Variability Timescales in the M87 Jet

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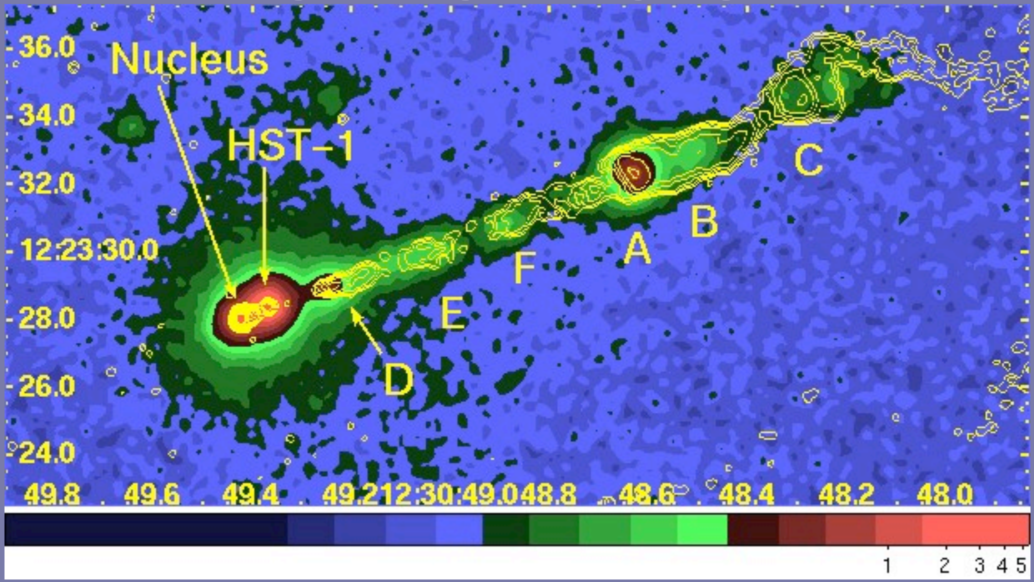
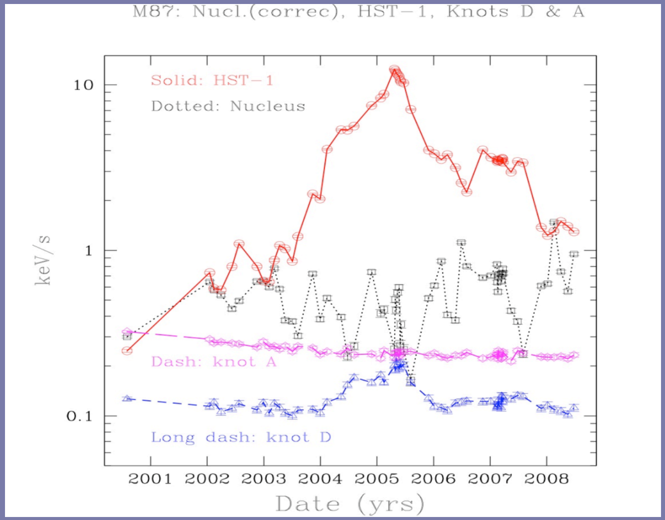
- **INTRODUCTION, METHODS, & PROBLEMS**
- **THE TEV CONNECTION: SITE OF EXCESS**
- **SIGNATURES OF E^2 LOSSES**
- **IMPULSIVE BRIGHTENING IN HST-1**

BACKGROUND



- Nucleus: varies between 0.2 and 1.5 keV/s
- HST-1 at 0.86" (60pc projected) is the site of giant flare: more than factor of 50!
- Knot D is affected by HST-1
- Knot A shows ACIS contamination

