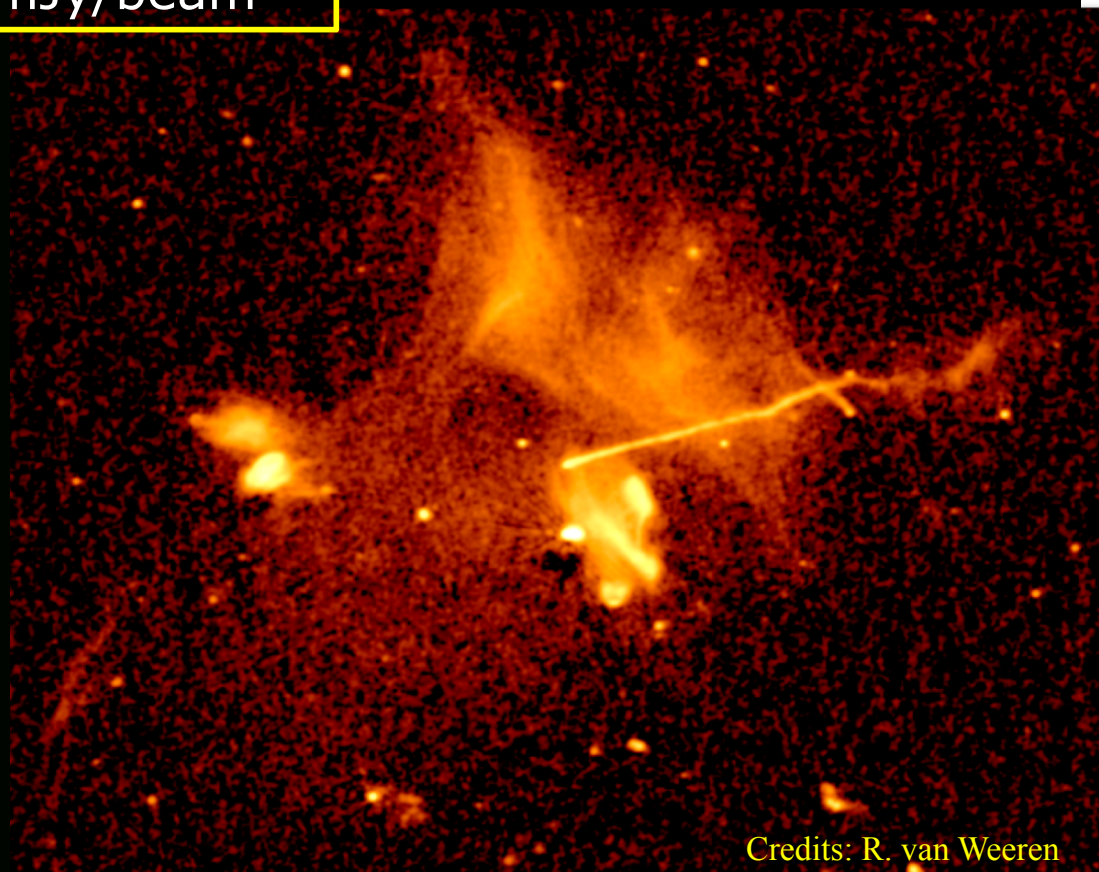
Bootes field,
LOFAR (150 MHz)



Credits: W. Williams

resolution ~ 5 arcsec
noise ~ 0.1 mJy/beam

Galaxy cluster Abell 2256,
LOFAR (150 MHz)



