γ 2022

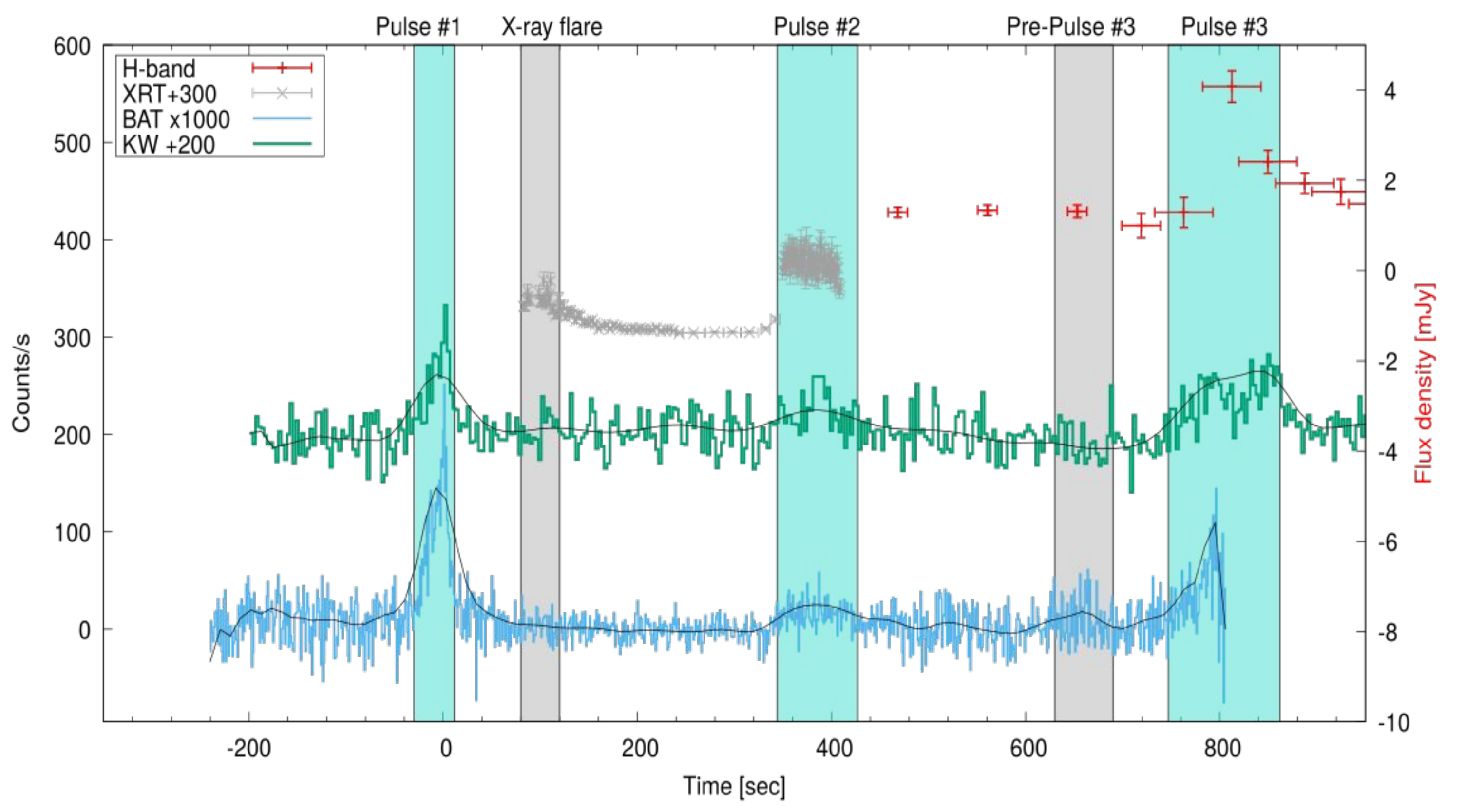
7th Heidelberg International Symposium on
High Energy Gamma-Ray Astronomy
Barcelona, July 4-8 2022