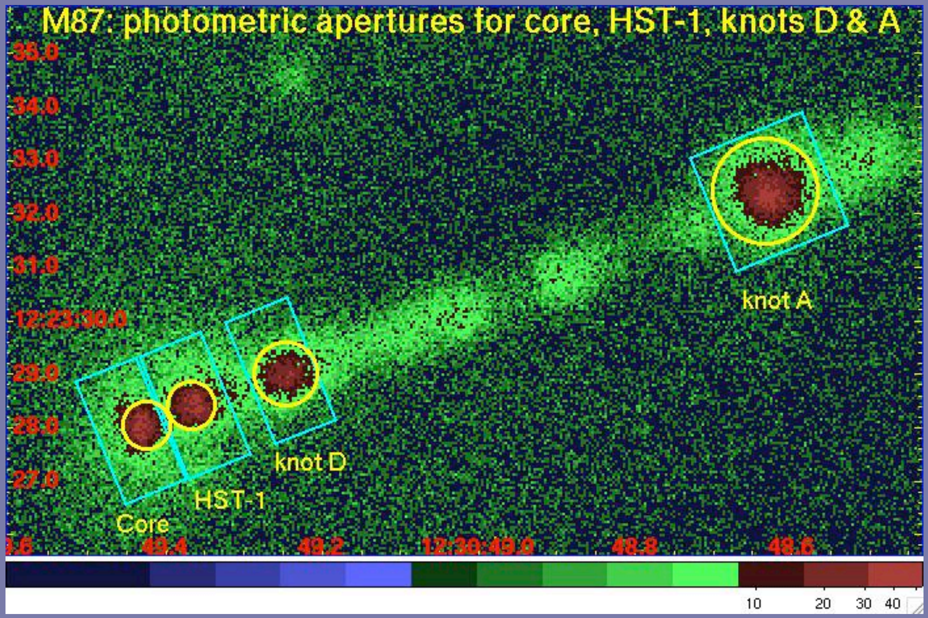


BACKGROUND: RADIO

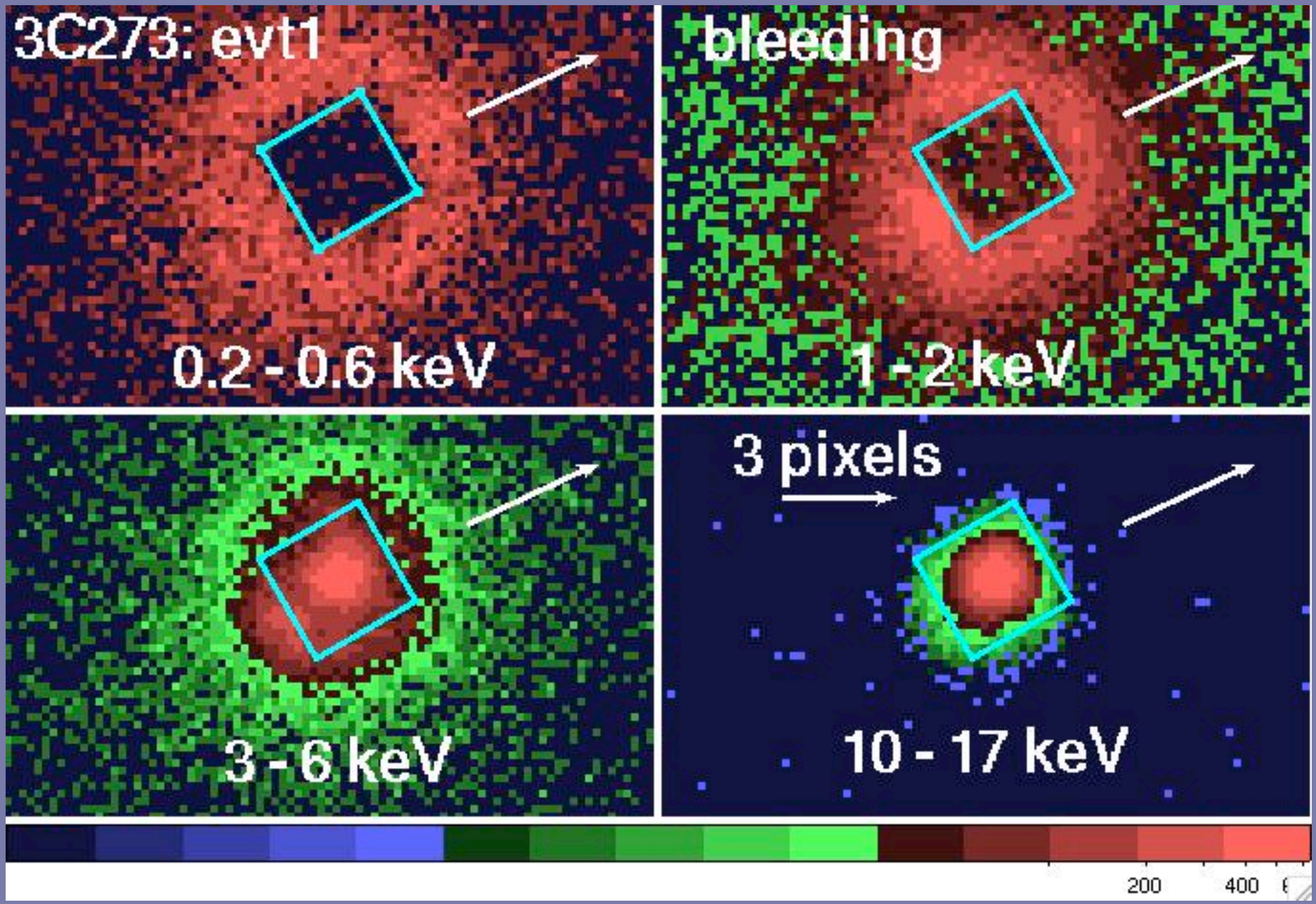
- From VLBA observations at 1.5 GHz, we find superluminal proper motions in HST-1 (~4c).
- For no acceleration, component was ‘emitted’ (from upstream end) ~ 2002 (prior to peak of major flare).

