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X-ray spectroscopy of merging galaxy clusters

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First-author articles

1. **Urdampilleta, I.**, Kaastra, J. S., & Mehdipour, M., 2017.
A&A, 601, A85. (**Chapter 5**)
X-ray emission from thin plasmas. Collisional ionization for atoms and ions of H to Zn
2. **Urdampilleta, I.**, Akamatsu H., Mernier, F., Kaastra, J. S., de Plaa, J., Ohashi, T., Ishisaki, Y., & Kawahara, H., 2018.
A&A, 618, A74. (**Chapter 2**)
X-ray study of the double radio relic Abell 3376 with Suzaku
3. **Urdampilleta, I.**, Mernier, F., Simionescu, A., Kaastra, J. S., de Plaa, J., Kara, S. & Ercan, E. N., 2019.
A&A, 629, A31. (**Chapter 4**)
Iron abundance distribution in the hot gas of merging galaxy clusters
4. **Urdampilleta, I.**, Simionescu, A., Kaastra, J. S., Zhang, X., Di Gennaro, G., Mernier, F., de Plaa, J., & Brunetti, G., 2019.
To be submitted to A&A. (**Chapter 3**)
X-ray study of Abell 3365 with XMM-Newton

Co-authored articles

1. Liyi, G., Akamatsu, H., Shimwell, T. W., Intema, H. T., van Weeren, J. R., de Gasperin, F., Mernier, F., Mao, J., **Urdampilleta, I.**, de Plaa, J., Parekh, V., Röttgering, H. J. A. & Kaastra, J. K., 2019.
Nature Astronomy.
Observational Evidence for a Pre-Merger Shock in Colliding Clusters of Galaxies
2. Mernier, F., Werner, N., de Plaa, J., Kaastra, J. S., Raassen, A. J. J., Gu, L., Mao, J., **Urdampilleta, I.**, & Simionescu, A., 2018.
MNRAS, 480 L95.

Solar chemical composition in the hot gas of cool-core ellipticals, groups, and clusters of galaxies

3. Mernier, F., de Plaa, J., Werner, N., Kaastra, J. S., Raassen, A. J. J., Gu, L., Mao, J., **Urdampilleta, I.**, Truong, N., & Simionescu, A., 2018.
MNRAS, 478 L116.

Mass-invariance of the iron enrichment in the hot haloes of massive ellipticals, groups, and clusters of galaxies

4. Kaastra, J. S., Gu, L., Mao, J., Mehdipour, M., Mernier, F., de Plaa, J., Raassen, A. J. J., & **Urdampilleta, I.**, 2017.
Journal of Instrumentation, 12, C08008.

Science with hot astrophysical plasmas

5. Akamatsu H., Gu, L., Shimwell, T. W., Mernier, F., Mao, J., **Urdampilleta, I.**, de Plaa, J., Röttgering, H. J. A. , & Kaastra, J. S, 2016.
A&A, 593, L7

Suzaku and XMM-Newton observations of the newly discovered early-stage cluster merger of 1E2216.0-0401 and 1E2215.7-0404

Additional articles

1. Ruiz, M., **Urdampilleta, I.**, Bombardelli, C., Ahedo, E., Merino, M., Cichocki, F. , 2014.
Proceeding of Space Propulsion Conference 2014

The FP7 LEOSWEEP project: Improving low earth orbit security with enhanced electric propulsion

2. Ruiz, M., **Urdampilleta, I.**, del Cura, J. M., Ahedo, E., Navarro-Cavallé, J., 2013.
Proceeding of 33rd International Electric Propulsion Conference 2013, IEPC-2013-273

Space Missions potentially benefit or enabled by prospective use of Helicon Plasma Thrusters

3. **Urdampilleta, I.**, Prieto-Ballesteros, O., Rebolo, R., Sancho, J., 2012.
Proceeding of European Planetary Science Congress 2012, EPSC2012-64
TALISE: Titan Lake In-situ Sampling Propelled Explorer

4. Fuente, I., Ruiz, M., Gutiérrez, J., **Urdampilleta, I.**, Del Campo, D., Nieto, S., 2004.
Proceeding of 55th International Astronautical Congress 2004, IAC.04-P.Q.12
LMG: A Multi-scenario Sample Return Mission to Mars

5. Anton, A., Carretero, D., Gutiérrez, J., **Urdampilleta, I.**, 2004.
Proceeding of 55th International Astronautical Congress 2004, IAC.04-J.6.09
Vibration Isolation in Microgravity Environments

