

Schede

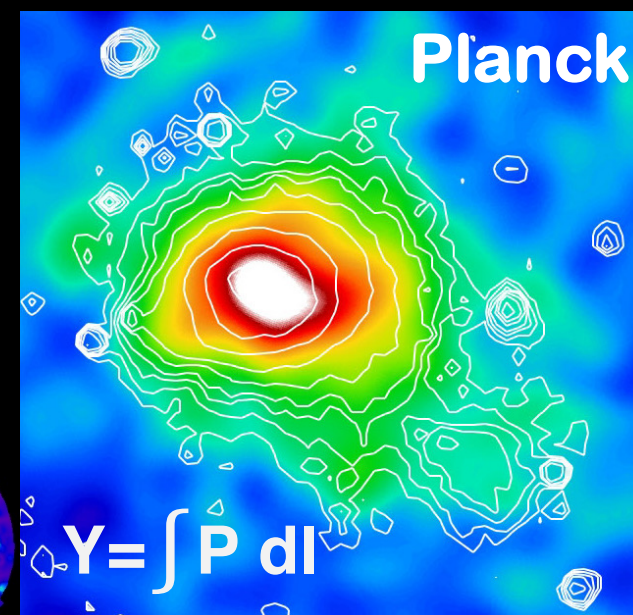
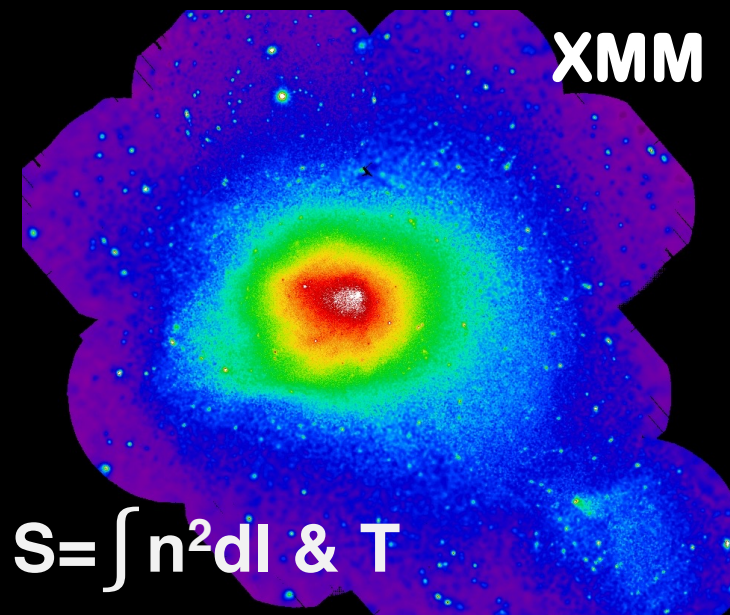
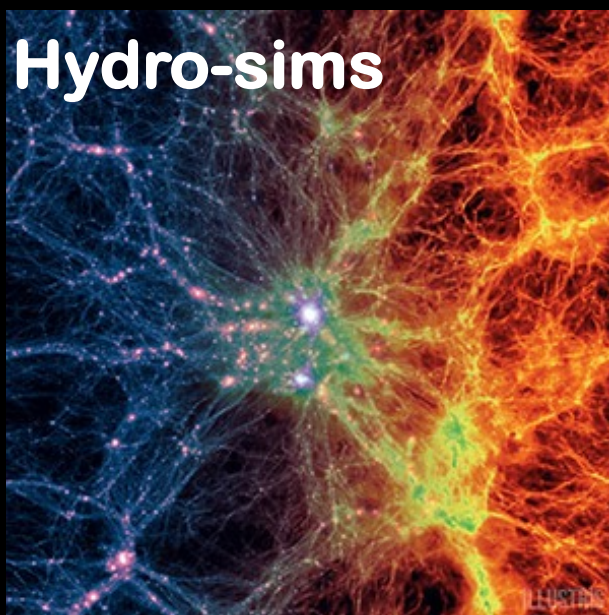
X-GALCLU: Galaxy Clusters in X-rays: the buildup of massive structures in the last 10 Gyrs

CHEX-MATE: XMM-Newton Heritage Galaxy Cluster Project

Stefano Ettori (INAF-OAS Bologna) on behalf of

#FTE INAF (associati): 14 (5) +19 (9)

FTE I/D (associati) 2021: 2.6/1.6 (0.7) +2.3/2.3 (0.9) ~10/yr



Scheda programma

X-GALCLU: Galaxy Clusters in X-rays: the buildup of massive structures in the last 10 Gyrs

In the last 20 years, our group is working on galaxy clusters and groups by fully exploiting both proprietary and archival X-ray data of objects resolved spatially up to redshift 1.5. Main objectives/results on:

- i. the reconstruction of the gas density, temperature and metal abundance profiles in well-selected samples (*e.g. Liu+18, Ghirardini+19, Ghizzardi+21*)
- ii. constraining with unprecedented accuracy the total and gas mass 3D distribution (*e.g. Sereno+18, Umetsu+18, Ettori+19*)
- iii. the accretion phenomena in the outskirts (*e.g. Eckert+19, Angelinelli+21*)
- iv. ICM properties in the cores, their physical link with the nuclear activity in the BCG, also as function of the cosmic epoch (*e.g. Yang+18, Liu+20*)
- v. the comparison between these observational constraints and the predictions from dedicated analytic models and hydrodynamical simulations (*e.g. Cui+18, Truong+18, Gaspari+19, Ettori+20*)

