

Non-thermal phenomena in Large-Scale-Structure: overview and INAF contribution

Gianfranco Brunetti



ISTITUTO DI RADIOASTRONOMIA

Small numbers...

6 full time staff
(IRA,OAC)

10+ coll. staff/associate

5+ post doc
4 PhD

~15 refereed PAPERS/yr (+LColl)

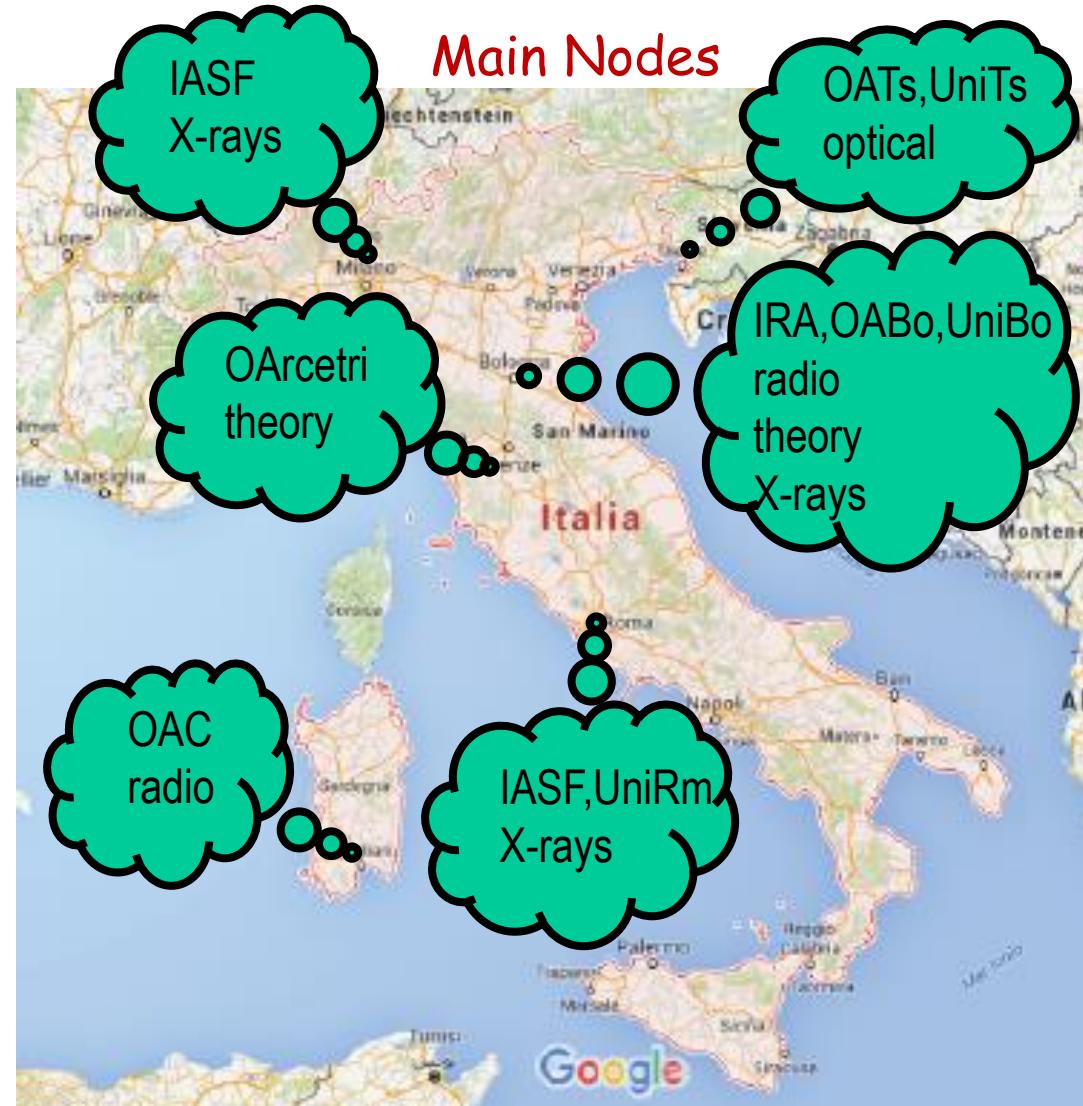
~10 /yr INVITED talks/review

AWARDS @ INAF:

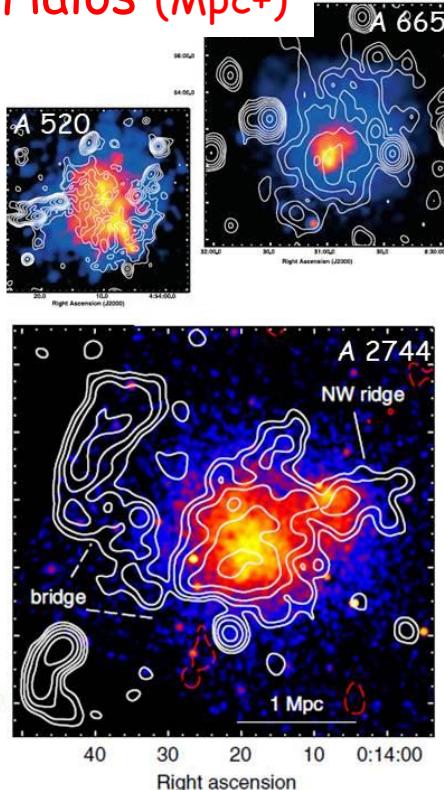
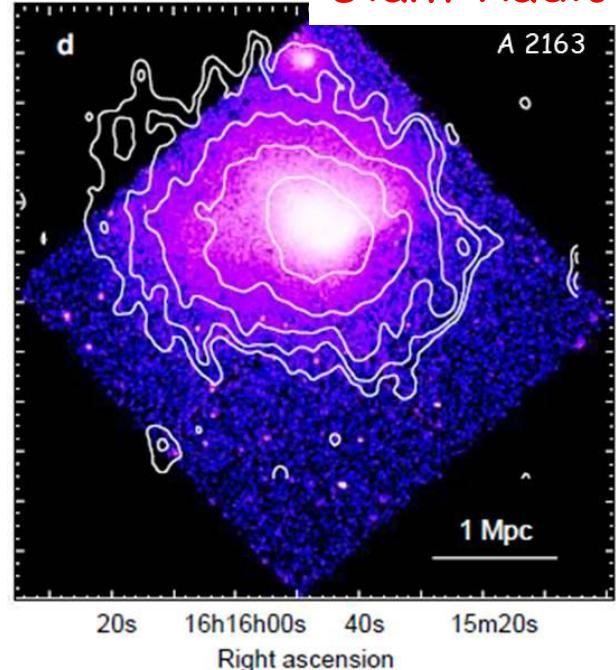
Bessel Research Award,

...
Shakti Duggal Award,
Giuseppe Borgia Prize,

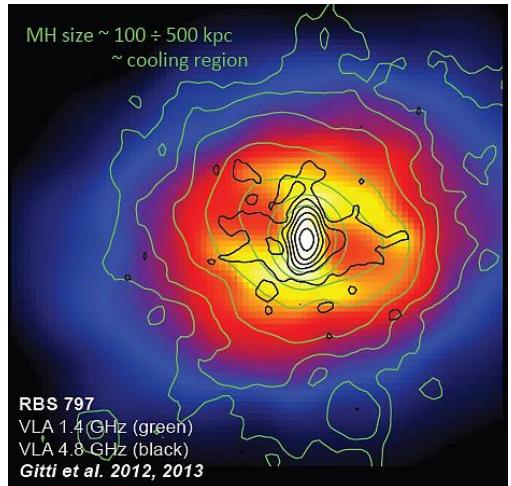
...
Tacchini, Livio Gratton



Giant Radio Halos (Mpc+)



Mini-Halos (100+ kpc)

