Coordinated Radio and High-Energy Observations of Cygnus X–3 with the Allen Telescope Array

Peter K. G. Williams, Geoffrey C. Bower, John A. Tomsick, Arash Bodaghee, and the Allen Telescope Array Team

UC Berkeley; pwilliams@astro.berkeley.edu

ABSTRACT

Cygnus X–3 is the first microquasar to have been definitively detected in γ–rays. During a minor flaring episode occuring around 2010 May, Cyg X–3 was observed with the Allen Telescope Array (ATA), *Fermi*, INTEGRAL, and several other facilities. The system flared in the γ–ray band on 2010 May 27. Unlike previous instances, in which a γ–ray flare is usually followed by a radio flare, this event appears to have been preceded by one. Such an ordering is difficult to explain in the usual physical picture. This kind of timing variability is well–known in the study of blazars, and ideas from that field, such as shock–in–jet models, may help explain the data.

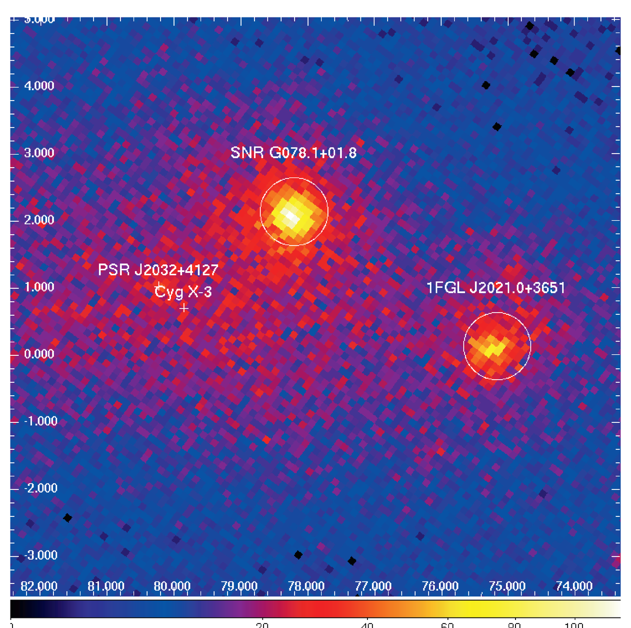
ACKNOWLEDGMENT

The first phase of the ATA was funded through generous grants from the Paul G. Allen Family Foundation. UC Berkeley, the SETI Institute, the National Science Foundation (Grant No. 0540599), Sun Microsystems, Xilinx, Nathan Myhrvold, Greg Papadopoulos, and other corporations and individual donors contributed additional funding.

SETI INSTITUTE

ALLEN TELESCOPE ARRAY

→ **Cyg X–3 and its environs as seen by Fermi.** Measuring the flux of Cyg X–3 with *Fermi* is difficult because of a nearby pulsar and its location in a region of extended emission. However, with ~day–length integrations and careful analysis, it can be successfully detected, as demonstrated by the detection of orbital modulation of its flux (Abdo et al., 2009).

