The soft X-ray transient EP241021A:
A cosmic explosion with a complex off-axis jet and cocoon from a massive star progenitor

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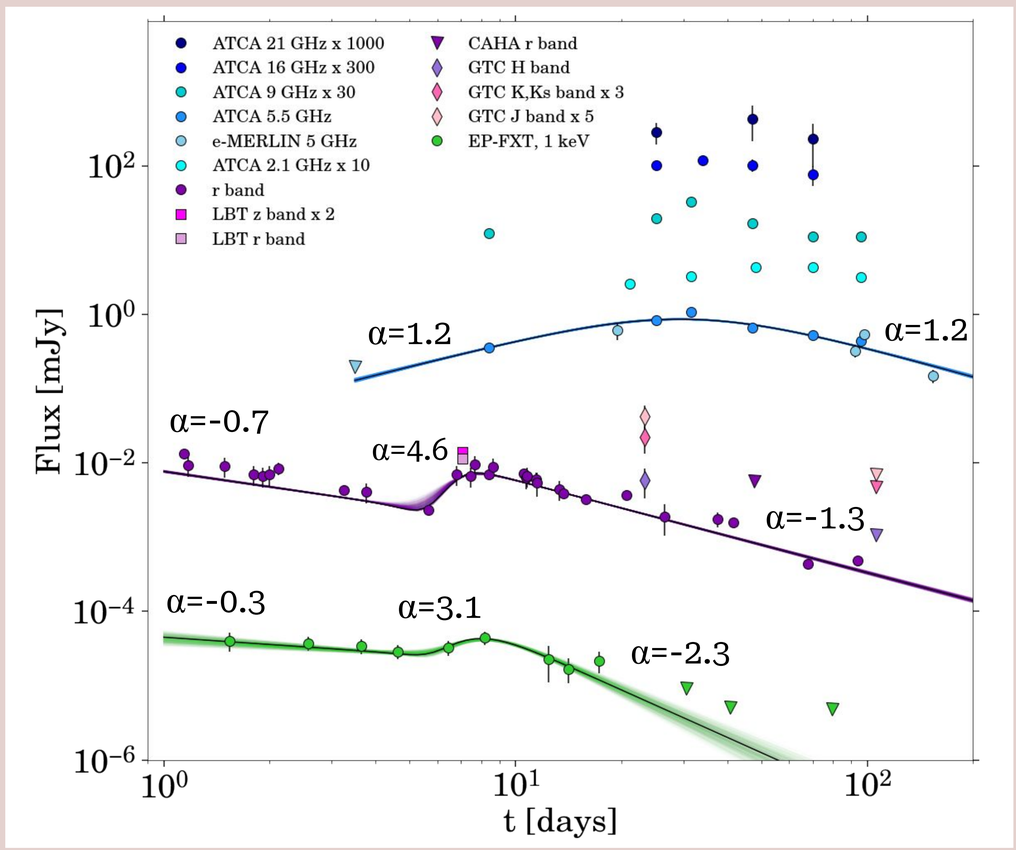
"THE FIFTH NATIONAL WORKSHOP ON THE SKA PROJECT"

ABSTRACT

EP241021a was discovered by Einstein Probe (EP) and likely belongs to the class of X-Ray Flashes (XRFs), fast X-ray transients connected to Gamma Ray Bursts (GRBs) representing their softer analogues. Here we present our extensive follow-up campaign in radio (uGMRT, ATCA, e-MERLIN, ALMA), but also in optical and in X-rays. Multiple components, generated from the interaction of a jet with the complex environment of the pre-existing massive star, shape the afterglow emission. The radio spectral coverage from 1 to ~200 GHz was fundamental to constrain the slower ejecta of EP241021a, which, in the end, revealed to be not so different from a GRB.