Methods: Intensities for light curves: -pileup mitigation-

- Filter evt1 for GTI, but not grade (recover migration)
- Multiply each event by its energy; sum from 0.2 - 17 keV
- For the nucleus, subtract 5% of HST-1

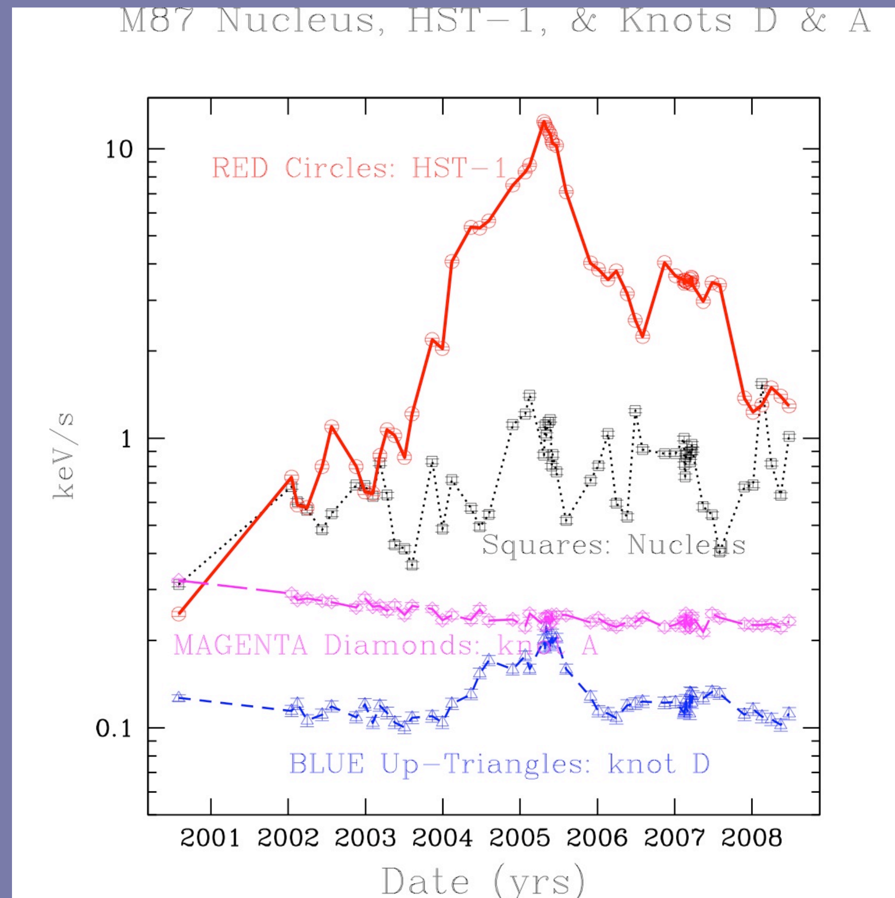


Problem: Pileup can produce a secondary peak in PSF from release of trapped charge at readout time



