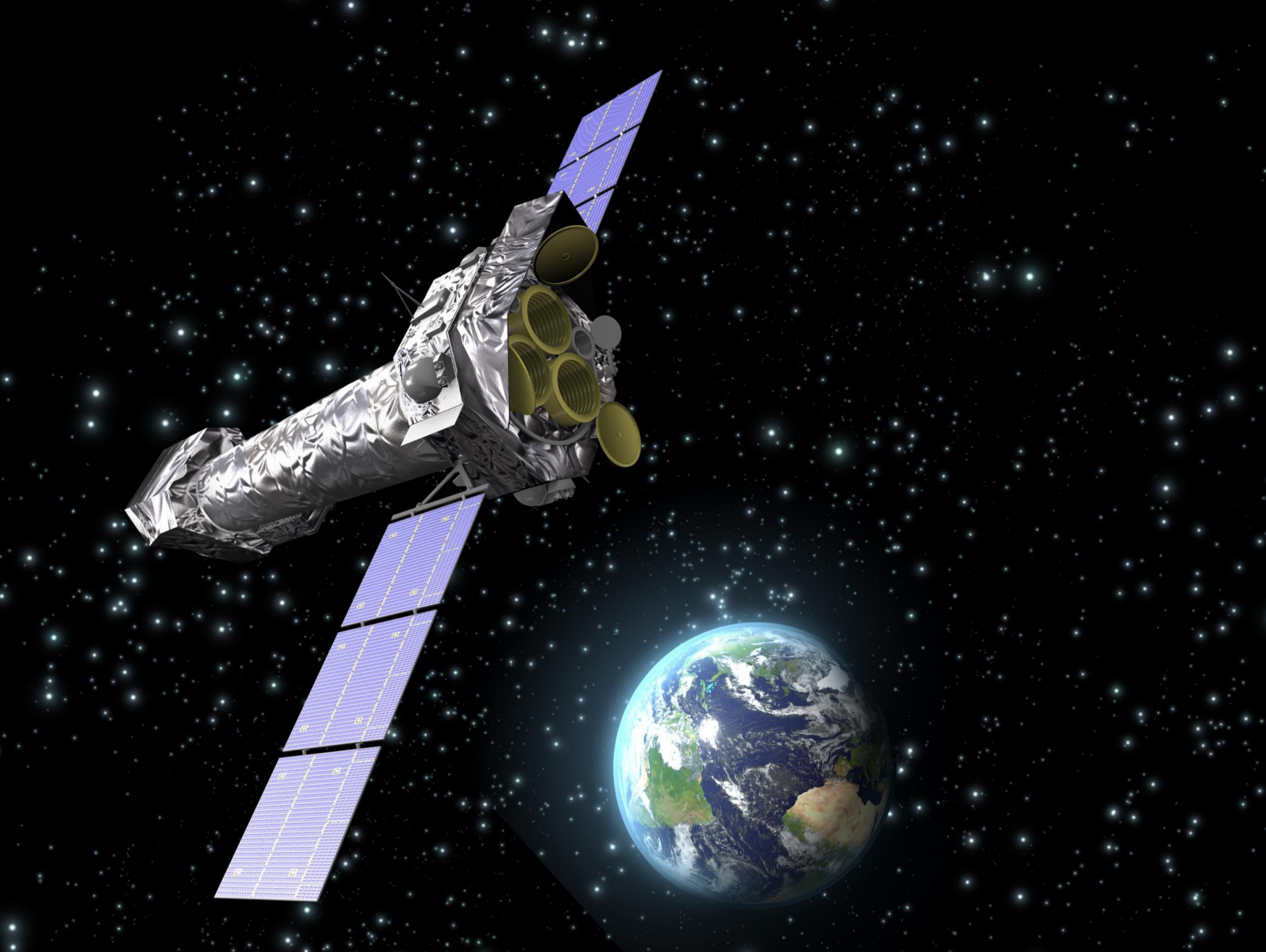


# X-ray astrophysics in Belgium

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X-ray emission is a powerful diagnostic tool of the most **extreme and energetic processes** taking place in the Universe. Thanks to PRODEX funding via Belspo, Liège University and the Centre Spatial de Liège got involved in the design and building of the Optical Monitor aboard *XMM-Newton*. The guaranteed observing time that was granted in return paved the way to a series of highly successful guest observer programs dedicated to the analyses of X-ray emission of **massive stars and their highly energetic stellar winds**.