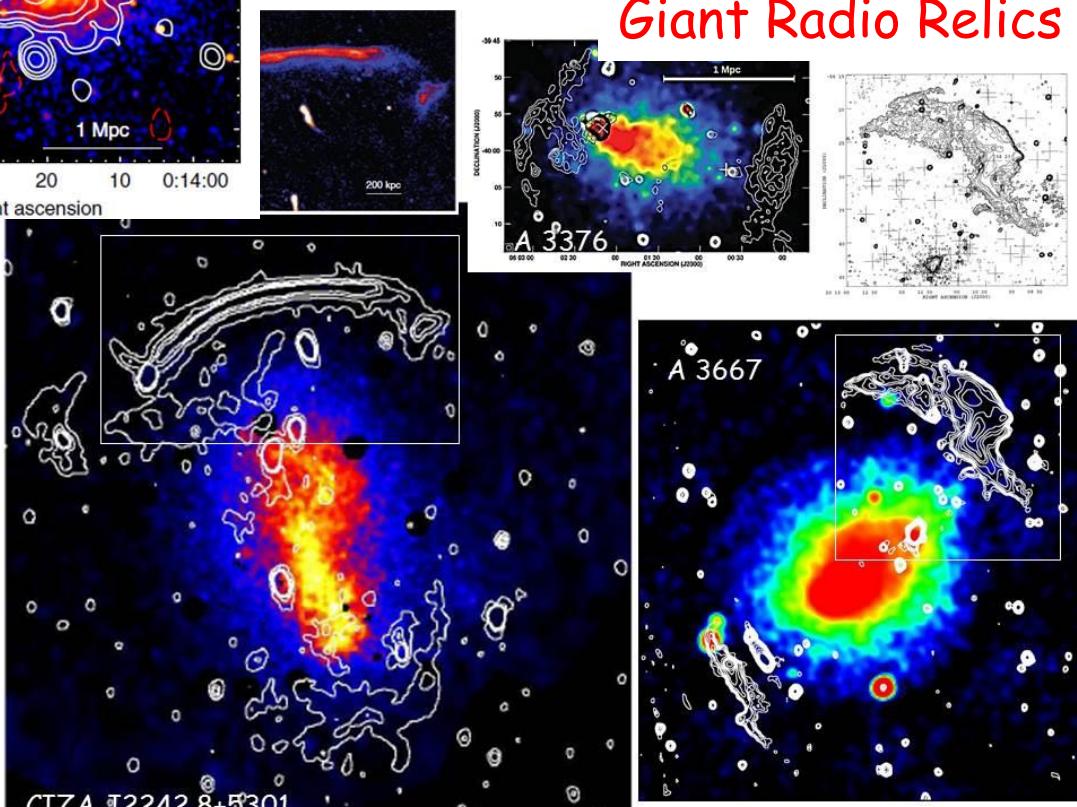


Cluster-scale radio emission

- GeV+ CR electrons
- μ G+ level magnetic fields
- Origin of CRs and B ?
- Impact on ICM physics ?
- Impact on cluster dyn/evol ?

[rev Brunetti & Jones 14, Feretti et al 12]

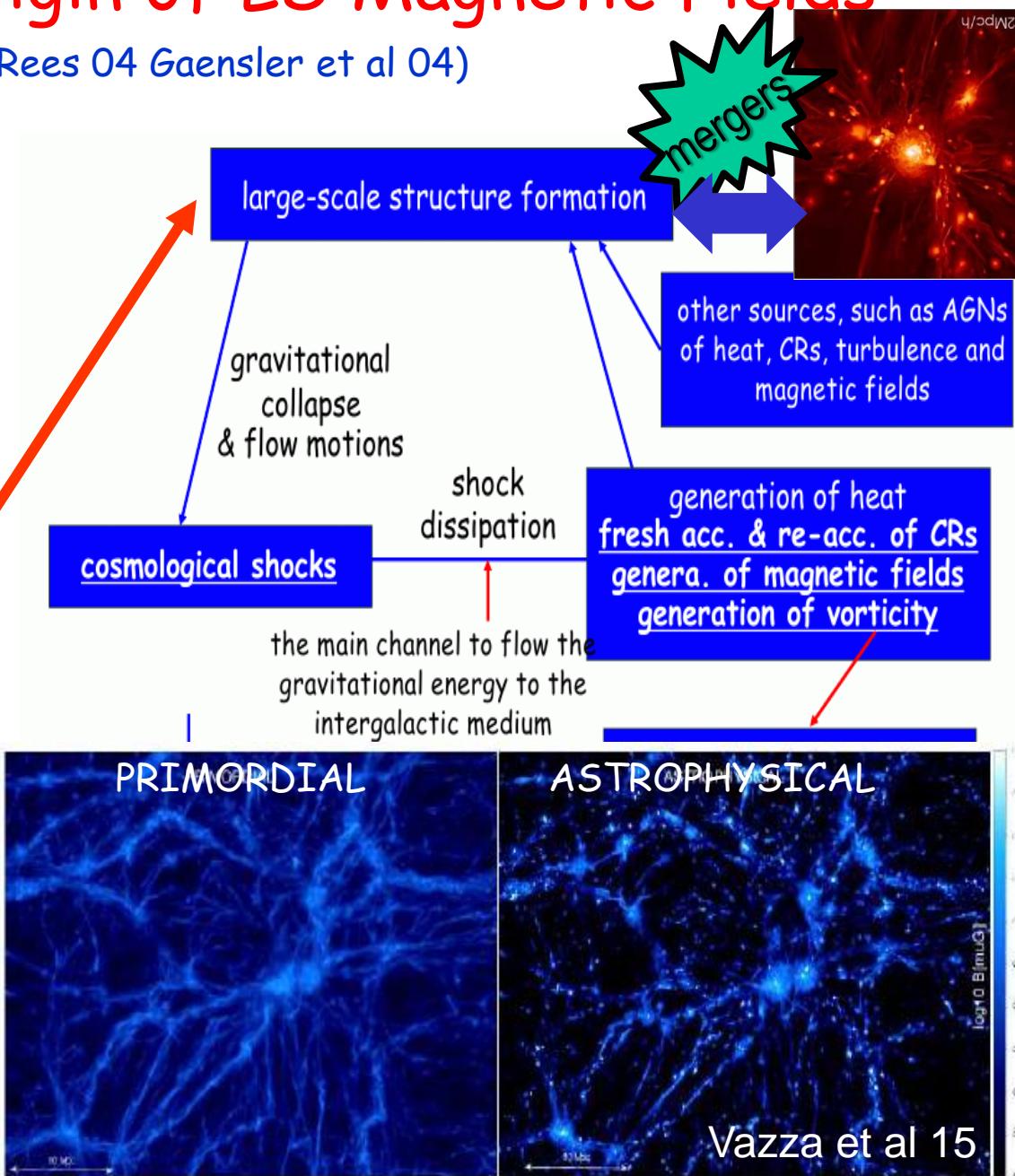
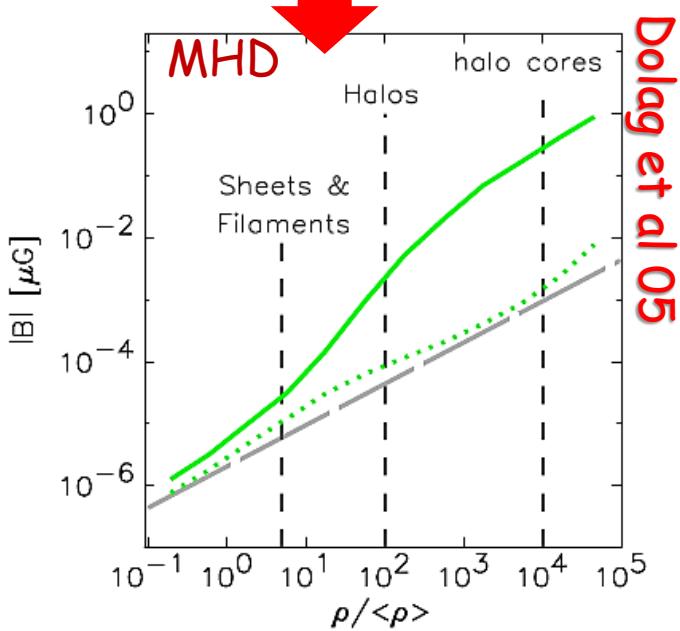
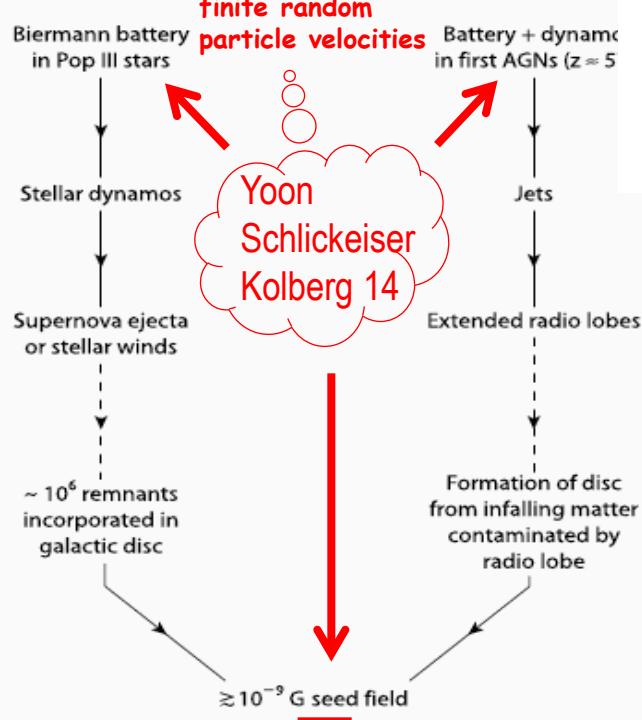
Giant Radio Relics