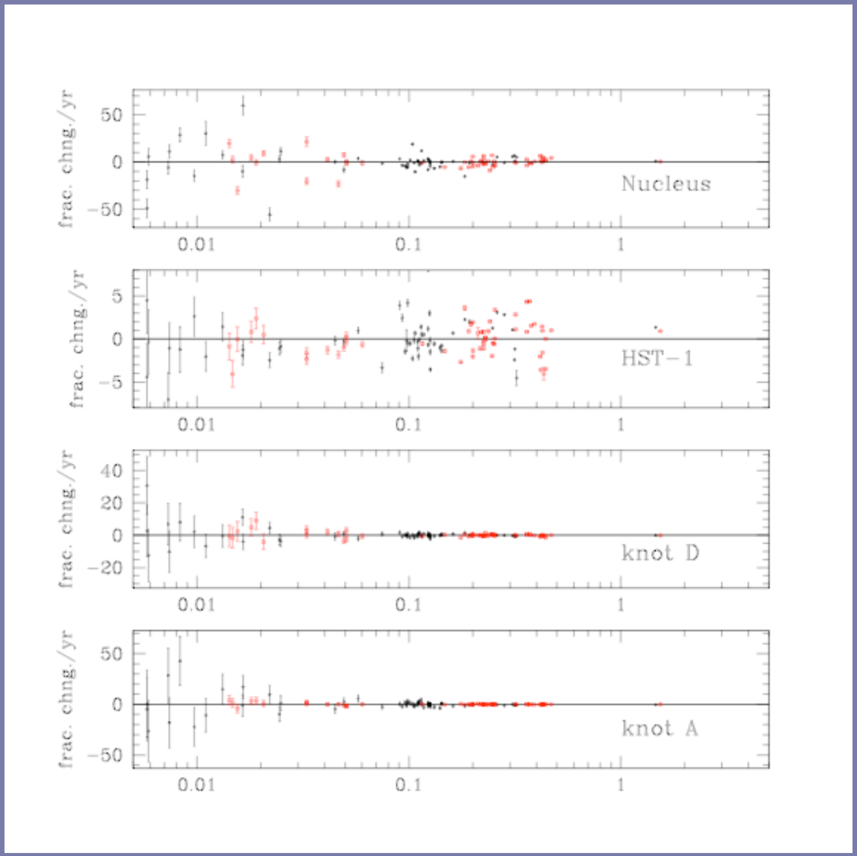
Problem: Cross-talk from HST-1

- The PA of the secondary peak rotates during the observing season.
- Before mid-March the major effect is on the nucleus; after that date it affects mainly knot D.
- For this reason, the best data for the nucleus is restricted to times when HST-1 < 4 keV/s



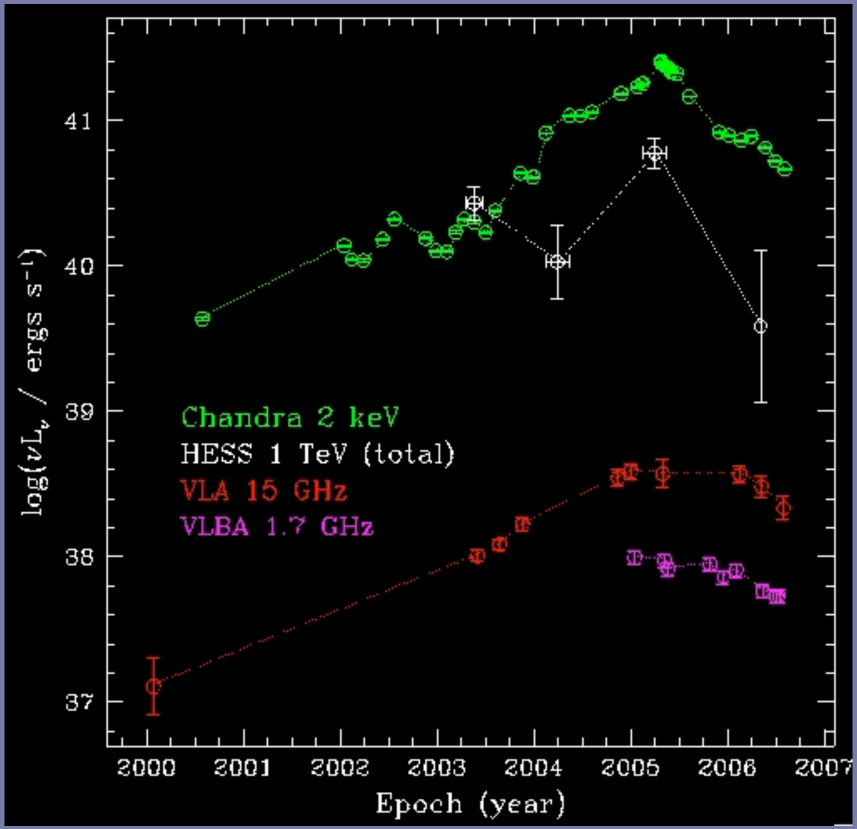
Methods: First Derivative of LC

- To study timescales, we calculate the slope between adjacent (black) and every other (red) observation.
- The fractional change per year for increasing intensities is fpy(+) = $[(I_2/I_1) - 1] / \Delta T$, and for decreasing intensities fpy(-) = $[1 - (I_1/I_2)] / \Delta T$
- Thus a value of fpy=±1 corresponds to a change by a factor of 2 in a year.