## Some highlights of our research

Constraints on **structures in the winds of single (non-magnetic) massive stars** via high-res. spectroscopy and temporal variability studies (e.g. Nazé et al. 2013, ApJ 763, 143; Hervé et al. 2013, A&A 551, A83; Rauw et al. 2015, A&A 580, A59).

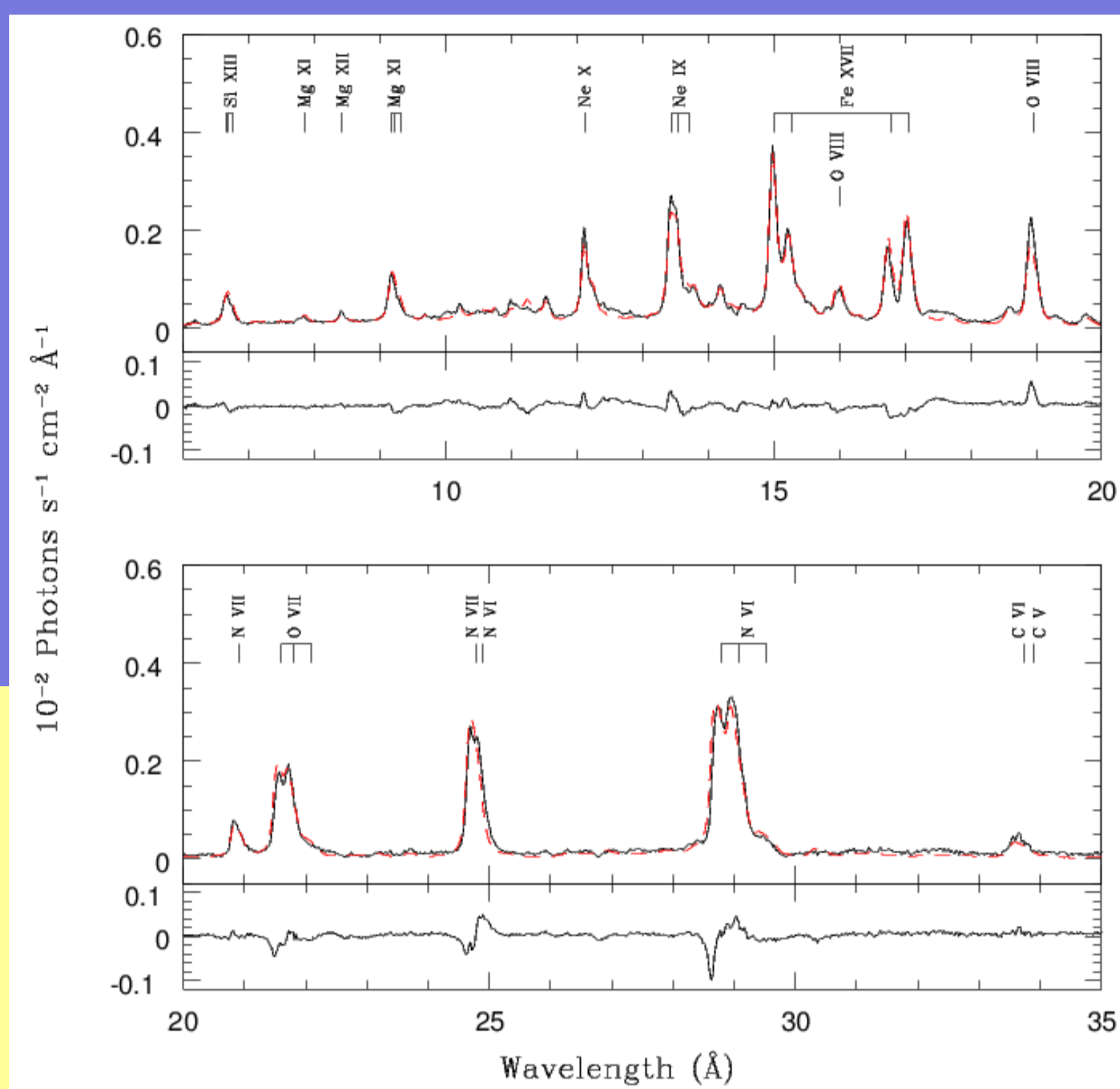
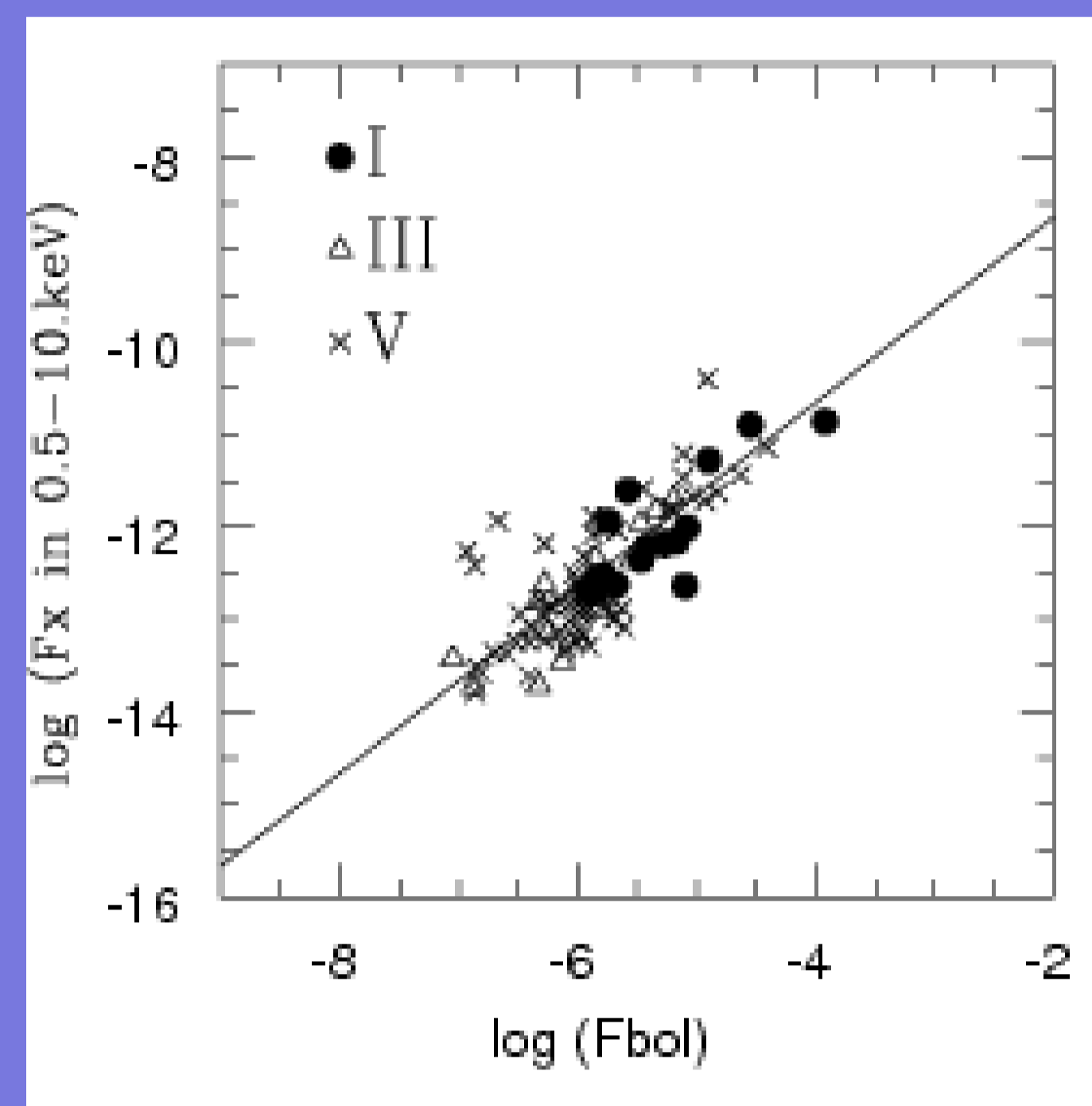
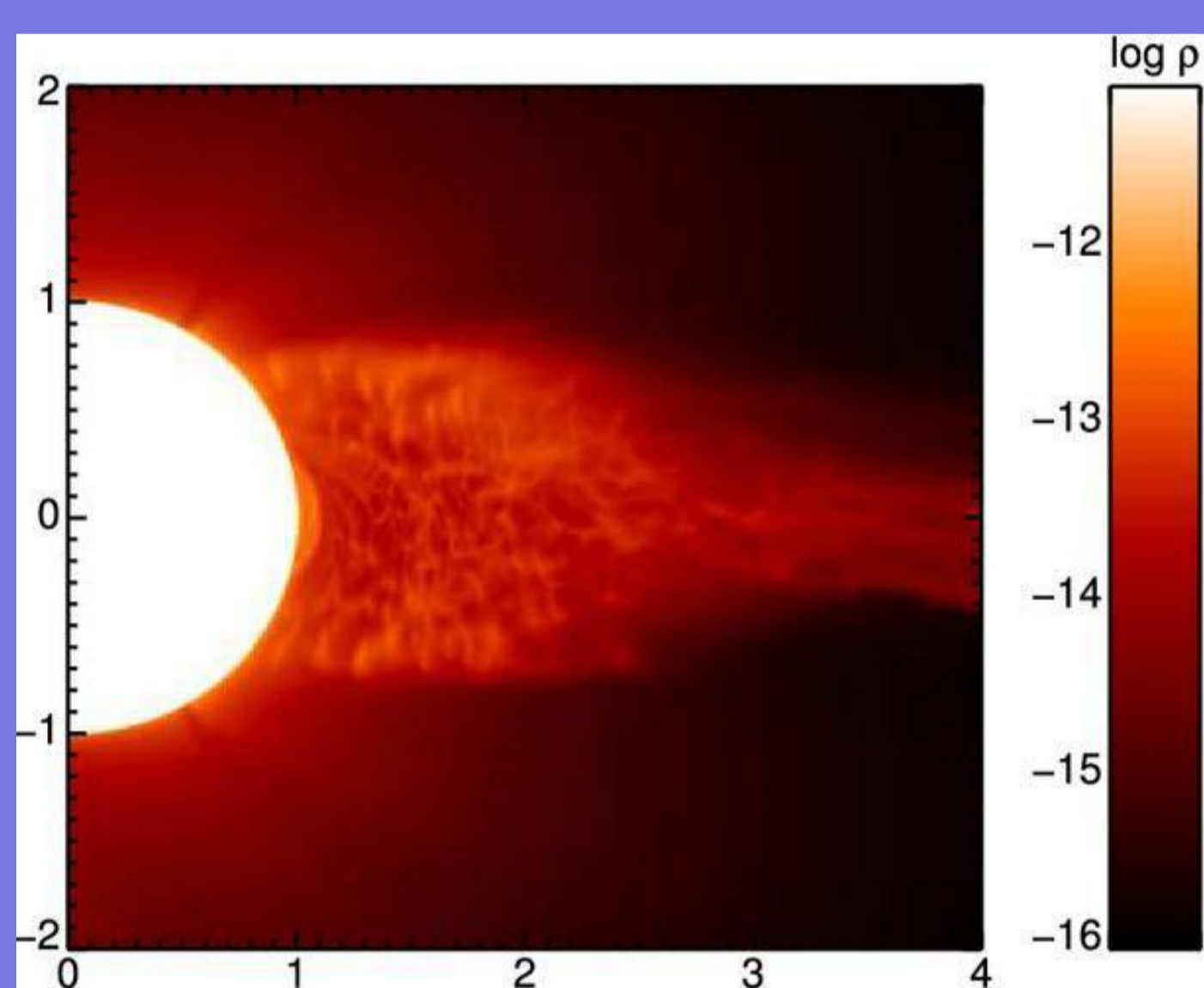