Scheda progetto

CHEX-MATE: XMM-Newton Heritage Galaxy Cluster Project

Team/Leadership INAF

INAF staff (~15 from 7 Institutes -OAS-Bo, IASF-Mi, OA-Mi, OA-Ts, OA-Fi, IRA-Bo, OA-Pd- +associates from Univ Bo, Ts, Rm1, Rm2) are **PI-s of observations obtained in open calls** (Chandra, XMM, NuSTAR: ~300 ksec/yr; but also mm -ALMA, NIKA2-, optical, radio).

In AO17, first Heritage program for XMM-Newton; **over-subscription factor of 10**; 6 Msec awarded to 2 only projects, one led by our group with 2 co-chairs (S. Ettori, INAF-OAS Bologna & M. Arnaud, CEA Saclay).

INAF has the co-PI-ship of CHEX-MATE, and plays a key role (with WG chairs, PI of follow-up observations).

An XMM-Newton Multi-Year Heritage Program

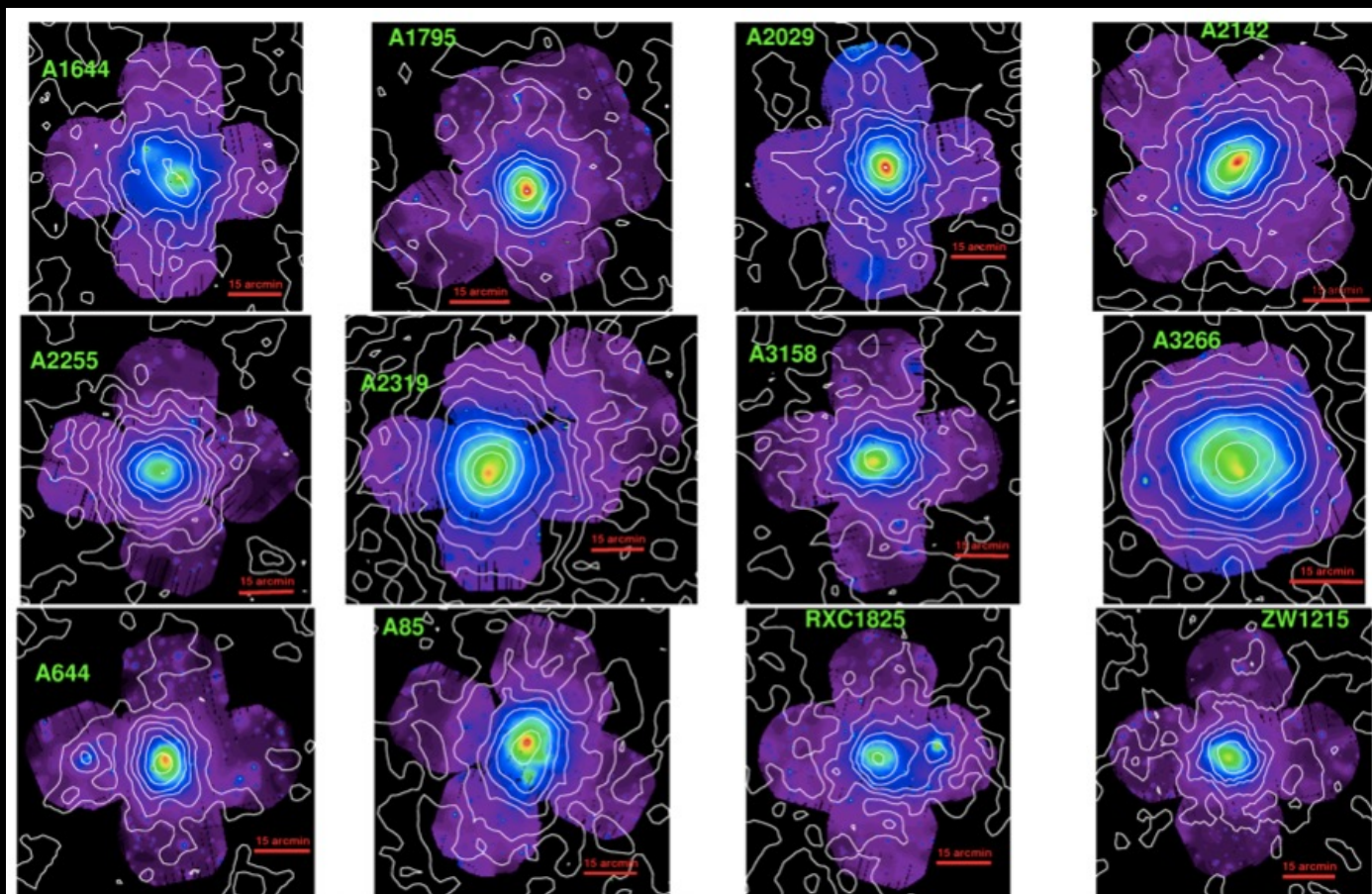
Witnessing the culmination of structure formation in the Universe

