

## FRANCO VAZZA

### CURRICULUM VITAE

#### **Personal Data:**

Born: Vittorio Veneto (TV) 19/09/1979

Nationality: Italian

Present Position: Post-Doctoral Fellow at Hamburg Observatory (GERMANY)

Present Address: Gojenbergsweg 112, Hamburger Sternwarte, 20129 Hamburg, Germany

Email: franco.vazza@hs.uni-hamburg.de

#### **Languages:**

Mother language: Italian

Others (self-valuation according to Language Skills Self-Assessment Grid of European Language Portfolio):

English: C1 - good

Spanish: B1 - intermediate

French: B1 - intermediate

German: B1 - intermediate

#### **Formation and Career:**

22 Jul 2004: Degree in Astronomy at the University of Padova (mark 105/100), supervisor Prof. G.Tormen

1 Sept 2004 - 31 Dec 2004: Research Grant from Department for Information Engineering, University of Padova (supervisor Prof. G. Tormen)

1 Feb 2005 - 30 Apr 2005 Research Grant from Astronomy Department, Bologna University (supervisor Prof. G. Setti)

1 Jul 2005- 31 Aug 2005 Research Grant from Astronomy Department, Bologna University (supervisor Prof. G. Setti)

1 Jan. 2006 - 31 Dec. 2008: PhD at the Astronomy Department at Bologna, winner of the INAF grant at the Radio Astronomy Institute of Bologna, supervisors Prof.G.Setti and Dott.G.Brunetti.

8 Apr - 6 Jul 2008: Marco Polo grant from University of Bologna, for 3 months visit at CASS institute in S.Diego (California-USA)

07 Apr 2009: Discussion and approval of PhD Thesis.

1 Jan 2009- 31 Jul 2010: Post-Doctoral Fellow at the IRA (supervisor Dr.G.Brunetti).

1 Sept 2010 - 31 July 2012: Post-Doctoral Fellow at Jacobs Univ.Bremen (advisor Prof.M. Brüggen).

1 Aug 2012 - till present: Post-Doctoral Fellow at Hamburg Observatory.

#### **Fellowships, Awards & Grants**

2006: visiting PhD student at Astronomy Department, University of Daejeon (South Korea)

2007: visiting PhD student at Max Planck Institute for Astrophysics, Garching (Germany)

2008: visiting PhD student at Center for Astrophysics and Space Science, San Diego-CA (USA)

2008: visiting PhD student at Center for Astrophysics, Cambridge-MA (USA)

2008: visiting PhD student at Max Planck Institute for Astrophysics, Garching (Germany)

2009: award for best contribution at “Cosmological Magnetic Field” Conference (31.05-5.06, Ascona, organized by ETH).

2010: winner of a “Taux3” grant from French Government and Scientific Bureau of French Embassy in Italy (declined)

09/2010-07/2012: Post-Doc Fellow at Jacobs University Bremen (Germany).

08/2012-till present: Post-Doc Fellow at Hamburg Observatory (Germany)

### **Additional Activity:**

1999-2007: support activity at the Amateur Astronomic Observatory of Associazione Astrofili Vittorio Veneto, with tens of public visits, lectures and conferences performed on Astronomy subjects;

2005: High School Teacher at the Liceo Classico Marcantonio Flaminio (Vittorio Veneto), teaching maths and physics (2 months);

2006 - 2010: support to outreach activities at the Visitor Center at Medicina (BO);

2003 - till present: monthly coworker of the Italian Astronomical magazine 'Le Stelle', for the redaction and commenting of astronomical news for the public.

### **Computing Proposals:**

Assigned computation time

2004 : 20 000 allotted CPU hours on SP4 (CINECA-Bologna)

2005: 40 000 allotted CPU hours on SP4/SP5 (CINECA-Bologna)

2006: 40 000 allotted CPU hours on SP5/CLX (CINECA-Bologna)

2007: 30 000 allotted CPU hours on SP5 (CINECA-Bologna)

2008: 70 000 allotted CPU hours on SP5/BCX (CINECA-Bologna)

2009: 400 000 allotted CPU hours on SP6 (winner of Italian National Key Project). (CINECA-Bologna)

2010: 20 000 allotted CPU hours on SP6 (CINECA-Bologna)

2010: 970 000 allotted CPU hours for the PRACE-1IP 7.1 call for application optimization at Julich Supercomputing Center (Germany)

2011: 800 000 allotted CPU hours on JUROPA cluster at Juelich (Germany)

2011: 150 000 allotted CPU hours on SP6 (CINECA-Bologna)

### **Computing Skills:**

Expert in Fortran77, Fortran90, IDL.

Good knowledge of C,C++,MPI, OpenMP.