Fig. 1: *XMM-Newton* RGS spectrum of  $\zeta$  Pup (black solid line) along with the best-fit model (red dashed line) of X-ray emission in the wind of a single massive star (Hervé et al. 2013).



In-depth studies of the **relation between X-ray and bolometric luminosity** for all kinds of massive stars using large homogeneous samples. (e.g. Sana et al. 2006, MNRAS 372, 661; Nazé 2009, A&A 506, 1055; Nazé et al. 2012, A&A 538, A47; Rauw & Nazé. 2016, arXiv:1608.04499).

Fig.2: Linear scaling relation between X-ray and bolometric luminosity for O-type stars observed within the 2XMM catalog (Nazé 2009).



Probing the **magnetospheres of massive stars** via X-ray emission generated in their magnetically confined winds (e.g. Nazé et al. 2014, ApJS 215, 10; Nazé et al. 2015, MNRAS 452, 2641; ud-Doula & Nazé 2016, AdSpR 58, 680).

Fig.3: Hydrodynamic simulation of the magnetically confined wind of the O-star CPD-28° 2561 (Nazé et al. 2015).

Pinpointing the physics of the **collision of stellar winds in massive binary systems** (e.g. Parkin & Gosset 2011, A&A 530, A119; Nazé et al. 2012, A&A 546, A37; Cazorla et al. 2014, A&A 561, A92; Gosset & Nazé 2016, A&A 590, A113; Rauw & Nazé 2016, AdSpR 58, 761).

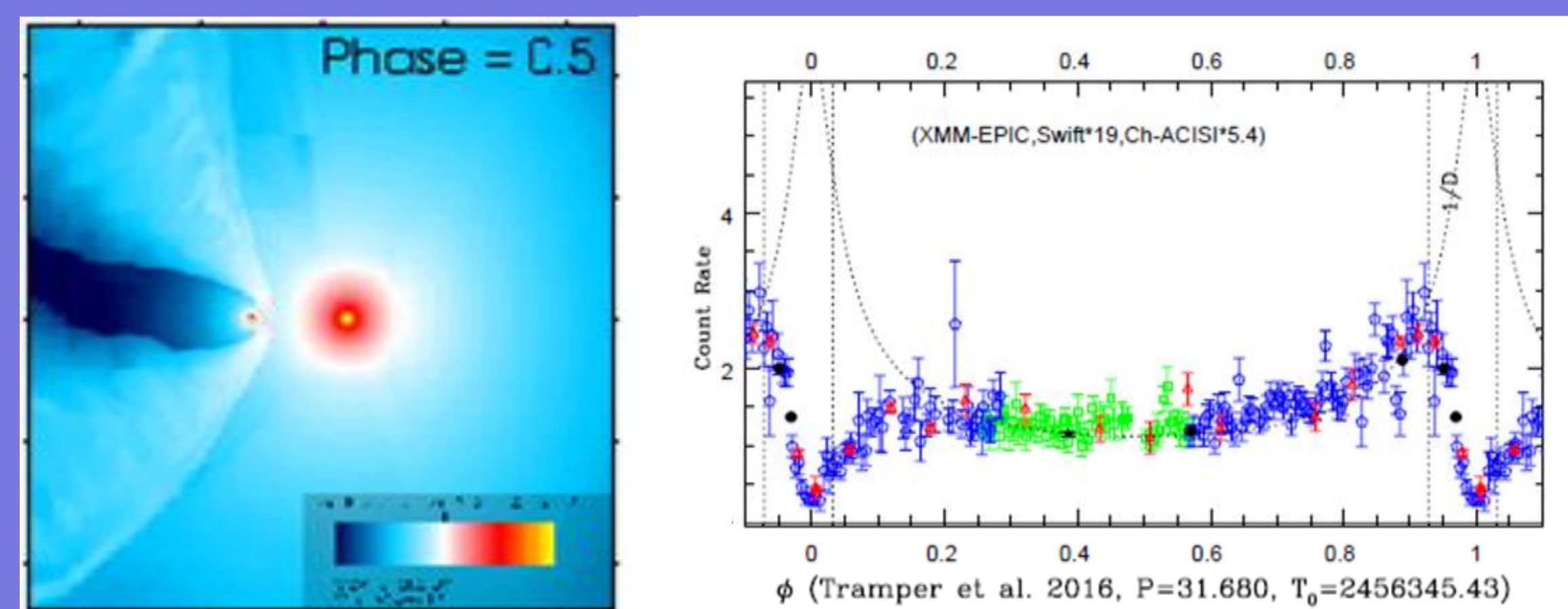


Fig.4: Left: Hydrodynamic simulation of the wind density in a wind-wind collision (Parkin & Gosset 2011). Right: X-ray light curve (combining *XMM-Newton* and *Swift* data) of the colliding wind massive binary WR21a (Gosset & Nazé 2016).

Investigations of the **interplay between high- and low-mass stars in stellar clusters** (e.g. Rauw et al. 2003, A&A 407, 925; Sana et al. 2007, MNRAS 377, 945; Rauw 2011, A&A 536, A31).