- **Steering Committee:** M. Arnaud (PI), S. Ettori (PI), D. Eckert, F. Gastaldello, R. Gavazzi, S. Kay, L. Lovisari, B. Maughan, E. Pointecouteau, G. Pratt, M. Rossetti, M. Sereno
- **WG-X-ray** (chairs: Pratt & Rossetti)
- **WG-SZ** (chairs: Pointecouteau & Sayers)
- **WG-lensing** (chairs: Gavazzi & Umetsu)
- **WG-optical** (chairs: Maurogordato & Sereno)
- **WG-radio** (chairs: Bonafede & Cassano)
- **WG-hydrosims** (chairs: Kay & Rasia)

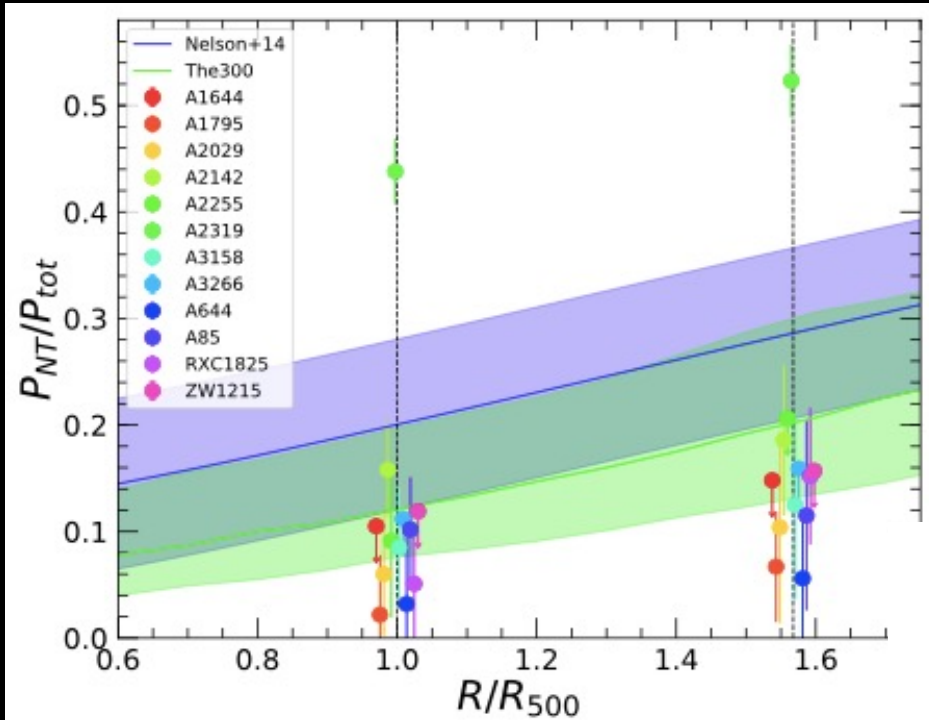
77 collaborators from 12 countries (France, Italy, Germany, Spain, Switzerland, UK, Australia, Chile, Japan, S.Africa, Taiwan, USA);
19 INAF (+9 associated)

Results/Perspectives

*In the period 2018-today, ADS lists ~180 refereed papers (with abs: “cluster” & 2360+ citations) with the 14 INAF staff in X-GALCLU as co-authors. **Out of 9 papers with 50+ citations, two are reviews & 3 are on X-COP results** (12 papers / 10 refereed / 7 1st author INAF-associated).*

