PhD name: Matteo Angelinelli
PhD Cycle: XXXV
Tutor: S. Ettori, F. Vazza

RESEARCH PROJECT: "Detecting the cosmic web in radio bands and X-ray "

My PhD work focuses on how galaxy clusters form by the accretion of sub-clumps and diffuse materials, and how the accreted energy is distributed in the X-ray emitting plasma. Indeed, on scales larger than tens of millions light years, the Universe is self-organized by gravity into a spiderweb, the Cosmic Web. Galaxy clusters are the knots of this Cosmic Web, but a strong definition of filaments (which link different knots) and of their physical proprieties, is still uncertain. Even if this pattern was determined by studying the spatial distribution of galaxies in the optical band, recently, also in the X-rays were obtained probes of filamentary structures around galaxy clusters. Therefore, given these observational facilities, the galaxy clusters' outskirts are the best candidate regions to detect filaments and to study their physical characteristics. However, from X-rays observations, we have only a few detections of cosmic filaments to date. Therefore, we use cosmological simulations to obtain constraints for future X-rays missions (e.g.: ATHENA) and to give some predictions on the matter that composes the filamentary part of the Cosmic Web.

Since the first year of my PhD, using simulated galaxy clusters extracted from the ITASCA sample (http://cosmosimfrazza.myfreesites.net/isc-project), a larger catalogue of clusters simulations produced with the Adaptive Mesh Refinement Code ENZO, we study matter clumps and filaments located in the peripheries of ITASCA clusters. We involved both clumps and filaments because, as already highlighted, it is very challenging in X-rays observations to identify filaments, but it is easier to identify matter's clump. Indeed, clumps are denser than the external medium and, being the X-rays emission proportional to the density square, their emissivity is much higher than the surrounding medium's one. Therefore, our work would like to be as realistic a prediction as possible of the best candidates for studying cosmic filaments, with the new generation of X-ray missions.
In numerical simulations is quite simple to disentangle between matter clumps, filaments and diffuse matter. We developed both a clump-finder and filament-finder for our simulations. The first is based on the clumps' baryon mass and clumps' dimension and we demonstrated that, in our simulations, we can find structure massive than $10^8 M_\odot$ and smaller than 500 kpc. The filament-finder is based on gas radial velocity and entropy. Indeed, we expect that cosmic filaments have high values of radial velocity, due to the gravity field of the central galaxy clusters, but their entropy is lower than the surrounding medium, otherwise, it would not be so challenging to detect them in the X-ray band.

Thanks to our new algorithms, in my PhD's second year, we study separately the two populations, but we also compare the density and the temperature of clumps and filaments. We find a quite high level of correlations for both the quantities analyzed and we conclude that, even if our simulations do not include feedback mechanisms, the idea of using clumps as tracers for filaments seems to be quite promising.

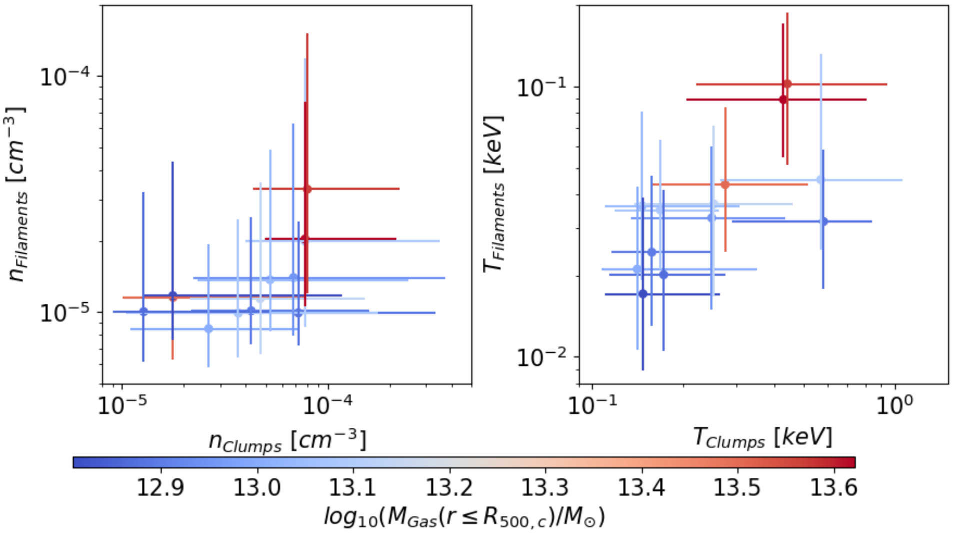

Figure 1- Comparison of density (in cm^{-3} units) and temperature (in keV units) for clumps (on the x-axis) and filaments (on the y-axis), for each single cluster. The dots are the median values, while the error bars are the 16th and 84th percentiles on both the axes. The color-coding is the same for both the panels and it identifies the $M_{500,c}$ cluster gas mass.

Moreover, only for the clump's populations, we study the possible variation of density and temperature field with the distance from the central galaxy clusters. We find that up to clumps are located far from $\sim 3R_{500,c}$ they are well represented by scaling relations not so different from the ones obtained for galaxy groups and clusters. Closer to the central galaxy cluster environment, the scaling relations are completely different from matter clumps and groups or clusters. This suggests that, once the clumps interact with the ICM of the central clusters, their density and temperature are affected by the interactions with the external medium and any information about the formation initial conditions is lost. All the results and the algorithms presented above are described in detail in our paper "Proprieties of clumps and filaments around galaxy clusters", recently accepted in Astronomy & Astrophysics.