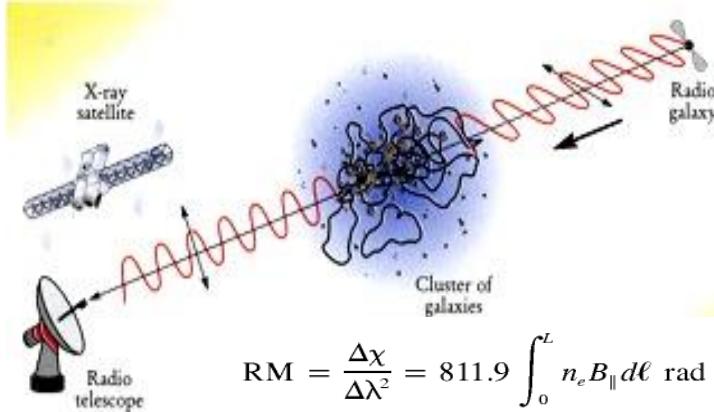
CIZA J2242.8+5301

Origin of LS Magnetic Fields

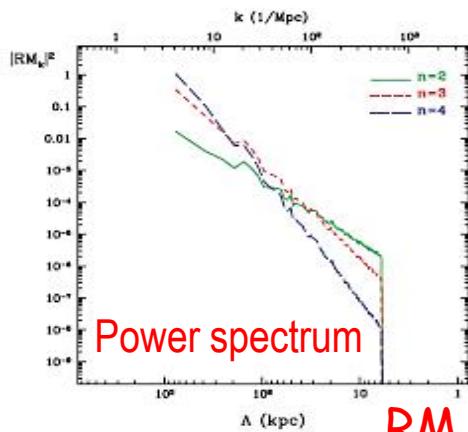
(eg Rees 04 Gaensler et al 04)



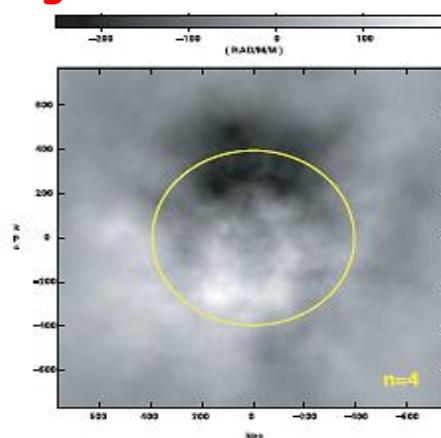
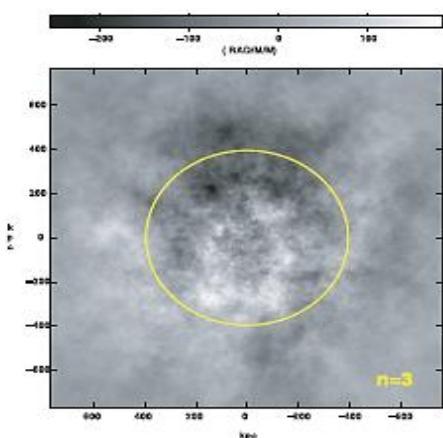
Seminal contributions from INAF in measuring LF Fields



$$RM = \frac{\Delta\chi}{\Delta\lambda^2} = 811.9 \int_0^L n_e B_{\parallel} d\ell \text{ rad m}^{-2},$$



RM images



Feretti et al 95

...

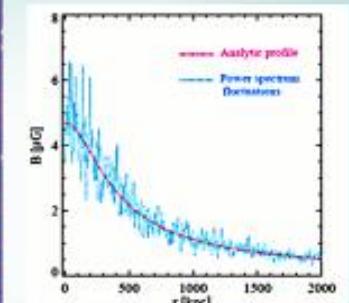
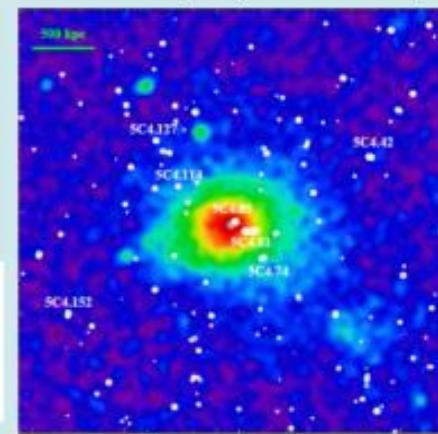
Murgia et al 04
Govoni et al 05

...

Bonafede et al 10, 13 ...

Talk by
Feretti

Magnetic field in Coma Cluster :
Strength, structure, radial profile with
RM from 7 sources



Bonafede et al. 2010

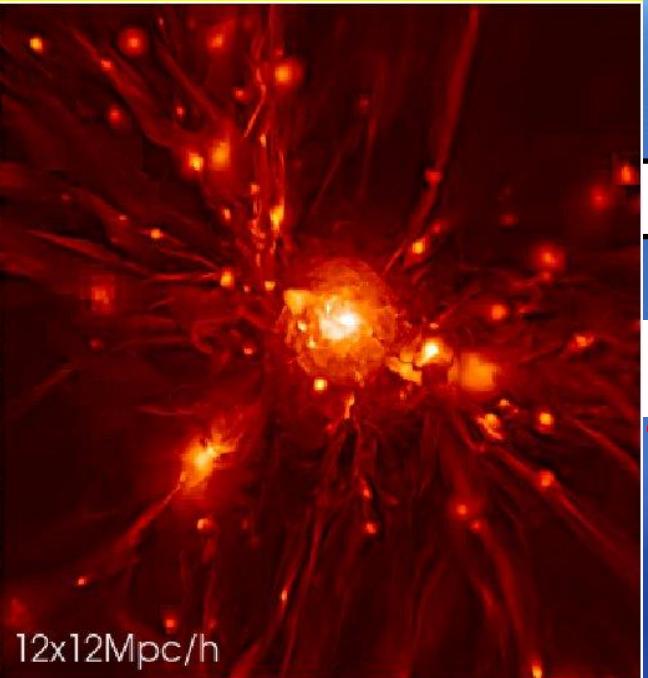
With SKA :
~1000 sources

→ Many clusters
→ Distant clusters

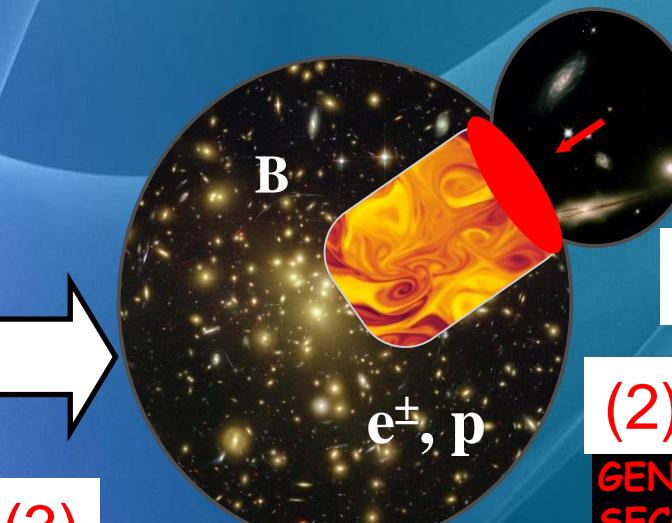
In future : fundamental info for
(plasma)physics of the ICM

