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From supernovae to galaxy clusters : observing the chemical enrichment in the hot intra-cluster medium

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Curriculum Vitae

I was born on June 27, 1989, in Uccle (in Dutch, "Ukkel"), one of the 19 municipalities of Brussels, in Belgium. Except for a period of two or three years (which I barely remember), in which we moved to a small town named Hannut, I spent almost the 20 first years of my life in Brussels. It was during my primary school (Le Jardin des Écoliers), after a class on the Solar System (and on the mysteries of Pluto, which was still a planet at that time, and for which we had no picture yet) that I naively decided to become an astronomer. I did my secondary studies at the Lycée Émile Jacqmain, where I graduated in "Latin-mathematics" in 2007 (cum laude). During those years, I regularly attended astronomy camps in Modave, where my interest for astronomy and astrophysics kept growing.

I did my Bachelor degree in physics at the Université Libre de Bruxelles, where I graduated in 2010 (cum laude). My Bachelor project was focused on the observation of variable stars using the telescope of the university, and was supervised by Sophie Van Eck. I finally left my home town in 2010, when I started my Master degree in space sciences at the University of Liège. On that time, I developed a strong interest for high-energy astrophysics on one hand, and extragalactic astrophysics on the other hand. I did my Master thesis with Gregor Rauw on the X-ray emission of massive stars in the M 17 nebula as observed by *XMM-Newton*. After my graduation in 2012 (magna cum laude), I stayed four more months at the University of Liège to work with Thierry Morel on optical observations of the massive star ζ Puppis. I devoted the next few months to tutor high school students in mathematics, physics, and chemistry before I moved to the Netherlands in June 2013 to start my PhD.

This thesis summarises the results of my PhD project, and on which I

worked both at SRON (Utrecht) and Leiden Observatory with Jelle Kaas-
tra and Jelle de Plaa. During these four years, I had the opportunity to
present my work at several conferences and workshops, in Dublin (Ire-
land), Tokyo (Japan), Sexten (Italy), Madrid (Spain), Paris (France), and
Beijing (China). I was also the lucky laureate of the "poster prize" of the
71st Dutch Astronomy Conference in Nunspeet (The Netherlands) in 2016.
I spent a few weeks of my PhD to visit colleagues in other institutes: Yu-
Ying Zhang, Lorenzo Lovisari, Thomas Reiprich, and Gerrit Schellenberger
(Argelander-Institut für Astronomie, Bonn, Germany), as well as Norbert
Werner (MTA-Eötvös University Lendület Hot Universe Research Group,
Budapest, Hungary), with whom I will work as a postdoc from September
2017. From the first years of my academic studies up to now, I occasion-
ally go back to Modave, this time as a "teacher", to share my knowledge
of astronomy with younger students (with the secret hope they will want
to become astronomer, too).

List of publications

First author publications

- **Mernier, F.**, de Plaa, J., Kaastra, Raassen, A. J. J., Gu, L., Mao, and Urdampileta, I.
Origin of central abundances in the hot intra-cluster medium - III. The impact of spectral model improvements on the abundance ratios
2017, A&A, submitted (this thesis, Chapter 5)
- **Mernier, F.**, de Plaa, J., Kaastra, J. S., Zhang, Y.-Y., Akamatsu, H., Gu, L., Kosec, P., Mao, J., Pinto, C., Reiprich, T. H., Sanders J. S., Simionescu, A., and Werner, N.
Radial metal abundance profiles in the intra-cluster medium of cool-core galaxy clusters, groups, and ellipticals
2017, A&A, in press (this thesis, Chapter 6)
- **Mernier, F.**, de Plaa, J., Pinto, C., Kaastra, J. S., Kosec, P., Zhang, Y.-Y., Mao, J., Werner, N., Pols, O. R., and Vink, J.
Origin of central abundances in the hot intra-cluster medium - II. Chemical enrichment and supernova yield models
2016b, A&A, **595**, A126 (this thesis, Chapter 4)
- **Mernier, F.**, de Plaa, J., Pinto, C., Kaastra, J. S., Kosec, P., Zhang, Y.-Y., Mao, J., and Werner, N.
Origin of central abundances in the hot intra-cluster medium - I. Individual and average abundance ratios from XMM-Newton EPIC
2016a, A&A, **592**, A157 (this thesis, Chapter 3)
- **Mernier, F.**, de Plaa, J., Lovisari, L., Pinto, C., Zhang, Y.-Y., Kaastra, J. S., Werner, N., and Simionescu, A.