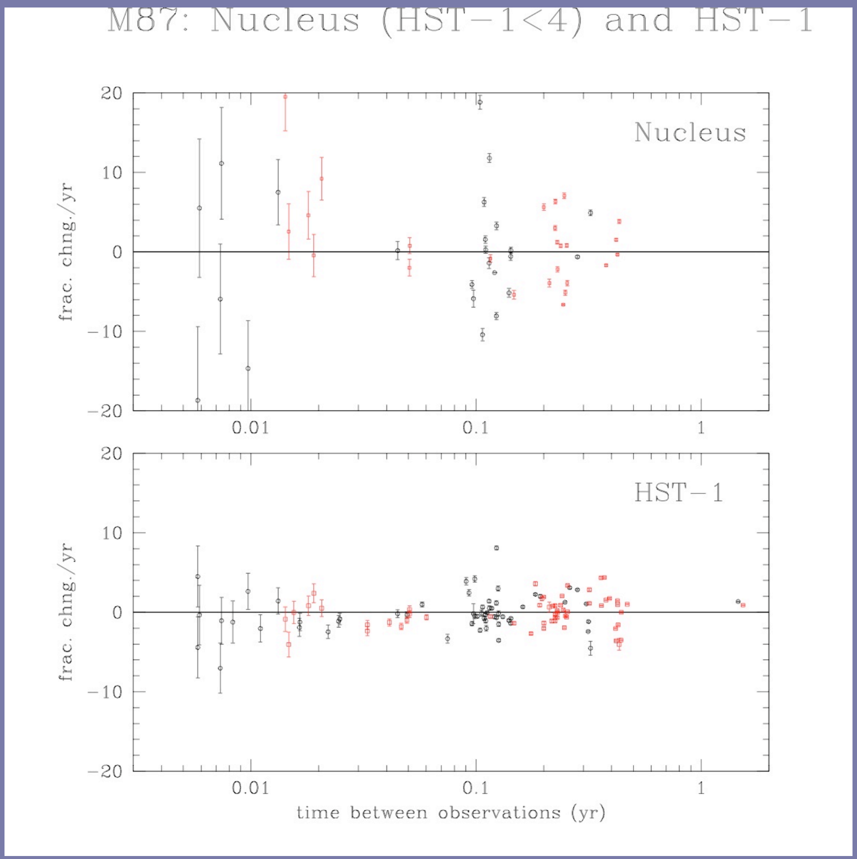
The TeV connection

The HESS group reported a higher gamma ray flux in 2005. They argued that because of rapid variability, the likely origin was the nucleus (close to SMBH) in spite of the similarity of their γ-ray light curve to the X-ray light curve of HST-1.

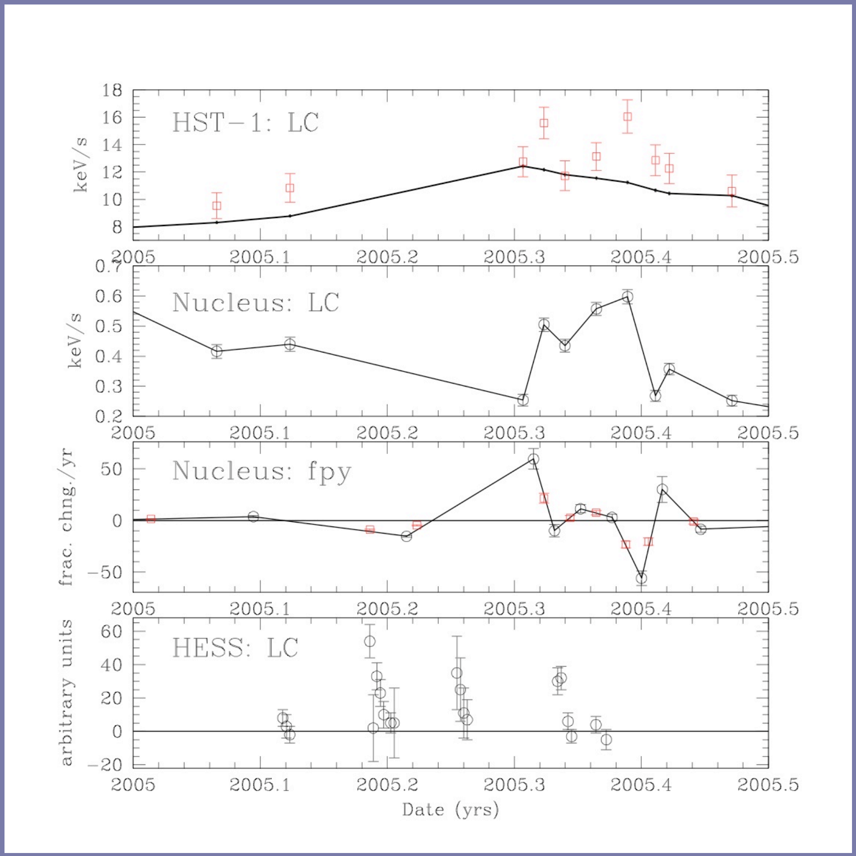


Comparing variability timescales between the nucleus and HST-1

- Both the 2005 HESS 'event' and the 2008 Feb (MAGIC & VERITAS) TeV flaring displayed variability over a few days.
- The Chandra data indicate that although the nucleus never experienced a giant flare like that in HST-1, its 'flickering" is characterized by larger values of fractional change per year.