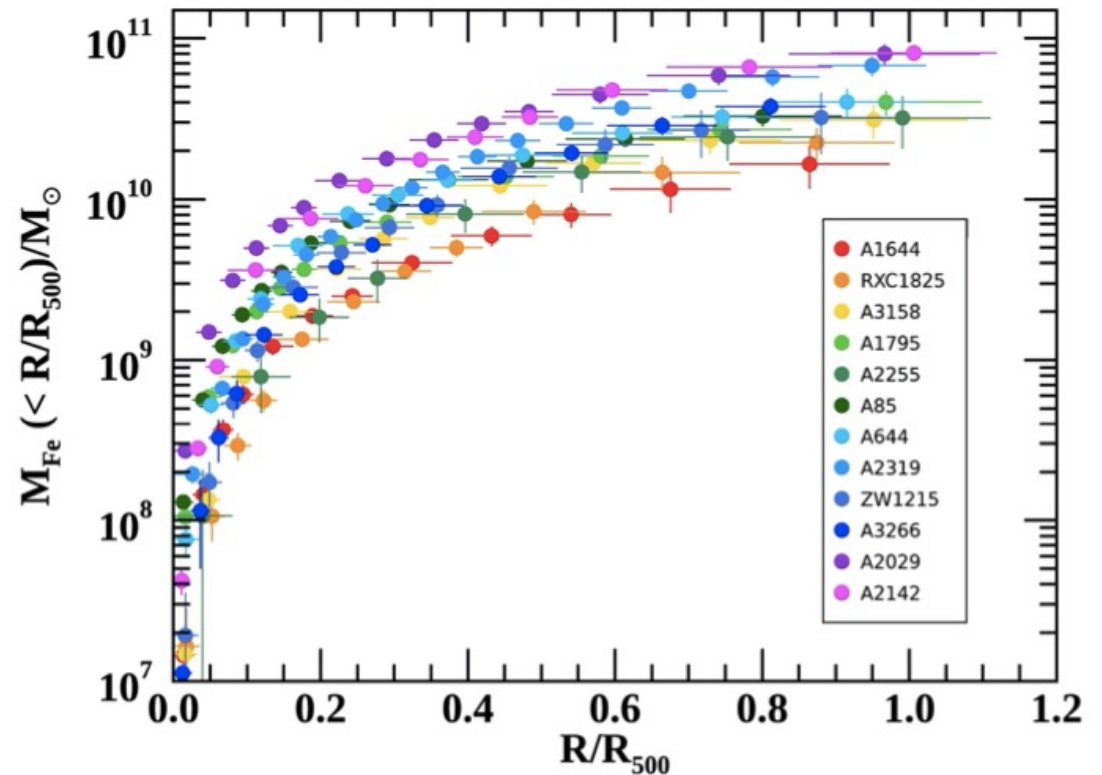


Results/Perspectives



Eckert, Ghirardini +19 on novel constraints on the level of non-thermal pressure support (*A&A Highlights*)

Ghizzardi, Molendi +21 on the first metal abundance profiles out to R_{500} & estimate that Fe in ICM $\sim 10\times$ in stars (*Media/NAF*)



