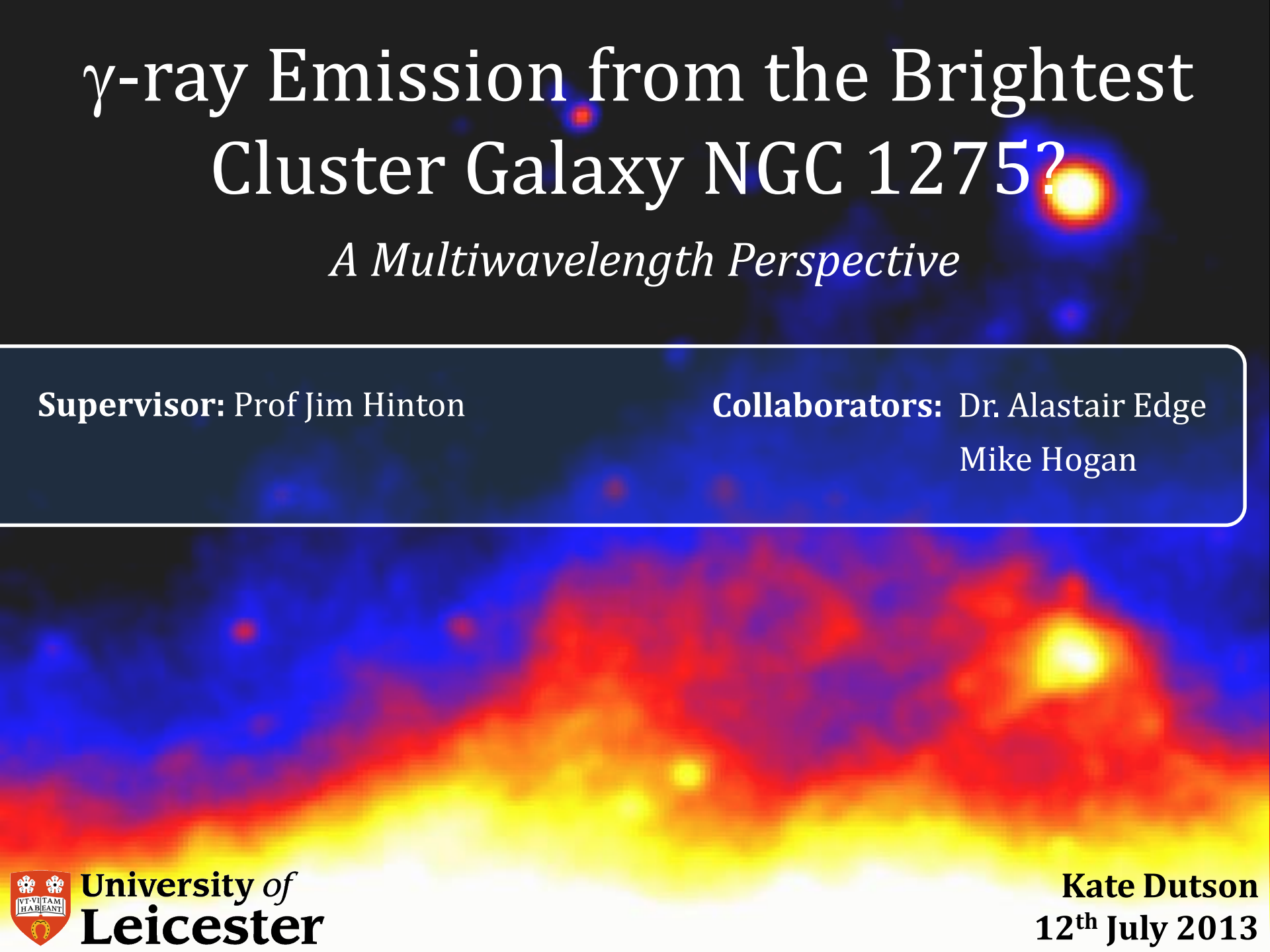
γ-ray Emission from the Brightest Cluster Galaxy NGC 1275?