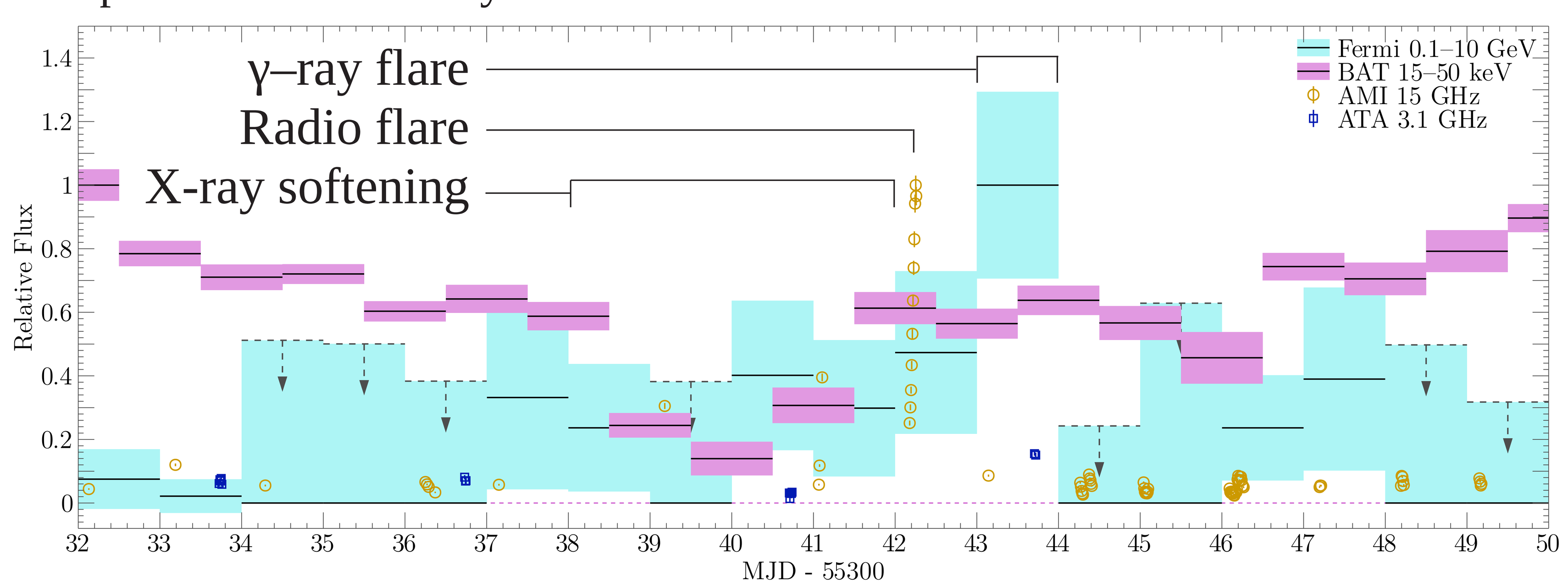


Motivation

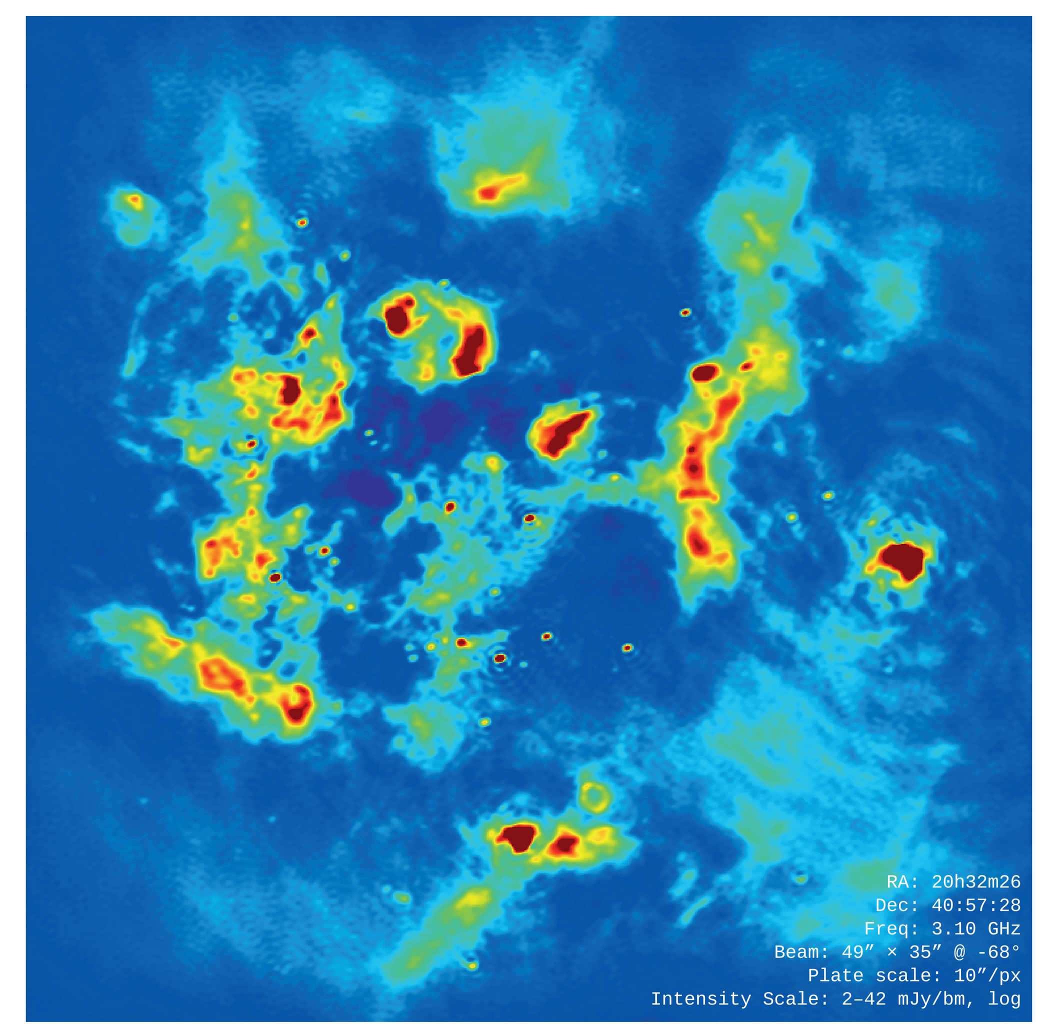
Microquasars—X-ray binaries that launch relativistic jets—are excellent laboratories for studying accretion onto black holes, thanks to their proximity and the short timescales on which they evolve. Cygnus X–3, a bright galactic microquasar, is the first such system to have been definitively detected in γ rays (Abdo et al., 2009, Tavani et al., 2009). Combining observations in this band with the established work in the radio and X–ray regimes should substantially increase the power of multiband monitoring as a tool for understanding this source and its brethren. Around 2010 May, Cyg X–3 entered its “minor flaring” state (Corbel & Hays, 2010; Tomsick et al., 2010). We began collecting data from a variety of facilities in the hopes of catching a significant flare.