THE VERY HIGH-REDSHIFT GRB 210905A

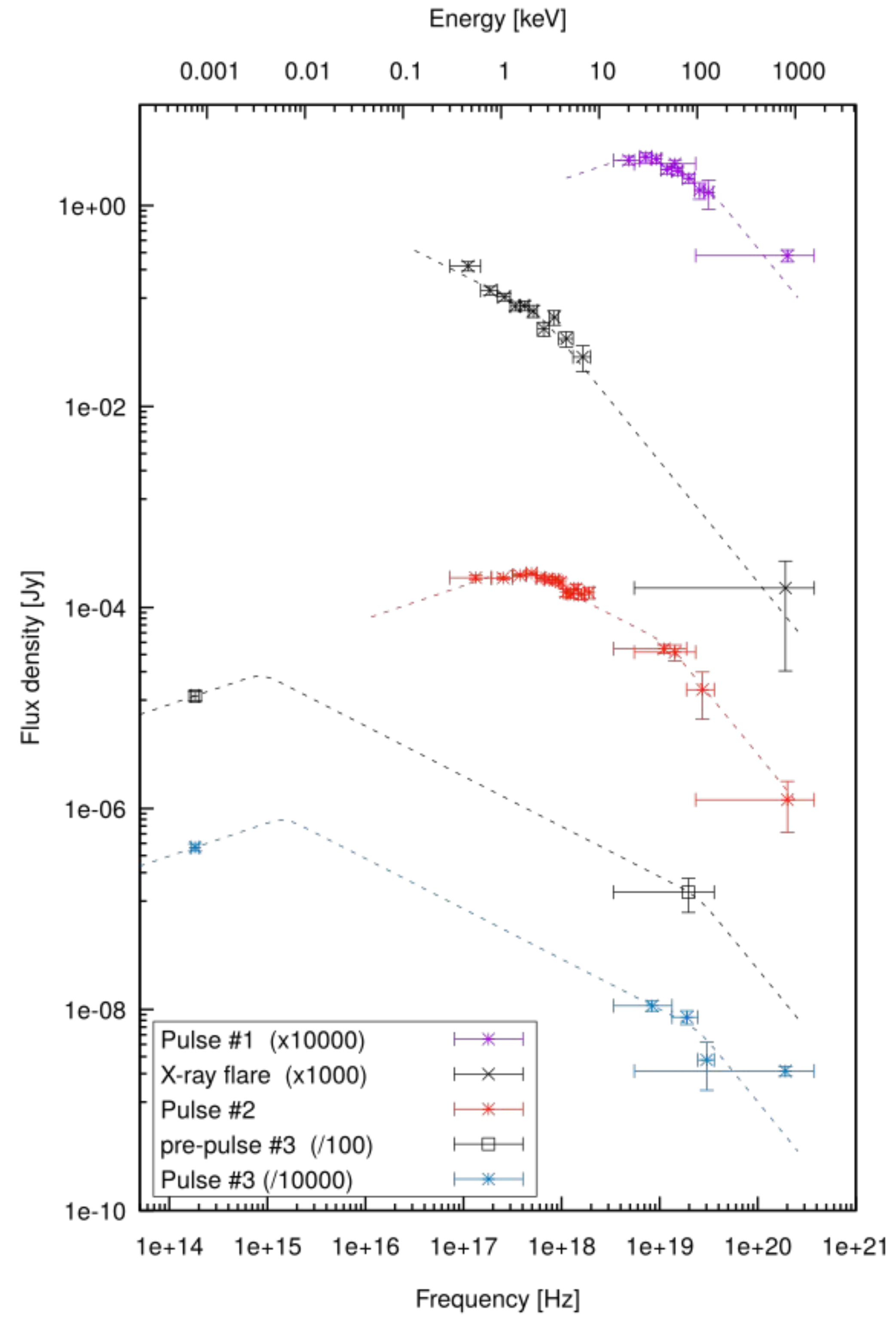
A. Rossi[1], D. D. Frederiks[2], D. A. Kann[3] on behalf of a larger collaboration

[1]INAF-OAS Bologna (Italy),[2]Ioffe Institute, St. Petersburg, Russia [3]IAA-CSIC Granada, Spain