CR-acceleration

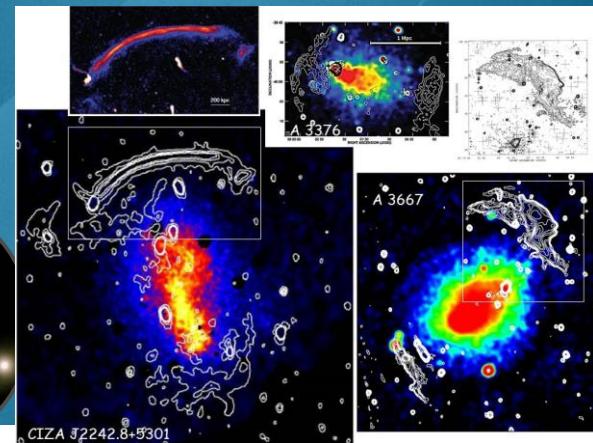
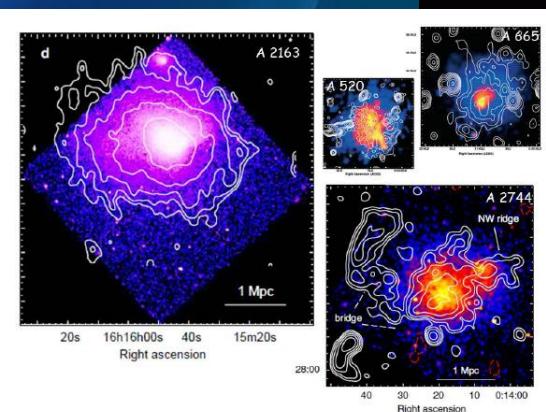
Mergers guide CRe acceleration/dynamics and/or amplify B



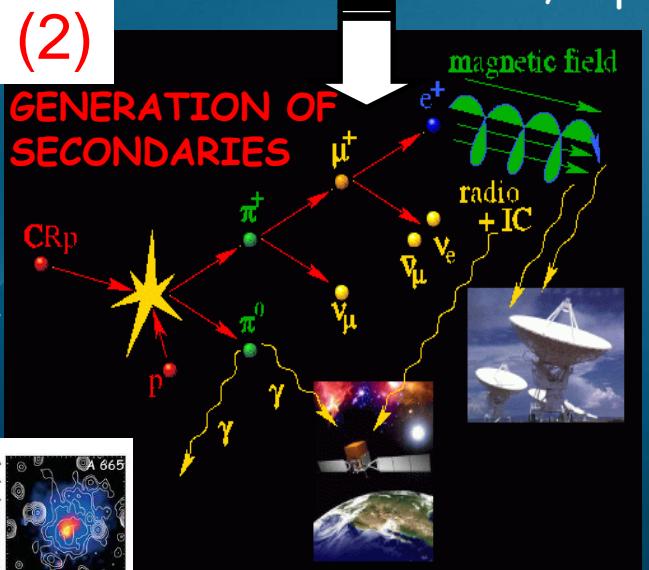
(eg Blasi + 07, Brunetti + Jones 14)



(3)
TURBULENCE
reaccelerates fossil CRe^\pm ,
 CRp and secondaries CRe^\pm



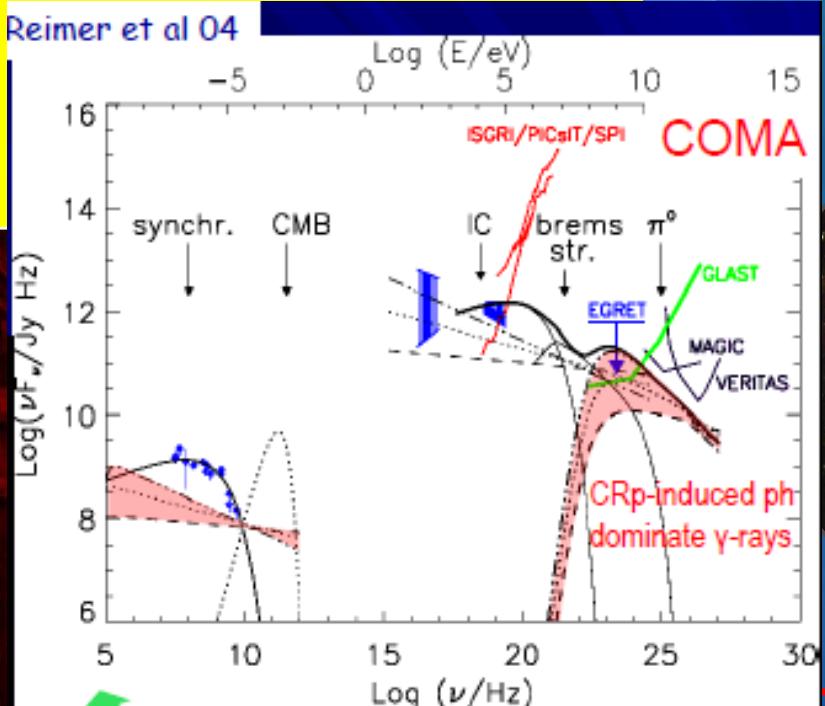
(1) SHOCKS
accelerate CRe^\pm, CRp



(2)
GENERATION OF SECONDARIES

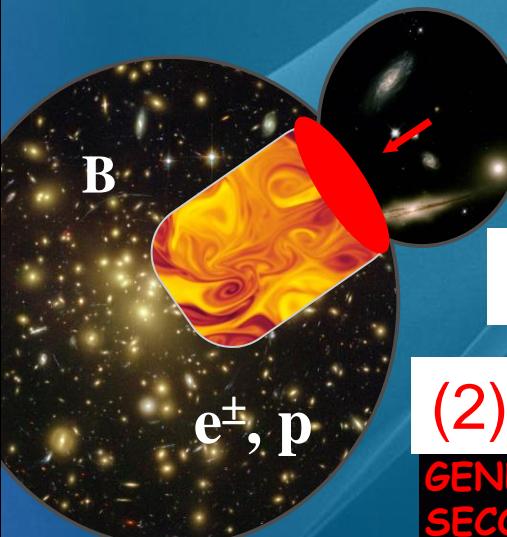
(4)
MAGNETIC RECONNECTION

CR-acceleration & emission

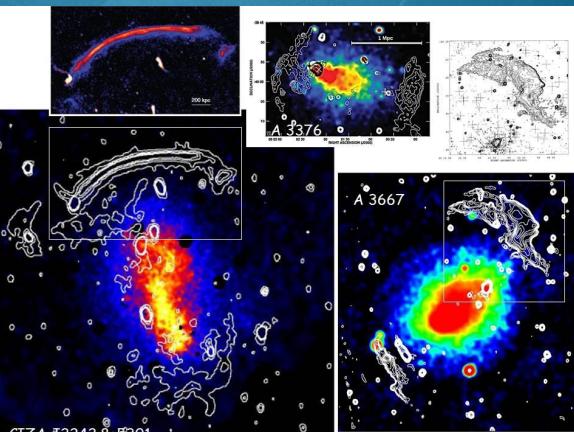
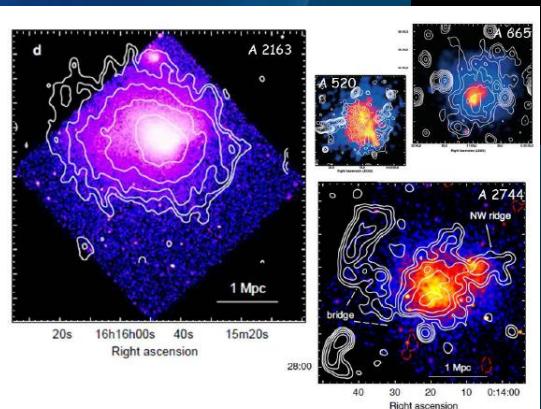