6. Gutiérrez, J., Cuadra, D., Flores, C., Fernández, P., Fuente, I., Martín, S., Meije, R., Pérez, M., Ruiz, M., Sabín, M., Torres, R., **Urdampilleta, I.**, Yarza, A., 2003.
Proceeding of 54th International Astronautical Congress 2003, IAC.03-W.P.01
Tethered inherently safe re-entry capsule

Curriculum Vitae

I was born on 20 August 1981, in San Sebastian (Gipuzkoa), Spain. I attended the High School in the same city, I. E. S. Jose Maria Usandizaga, where I obtained the International Baccalaureate (IB) Diploma. In 1999, I moved to Madrid to study Aerospace Engineering in the School of Aeronautical and Space Engineering (ETSIA), Universidad Politécnica de Madrid, at that time the only university of Spain offering this degree. I graduated in November 2006 with a thesis on an Earth Observation Satellite project.

During my university period, I participated actively in different programs offered by the European Space Agency (ESA) Education Office. In 2002, I was granted to attend the World Space Congress in Houston (US), an event only happening every 10 years, where COSPAR and the 53th International Astronautical Congress (IAC) took place together for two weeks. The same year, I also participated in the reentry capsule design, YES 2 (Young Engineering Satellite), as part of the ETSIA team. In 2003, I was finalist in the 1st Aurora Design Contest with a multi-landing Mars Sample Return mission called LMG (Little Martian Grasshopper). This year I was also granted to attend the 54th IAC in Bremen (Germany). In 2004, I was selected to participate in the 7th Parabolic Flight Campaign with the experiment VMD (Microvibration Measurements Device).

In addition to all these space related activities, in 2003 I attended a summer course in Patras (Greece) organized by the student association BEST (Board of European Students of Technology). After this experience, I decided to join them in the Madrid local group, where I was an active member from 2003 to 2006. I participated in the organization of the summer courses in 2004 and 2005, being one of the main organizers in 2005. I also was part of the Board as the treasurer in the course 2004-2005. Thanks to BEST I travelled around Europe to attend different engineering and technology courses at the University of Patras, L'École Polytechnique of Paris and Tallinn University of Technology.

In December 2006 I started to work at INTA (National Institute of Aerospace Technology) in the helicopters airworthiness department with Angel Centenera and Alfonso Barrado. In June 2007 I moved to GMV as Mission Analysis specialist. There I worked on the phase 0 study of the 7th Earth Explorers of ESA (TRAQ, Biomass, FLEX, CoreH2O, Premier y A-Scope) together with Fernando Alemán and Javier Atapuerca in the Earth Observation group.

At the end of 2007 I was selected by the Education Ministry to participate in the International Organizations grant. For this reason, in May 2008, I joined the Earth Observation Programme Future Mission Division, at ESA-ESTEC (The Netherlands) under the supervision of Miguel Aguirre and Luca Massotti. In this period my labour was focused on the development of an AOCS (Attitude and Orbital Control Subsystem) Simulator for Geostationary satellites (Meteosat Third Generation and GEO-Oculus), which would be integrated into the INR (Image and Navigation Registration) end-to-end simulator. Afterwards, I carried out the feasibility study and the preliminary design of the C-band Bistatic InSAR (Synthetic Aperture Radar) Concept for Coastal Current Estimation.

In September 2009 I came back to Madrid to the Aerospace Division at the engineering company SENER. During five years I was involved in many different projects such as validation and documentation of AOCS simulator under the supervision of Lorenzo Tarabini, preparation of Proba 3 Ground Demonstration to be carried out in JPL working with Antonio Ayuso, development of Solar Orbiter and Interplanetary Mission Simulator together with Guillermo Rodríguez, and development of a Mission Analysis Tool for 3MI instrument on board of Metop-SG satellite, project led by Jaime Sanchez Paramo, among others.

During 2010, I participated as Project Manager and System Engineer in the space project known as Future Science Mission Analysis, in collaboration with the Spanish Astrobiology Center, CAB. This project was initiated by Juan Manuel del Cura and I could work closely with CAB scientists as Miguel Mass-Hesse on the conceptual design of a Far Infrared Interferometer Mission, and Olga Prieto-Ballesteros on a Titan lakes Exploration Mission. From this last project we came out, together with Rafael Rebolo and Jaime Sancho, with a conceptual design of a Titan lakes zodiac called TALISE (Titan Lake In-situ Sampling Propelled Explorer).