A Multiwavelength Perspective



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Mike Hogan

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12th July 2013

An Outline…

- A Case Study of a Galaxy Cluster
  - NGC 1275 – a non-thermal picture
  - Emission scenarios and scales
- Some words about *Fermi*
  - The analysis procedure
- The work
  - Temporal and spectral analysis
  - Preliminary results and interpretation

Galaxy Clusters

- Largest gravitationally-bound structures in the Universe
- Bremsstrahlung X-rays reveal hot intra-cluster gas (10^7 – 10^8 K)
- Presence of dark matter inferred
- *Cooling flows* where

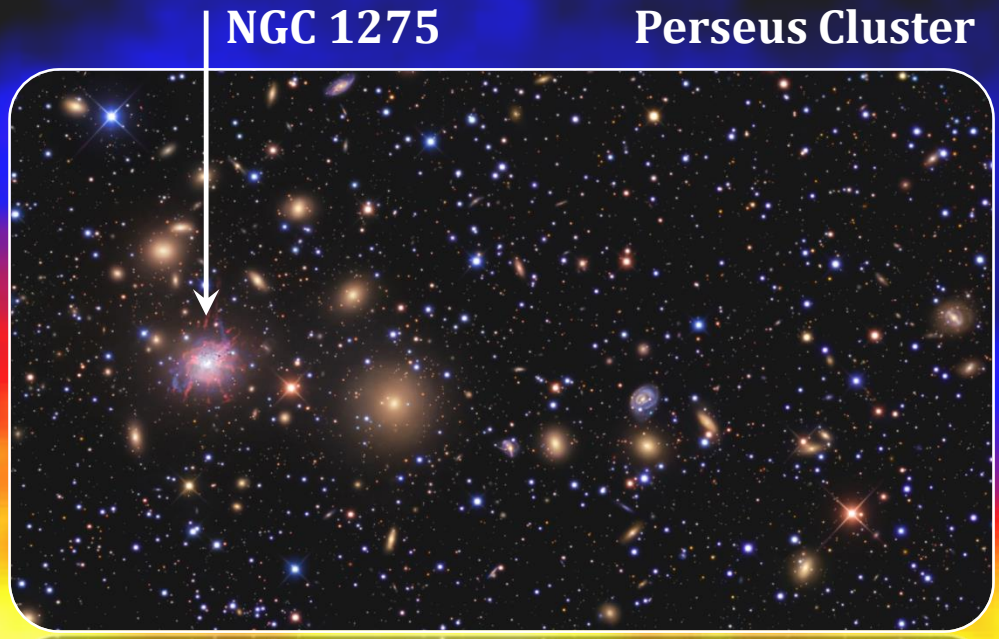
$$t_{\mathrm{cool}} < t_{\mathrm{age}}$$

