High Energy Phenomena in Relativistic Outflows III (HEPRO III)

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AN EXPERIMENT TO LOCATE THE SITE IN M87 OF TeV FLARING

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We describe a Chandra ToO project designed to isolate the site of TeV flaring in the radio galaxy M87. To date, we have triggered the Chandra observations only once (2010 April) and by the time of our first observation, the TeV flare had ended. However, we found that the X-ray intensity of the unresolved nucleus was at an elevated level at the time of our first of 9 observations. Of the $\sim$70 observations we have made of the M87 jet covering 9 years, the nucleus was measured at > 1 keV/s only 3 times. Two of these occasions can be associated with TeV flaring, and at the time of the third event, there were no TeV monitoring activities. We discuss the implications of these data.

Keywords: galaxies: active; galaxies: individual(M87); galaxies: jets; X-rays: general

1. The Problem

Although M87 is normally a weak source at TeV energies, occasionally there is flaring activity which lasts for some days. During these times, the observed TeV intensity can peak at $\geq$ 10% Crab. To date there have been 3 well documented flarings:

- 2005 April - H.E.S.S. found highly variable TeV emission with typical timescales of a few days[1]. Since this event coincided with the peak of the giant flare (radio/uv/X-ray) from the knot HST-1 which lies at $0.86''$ (60pc in projection) from the nucleus of M87, there has been an on-going debate as to whether the TeV emission originated near the SMBH or from HST-1.
- 2008 Feb - A second flaring event was observed by several Cherenkov observatories. By chance, a series of VLBA observations was underway by R. C. Walker at 43 GHz: the milli arcsec nucleus progressivly brightened[2].
- 2010 Apr - This event was observed by H.E.S.S., MAGIC, and VERITAS[3]. Once the reality of the flaring was established, a Chandra ToO was triggered and these results are the subject of this presentation. Although HST-1 has declined from its peak intensity in 2005 to levels similar to those in 2000, the nuclear X-ray emission was at a somewhat higher level than usual. However, no activity at 43 GHz was detected from the nucleus. For more details, see the contribution by Raue at this meeting.

From the TeV variability time scale, it is deduced that the TeV emitting region is of the order of a few light days times δ, the unknown beaming factor. Although we have not found such short time scale variability in the X-rays from HST–1, the nucleus has a somewhat shorter time scale for variability than the 20 days of HST-1[6].

So the open question is, can we determine the site of the TeV flaring by identifying common features in the X-ray lightcurves of any of the labelled features in fig. 1 with the TeV lightcurve?

2. The Experiment

The basic idea for the Chandra ToO is to trigger a series of observations when the TeV exhibited a level of 7% Crab. With luck, we had hoped that the X-ray light curve of either the nucleus or HST-1 would divulge some feature that would correspond to the TeV excursions. The main problem for this experiment is the brevity of the TeV flaring compared to the time it takes for mission planning to alter the observing schedule and upload a revised observing schedule.

Our strategy was to make the first observation as soon as possible, and then to follow the first with 4 more 5ks observations spaced at intervals of between 1.5 and 3 days. We then had 4 more observations, the first of which would start at the beginning of the next dark of the moon fortnight, and these would be spaced by 3 ± 1 days.

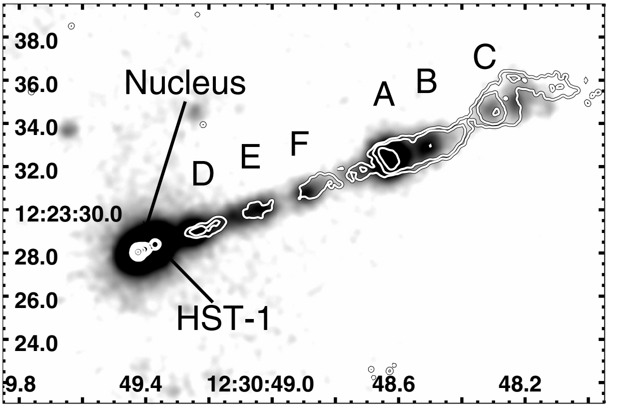

Fig. 1. A Chandra X-ray image of the M87 jet with 8 GHz radio contours overlaid.

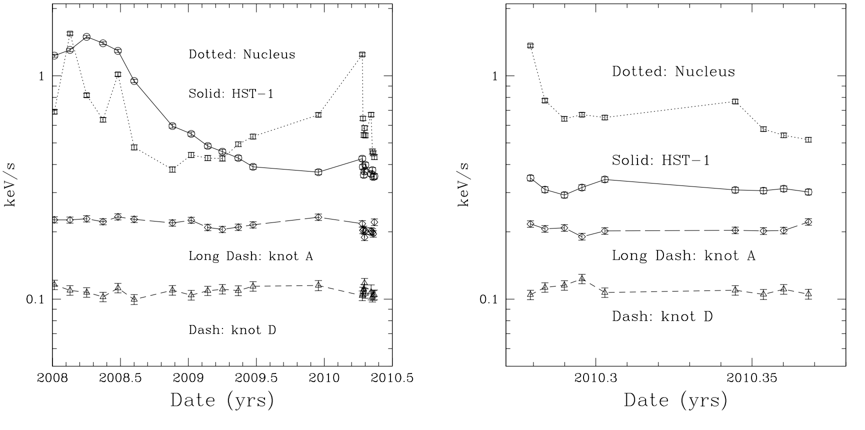

Fig. 2. The X-ray lightcurves for the nucleus, HST-1, knot D, and knot A. *left* The X-ray lightcurves for two years preceeding the 2010 Apr flaring. *right* The 9 observations of this experiment. The y axis corresponds to 9 April; our first observation was on 11 April. Shortly before our first observation, there were no more TeV detections.

On Friday, 9 April 2010 the trigger level was realized and our first observation was late in the day on Sunday, 11 April. Unfortunately, the final elevated TeV level occurred on Saturday night; by Sunday night when we observed, the TeV emission was too low for detection.

3. The Results

If the predominant emission mechanism for the nuclear X-rays is synchrotron emission as it is for HST-1[4,5,6], then there must be a sizable population of high energy relativistic electrons whose IC emission will be in the TeV range. In fig. 2 we show the light curves for the nucleus and knots HST-1, D, and A. In the right panel, note the high level of the nucleus at our first observation and the sharp drop to more normal levels by the time of the second observation. For comparison, the left panel of fig. 2 shows the same sort of lightcurves for the preceeding 2 years.

In one sense, our experiment failed, but in another, it yielded tantalizing hints that we most likely witnessed the tail end of a period of X-ray flaring associated with the TeV flaring. The intriging question is what we might have seen if Chandra observations had begun a few days earlier. If the slope of the nuclear light curve before our first observation was similar to that between the first two observations, the X-ray intensity of the nucleus during the TeV flaring would have been remarkable.

During our 8 years of monitoring the M87 jet with Chandra, the nuclear emission has seldom been larger than 1 keV/s: on two occasions (2008 Feb 16 and 2010 Apr 11) these levels were in close proximity to TeV flaring. A third time (2006 Jun 28), there was no TeV coverage, and for the 2005 April TeV flaring, our data are not reliable because of second order pileup affects associated with HST-1. A more detailed analysis of these data, including evidence for a spectral dependency on the rate at which the nuclear intensity dropped between our first two observations, is scheduled to appear in the 10 Dec 2011 issue of the ApJ[7].

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