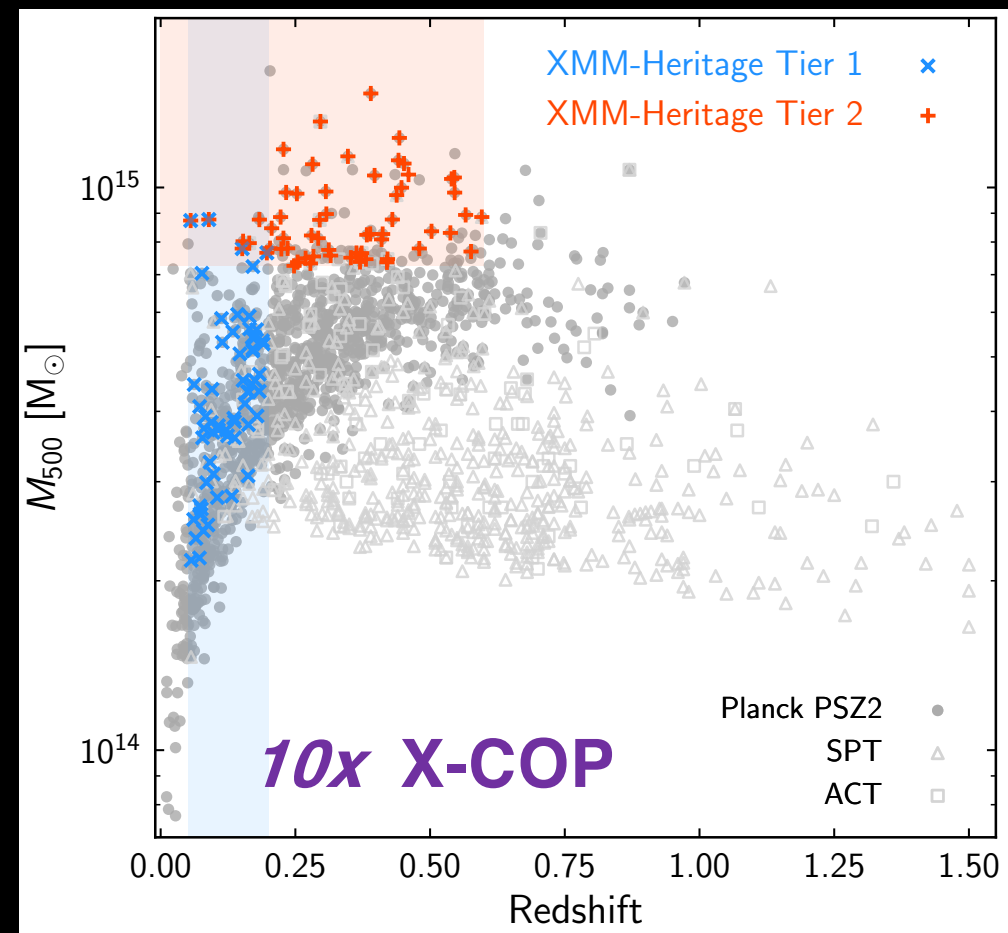
An XMM-Newton Heritage Program

Witnessing the culmination of structure formation in the Universe

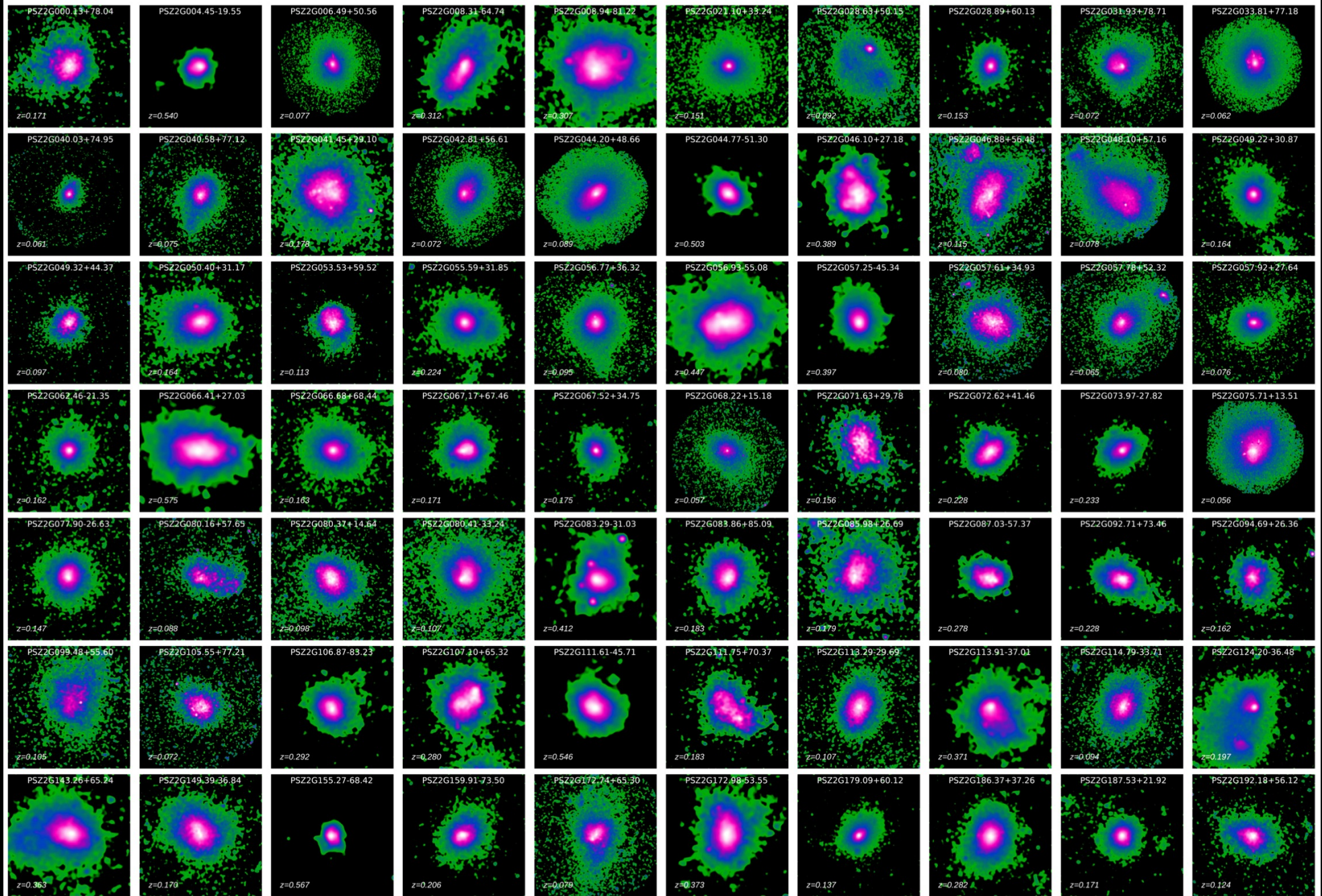
URL: xmm-heritage.oas.inaf.it

CHEX-MATE (the **C**luster **H**eritage project with **X**MM-Newton: **M**ass **A**ssembly and **T**hermodynamics at the **E**ndpoint of structure formation):
3 Msec over the period 2018-21 to survey *homogeneously*
118 Planck-SZ selected objects comprising an unbiased census of:

- *the population of clusters at the most recent time ($z < 0.2$)*
- *the most massive objects to have formed thus far in the history of the Universe*