The Data

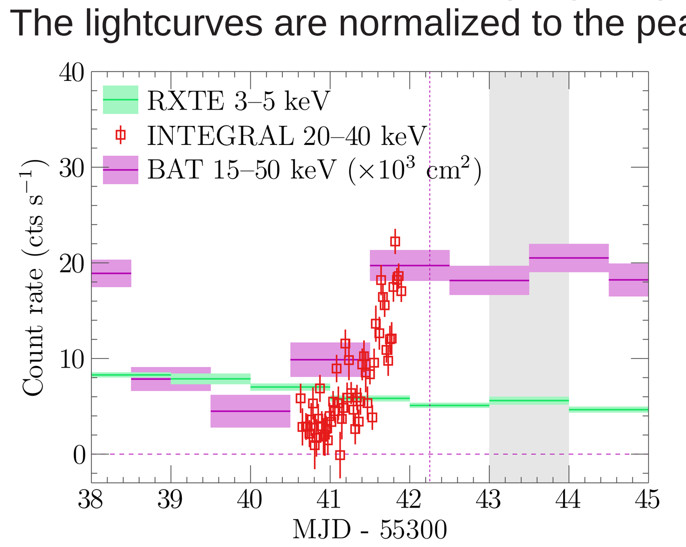
We observed Cyg X–3 with the ATA and INTEGRAL and reduced public data from *Fermi*. We additionally obtained data from monitoring campaigns using the AMI and RATAN-600 radio telescopes (Pooley & Fender, 1997; Trushkin, 2000; Trushkin et al., 2006). Quick-look results provided by the ASM/RXTE team and Swift/BAT transient monitor results provided by the Swift/BAT team were also incorporated into our analysis.