Pandora's Cluster

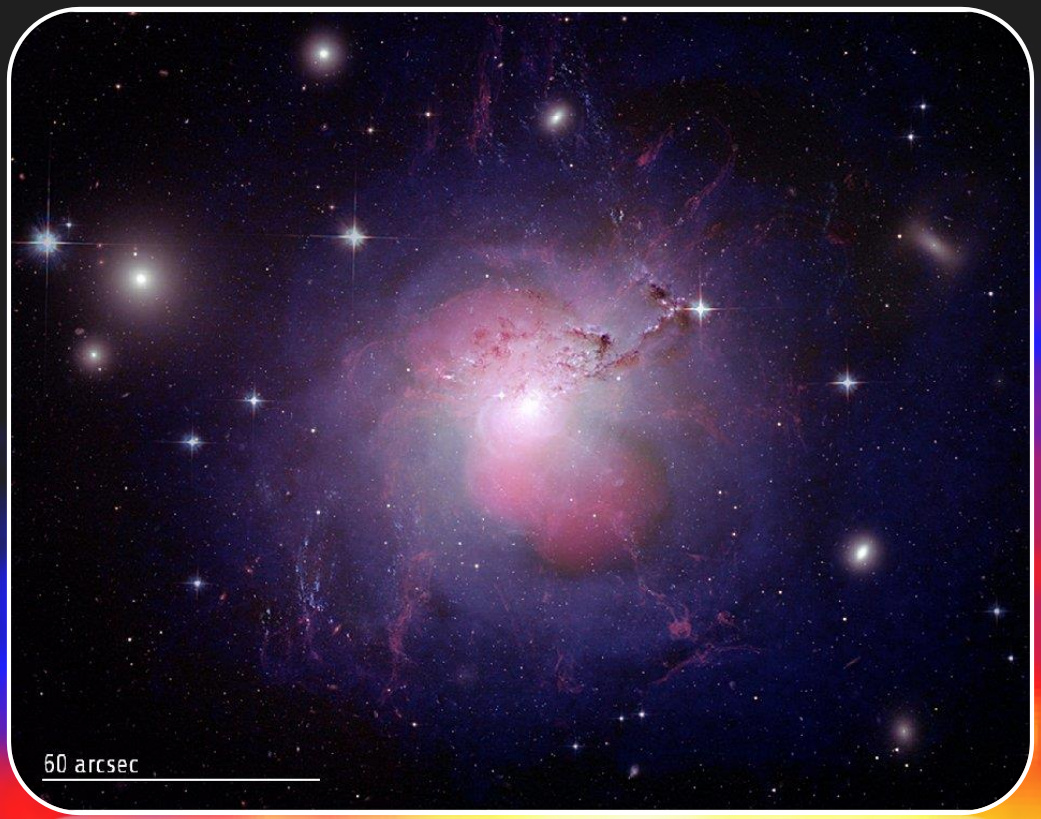
Galaxy Clusters - BCGs

- In *cooling-core* clusters suppression of the cooling flow is observed, necessitating some reheating mechanism…
- Feedback from the central Brightest Cluster Galaxy (BCG) suggested.
- Gamma rays from AGN-driven processes

Prototypical case:



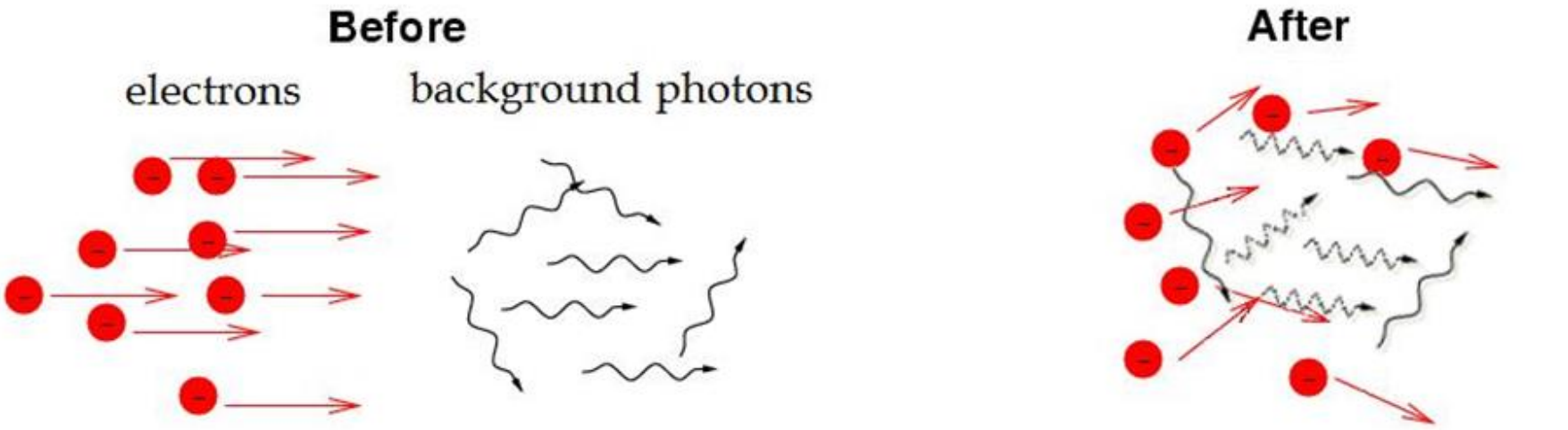
NGC 1275 – A Non-thermal picture



- S-shaped radio lobes and relic 'ghost' bubbles suggest misaligned blazar of precessing jets blowing bubbles of relativistic plasma into the ICM
- Anticorrelation of radio (pink) and X-ray (blue) emission features

γ-rays from Clusters and BCGs?

- Gamma radiation is a tracer of Cosmic-ray acceleration.
- Clusters of galaxies are reservoirs of non-thermal particles.
- HE Emission via inverse Compton scattering:



γ-rays from Clusters and BCGs?