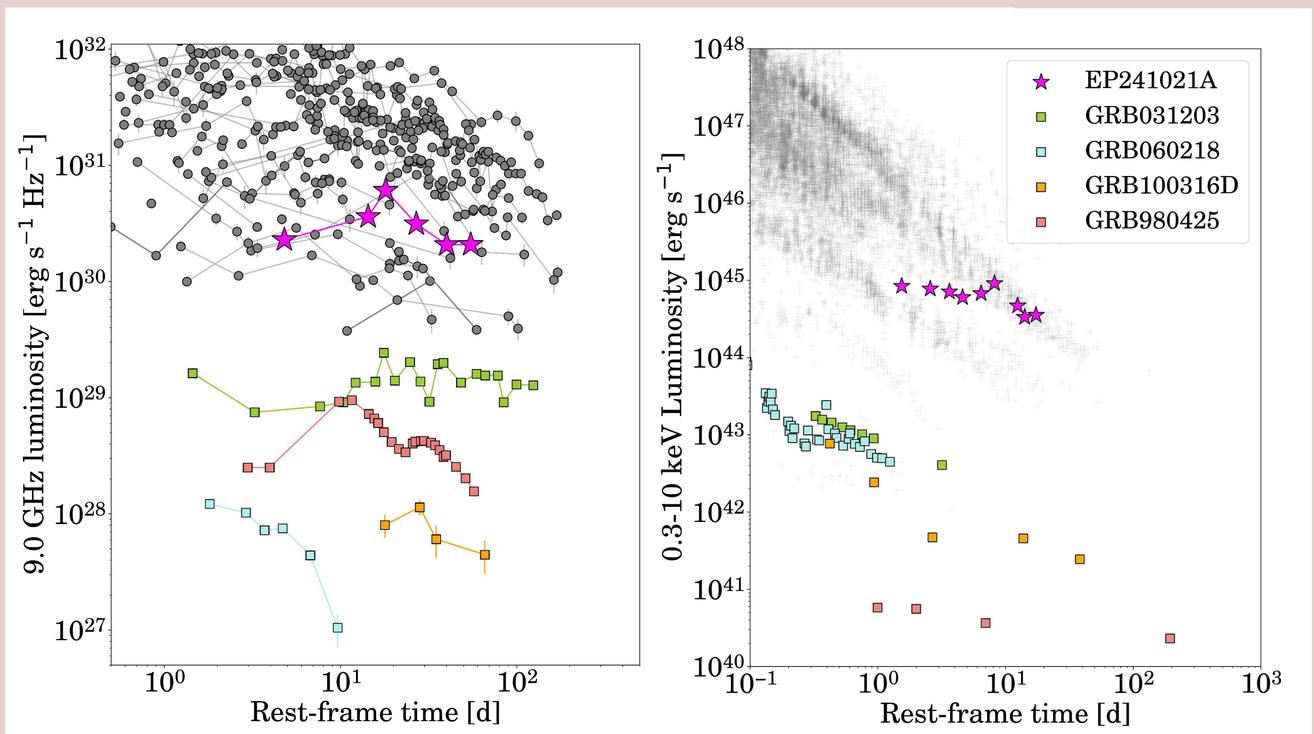
DATASET



EP241021a broadband light curve. EP-FXT X-ray data are represented in green; optical data are represented in shades of purple and pink; radio data are represented in shades of blue. The solid black lines and shaded-colored regions represent the best fit and the 500 best likelihood fits of the data using phenomenological power law models. The slopes of each power law (Flux $\propto t^{\alpha}$) are written in the plot.