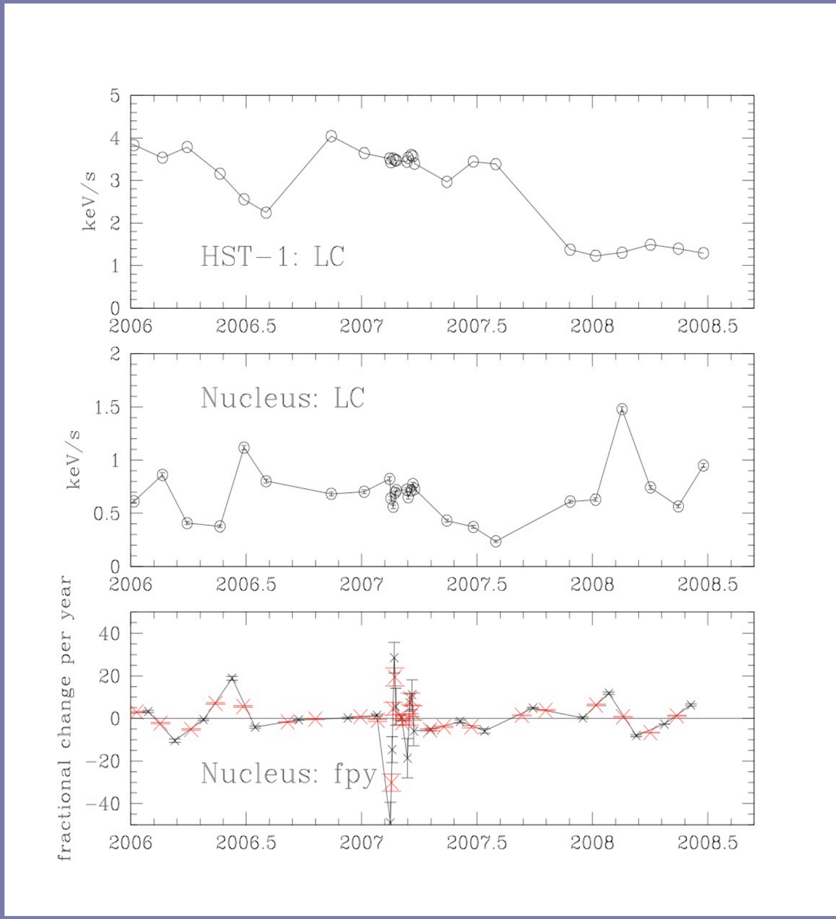
The First TeV Event



2005 Apr (peak of HST-1 flare): Although there is possible contamination of the nucleus by HST-1 di/dt(nucleus) reached +50 (doubling time of < 7 days). [During a short campaign of weekly Chandra observations]

The Second TeV Event

2008 Feb: At the time of the TeV flaring observed by MAGIC and VERITAS the nucleus reached its highest observed level and di/dt = 11.8±0.5. [Normal monitoring; every 6 weeks]



The TeV Connection: Summary

In favor of the nucleus:

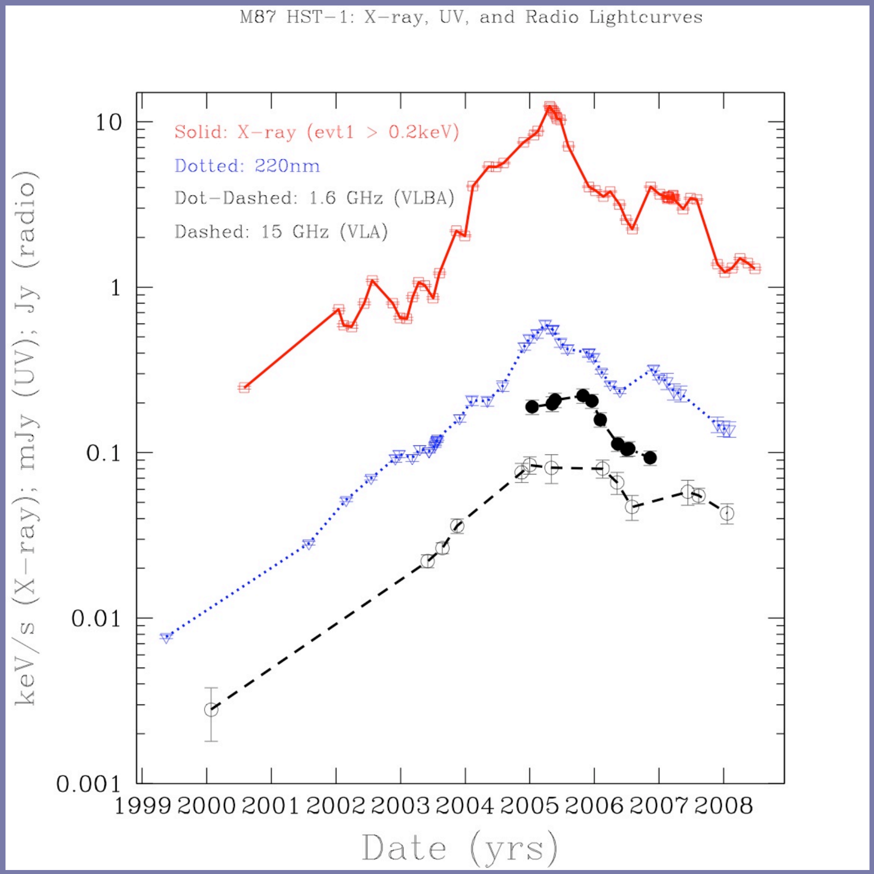
- Easier to get source size ~ few light days
- Faster flickering in X-rays
- Coincidence in 2008 Feb TeV flaring with X-ray level and di/dt

In favor of HST-1:

- The observed (radio) size of HST-1 is of order 0.7 light years and the inferred size from the X-ray variability is of order 0.2 light years ($*\delta$).
- Coincidence of peaks in light curve (2005).
- With an SSC model, we expect to get IC scattering at TeV frequencies.
- There is much less of a problem getting TeV photons out of HST-1 than out of the nucleus.