INAF ISTITUTO NAZIONALE DI ASTROFISICA

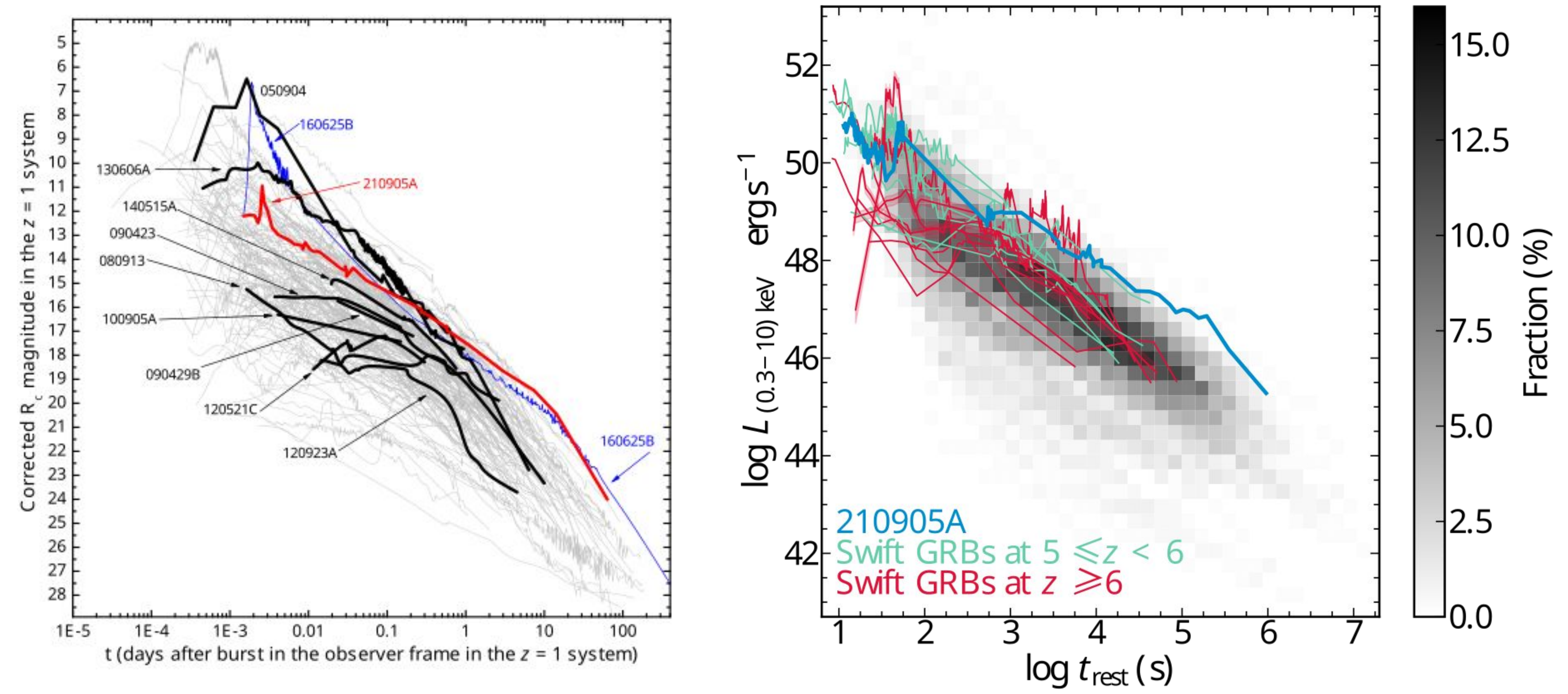


Multi-band prompt emission light curve of GRB 210905A as seen by *Swift*/BAT (15 − 350 keV, 6 s binning, counts/s × 1000, cyan), Konus-*Wind* (20 − 400 keV, 5.9 s binning, counts/s + 200, green points), *Swift*/XRT (counts/s + 300, grey points) and *REM*/H-band (Flux density, red points). The evolution of the gamma-ray emission is highlighted with a black smoothed spline to guide the eye. We have modelled the spectral energy distribution (SED) of the intervals corresponding to the three main pulses and the small pulses are highlighted by turquoise and grey-shaded areas, respectively.