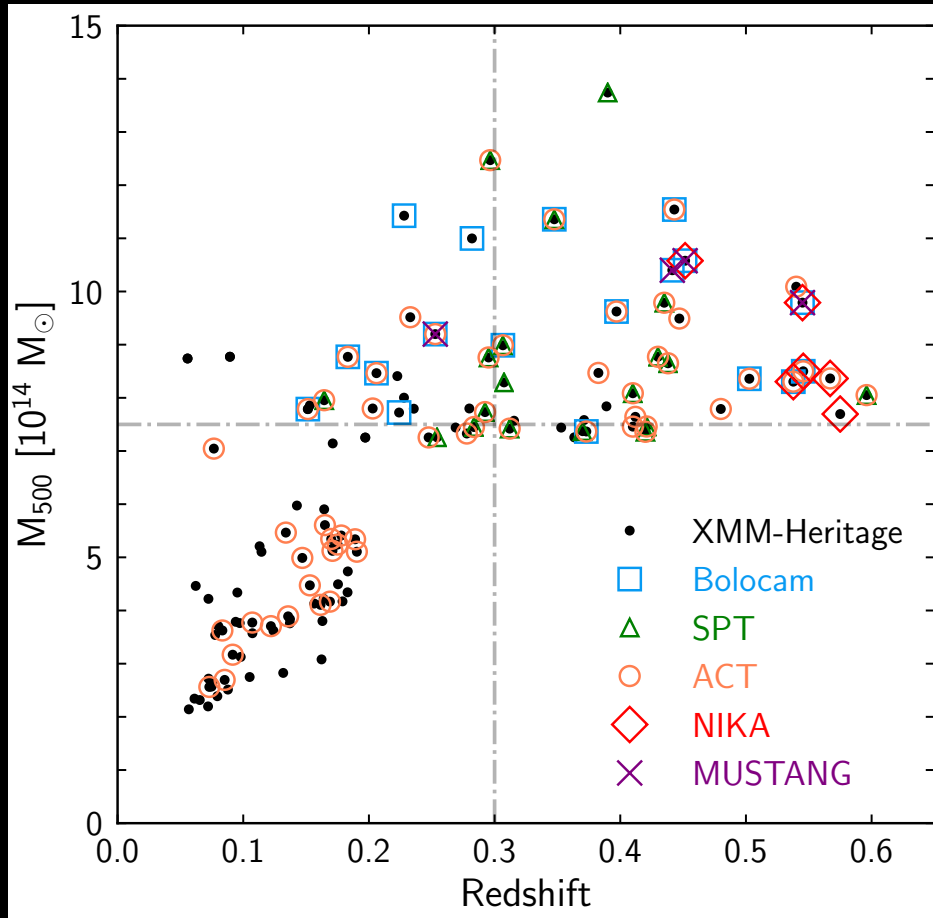


CHEX-MATE gallery *arXiv:2010.11972 (MediaNAF)*

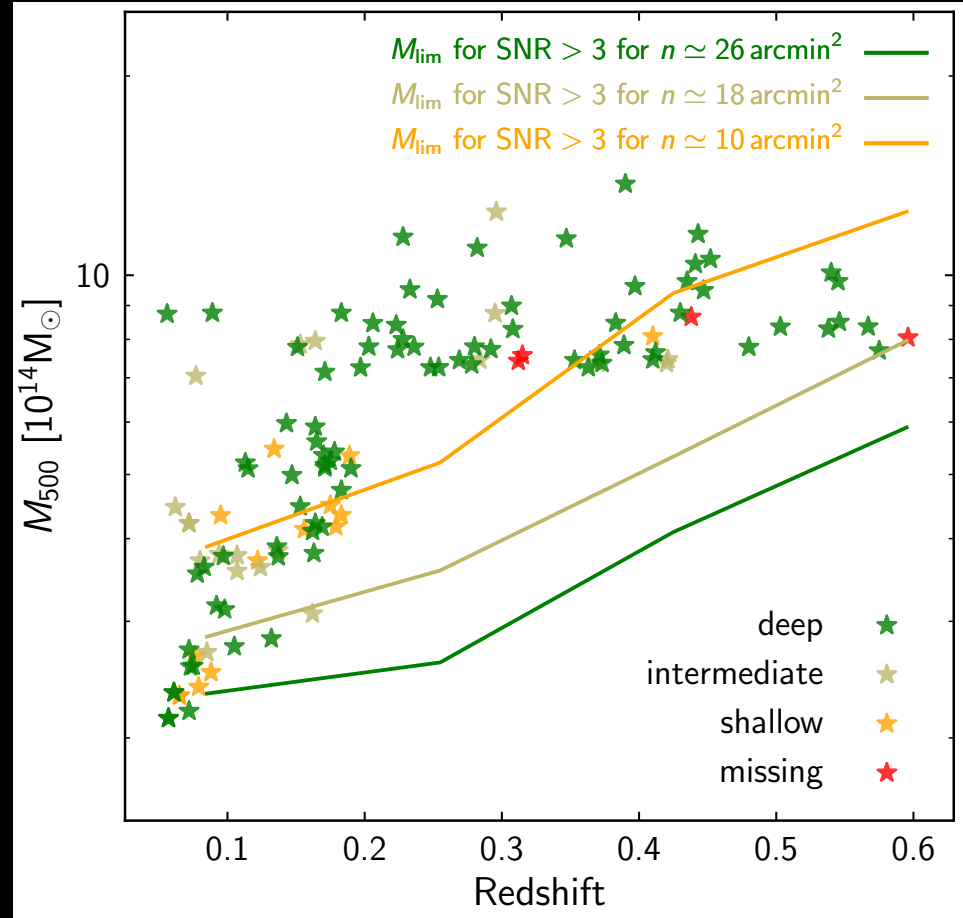


CHEX-MATE multi- λ *arXiv:2010.11972*

SZ



Lensing

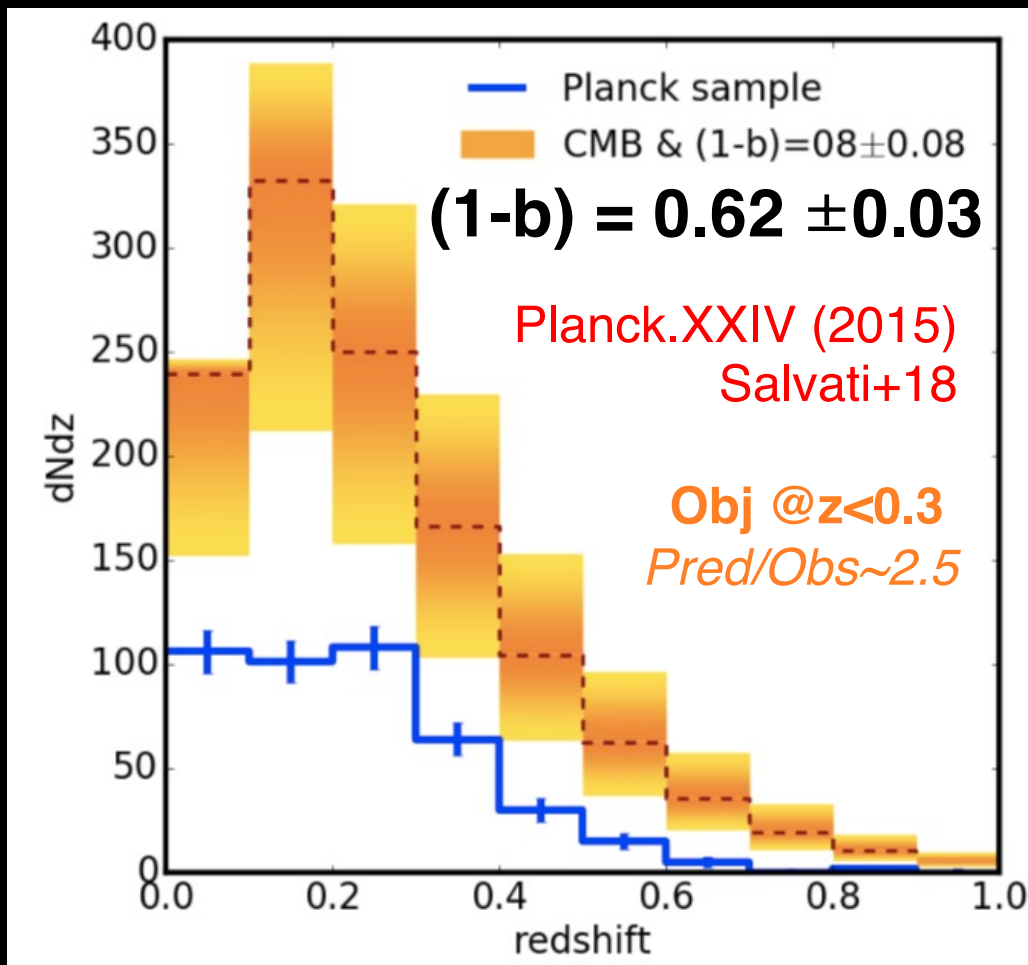


SZ data (including Planck) are public
62 objects with published WL analysis (see *LC² catalog*, Sereno 15);
26+ objects will have dedicated proposals (*HSC/Subaru PI: Sayers*;
Megacam/CFHT, PI: Gavazzi/Umetsu; *OmegaCam/VST PI: Sereno*)

Goals of CHEX-MATE

Selection for the 3 Msec program:

SNR > 6.5; $z \in [0.05, 0.6]$; $M_{\text{Tier-2}} > 7.25e14$



- Assess the relative importance of gravitational and non-gravitational processes in shaping cluster properties
- Probe the dynamical collapse of the gas on different scales
- Construct a consistent picture of cluster mass estimates
- Provide a unique reference for evolution studies and numerical modelling
- Legacy for Next Generation missions

Financial support

X-GALCLU has collected ~900 kEUR in the last 15 years. Currently, we are relying on the residual funds from contract on data analysis (ASI/INAF n. 2017-14-H.0; 60 kEUR; PI: Etti; 1st tranche).

CHEX-MATE

- Mainstream (2018: 34 kEUR; PI: Etti; *hw+missions only*)
- ASI-INAF n. 2017-14-H.O., “Attività di Studio per la comunità di astrofisica delle alte energie”, 2nd tranche (2019: 122 kEUR; PI: Etti; *postdocs+missions*)
- Support for Team meeting at ISSI (Bern; 2018)
- Two NASA/ADAP: 2019-2021/PI: Lovisari; 2021-2023/PI: Sayers (to cover also activities described in *scheda CLUMP*)