Miniati et al 01, Brunetti & Blasi 05,
Blasi et al 07, Pfrommer et al 08,
Brunetti & Lazarian 11

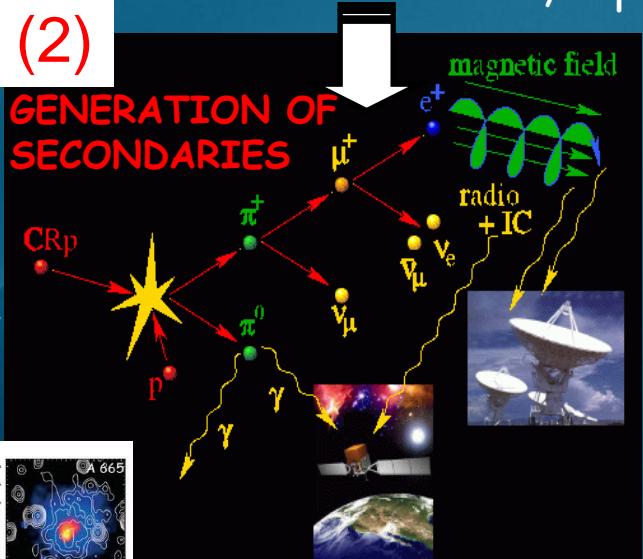
(eg Blasi + 07, Brunetti + Jones 14)



INFLUENCE
generates fossil CRe^\pm ,
secondaries CRe^\pm

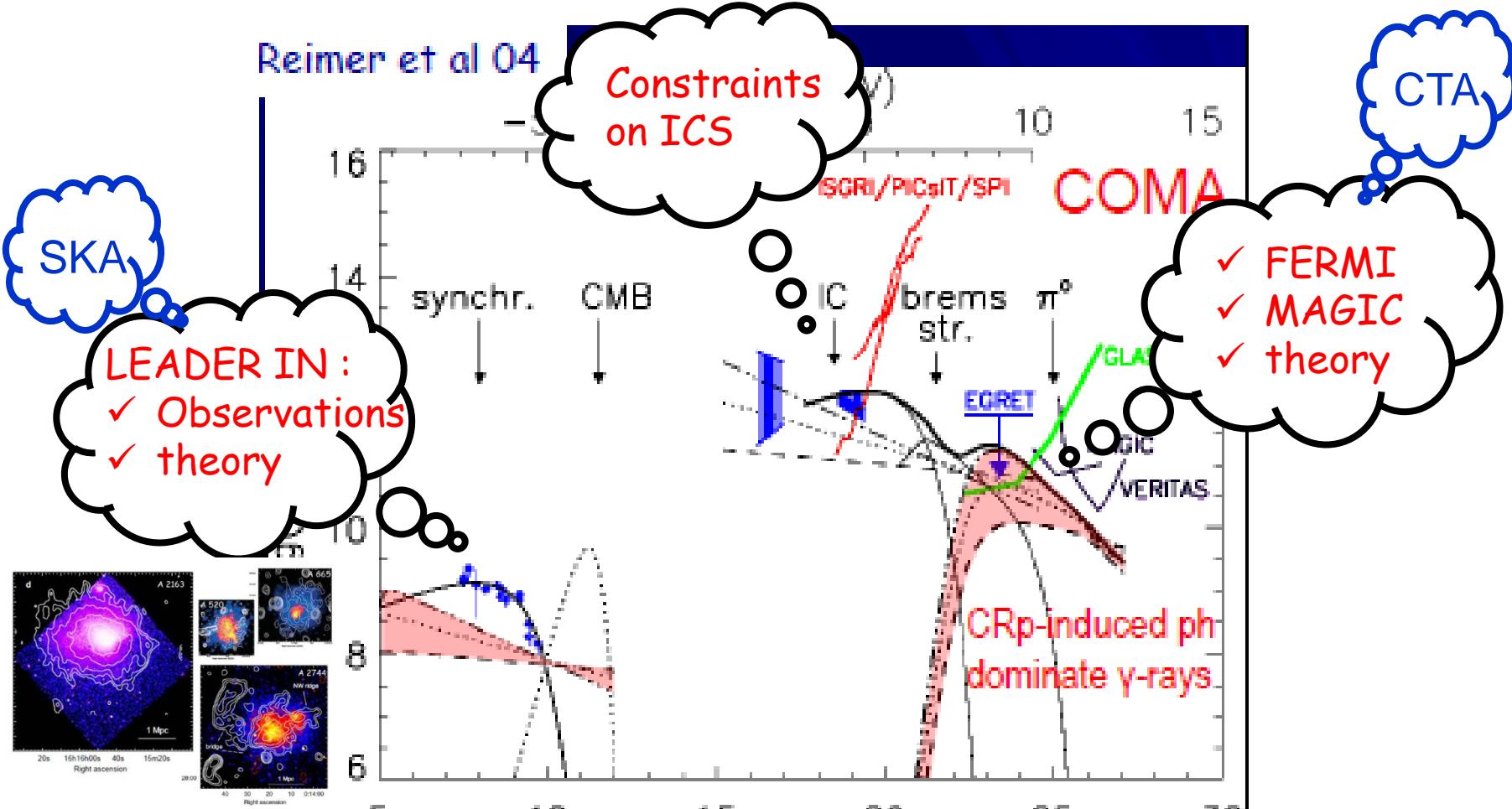


(1) SHOCKS
accelerate CRe^\pm, CRp



(4)
MAGNETIC RECONNECTION

IMPORTANT CONTRIBUTION FROM INAF



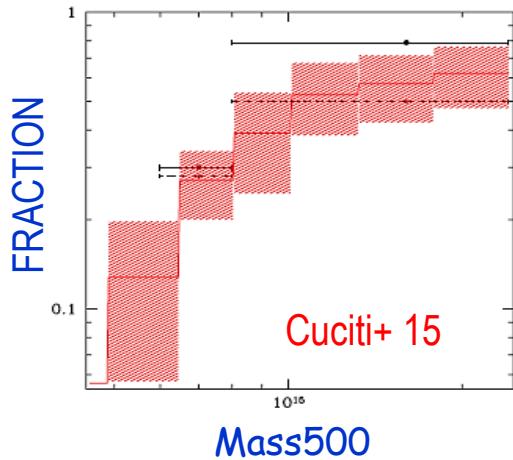
Miniati et al 01, Brunetti & Blasi 05,
Blasi et al 07, Pfrommer et al 08,
Brunetti & Lazarian 11

Properties of Cluster-scale radio emission

- INAF 'pioneered' this field -

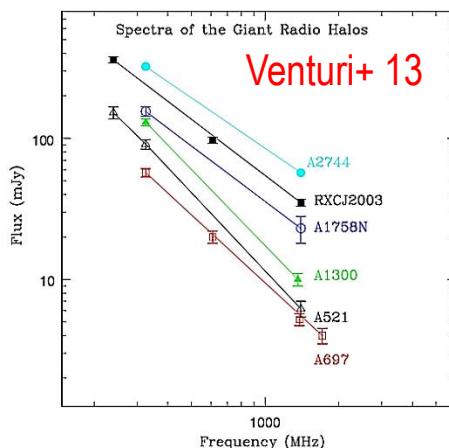
(1)

- How common is cluster-scale radio emission ?



- Connection with thermal properties (dynamics, mass,...)