Credits: R. van Weeren

LOFAR imaging challenges

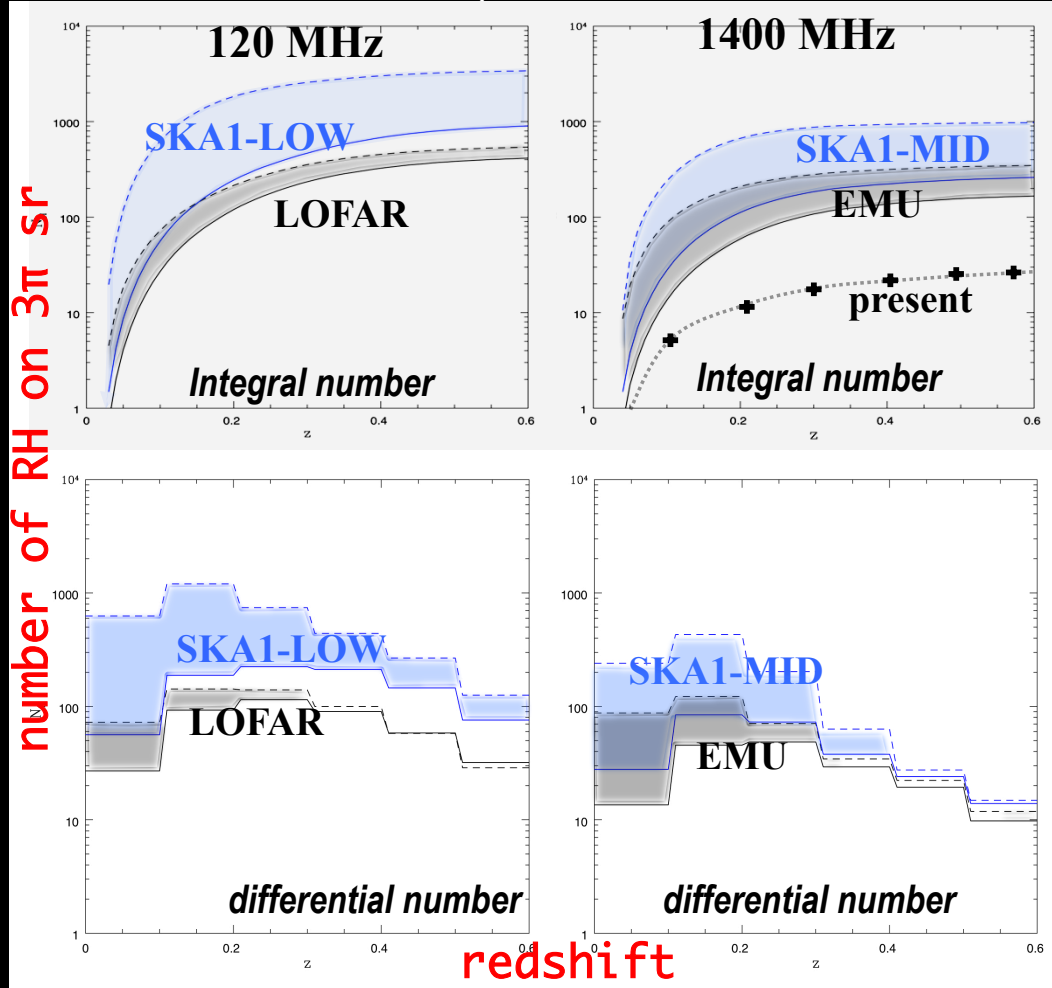
- wide field imaging
- RFI
- Data Volume/Rates
- Direction Dependent Effects (Ionosphere,...)



