# Does Cygnus X-3 Emit Gamma Rays?


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GLAST Lunch

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# Things that aren't controversial

- Cygnus X-3 is one of the brightest x-ray sources. It has been known since 1967. It has a period of 4.79 hours, so it must be a binary.
- It's a radio source. It flares by ×1000 once or twice a year for a few days. There are jets, so it is classified as a microquasar.
- There is an EGRET source, 3EG J2033+4118, whose position is consistent with Cyg X-3.

# Why it get complicated (1): dust

It's hard to see. Cyg X-3 has a galactic latitude of 0.7°, and it's located in the Cygnus spiral arm. There is so much dust obscuration that it can't be seen in optical wavelengths.

Infrared observations in 2000 finally verified that the 4.8 hour period is a binary orbit. If the compact object is a neutron star, then the companion has mass 5-11 solar masses. If it's a black hole, then its mass is less than 10 solar masses.

There is no sign of hydrogen, only helium and nitrogen. That means the star is a peculiar one, perhaps a Wolf-Rayet.

The distance estimate is about 9 kpc, based on radio and X-ray absorption and scattering.

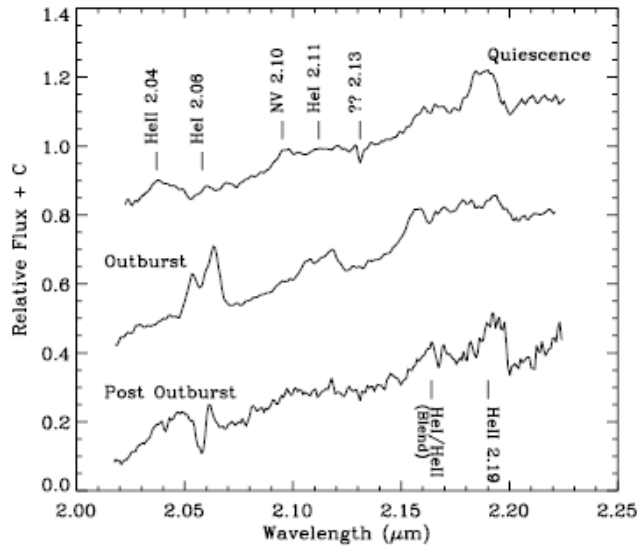



FIG. 1.—*K*-band spectra of Cyg X-3, each displayed with an arbitrary flux offset *C* for clarity. The quiescent spectrum shown at top was taken 1996 June 6 (epoch A, as defined by FHP99). The middle spectrum was taken 1997 June 19 (epoch C) during very extreme radio and X-ray flaring of the system. The bottom spectrum was taken 1997 October 15 (epoch D). During this time, small X-ray flaring was still occurring, but the system was now in "postoutburst."

# Why it gets complicated (2)

- The X-ray brightness varies greatly from one 4.8 hour period to the next. There is some phase scatter. The radio emission isn't periodic at all.
- In this part of the sky we are looking lengthwise along a spiral arm. It's crowded with lots of young stellar objects of all sorts. There are at least 4 EGRET point sources in close proximity.
- The 4.8 hour period is about 1/5 of a day. This can cause aliasing for ground-based observatories. A similar thing happens to satellites because 4.8 hours is about 3 rotations in low-earth orbit.

# Radio morphology

Jets have been seen on scales of milli-arcseconds, arcseconds, and arcminutes.