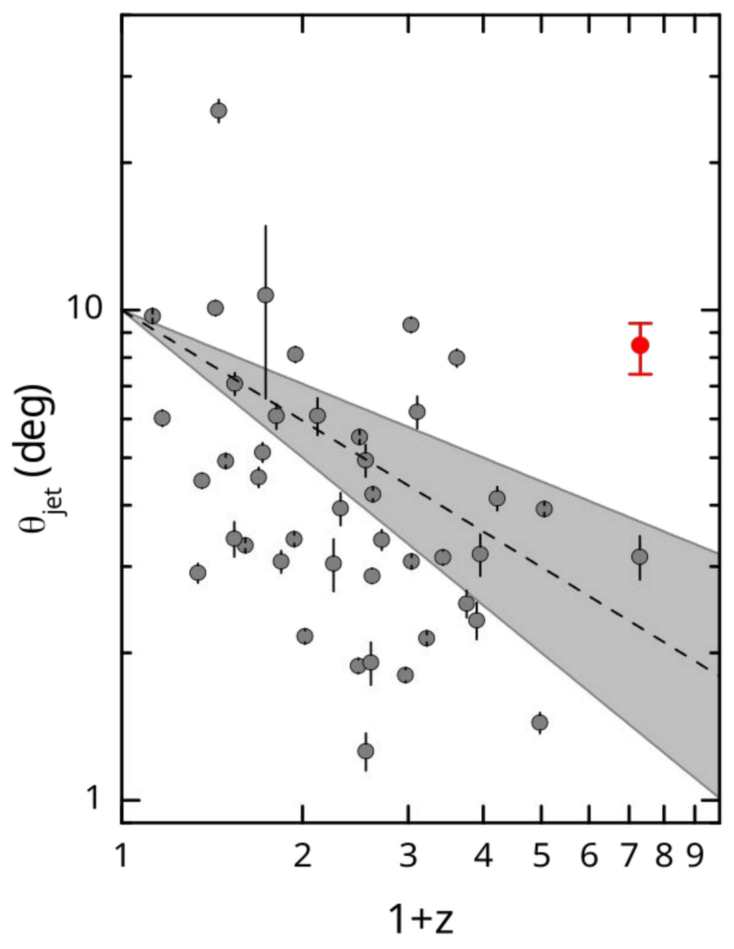


Prompt synchrotron emission: Optical/NIR to gamma-ray SEDs of the prompt phase at five different epochs. All SEDs have been modelled with a double broken power-law following the expectations from synchrotron theory. Therefore, the spectral indices are 1/3, −1/2, −1.3. Note that we could not constrain the low-energy break during the X-ray flare. In the fourth SED, we have simply scaled the solution from the last epoch (there is no Konus-*Wind* detection during this epoch). X-ray data are corrected for Galactic and intrinsic absorption.

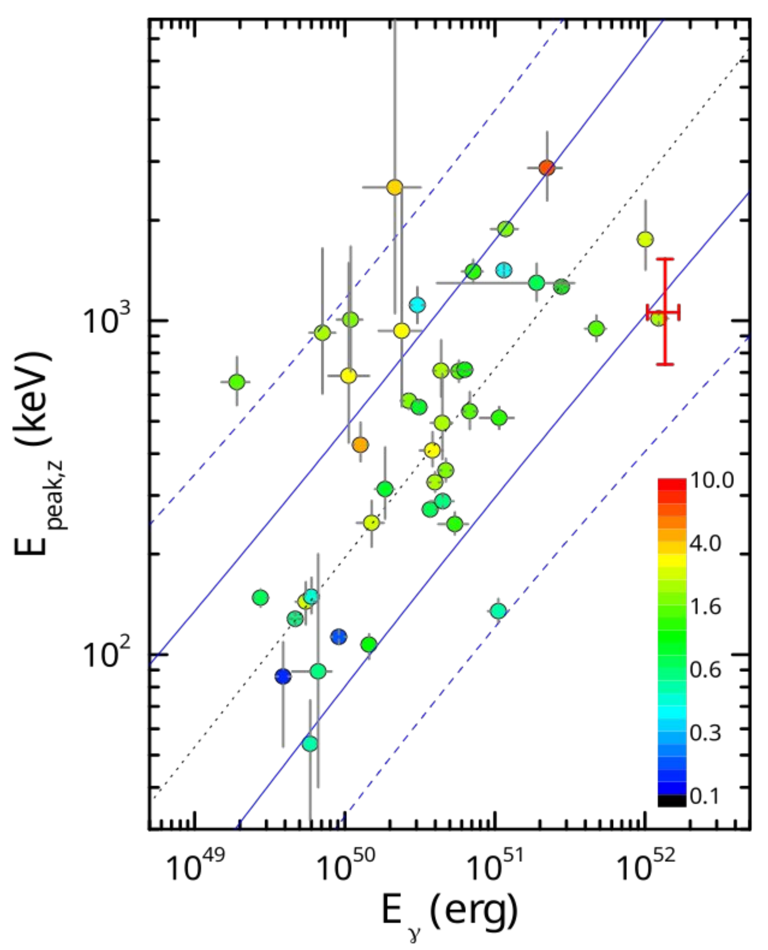
Abstract: We present the discovery of the very energetic GRB 210905A at a high redshift of z=6.312 and its luminous X-ray and optical afterglow. With an isotropic gamma-ray energy of E_{iso}~10^{54} erg, GRB 210905A lies in the top 7% of GRBs in the Konus-*Wind* Catalog in terms of energy release. Its afterglow is also among the most luminous ever observed, in particular in the optical at >0.5 d (rest frame). I will show that while the early afterglow light curve can be explained by energy injection, the spectral energy distribution is in agreement with slow cooling in a constant-density environment. We derived a half-opening angle of ~8 degrees, the highest ever measured for a z>6 burst but within the range covered by closer events. This argues against recent claims of an inverse dependence of the half-opening angle on redshift. The collimation-corrected gamma-ray energy release of $1x10^{52}$ erg is also among the highest ever measured. Despite the great released energy, our findings demonstrate that the properties of this burst are in agreement with those of less distant bursts.