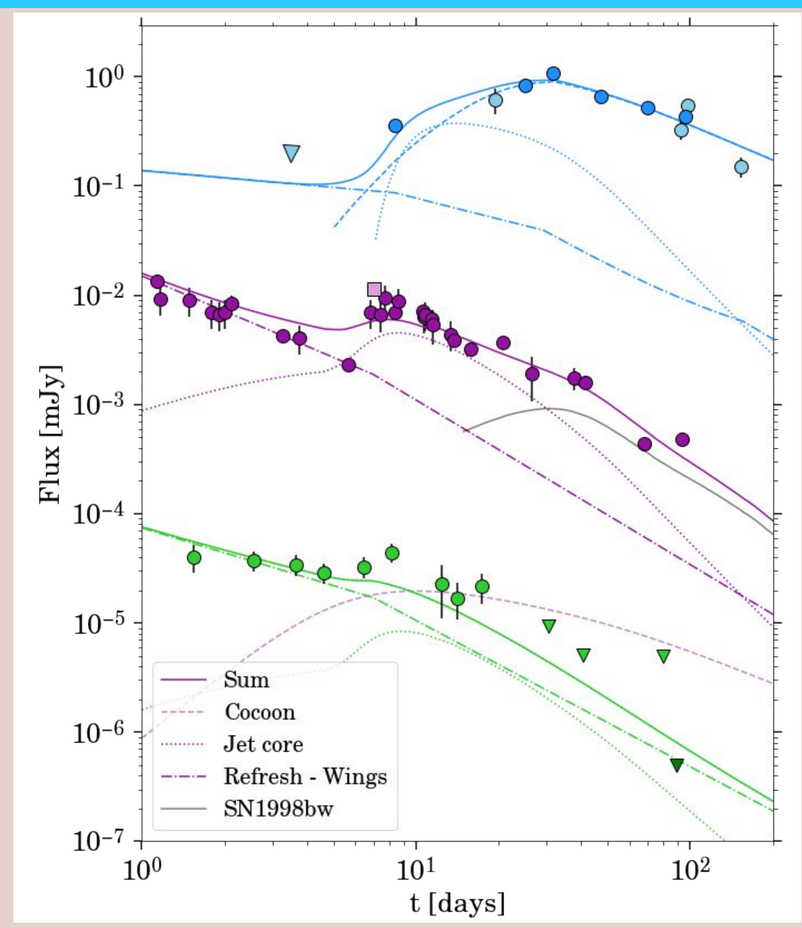
RADIO AND X-RAY LUMINOSITY

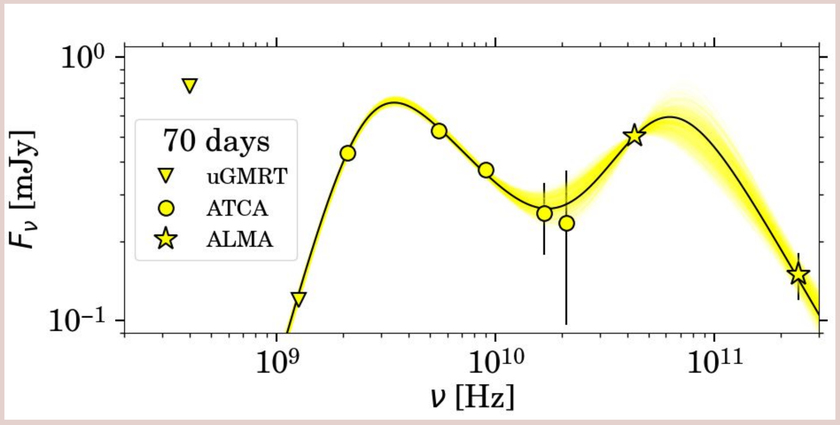
EP241021a X-ray (0.3-10 keV, see right Fig. below) afterglow luminosity at early times (before the bump) is placed at the lower end of cosmological GRBs, between the majority of the GRB population and low-luminosity GRBs, such as GRB060218, GRB100316D, and GRB980425. The radio luminosity further supports this association (see left Fig. below). Instead, the late X-ray luminosity is consistent with the standard GRB population. This could suggest that the EP241021a **X-ray emission after the peak is likely due to a relativistic jet**, while the **early X-ray and the full radio** light curve could be due to **less energetic components**.



ALL THE EP241021a COMPONENTS

The physical modeling of EP241021a suggests that **several components come into play** (Fig. on the right). The system at small polar angles is composed of a **structured jet** with an energetic **top-hat core** and external **wider and low-Lorentz-factor wings**, see a sketch below. Our line of sight is within the wings, but outside the collimated core. This results in the emission being dominated first by the wings (dot-dashed lines), and later by the collimated core (dotted lines), once it enters our line of sight. We cannot rule out the presence of a Supernova; in fact, it would provide a natural explanation for the shallow decline of the optical light curve at late times (grey line). The sum of all components is represented by a solid line.

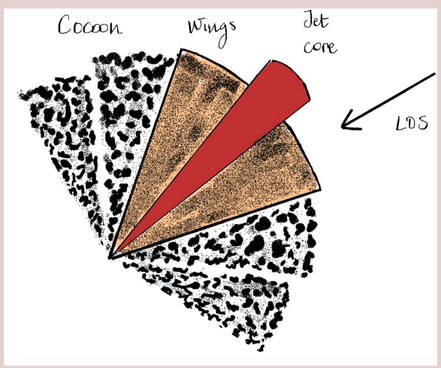




The radio emission at ν < 20 GHz is produced by a **spherical mildly relativistic ejecta, a cocoon**, at large polar angles. The spectrum is self-absorbed, with a peak frequency of ~5 GHz. Possibly, this is a stratified cocoon with **two different velocities**, explaining the second spectral peak found at 70 days and ν > 20 GHz.

CONTEXT

After the **collapse of a massive star**, hydrodynamical simulations do predict the presence of a stratified cocoon and a structured jet, where the wings represent a transition area between the relativistic jet core and the cocoon.



CONCLUSIONS

EP241021a emission aligns with a collapsar scenario. EP has revealed a landscape that remained hidden for years. **Wide-band radio follow-up with SKA will be fundamental** as each energy band provides a piece of the story, and only by combining them can we gain a complete understanding of the system producing the observed transient.

REFERENCE