- Spectrum of diffuse cluster-scale emission



Statistical studies

Feretti+Giovanini 95

...
Giovanini + 99
NVSS+X-rays

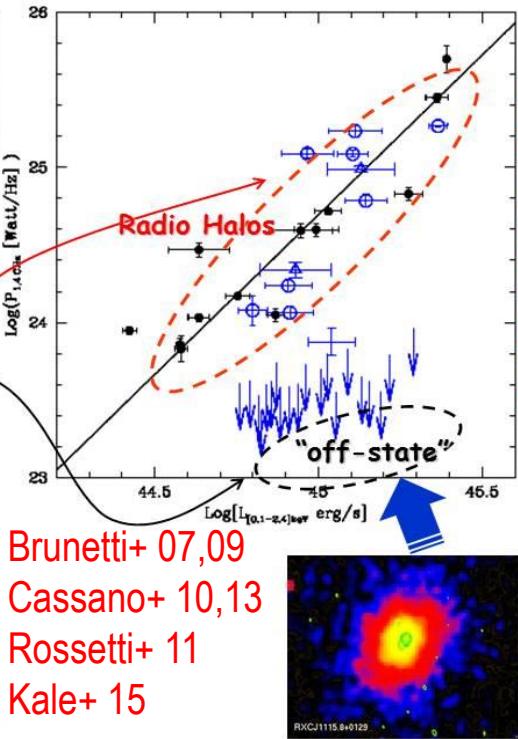
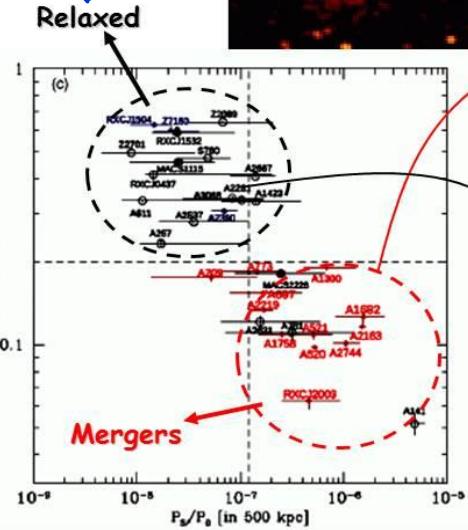
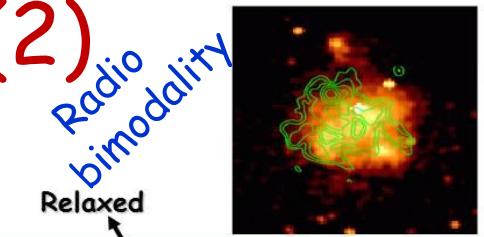
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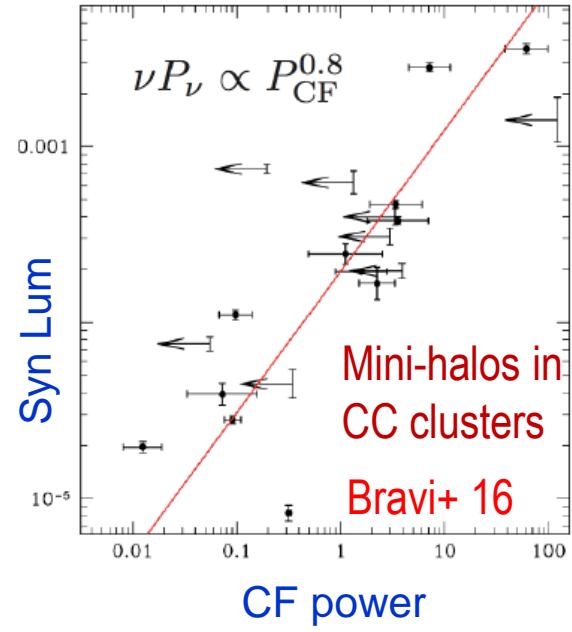
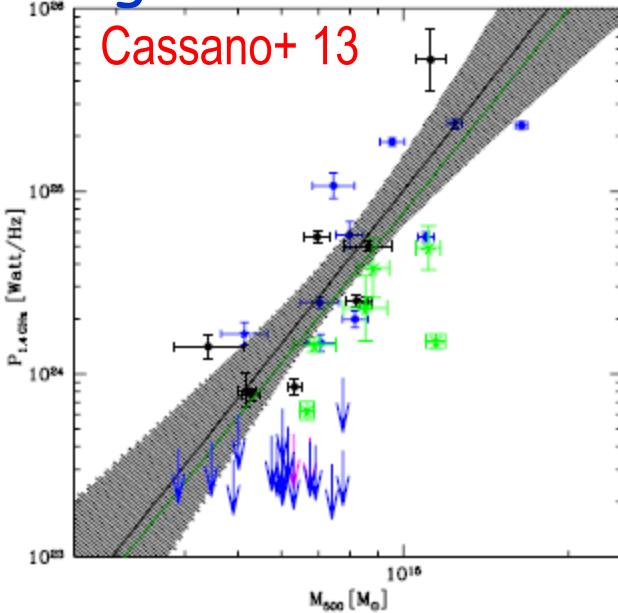
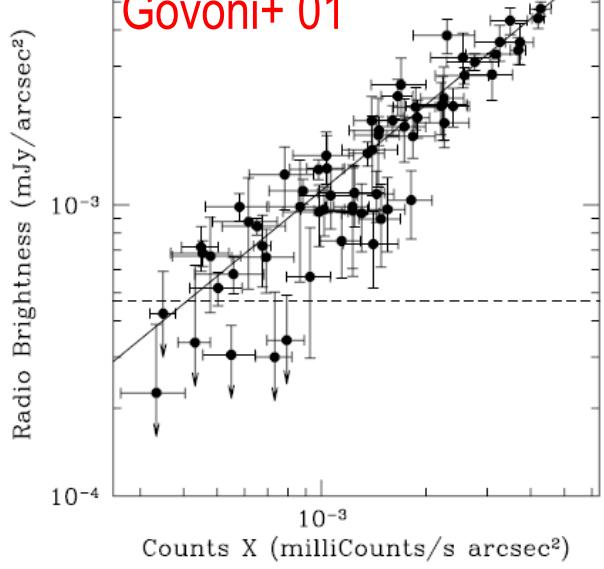
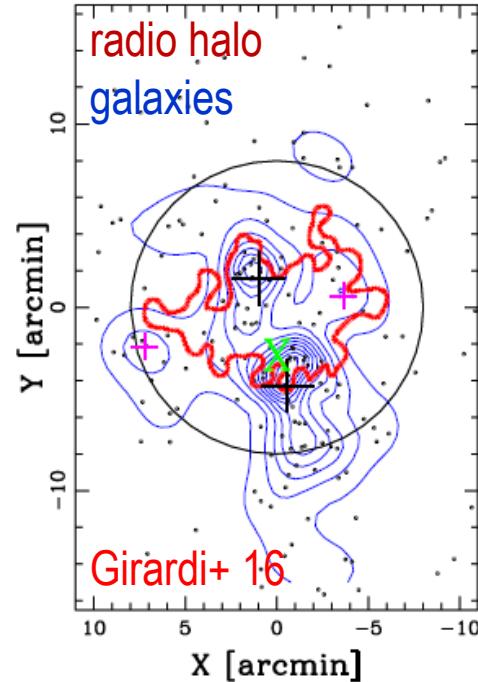
Surveys with GMRT
+ follow ups 500+ hr

Venturi + 2007
Venturi + 2008
Kale + 2013
Kale + 2015

(2) Radio bimodality



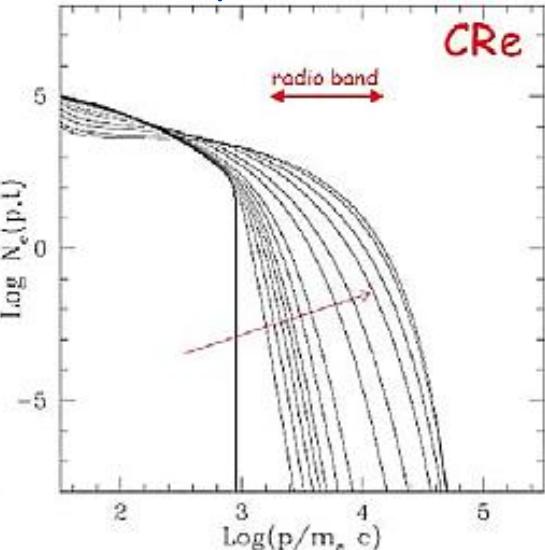
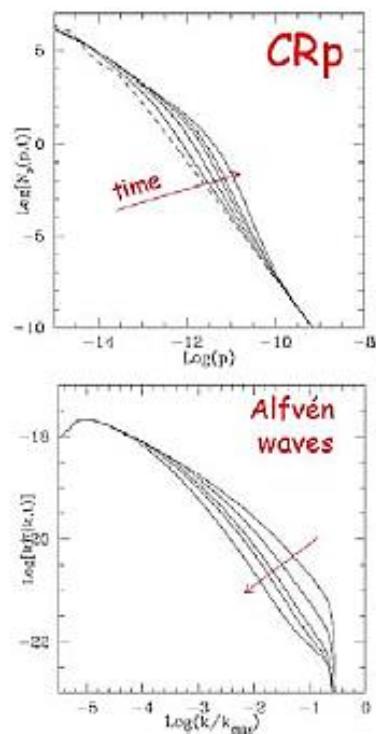
Connection with mergers