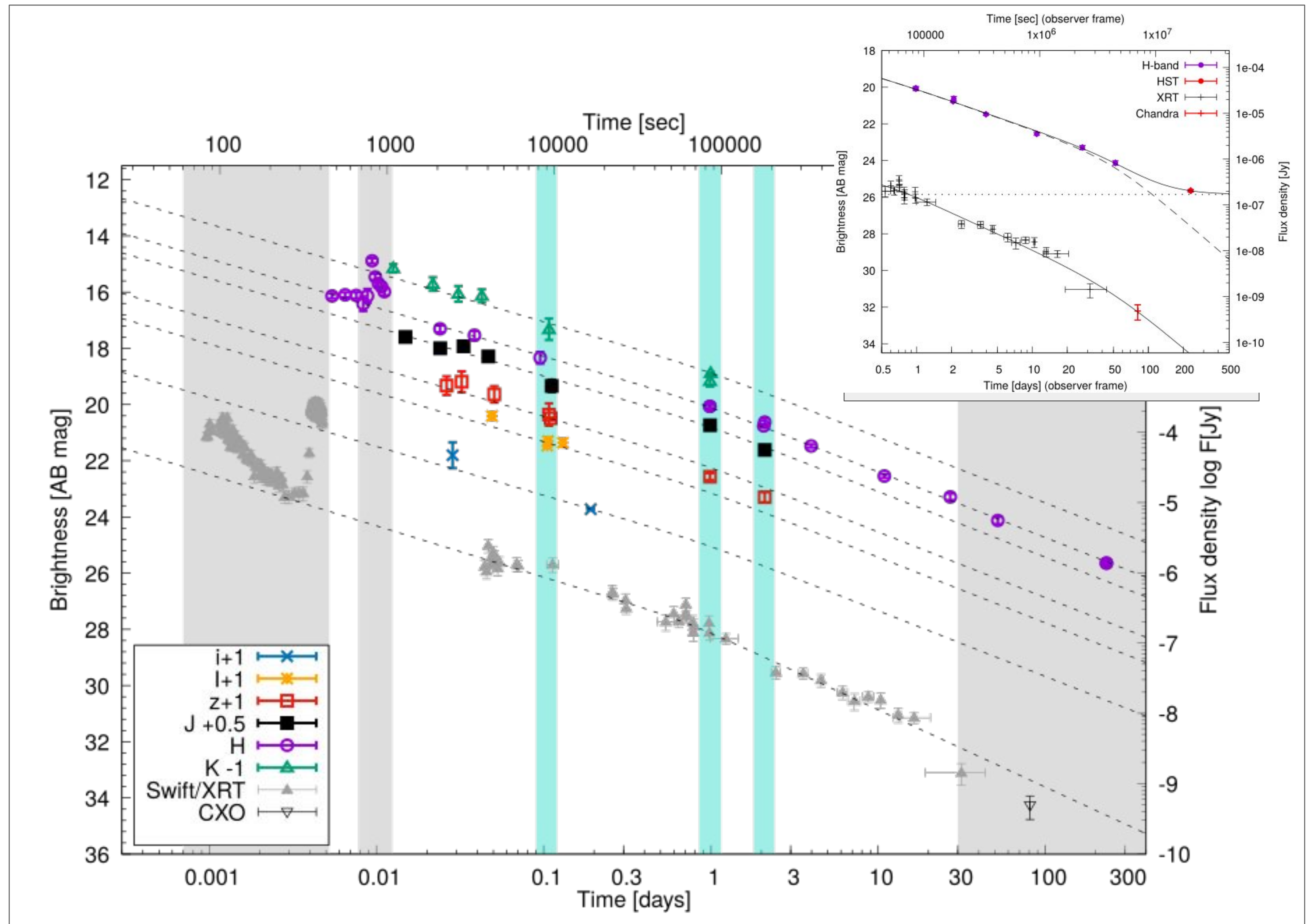


The afterglow of GRB 210905A is one of the most luminous ever detected. **Left:** The optical afterglow compared to a sample of optical afterglows which have all been shifted to z = 1, from Kann et al. (2022 in prep.). Light grey are LGRBs, thicker black lines GRBs with redshifts z > 6. The late-time break in the light curve is clearly visible. **Right:** The X-ray afterglow of GRB 210905A (blue line) in the context of other high-redshift GRBs (green and red) and the world-sample of Swift GRBs with known redshifts (grey density plot). The colour table on the right side translates a grey shade at a given luminosity and time into a fraction of bursts.



Collimated parameters of GRB 210905A (red) compared to a KW sample of 43 long GRBs from Tsvetkova et al. (2017, 2021). **Left:** Half-opening angle θ_{jet} versus redshift. The dashed line within the grey area shows the relation found in Lloyd-Ronning et al. (2020) with its error. GRB 210905A is an outlier event located at 2−3σ from this relation. The half-opening angle of this GRB (θjet~8 deg) is consistent with the median value of $\theta_{jet}=7.4^{+11}_{-6.6}$ deg for GRBs at z ~ 1 (Laskar et al., 2014, 2018). **Right:** E_γ − $E_{peak,z}$ diagram. The colour of each data point represents the burst's redshift. GRB 210905A follows the "*Ghirlanda*" relation (plotted together with its 68% and 90% prediction intervals). GRB 210905A has the highest E_γ in the Konus-*Wind* catalogue. This and the large $E_{peak,z}$ suggest a large bulk Lorentz factor Γ_0 of the jet.