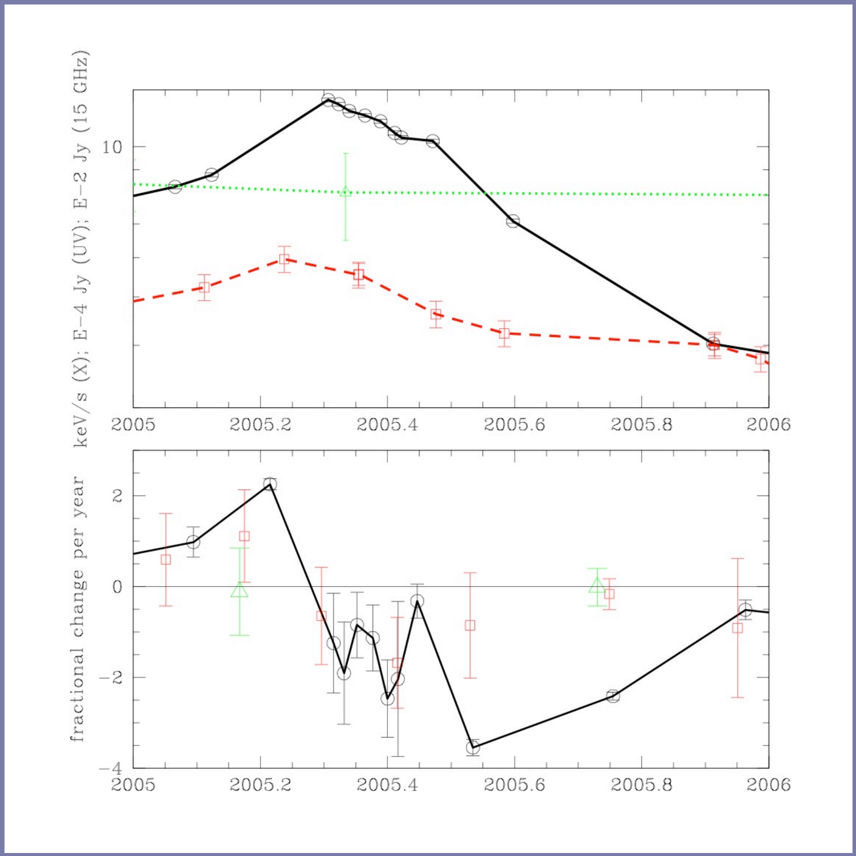
Signatures of E^2 Losses for HST-1

- If all frequencies decay together, expansion losses dominate or the beaming factor is changing.
- If E^2 losses (synchrotron & IC) are important, we expect longer decay times for lower frequencies.