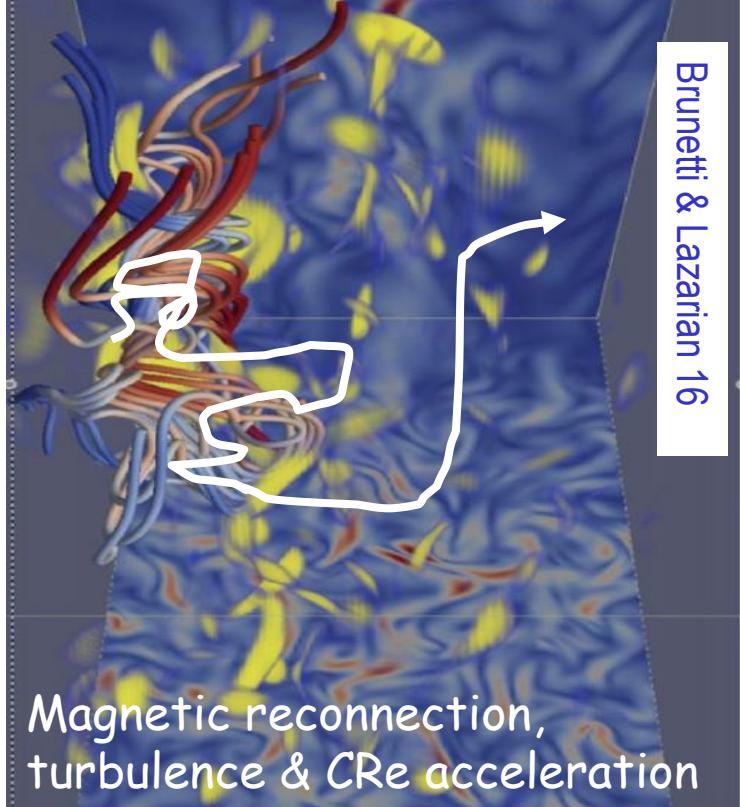
Scaling relations

THEORY: STOCHASTIC ACCELERATION

Spectral evolution of
CRe, CRp, turbulence

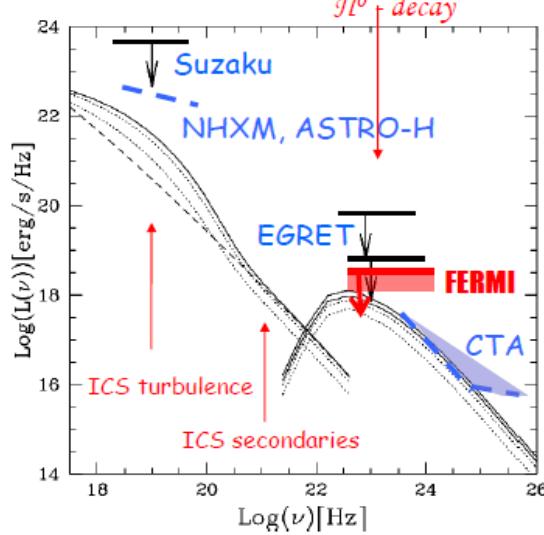
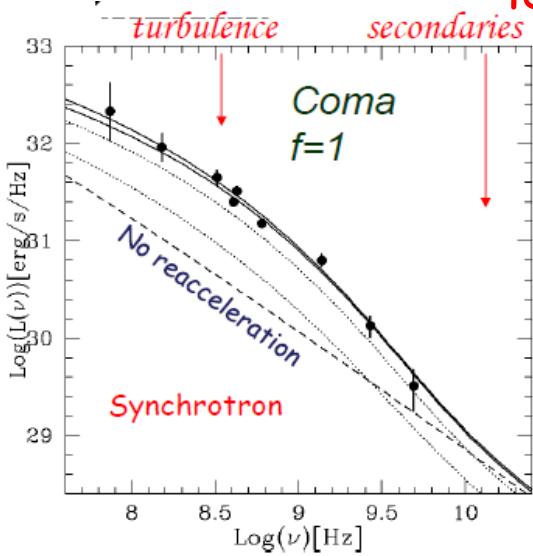


Brunetti, Blasi, Cassano, Gabici (2004)



Brunetti & Lazarian 16

Radio to gamma-ray SED
lepto-hadronic models



Brunetti & Lazarian 11

INAF proposed the most
popular models in the field

Blasi & Colafrancesco 99

Brunetti + 01

Gitti + 02

...

Brunetti+ 04, Brunetti & Blasi 05

Cassano + 06

Brunetti & Lazarian 07

...

Brunetti & Lazarian 11,16

Future 1: INAF inspired the LOFAR science case

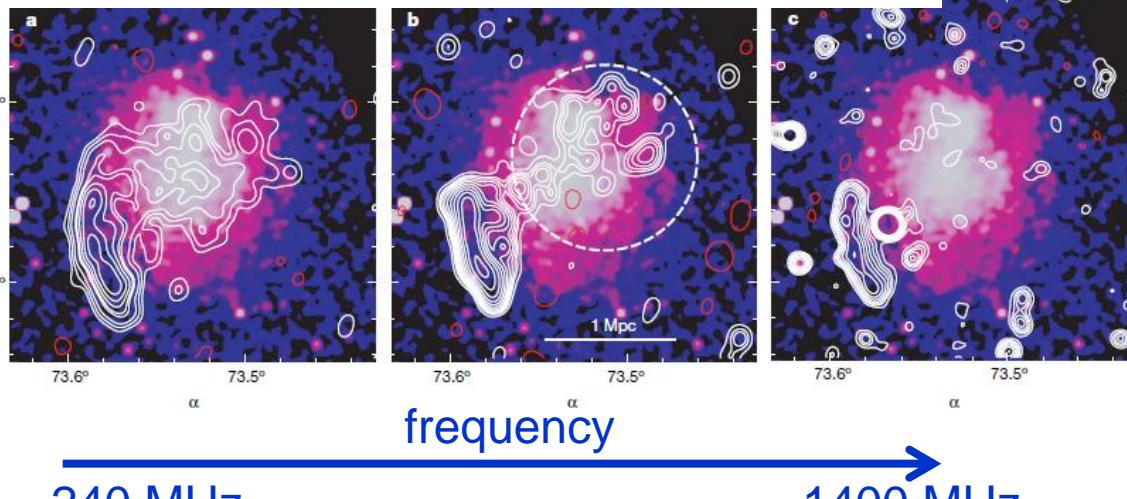
nature

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

LETTERS

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

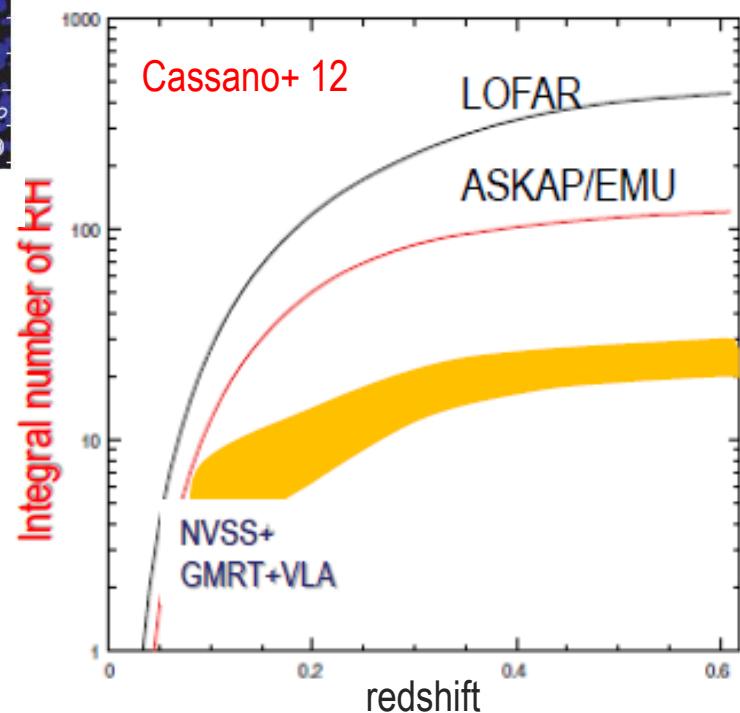
G. Brunetti¹, S. Giacintucci^{1,2}, R. Cassano¹, W. Lane³, D. Dallacasa⁴, T. Venturi¹, N. E. Kassim³, G. Setti^{1,4}, W. D. Cotton⁵ & M. Markevitch²