### **School of Astrophysics and Others:**

- 2005 "Scuola Estiva di Calcolo Parallelo" at CINECA (BO), Italy
- 2006 "Scuola Nazionale di Astrofisica" at Bertinoro (FC), 7-12/05/06, Italy
- 2006 "Scuola Nazionale di Astrofisica" at Trieste, 1-7/10/2006, Italy
- 2007 "Scuola Nazionale di Astrofisica" at Maracalagonis, 20-26/05/07, Italy
- 2008 "Corso di C e C++" at CINECA (BO), Italy

### **Teaching**

2011 Serie of lectures on particle acceleration mechanisms and non-thermal process in the intra cluster medium, for last year graduate students at Bologna University, Astronomy Department (Course held by Prof. Fabrizio Brighenti).

2011 Lecture to master students at Jacobs Univeristy Bremen, on numerical simulations of turbulence and shock acceleration in the intra cluster medium.

### **Contributed talks at conferences and workshops**

2006 KASI-APCTP Joint Workshop: "Origin, Propagation and Interaction of Energetic Particles" 17-19 May, Daejeon, South Korea

2007 "X-RAY Surveys: Evolution of accretion, star formation and large scale structures", Rodos island (Greece), July 02 - July 06

2007 XXXVII Young European Radio Astronomers Conference 4-7 September, Bordeaux, France

2008 "Turbulence and Dynamos" from 17 March to 21 March, Nordita, Stockholm, Sweden

2008 "Computational Astrophysics in Italy: results and perspectives", Rome - March 12, 2008

2009 "Cosmological Magnetic Fields", 31.05-05.06, Ascona, Switzerland.

2009 "Shock Waves, Turbulence and Particle Acceleration" 18.11-21.11, Pohang, South Korea

2010 "Magnetic fields on scales kiloparsecs to kilometres: properties and origin conference." Crakow, Poland

2010 "Galaxy Clusters: Observations, Physics and Cosmology " Garching bei München, 26 - 30 July 2010

2011 "Advances in computational astrophysics: methods, tools and outcomes", Cefalu, Italy 13-17 June 2011

2012 "Turbulence in Cosmic Structure Formation Conference", March 5-8, 2012, ASU Main Campus, Tempe, AZ, USA

### **Invited oral contribution at conferences and workshops**

2010 "Non Thermal Phenomena in Colliding Galaxy Clusters", 15-18 November 2010, Nizza

2012 "New Horizons in Computational Astrophysics " AstroSim conference, 29th January - 3rd February 2012 in Davos, Switzerland

2012 "Maison de la Simulation", PRACE conference, 4th-6th June 2012, Orsay, France

### **Publications (last page for the full list)**

I have 19 papers published in referred and non-referred astrophysical journals (16 of them

being the first author), which more than 430 citations to date, and an h-index of 10 to date (first-author h-index: 8).

I am also author of 4 (non refereed) contributions to proceedings of conferences.

### **Commitments**

2006/09 - PI of an international team (Italy, South Korea and Germany) of numerical scientists involved in an extensive comparison of numerical methods for large scale cosmology.

2006/12 - PI of a several large scale numerical projects at Supercomputing Centre in Italy (CINECA) and Germany (Juelich), for the development, testing and production of cosmological simulations with grid and SPH methods.

2011 - Referee for allocation time of numerical proposals at CINECA (Italy)

2010/12 - Referee for Astronomy & Astrophysics (A&A) and The Astrophysical Journal (ApJ).

2012 Referee for The Astrophysical Journal (ApJ).

2011-2012 Coauthor of observational proposals at Radio wavelengths (EVLA and GMRT, PI A. Bonafede) and at X-ray (XMM, PI. D. Eckert). **Additional Publications**

- Master Thesis: “Turbulence in the ICM of simulated Galaxy Clusters” (2004)  
Download at [http://dipastro.pd.astro.it/cosmo/franco/thesis\\_franco.html](http://dipastro.pd.astro.it/cosmo/franco/thesis_franco.html)
- PhD Thesis: “Shocks and Turbulence in Simulated Large Scale Structures” (2009)  
Download at [http://www.ira.inaf.it/~vazza/tesi\\_vazza.pdf](http://www.ira.inaf.it/~vazza/tesi_vazza.pdf)

Personal web page: <http://www.ira.inaf.it/~vazza>

## RESEARCH ACTIVITY

I am an extragalactic astrophysicist mainly focused on the study of non-thermal mechanism associated to the hierarchical time evolution of large scale structures (e.g. galaxy clusters). I mainly develop, test and use high resolution hydro-numerical methods for cosmology. Over years I have developed and tested also complex algorithms of analysis for such simulations, and focused on the close comparison with available observational data at various wavelengths. One of the main goal of my research is to put constraints on the efficiency of viable mechanisms of particle accelerations likely at play in galaxy clusters evolution: diffusive shock acceleration, turbulent acceleration and feedback of cosmic rays particles on the evolution of the thermal pool of the intra cluster medium.