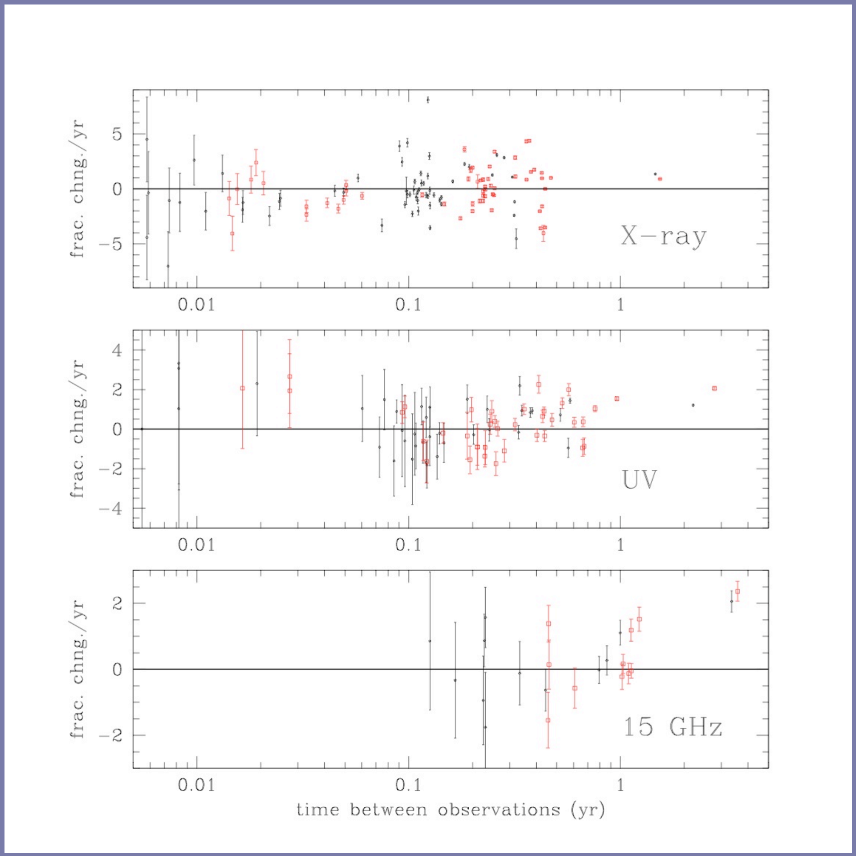


The 2005 Decay

- During the decay of the giant flare, there is a shoulder in the UV light curve.
- fpy = -3.5±0.2 for X-rays
  fpy = -0.85 ± 1.16 for UV
- If the X-ray value were to arise from synchrotron losses, B ≈ 1 mG for δ=4, the same field strength found by equipartition calculations.

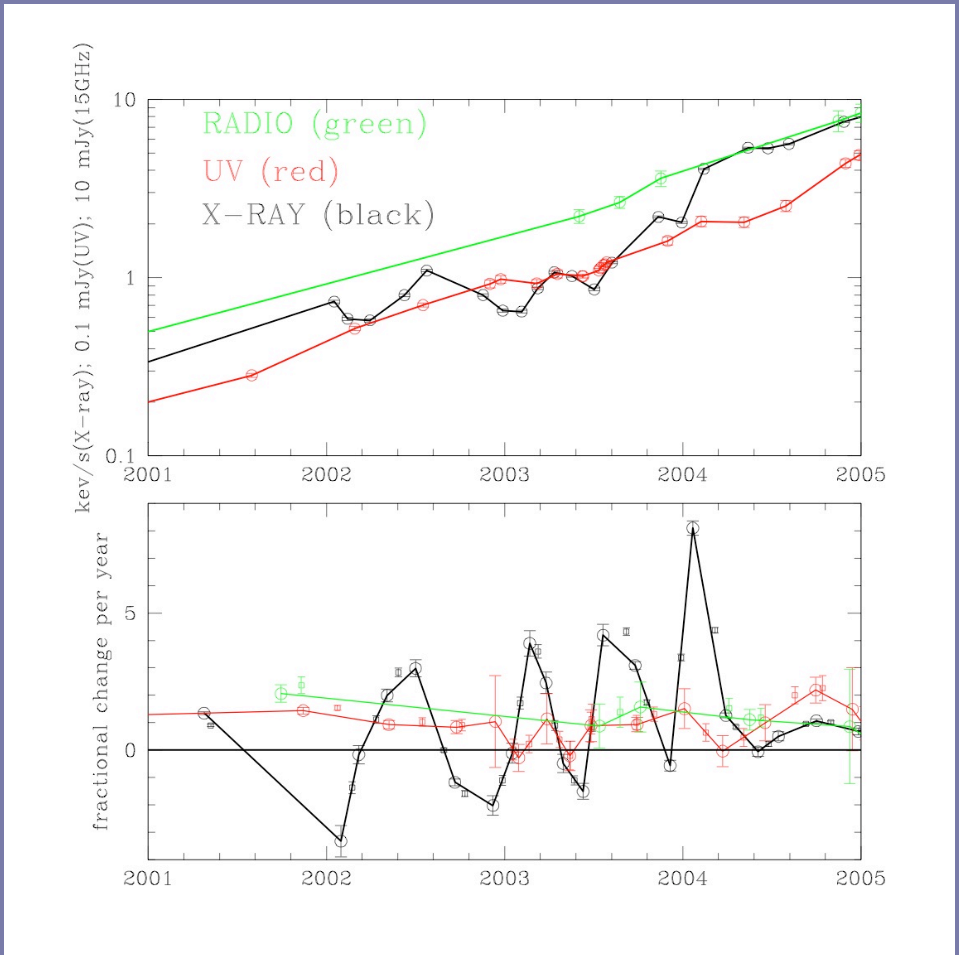


Comparative di/dt values: X-ray, UV, & Radio



- Granted the large error bars & poor sampling in the radio, the most negative values of fpy are -5 for X-rays; -2 for UV, and -1 for radio.
- We suspect that while expansion losses play a significant role, E^2 losses contribute to the frequency dependence.
- These data are inconsistent with a simple expansion for a simple power law.

Discovery of impulsive brightening in HST-1



The River Analogy

- A jet is like a smoothly flowing river; observable emission arises only where there is white water.
- Even though HST-1 increased its emission by more than a factor of 50, the power so dissipated is less than one percent of the total power believed to be flowing down the jet.
- A large rock may have been dropped into the river; or perhaps there was a release of water from an upstream dam………

A Wager

Although I have not been able to identify a criterion for deciding the outcome, I wager the classical bottle of wine that:

The oscillations in brightening and fading of HST-1 arise from a local instability or naturally occurring characteristic frequency rather than from a change in the power flow of the entire jet.

[this is a personal wager, and does not involve my co-authors!]

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