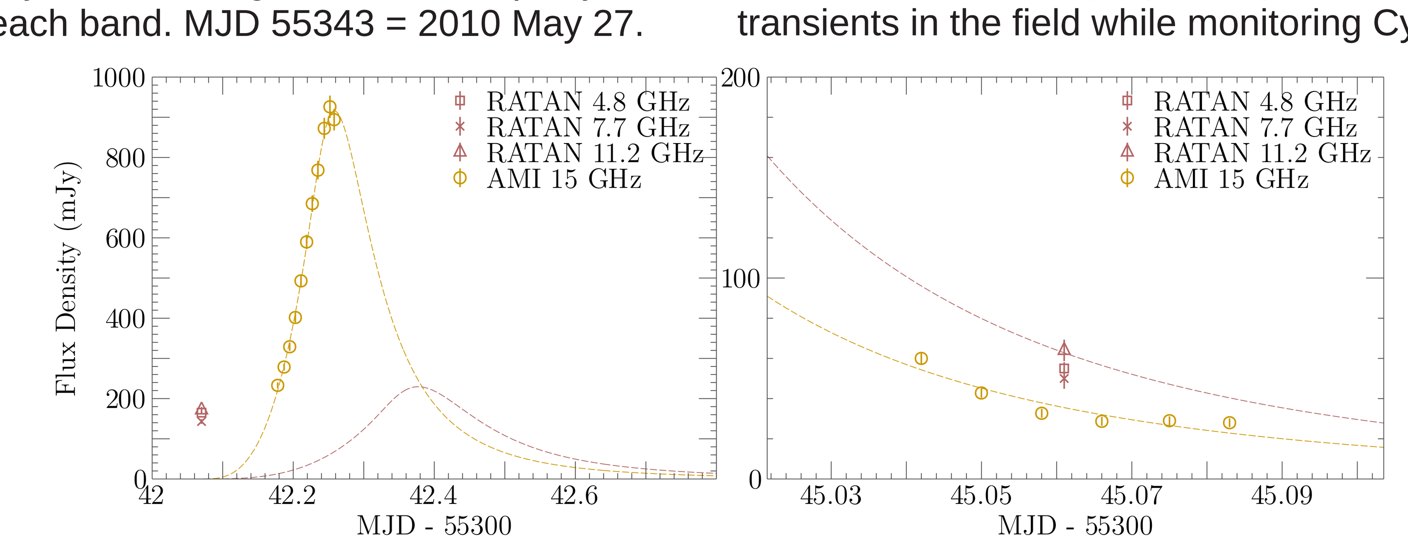
↑ **Chronology of a flare.** Three-band lightcurve of Cyg X–3 shows the relative timing of events in the outburst. While the radio sampling is sparse, observed activity is low during and after the γ–ray flare. The lightcurves are normalized to the peak observed flux in each band. MJD 55343 = 2010 May 27.



↑ **Unique ATA capabilities.** This radio map, centered on Cyg X–3, is 2.13° on a side and is made from repeated observations of a single pointing center. We search for radio transients in the field while monitoring Cyg X–3.



← **Detailed X-ray coverage.** Intensive INTEGRAL observations capture the X-ray evolution of Cyg X–3 as it exits the soft state. Much of the apparent jitter in the data is due to orbital modulation on a 4.8 h period. Vertical markers locate the radio and γ–ray peaks.



← **Radio modeling.** The radio emission can be modeled as an expanding blob of relativistic gas (van der Laan, 1966). Dashed lines denote best-fit models at 4.8 and 15 GHz. The largest radio flare has faded by the time of the γ–ray peak. Note the differing axis scales.

Interpretation

Earlier γ–ray detections of Cyg X–3 have often come ~days before notable radio flaring (Abdo et al., 2009; Tavani, et al., 2009), which is consistent with both the observed γ–ray orbital modulation and a plausible physical picture in which the high-energy emission is due to inverse Compton upscattering of the companion's dense stellar wind. **Our observations strongly suggest a reversed sequencing in the event described here.** Such inconsistent timing properties are commonly observed in blazars (Aller et al., 2010), but the small scale of the Cyg X–3 system makes it difficult to explain how the multiband timing properties of flares could vary so much. Two substantially different mechanisms may be responsible for the γ–ray emission of Cyg X–3.

Next Steps

Shock–in–jet models (e.g., Lindfors et al., 2007) should be investigated, since they may be able to produce γ–ray emission that is delayed compared to the bulk of the radio activity. Because the association of the γ–ray peak with the observed radio flare is so central to our interpretation, the radio emission of Cyg X–3 in its minor flaring state should be statistically characterized, so that the likelihood of other interpretations (e.g. a large, unobserved flare) can be assessed.

References
Abdo AA et al. 2010 Science **326** 840.
Aller MF et al. 2010 arXiv 1007.0258v1.
Corbel S & Hays E. 2010 ATel #2646.
Lindfors EJ et al. 2007 A&A **473** 923.
Pooley GG & Fender RP. 1997 MNRAS **292** 925.
Tavani M et al. 2009 Nature **462** 620.
Tomsick JA et al. 2010 ATel #2644.
Trushkin SA. 2000 A&AT **19** 525.
Trushkin SA et al. 2006 PoS(MQW6)015.
van der Laan H. 1966 Nature **211** 1131.