X-ray, optical, and NIR light curves: The dashed lines show the fit to each single band assuming a smoothly broken power-law model. The grey intervals are not considered in this modelling of the light curves. The shallow light curve decay before 1 day is explained with energy injection from the central engine. The late light curve (>1 day) was fitted separately (top right panel) and we find evidence for a jet break at ~50 days with an additional constant component in the NIR, likely the host galaxy. Those regions in light blue have been used for the SED fitting.

Conclusions.

- **GRB 210905A** was a long burst at redshift z = 6.312.
- **The prompt phase is interpreted as synchrotron emission**, similar to other bursts at lower redshifts.
- **High energetics:** among the sample of ten z>6 GRBs known to date, GRB 210905A stands out as having among the highest energy release and among the highest afterglow luminosity at late times.
- **The half opening angle** is larger than that of other z>6 bursts, but similar to those a z~1, thus questioning the putative inverse dependence of the half-opening angle on redshift.
- **Central engine:** The large collimated total energy budget >10^{52} erg likely excludes the magnetar as a central engine. The Kerr black hole is the preferred scenario.
- **GRB 210905A follows the Ghirlanda relation** (as well as Amati and Yonetoku relations, shown in the paper).
- **The origin of GRB 210905A** is likely similar to low-redshift GRBs.
- **GRBs at z > 6 are rare events but are just the tip of the iceberg of a larger population that future proposed missions promise to uncover.**

A complete analysis of our GRB 210905A observations is reported in **Rossi et al., 2022, submitted to A&A, arXiv:2202.04544**