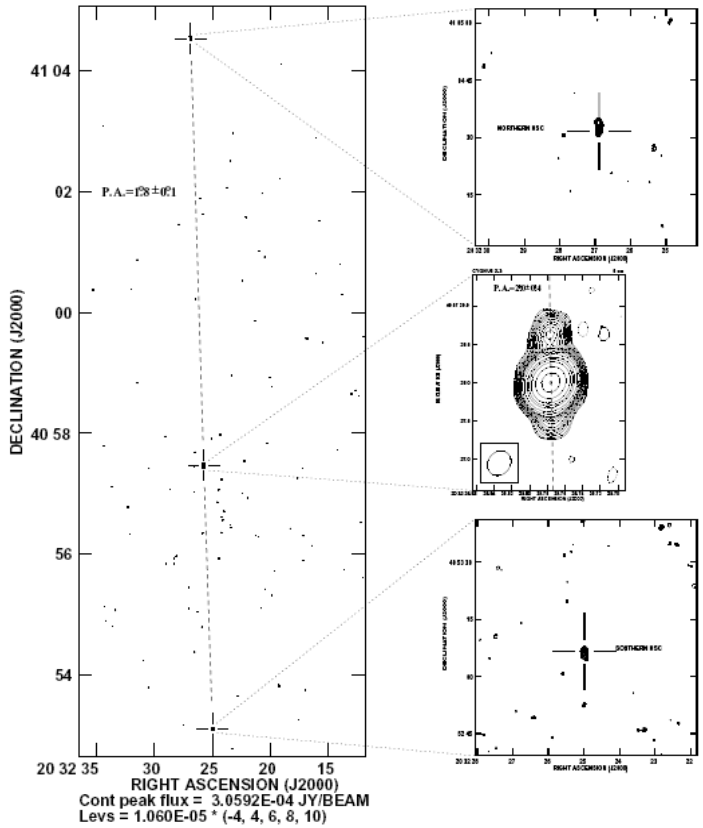



Fig. 1. Natural weight 6 cm map of the Cygnus X-3 field. This map covers almost the totality of the antenna primary beam and shows the existence of two radio sources perfectly aligned with the PA of the inner radio jets. A close-up look at the locations is given on the right top and bottom pannels. Note the remarkable effect of the bandwidth smearing that affected the archival data which caused the sources to appear elongated. The central pannel was taken from Marti et al 2001 and included for illustrative purposes corresponding to other observation of the Cygnus X-3 arc-second radio jets.

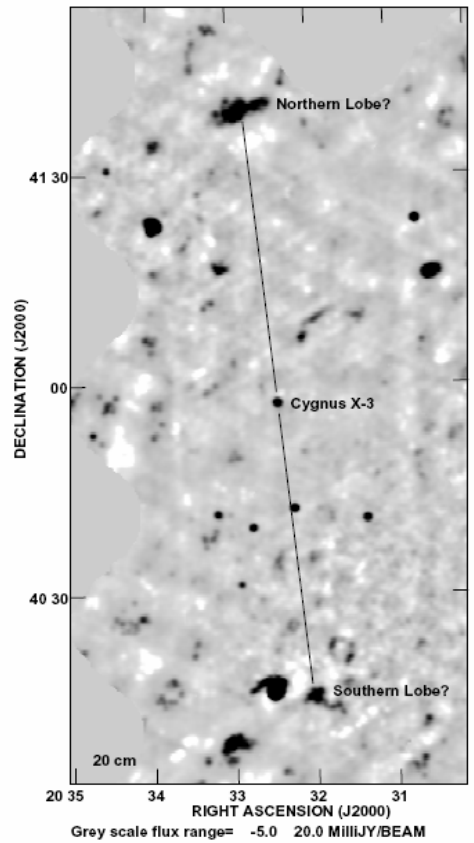
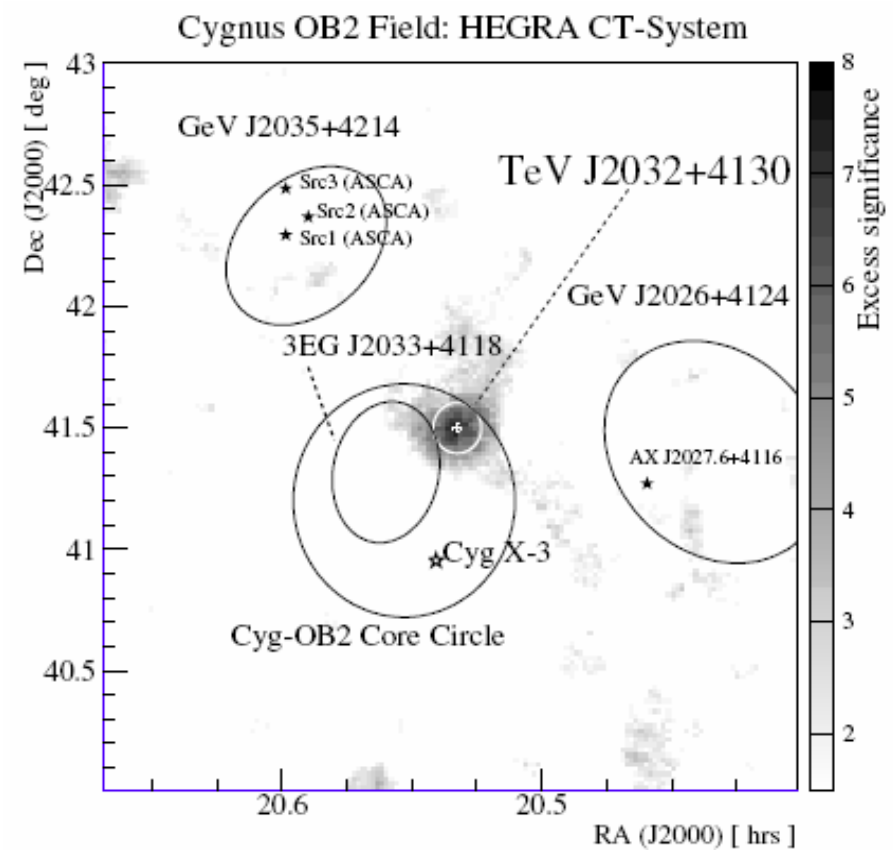