In 2011, I collaborated on the Vega ISVV (Independent Software Verification and Validation) project led by Alfonso López as GNC (Guidance, Navigation and Control) specialist. In 2012, I supported the HPT (Helicon Plasma Thruster) project led by Mercedes Ruiz as Mission Analysis specialist and I joined the System Engineering Team of PROBA-3 with José María Fernández. During my last year in SENER, 2013–2014, I worked as System Engineer of the LEOSWEEP (Improving Low Earth Orbit Security With Entranced Electric Propulsion) project managed by Mercedes Ruiz.

Encouraged by my experience working with scientists of CAB in 2011, I decided to start the Master's Degree in Astrophysics at the Universidad Complutense de Madrid, UCM. During the course 2011–2012 I attended some courses of the master. I restarted the classes again in September 2013, finishing the master in 2014 with a Master Thesis focused on the Observation and Analysis of Geomagnetic Field Effects on the Imaging Technique of Very High Energy Gamma-Rays with MAGIC Telescope, under the supervision of Emiliano Carmona.

In 2014 I started my PhD with Jelle Kaastra in SRON (Utrecht) and Leiden Observatory centered on *X-ray spectroscopy of merging galaxy clusters*. In my first project, I updated the plasma code SPEX, concretely the Collisional Ionization model, as part of the SPEX development team. Our duties were focused on preparing SRON plasma code for the upcoming observations from *Hitomi* satellite. For this reason, as part of this activity, in 2015 I attended a JP/NL bilateral workshop in Tokyo (Japan), the AtomDB workshop and

The Universe in High-Resolution X-ray Spectra conference in Boston (US). During my second project, I worked with Hiroki Akamatsu on the merging galaxy cluster Abell 3376. I presented the results of this study at SEA (Spanish Astronomy Society) Scientific Meeting 2016 in Bilbao (Spain), The X-ray Universe conference in Rome (Italy), Diffusive Synchrotron Emission in Clusters of Galaxies-What's Next? workshop in Leiden (The Netherlands) and SnowCluster in Utah (US). In the third project I performed together with François Mernier the study of iron abundance distribution of six merging galaxy clusters. It has been recently presented in the astrophysics of hot plasma in extended X-ray sources conference in Madrid (Spain). The last project is devoted to the X-ray study of the merging galaxy cluster Abell 3365 using *XMM-Newton* observations and I worked under supervision of Aurora Simionescu. From December 2019 I will start working in the Space Surveillance and Tracking (SST) program of the European Commission in the CDTI (Centre for the Development of Industrial Technology) as Aerospace Engineer.

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Life is a grand adventure that we live day by day. Only those ones that decide to take a risk can live it intensively, although it means to have good and bad moments along the way. For this reason, some years ago I decided to come back to the Netherlands to start a new adventure of doing a PhD on Astrophysics. This wouldn't be possible without the unconditional support of my beloved travel mate, David. He decided to follow me and live this adventure together. He has made the way easier, being close to me in all the moments, giving me strength to continue and finish it. Thank you very much my love. Two years ago a new traveler joined us, Shiva, my sweetie cat. I don't know what I would have done without her and her furry hugs.

This adventure wouldn't have started without Jelle Kaastra and Jelle de Plaa. Thank you for giving me the opportunity of beginning this PhD at SRON and knowing better the scientific part of the space missions. I have learned a lot from you and my stay at SRON. Thanks as well for all your support not only in the professional but also in the personal aspects during all these years. I thank Hiroki for introducing me in the amazing world of the merging galaxy clusters. I have enjoyed a lot working in this topic and being part of a great scientific community. I couldn't be more grateful with Francois, you have done things easy and straightforward, you have trusted on me and given the motivation I needed to finish the PhD. Finally, Aurora thanks for your help in the fourth paper and your useful advices. I thank as well the Top Grant of NWO for the financial support.

In SRON I had the opportunity to be part of the SPEX Team (Jelle Kaastra, Jelle de Plaa, Ton, Liyi, Junjie and Misssagh). Thanks for the atomic physics meetings, specially to Ton for teaching me new vocabulary like triplet, quatuorlet and all the possible transitions. Thanks to Junjie and Francois for helping me during the PhD and being part of the nice group of galaxy clusters. I am very grateful to my officemates Manuel, Carlo and Aurora, we had interesting conversations and shared great moments. Carlo, you know that since you left I missed you a lot, your happiness everyday, always with a smile. In SRON I could also meet some exceptional scientists, which have inspired and motivated me, thanks to Elisa, Margherita, Laura, Marianne, Catia, Sascha, Kristhell, Francesca, Zuzanna, Aurora and Ioanna. Elisa, thank you so much for being there and for your motivation. Catia, I am so glad that our paths crossed at SRON, thanks for listening, for the good advices and for always

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