To obtain a realistic observational prediction of what we would learn in the next future about clumps and filaments, we are also working to simulate what the X-rays telescope ATHENA would observe on the clusters' peripheries. To perform these simulations, we are using the SIXTE simulator in combination with a sub-sample of the clusters used in the work described above, and we produced some interesting preliminary results. In detail, we are developing a procedure that involves both the instruments onboard the ATHENA satellite, WFI and X-IFU. Thanks to its larger FoV, we use WFI to detect clumps in the outskirts of simulated galaxy clusters. For each of these clumps, we run a simulated XIFU exposure to obtain spatially resolved high-resolution X-ray spectra of the plasma and to infer from them some fundamental physical quantities like gas density, temperature, metallicity, and components of the velocity both turbulent and along the line of sight. This procedure, with detail on the validation process and results on the feasibility study, will be described in a dedicated work and will be extensively applied in both the papers in which I am involved for the A&A Special Issue that will support the ESA adoption of the ATHENA mission.

WORKSHOPS, CONFERENCES & MEETINGS

1st year:

11/05/20	Remote – "SIXTE Webinar"
29/06 – 03/07/20	Remote – "European Astronomical Society Annual Meeting - EAS2020" Talk: "Identify and characterizing the filamentary structures around galaxy clusters"
06/07 – 10/07/20	Remote – "Virtual 'The Three Hundred' collaboration meeting" Talk: "Clumps & Filaments in clusters outskirts"
16/09/20	Remote – "Athena SWG 1.4 Workshop"

2nd year:

22/09 – 12/11/20	Remote – "IAU Workshop"
02/11 – 06/11/20	Remote – "12th XIFU Collaboration Meeting" Talk: "Accretions in galaxy clusters"
09/12/20	Remote – "AthenaBo Meeting"
08/02 – 10/02/21	Remote – "CHEX-MATE Collaboration Meeting"
03/05 – 05/05/21	Remote – "13th XIFU Collaboration Meeting" Talk: "Accretions in galaxy clusters"
28/06 – 02/07/21	Remote – European Astronomical Society Annual Meeting - EAS2021" ePoster: "Exploring remote cluster outskirts and filaments with the next generation of X-ray observations"
12/07 – 16/07/20	Remote – "The Three Hundred Collaboration Meeting" Talk: "Clumps & Filaments: accretion phenomena around galaxy clusters"

PhD SCHOOLS

2nd year:

22/03 – 26/03/21 Remote – "17th advanced school on parallel computing" Auditor

14/09 – 18/09/21 Remote/Bologna – "ONSCI – Officina di Narrazione della Scienza"

INTERNAL COURSES

1st year:

27/05 – 22/07/20 Remote - Virtual Seminar on Multimessenger Astronomy, Summer Semester 2020

17/09 – 22/09/20 Remote – "Gaia: Great Advances In Astrophysics"

2nd year:

30/11 – 04/12/20 Remote – "The interstellar medium"

19/04 – 23/04/21 Remote – "Gamma Ray Bursts: from observations to physical properties "

06/05 – 14/05/21 Remote – "Writing, talking and presenting Science"

ISA LECTURES

1st year:

12/11/19 "This Turbulent Turbulent World"

19/05/20 "Exploration of small bodies of the Solar System: focus on comets"

RESEARCH PERIOD ABROAD

2nd year:

18/10 – 04/02/22 Marco Polo Project at Ludwig Maximilian University (LMU) under the supervision of Dr. Klaus Dolag

COMPETITIVE TELESCOPE/COMPUTER TIME ALLOCATIONS

OTHER RELEVANT ACTIVITIES

1st year:

Enrollment at "ATHENA SWG 1.2" and "ATHENA SWG 1.4"

Enrollment at "The 300 Collaboration"

2nd year:

CLA UniBo English Course – Level B2++

Co-Host of Podcast "Dottorato et al." (available on Spotify)

PUBBLICATIONS

2018:

"**The turbulent pressure support in galaxy clusters revisited**",
Vazza, F.; **Angelinelli, M.**; Jones, T. W.; Eckert, D.; Brüggen, M.; Brunetti, G.; Gheller, C.
MNRAS: Letters, Volume 481, Issue 1, p.L120-L124
DOI: 10.1093/mnras/staa975

2019:

"**Detecting shocked intergalactic gas with X-ray and radio observations**"
Vazza, F.; Ettori, S.; Roncarelli, M.; **Angelinelli, M.**; Brüggen, M.; Gheller, C.
A&A, Volume 627, id. A5, 19 pp.
DOI: 10.1051/0004-6361/201935439

2020:

"**Turbulent pressure support and hydrostatic mass bias in the intracluster medium**"
Angelinelli, M.; Vazza, F.; Giocoli, C.; Ettori, S.; Jones, T. W.; Brunetti, G.; Brüggen, M.; Eckert, D.
MNRAS,Volume 495, Issue 1, pp.864-885
DOI: 10.1093/mnras/staa975

2021:

“**Proprieties of clumps and filaments around galaxy clusters**”
Angelinelli, M.; Ettori, S.; Vazza, F.; Jones, T. W.
A&A, Forthcoming article
DOI: 10.1051/0004-6361/202140471

“**Exploring the relation between turbulent velocityand density fluctuations in the stratifiedintracluster medium**”
Simonte M.; Vazza F.; Brighenti F.; Brüggen M.; Jones T. W.; **Angelinelli M.**
Submitted A&A

Scheduled for 2022:

“**WFI+XIFU view on the properties of the accreting clumps in the clusters' outskirts**” (**A&A Athena Special Issue**)
Angelinelli, M.; Ettori, S.; Vazza, F.
In prep.

“**Unveiling Athena‘s potential to study of radio relics with X-ray spectroscopy**” (**A&A Athena Special Issue**)
Wittor D.; **Angelinelli M**.; Rajpurohit K.; Ettori S.; Vazza F.
In prep.