- PRIN-INAF 2019 (PI: Gastaldello) on multi- λ coverage: just below the cut
- PRIN-MUR 2020 (PI: Etti)

Financial support

PhD

- **2015:** INAF PhD at OAS Bologna (*student: Vittorio Ghirardini*) on X-COP (X-ray)
- **2016:** INAF PhD at OA Arcetri (*student: Ang Liu*) on X-ray GC
- **2019:** INAF co-funded a PhD at OAS Bologna (*student: Matteo Angelinelli*) on the mass accretion around galaxy clusters using cosmological hydrodynamical simulations
- **2020:** INAF PhD at OAS Bologna (*student: Giulia Campitiello*) on CHEX-MATE (X-ray and radio data)
- **2021:** INAF PhD at IASF Milano (*student: TBD*) on galaxy clusters

Critical aspects

- We want **to guarantee continuity** on man-power to the ongoing activities @INAF, to maintain international primacy of Italian community & to prepare the young generation for the upcoming instruments (*eROSITA/2019, XRISM/2022, Athena/~2032*)
- **Primary necessity is the extension of the current PostDocs** (presently, one @IASF-Mi, one @OAS-Bo) that can be renewed only yearly; current funds (*also related to other projects*) cover up to 2 years (max)
- **INAF might consider to open some long-term (3-5 yrs) TD positions for “strategic” projects (through open calls; AstroFit-like)**
- **ASI for analysis of high-E data: new contract?**
- **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**
- **On the expertise needed**: software engineer to develop efficiently codes for data reduction/analysis (*also to share with other projects; e.g. at IASF-Mi*); HW: multi-core for e.g. spectral analysis (→*XRISM, Athena*)