FIG. 5.—Wide-field NVSS map of the Cygnus X-3 region at the 20 cm wavelength and with 45″ resolution. The existence of two H II "lobe" regions in a perfectly symmetric position with respect to Cygnus X-3 is evident. The position angle of this alignment is also quite consistent with that of the arcsecond radio jets.

# TeV and above

- Reports of detections from 0.1 TeV up to 20 PeV began in 1972. Cyg X-3 was one of the few sources confirmed by more than one observing group. It almost single-handedly caused the field of UHE gamma astronomy to continue.
- Brazier et al. (1990) saw 12.59 ms periodic emission during several bursts of a few minutes duration at X-ray maximum.
- Modern UHE measurements show that Cyg X-3 might not be there at all.



# 100 MeV pre-EGRET

- SAS II: strong 4.8-hour pulsation
- COS-B: not detected at all

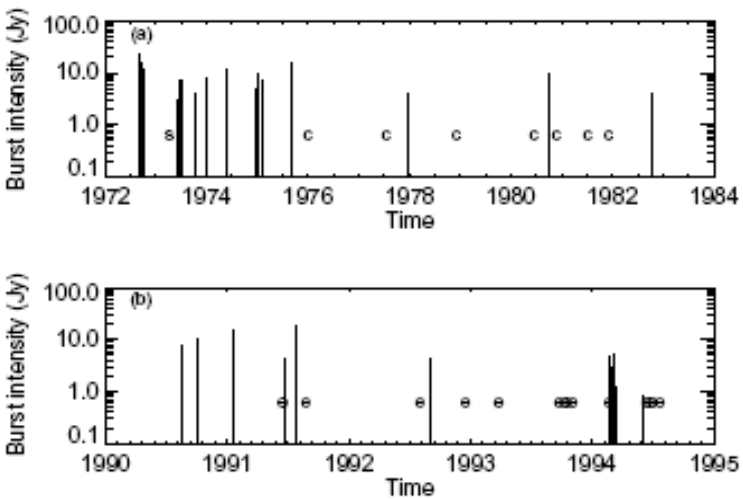



FIG. 1.—Times of occurrence and peak intensities of radio bursts in Cygnus X-3 are shown. (*a*) Covers the period 1972–1983 (see Woodsworth 1983 for details) and (*b*) covers the period 1990–1994.5 (see Waltman et al. 1995 for details). Exposure times of *SAS 2* and *COS B* on Cyg X-3 are shown by the letters "s" and "c," respectively, in (*a*), and those of EGRET are shown by the letter "e" in (*b*).

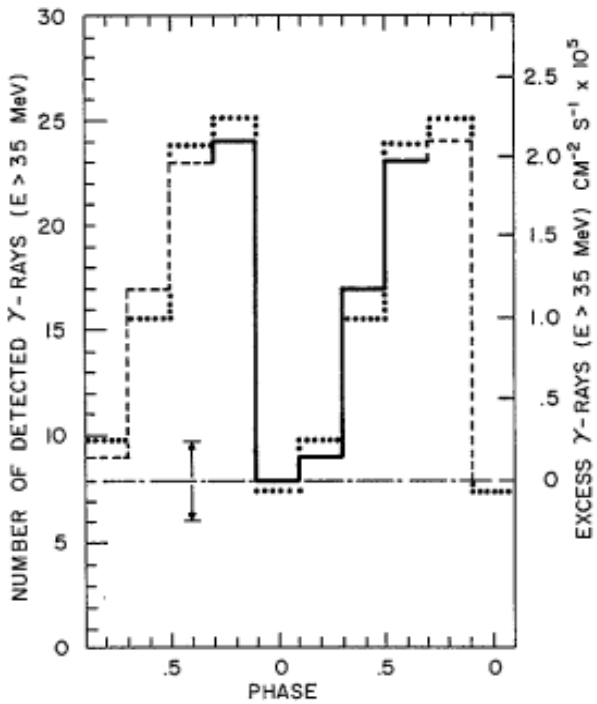



FIG. 1.—The solid line shows the distribution of arrival times of all detected γ-rays ($E > 35$ MeV) from the region of Cyg X-3 in fractions of the ($0^d1996814 \pm 0^d0000005$) period. The zero of time corresponds to the X-ray minimum defined by Parsignault *et al.* (1976). Dashed portions of the plot are repeated parts of the single period distribution, shown to emphasize the periodicity. The dotted lines show the number of γ-rays normalized to the average SAS-2 exposure to Cyg X-3. The dot-dashed line shows the estimated contribution from diffuse celestial and galactic radiation, together with its uncertainty. The scale on the right shows the conversion of the excess to photon flux, which contains an additional systematic uncertainty of about 10%.