**NEW APPROACH TO
RADIO DATA ANALYSIS,
NEW TECHNIQUES
REQUIRED**

Future: long term... **SKA1-LOW & SKA1-MID**

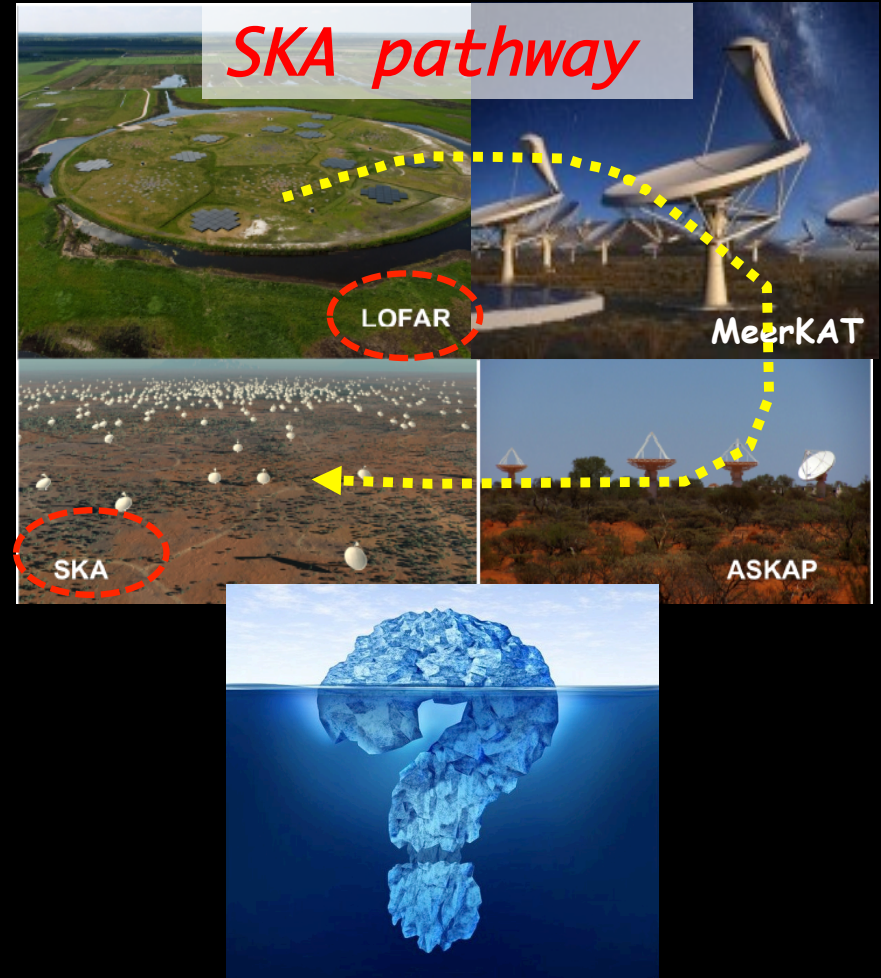
Cassano et al. 2015, 2016



from $\sim 30-40$ RH

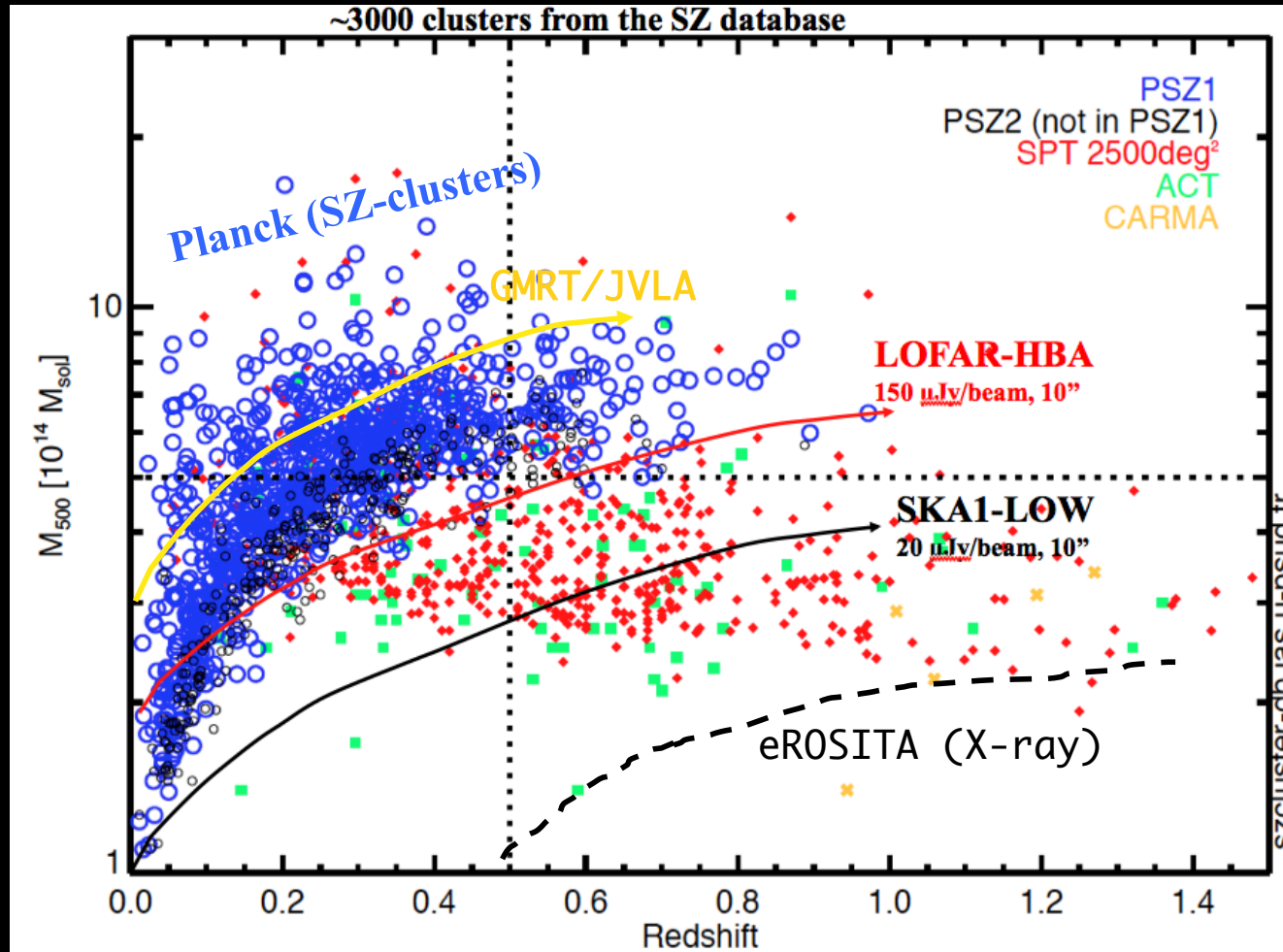
ASKAP(EMU) $\Rightarrow \sim 300$
 SKA1-MID $\Rightarrow \sim 750$ } 1-2 GHz