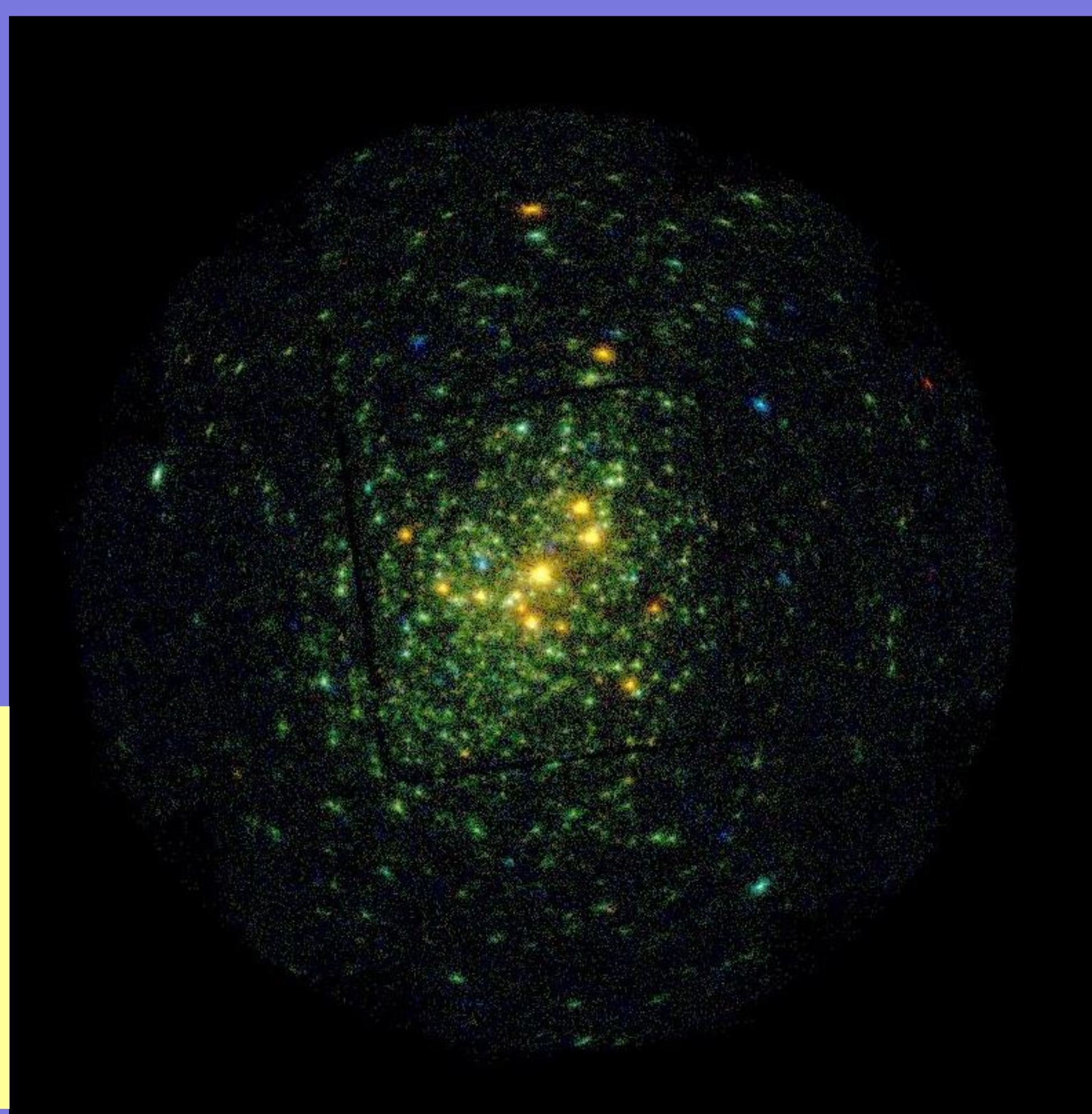
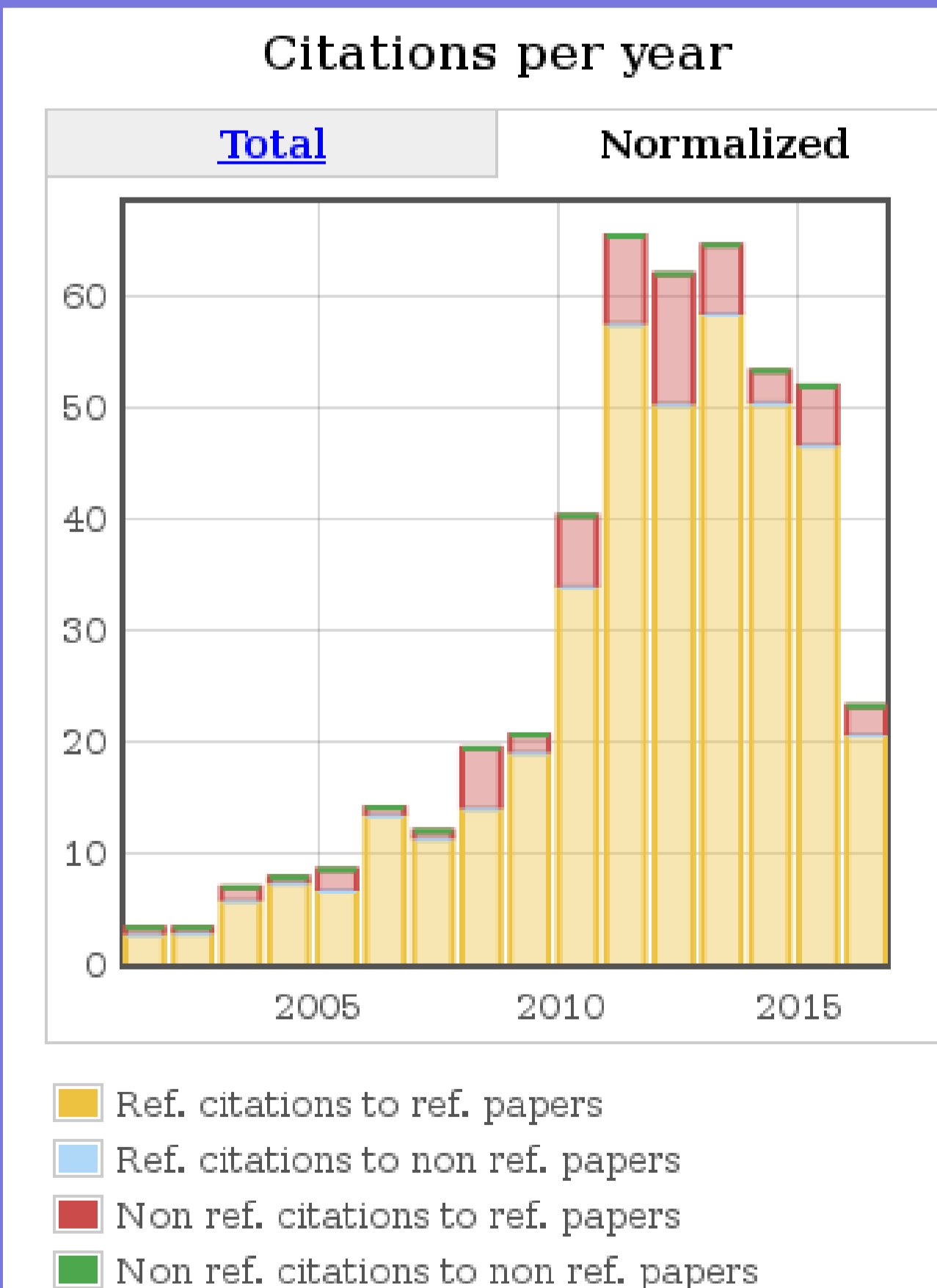


Fig.5: *XMM-Newton* EPIC picture of the open cluster NGC6231 (Sana et al. 2007) revealing a large population of low-mass stars (green) in addition to the O-stars (yellow).

To this day, our X-ray related studies, supported by PRODEX and Belspo, led to

- **95 articles in leading refereed journals,**
- **over 2200 citations,**
- **9 PhD theses and 11 master theses,**
- **10 press or image releases,**
- **many outreach articles and public talks to raise awareness of (X-ray) astronomy and ESA.**



## The future

X-ray astrophysics in Belgium has a bright future beyond the retirement of the *XMM-Newton* mission. Thanks to PRODEX, we joined the proto-consortium that aims at designing and building the X-ray Integral Field Unit spectrograph (X-IFU, Barret et al. 2016, Proc. SPIE 99052F) for ESA's next generation X-ray observatory *Athena* (launch 2028). See also talk by Etienne Renotte (CSL).