Abundance and temperature distributions in the hot intra-cluster gas of Abell 4059
2015, *A&A*, **575**, A37 (this thesis, Chapter 2)

Co-author publications

- Mao, J., de Plaa, J., Kaastra, J. S., Pinto, C., Gu, L., **Mernier, F.**, Hong-Liang, Y., Zhang, Y.-Y., and Akamatsu, H.
Nitrogen abundance in X-ray halos of clusters and groups of galaxies
2017, *A&A*, submitted
- Albert, J. G., Sifón, C., Stroe, A., **Mernier, F.**, Intema, H. T., Röttgering, H. J. A., Brunetti, G.
Complex Diffuse Emission in the $z=0.52$ Cluster PLCK G004.5-19.5
2017, *A&A*, submitted
- de Plaa, J., Kaastra, J. S., Werner, N., Pinto, C., Kosec, P., **Mernier, F.**, Lovisari, L., Akamatsu, H., Schellenberger, G., Hofmann, F., Reiprich, T. H., Finoguenov, A., Ahoranta, J., Sanders, J. S., Fabian, A. C., Pols, O. R., Simionescu, A., Vink, J., and Böhringer, H.
CHEERS: The chemical evolution RGS sample
2017, *A&A*, submitted
- Akamatsu, H., Fujita, Y., Akahori, T., Ishisaki, Y., Hayashida, K., Hoshino, A., **Mernier, F.**, Yoshikawa, K., Sato, K., and Kaastra, J. S.
Properties of the cosmological filament between two clusters: A possible detection of a large-scale accretion shock by Suzaku
2017, *A&A*, in press
- de Plaa, J., and **Mernier, F.**
CHEERS: Future perspectives for abundance measurements in clusters with XMM-Newton
2017, *Astron. Nachr.*, in press
- Akamatsu, H., Gu, L., Shimwell, T., **Mernier, F.**, Mao, J., Urdampilleta, I., de Plaa, J., Röttgering, H. J. A., and Kaastra, J. S.
Suzaku and XMM-Newton observations of the newly discovered early-stage cluster merger 1E2216.0-0401 and 1E2215.7-0404
2016, *A&A*, **593**, L7
- Ichinohe, Y., Werner, N., Simionescu, A., Allen, S. W., Canning, R. E. A., Elhert, S., **Mernier, F.**, and Takahashi, T.
The growth of the galaxy cluster Abell 85: mergers, shocks, stripping and seeding of clumping
2015, *MNRAS*, **448**, 2971

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Here we are: the end of four rich and exciting years spent at both Leiden observatory and SRON, but also full of great moments outside work. Writing the "acknowledgements" part of this manuscript is rather easy (because this thesis would not have been possible without the valuable help of so many people), and at the same time rather difficult (because I must take care of not forgetting anyone to thank).

First of all, this thesis was made possible thanks to Jelle de Plaa, who successfully obtained most of the very deep *XMM-Newton* data analysed here, and who built the entire CHEERS project. But far beyond that, Jelle was always available and ready to help me, from the very first days to the very last steps of my PhD thesis. I will never be grateful enough for all the expertise I have learned from him. Thank you Jelle! One Jelle may hide another, and I'm also very grateful to Jelle Kaastra for all his useful scientific and non-scientific advice, as well as for his constant optimism and support throughout these four years.

To become a doctor, you first need to get a PhD position. This requires two ingredients: (i) a deep passion for astronomy and (ii) people who greatly support you and recommend you. This is why I deeply thank: (i) my high school physics teacher Albert Friadt and all the members of the association "Jeunesse et Science" for having made me an astro-addict, and (ii) Gregor Rauw, Yaël Nazé, Thierry Morel, and Michaël De Becker for all their help and support during my Master thesis and during my search for a PhD position.

A PhD thesis is nothing either without excellent collaborators. It was a pleasure for me to work with Hiroki, Junjie, Igone, Liyi, and Ton as great colleagues within the cluster group at SRON. I also enjoyed working with

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