LOFAR $\Rightarrow \sim 500$
 SKA1-LOW $\Rightarrow \sim 2600$ } 150-200 MHz



Are we seeing the tip of the iceberg?
 How many RH await discovery?

RHs to detect galaxy clusters in radio survey



LOFAR-HBA (rms=150 $\mu\text{Jy}/\text{beam}$) and **SKA1-LOW** (rms=20 $\mu\text{Jy}/\text{beam}$) surveys:

- detection of clusters with RH up to high z
- competitive with X-ray and SZ-survey in the detection of galaxy clusters
- SKA1 will provide fundamental complementary information to the next-generation of multi-wavelength surveys (**DES**, **LSST**, **Euclid**, **eROSITA**)

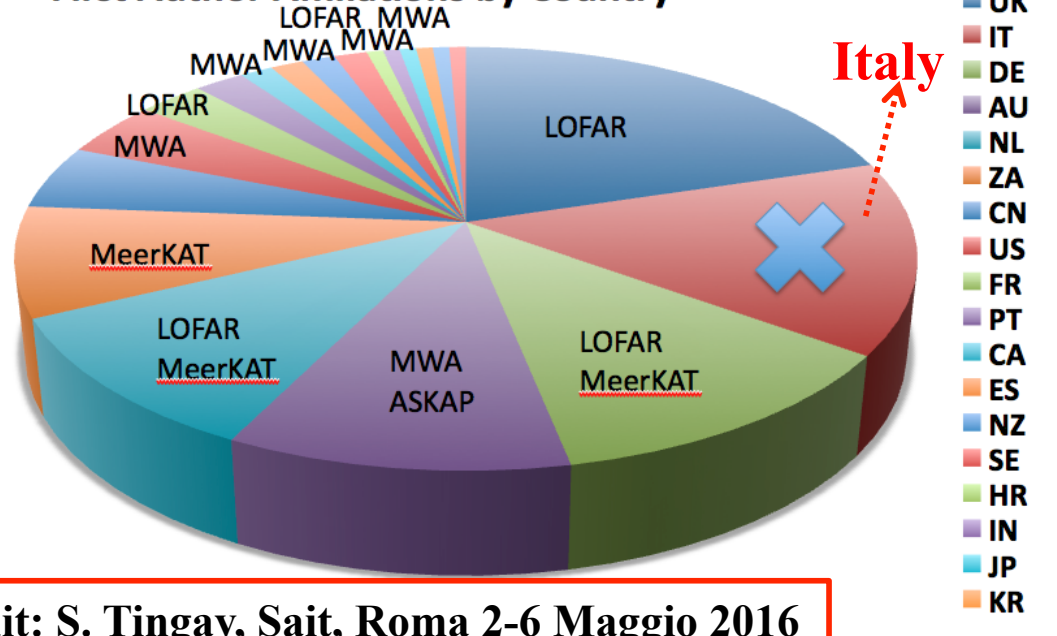
Galaxy clusters are a transformational science case for SKA...

◆ Golden Age of radioastronomy \leftrightarrow Pathway to SKA (Italy is a full member)

LOFAR, MWA (now) \rightarrow ASKAP, MeerKAT (1 year timescale) \rightarrow ... SKA1

SKA science case:
135 chapters

First Author Affiliations by Country



Italian 'anomaly':

- great interest in the Italian astrophysical community for the SKA
- Italy is the only country without SKA pathfinders/precursors

Credit: S. Tingay, Sait, Roma 2-6 Maggio 2016

To be prepared to a *full exploitation of SKA* (data handling, analysis and calibration, leading role in KSP,...) the Italian community needs the scientific and technical expertises that can be acquired only with a *deep involvement in SKA precursors\pathfinders*.