Detailed list of activities:

- **Shock Waves and Cosmic Rays Acceleration in Galaxy Clusters** : using as a reference tool the Eulerian cosmological code ENZO, I produced a large sample of cosmological runs for a large volume of the universe and several hundreds of galaxy clusters with appropriate mass and spatial resolution. I developed a dedicated scheme to characterize shock waves developing during Large Scale Structure formation processes and to measure in an accurate way their Mach number and related energetics, studying the influence of numerical setups and modeled physics on the main quantity. I adopted standard recipes to associate Mach numbers with an efficiency in the acceleration of Cosmic Rays Hadrons via Fermi processes, and I studied the population of Cosmic Rays concentrated within galaxy clusters and filaments. An extended comparison of this data to those present in literature was investigated, showing the high accuracy and the overall consistency of results with known upper limits as derived from existing Radio and Gamma observations. The main methods of the above analysis have been tested also with a smaller sample of cosmological numerical simulations produced by the Eulerian Code HYDROPAD, created by C.Gheller. The main results of this line of research were reported in: **Vazza, Brunetti & Gheller (2009) a,b; Vazza et al.(2009); Vazza et al.(2010).; Vazza, Bruggen, Gheller & Brunetti 2012 MNRAS**
- **Turbulent Energy Support in Galaxy Clusters**: using as a reference the cosmological Smoothed Particle Hydrodynamics code GADGET (Springel, Yoshida & White 2001) a sample of high resolution numerical simulations of massive galaxy clusters has been analyzed, conceiving an original algorithm to disentangle chaotic motions from laminar ones. This allowed for extracting with high accuracy the onset of turbulent motions driven within the cluster plasma by the crossing of sub-clusters and by generated shock waves, and to follow their dependency on cluster evolutions over time. A recipe to join the information of cluster plasma turbulence to re-acceleration processes of mildly relativistic electrons via coupling with MHD waves has been investigated, confirming the plausibility of the 'Re-acceleration Scenario' as explanation of the origin of observed Radio Halos. Results of this line of research were reported in: **Dolag et al.(2005); Vazza et al. (2006)**
- **High resolution AMR simulations of Turbulence and Shock Waves in Galaxy Clusters**: the onset and further evolution during cosmic time of the turbulent motions following merger events was studied with an original implementation of Adaptive Mesh Refinement methods, which refines the number of cells where a new control variable (linked to the small scale variability of the velocity field) is adopted. This allows for increasing to an unprecedented level the spatial resolution achieved in the description of turbulent eddies and shock waves generated in very large volume numerical simulations. This method made possible to study in detail the evolution of the power spectrum of turbulent motions, which is so far an unexplored issue in cosmological numerical simulations. Results of

this line of research were presented in: **Vazza et al.(2009 - Highlight of A&A for Vol.II Sept.09); Vazza et al.2010,a,b; Vazza, Roediger & Bruggen 2012 A&A, in press.; Vazza et al. 2012 MNRAS.**

- **Dynamics of Tracers Particles in the Intra Cluster Medium:** I build and tested an algorithm to track the propagation of mass-less particles which can be injected and advected at any time in the Eulerian representation provided by the ENZO code. This allows for increasing the range of studies which can be actually performed with high-resolution, Eulerian simulations with ENZO, and performing first exploratory investigations about the mixing properties of the ICM (i.e. transport processes of metals and Cosmic Rays) in a sample of massive galaxy clusters. The results of this line of research were presented in: **Vazza, Gheller & Brunetti (2010); Vazza (2011) MNRAS**
- **Study of the azimuthal scatter in the gas distribution in clusters:** using a combined set of ENZO-AMR and GADGET2 cluster simulations, we studied the intrinsic degree of azimuthal scatter contained in the 3-D distribution of thermal gas in clusters. Due to the chaotic processes following the hierarchical assembly of matter in galaxy clusters, departures of the order of  $\sim 20 - 40$  per cent in each cluster observable (density, temperature, entropy and X-ray luminosity) must be expected from different azimuthal sector for the same target object. This poses an intrinsic limitation to the accuracy with which global cluster parameters (such as mass) can be inferred from the long exposures pointing of partial cluster sections at the outer radii. The results of this research are described in: **Vazza, Roncarelli, Ettori & Dolag 2010. and Eckert et al. 2011, A&A in press**
- **Comparison of Cosmological Numerical Codes and Shocks Detecting Schemes:** I joined an international research group (which K.Dolag, D.Ryu, H.Kang, T.Jones, G.Brunetti, C.Gheller) studying the mutual convergence of three of the most used cosmological numerical codes (GADGET, ENZO and the ES-TVD code by D.Ryu). Using an identical cosmological setups of initial conditions for the three codes, the group produced a set of large scale simulations at several resolutions, studying in details dark matter properties and thermal properties for all simulations at present epoch. The overall level of consistency among codes is pretty good, on average of the order of 10 % for the most relevant statistics involved in our analysis (halos mass functions, halos baryon fractions, density and temperature distributions, etc). On the other hand, remarkably larger differences are measured from code to code in all measures more strictly depending on the particular accretion history of the simulated structures, such as entropy distributions and shocks occurrency. Currently, I am Principal Investigator for the comparison of shock waves produced in the three codes of the project, and to their properties related to Cosmic Rays acceleration processes. In order to do this, the original detection scheme proposed by all authors are compared in details, and the regimes of convergency or disagreement are under investigation. This research promises to be a major step forward for the community of simulators involved in Cosmic Rays acceleration processes using numerical simulations. The results of this comparison are reported in **Vazza, Dolag, Ryu, Brunetti, Gheller, Kang & Pfrommer 2011 MNRAS**