PRIN-MUR 2020 (INAF, UniBo, UniTV)

Stress-tests for the concordance cosmological model: the role of galaxy clusters

	Datasets	New dedicated exposures
X-ray	<ul style="list-style-type: none"> XMM-Newton (4.1 Msec archived for 71 objects; 3 Msec of dedicated observations to homogenize the exposures for the entire sample): 118 Chandra (10.0 Msec archived): 101 	<ul style="list-style-type: none"> 3.0 Msec with XMM-Heritage program (PI: <i>M. Arnaud & S. Ettori</i>) 10 ksec Chandra snapshots of 8 objects with no X-ray exposures to define the center
SZ	<ul style="list-style-type: none"> Planck (100, 143, 217, 353, 545, 857 GHz; res. 10': 118 SPT-SZ (95, 150, 220 GHz; res 1.75'): 9 SPT-ECS (95, 150 GHz; res 1.2'): 10 ACT-DR4 (98, 150 GHz; res 1.4'): 56 Bolocam (140 GHz; res. 0.97'): 18 NIKA-1, NIKA-2 (150, 260 GHz; res. 0.30'): 5 MUSTANG-1, MUSTANG-2 (90 GHz; res. 0.15'): 4 ALMA (92 GHz; res. 0.07'): 1 	
Optical	<ul style="list-style-type: none"> 62 (out of 118 objects) have published WL analysis (see Literature Catalogs of weak Lensing Clusters of galaxies (LC² - Sereno 2015). HSC-SPP footprint: 5 CFIS footprint: 33 Tier-1 clusters Targeted observations of 31 clusters (26 unique clusters not covered at all by archival data) SDSS & DES (for photometry and richness): 76 & 25 	<ul style="list-style-type: none"> 32h at HSC@Subaru (proposals S19B-TE220-K, S20A-TE129-KQ, S20B-TE212-KQ, PI <i>J. Sayers</i>) 21h at Megacam@CFHT (PI <i>R. Gavazzi/K. Umetsu</i>) 23h at OmegaCam@VST (proposals 0104.A-0255(A) and 105.2095.001, PI <i>M. Sereno</i>)
Hydro-simulations	<ul style="list-style-type: none"> The300 (codes: GADGET AGN; GIZMO; MUFASSA/SIMBA; ~440 objects with $M_{500} > 1e14 M_{\odot}$ at $z=0$; ~30 with $M_{500} > 7e14 M_{\odot}$ at $z=0.5$; ref. https://www.nottingham.ac.uk/~ppzfrp/The300/index.php) Magneticum (codes: GADGET DM/AGN; ~230,000 clusters with $M_{500} > 1e14 M_{\odot}$ at $z=0$; ~300 with $M_{500} > 7e14 M_{\odot}$ at $z=0.5$; ref. https://c2pacosmosim.uc.lrz.de/) BAHAMAS+MACSIS (codes: GADGET DM/AGN; ~390 clusters with $M_{500} > 1e14 M_{\odot}$ at $z=0$; ~100 with $M_{500} > 7e14 M_{\odot}$ at $z=0.5$; ref. https://www.astro.ljmu.ac.uk/~igm/BAHAMAS/) A wide range of other runs available within the collaboration, that are also very useful for addressing specific science projects using the CHEX-MATE data 	

Datasets that will be analyzed in CHEX-MATE, a SZ-selected sample of 118 objects (61 in Tier-1, 61 in Tier-2, with 4 in common).

The number in bold font indicates the number of objects.

The hydro-simulations are available as in-kind contribution to the collaboration from the members: G. Yepes (Madrid Univ) for "the300"; K. Dolag (Munich Univ Obs) for "Magneticum"; S. Kay (Manchester Univ) and D. Barnes (MIT) for "BAHAMAS+MACSIS".

PRIN-MUR 2020 (INAF, UniBo, UniTV)

Stress-tests for the concordance cosmological model: the role of galaxy clusters

	INAF	UniBO	UniTV	Ext.Coll.
WP-X Lead: INAF	Ettori, Rossetti, De Grandi, Ghizzardi, Molendi <i>PostDoc (2 yrs)</i>		Bourdin, Mazzotta	Arnaud (Saclay), Eckert (Geneva Univ), Maughan (Bristol Un), Pratt (Saclay)
WP-S Lead: UniTV	Ettori, Rossetti, Sereno		Bourdin, Mazzotta <i>PostDoc (2 yrs)</i>	Sayers (Caltech), Pointecouteau (IRAP Toulouse)
WP-L Lead: INAF	Sereno, Radovich, Bardelli <i>PostDoc (2 yrs)</i>	Marulli, Moscardini		Gavazzi (Obs Paris), Umetsu (Taiwan Univ), Okabe (Hiroshima Univ), Maturi (Heidelberg Univ), Kuijken (Leiden Obs)
WP-T Lead: UniBO	Ettori, Sereno	Marulli, Moscardini <i>PostDoc (2 yr)</i>		The300 (contact: Yepes), Magneticum (Dolag), BAHAMAS+ MACSIS (Kay)
WP-P	ALL	ALL	ALL	ALL
WP-O Lead: INAF	INAF/Media (Guglielmo, Bardelli, Rossetti, Zucca)			