# EGRET

EGRET resolves 4 point sources in the Cygnus region, one of which is consistent with the position of Cyg X-3. Take that with a grain of salt.

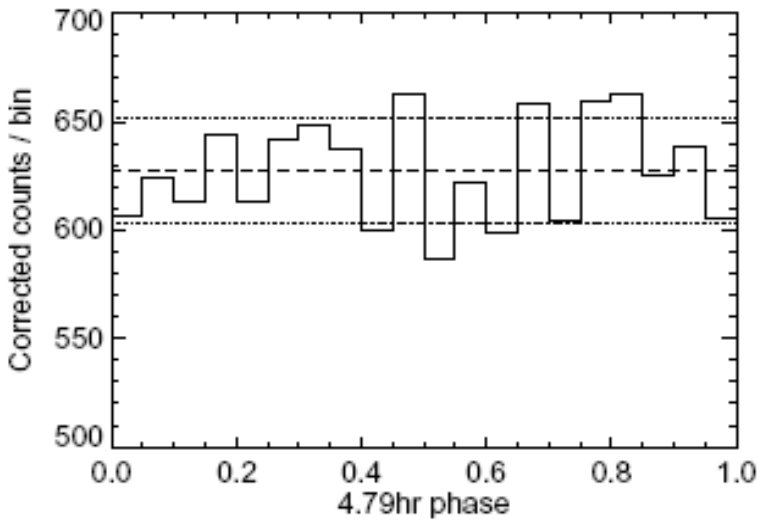


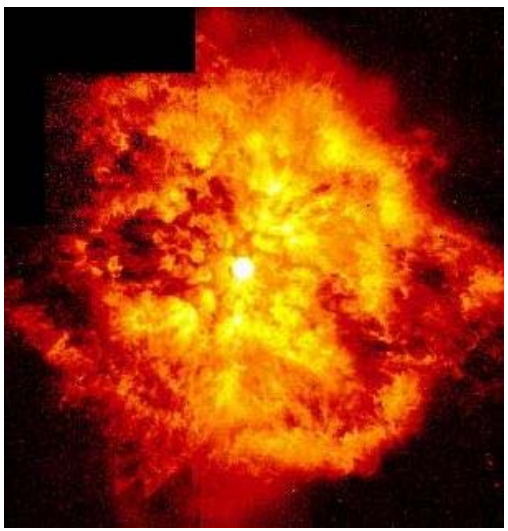

FIG. 2.—Phase histogram of event times of gamma rays at energies greater than 50 MeV arriving from the direction of Cygnus X-3 is shown by the solid line. The average and 1 $\sigma$ error bars are shown by the dashed and dotted lines, respectively. Event numbers in each phase bin are corrected for nonuniform exposure.

Mori et al. (1997) found no sign of 4.8-hour pulsation at a level much lower than SAS II.

There was also no sign of periodic variation at 12.59 ms in 10-minute windows at X-ray maximum.

# Wolf-Rayet stars

A W-R star is "A hot (25,000 to 50,000 K), massive (more than 25 solar masses), luminous star in an advanced stage of evolution, which is losing mass in the form a powerful stellar wind. Wolf-Rayets are believed to be O stars that have lost their hydrogen envelopes, leaving their helium cores exposed, often in a binary system, and that are doomed, within a few million years, to explode as Type Ib or Ic supernovae. There are two spectral subclasses of Wolf-Rayets: type WN, which have prominent emission lines of helium and nitrogen, and type WC in which carbon, oxygen and helium lines dominate. They are named after the French astronomers Charles Wolf (1827-1918) and Georges Rayet (1839-1906) who studied the first example in 1867. "



HST image of WR124 in H$\alpha$

W-R stars lose $10^{-6}$ to $10^{-5}$ solar mass per year at up to 5000 km/s. The wind is driven by radiation pressure. This enormous wind is a possible gamma source if it shocks on a dense interstellar medium. If Cyg X-3 has a W-R star, it's the only known W-R/compact binary.

# The GLAST connection

- We need GLAST's angular resolution to sort out the mess in the Cygnus region. Is there really a point source at the right spot?
- If Cyg X-3 has rare gamma outbursts, we need long-term quasi-continuous monitoring.