# Bibliography

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- Vazza, F.**, Tormen, G., Cassano, R., Brunetti, G., & Dolag, K. 2006, **MNRAS**, 369, L14 “Turbulent velocity fields in smoothed particle hydrodynamics simulated galaxy clusters: scaling laws for the turbulent energy”
- Vazza, F.**, Brunetti, G., & Gheller, C. 2009, **Memorie della Societa Astronomica Italiana Supplementi**, 13, 151, “Cosmological shocks in Eulerian simulations: main properties and cosmic rays acceleration”
- Vazza, F.**, Brunetti, G., & Gheller, C. 2009, **MNRAS**, 395, 1333 , “Shock waves in Eulerian cosmological simulations: main properties and acceleration of cosmic rays”
- Vazza, F.**, Brunetti, G., Kritsuk, A., Wagner, R., Gheller, C., & Norman, M. 2009, **A&A**, 504, 33 “Turbulent motions and shocks waves in galaxy clusters simulated with adaptive mesh refinement”
- Vazza, F.**, Gheller, C., & Brunetti, G. 2010, **A&A**, 513, A32, “The Mixing and Transport Properties of the Simulated ICM: a Study with Tracers”
- Vazza, F.** 2011, **MNRAS**, 1724, “The entropy core in galaxy clusters: numerical and physical effects in cosmological grid simulations”
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- Vazza F.**, Roncarelli M., Ettori S., Dolag K., 2011, **MNRAS**, 413, 2305 ”The scatter in the radial profiles of X-ray luminous galaxy clusters as diagnostic of the thermodynamical state of the ICM”
- Vazza F.**, Dolag K., Ryu D., Brunetti G., Gheller C., Kang H., Pfrommer C., 2011, **MNRAS**, 1718, ”A comparison of cosmological codes: properties of thermal gas and shock waves in large-scale structures”
- Vazza F.**, Brunetti G., Gheller C., Brunino R., Brüggén M., 2011, **A&A**, 529, A17 , ”Massive and refined. II. The statistical properties of turbulent motions in massive galaxy clusters with high spatial resolution”
- Vazza F.**, 2011, arXiv, arXiv:1101.2205 ”Merger and non-merger galaxy clusters in cosmological AMR simulations”
- Eckert D., **Vazza F.**, et al., 2011, arXiv, arXiv:1111.0020, ”The gas distribution in galaxy cluster outer regions”

- Vazza, F.**, Brüggen, M., Gheller, C., & Brunetti, G. 2012, arXiv:1201.3362 **MNRAS** in press, "Modelling injection and feedback of Cosmic Rays in grid-based cosmological simulations: effects on cluster outskirts"
- Vazza F.**, Brueggen M., Gheller C., Brunetti G., 2011, arXiv, arXiv:1109.3337 "The injection and feedback of Cosmic Rays in large-scale structures"
- Vazza F.**, Brüggen M., van Weeren R., Bonafede A., Dolag K., Brunetti G., 2012, MNRAS, 421, 1868 "Why are central radio relics so rare?"
- Bonafede A., Brüggen M., van Weeren R., **Vazza, F.** et al., 2012, MNRAS, 426, 40, "Discovery of radio haloes and double relics in distant MACS galaxy clusters: clues to the efficiency of particle acceleration"
- Vazza F.**, Roediger E., Brüggen M., 2012, **A&A**, 544, A103, "Turbulence in the ICM from mergers, cool-core sloshing, and jets: results from a new multi-scale filtering approach"
- Vazza F.**, Brueggen M., Gheller C., 2012, **MNRAS** in press, arXiv:1210.3541, "Thermal and non-thermal traces of AGN feedback: results from cosmological AMR simulations"