Talk by
Bonafede

Models predict that the majority of cluster-scale radio emission should glow-up at low frequencies !

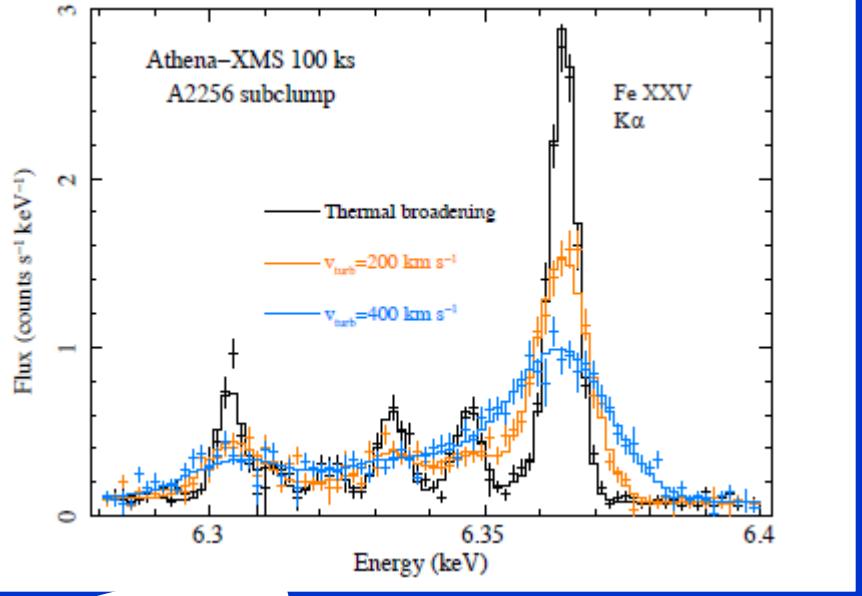
LOFAR will enter into an unexplored parameter-space



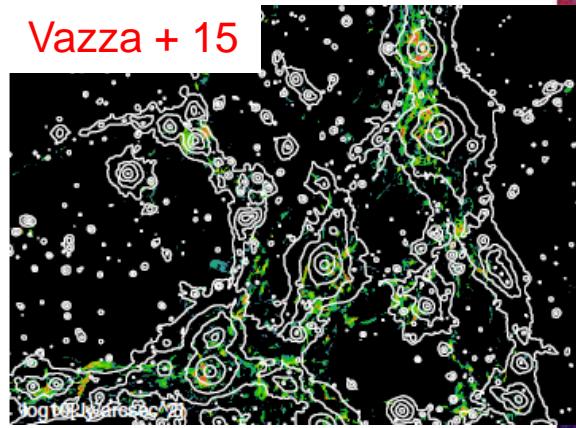
INAF people involved in Science Programs with SKA precursors/pathfinders : LOFAR, ASKAP, MeerKAT, MWA

Future 2: long term... SKA & Athena

- # energy transport (plasma-ICM)
- # turbulence
- # connection with CRs acceleration

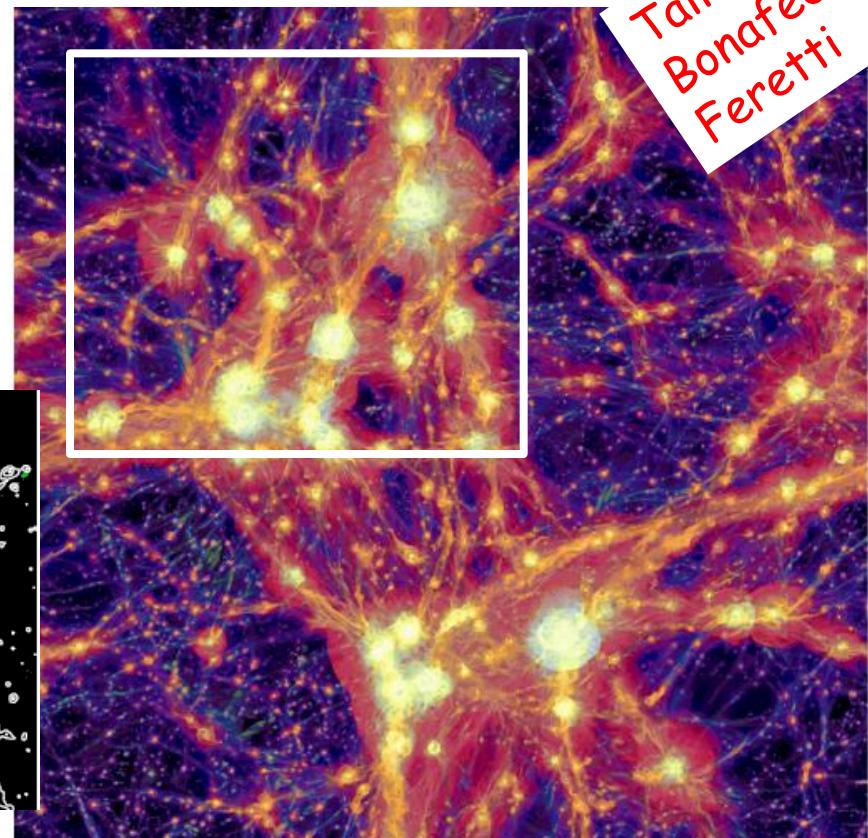


Talk by
Gastaldello

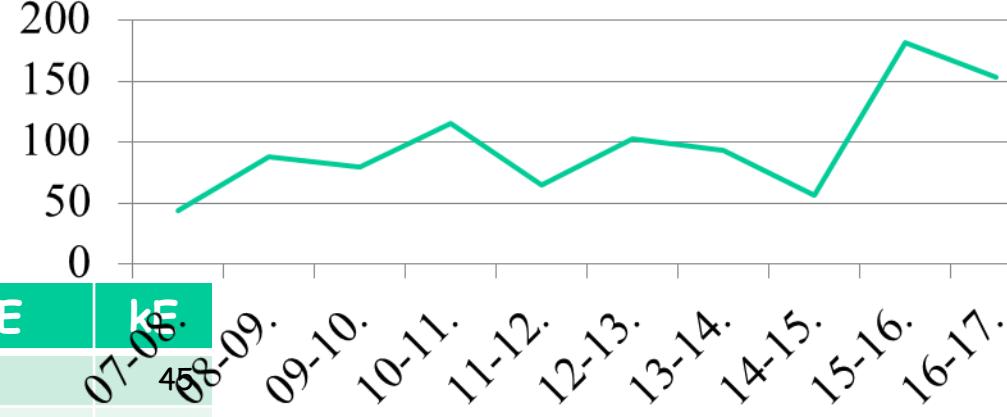


Beyond Cluster-scale

- # physics basically unknown
- # magnetic field amplification
- # CRs transport/acceleration



FUNDS (2007+)



Personnel (+FFO, Uni)

INAF-PhD (2)

ERC (2)

AstroFIT (1)

Feodor Lynen Fellowship



Alexander
von Humboldt
Stiftung / Foundation