- Gamma radiation is a tracer of Cosmic-ray acceleration.
- Clusters of galaxies are reservoirs of non-thermal particles.
- HE Emission via inelastic proton-proton collisions:

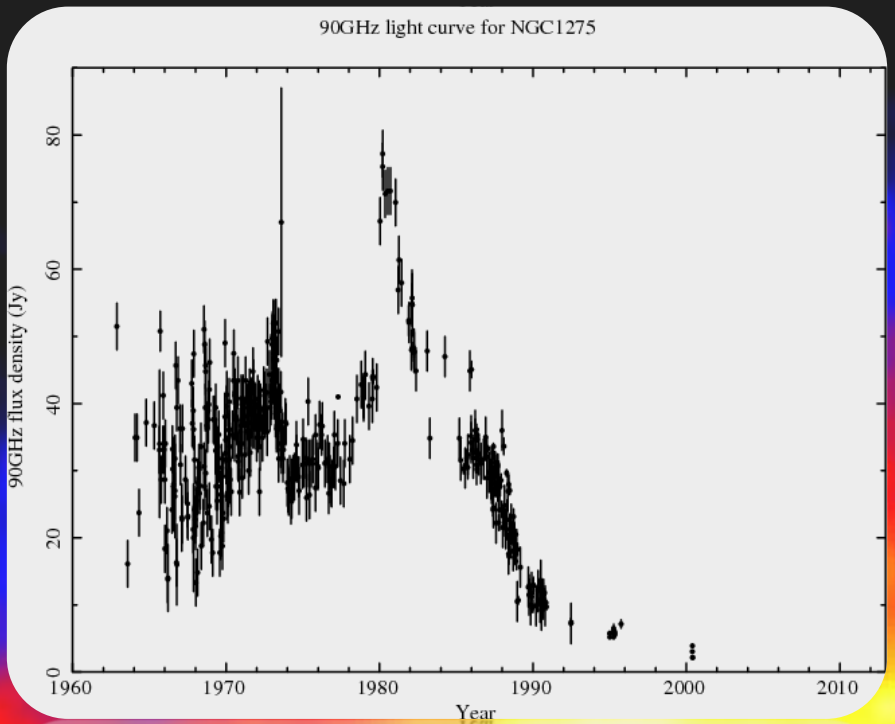
$$p + p \rightarrow p + p + \pi^0 \qquad \pi^0 \rightarrow \gamma\gamma$$

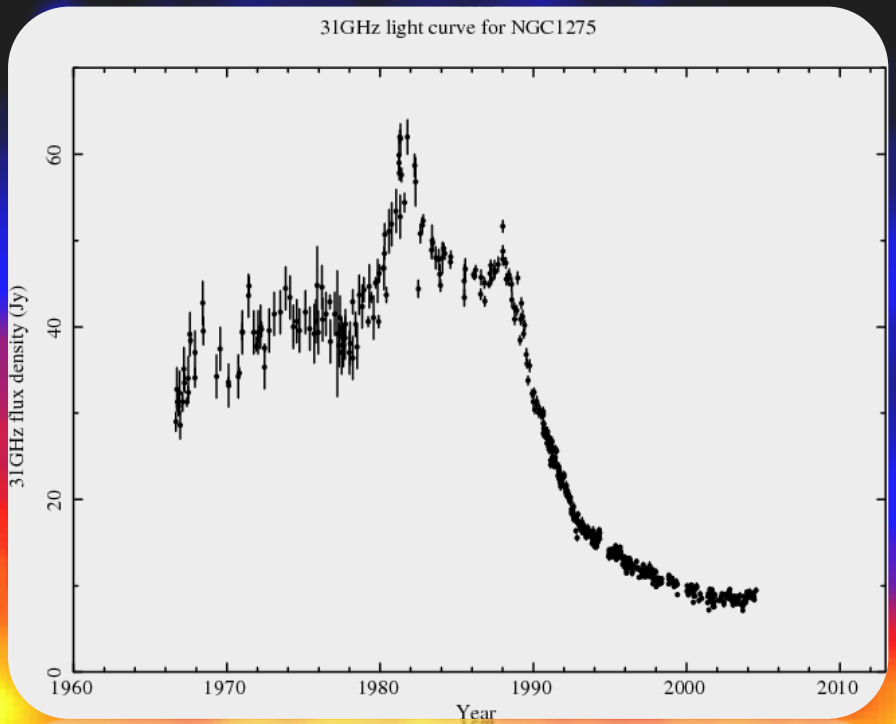
$$p + p \rightarrow p + n + \pi^+$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu \rightarrow e^+ + \nu_e + \nu_\mu + \bar{\nu}_\mu$$

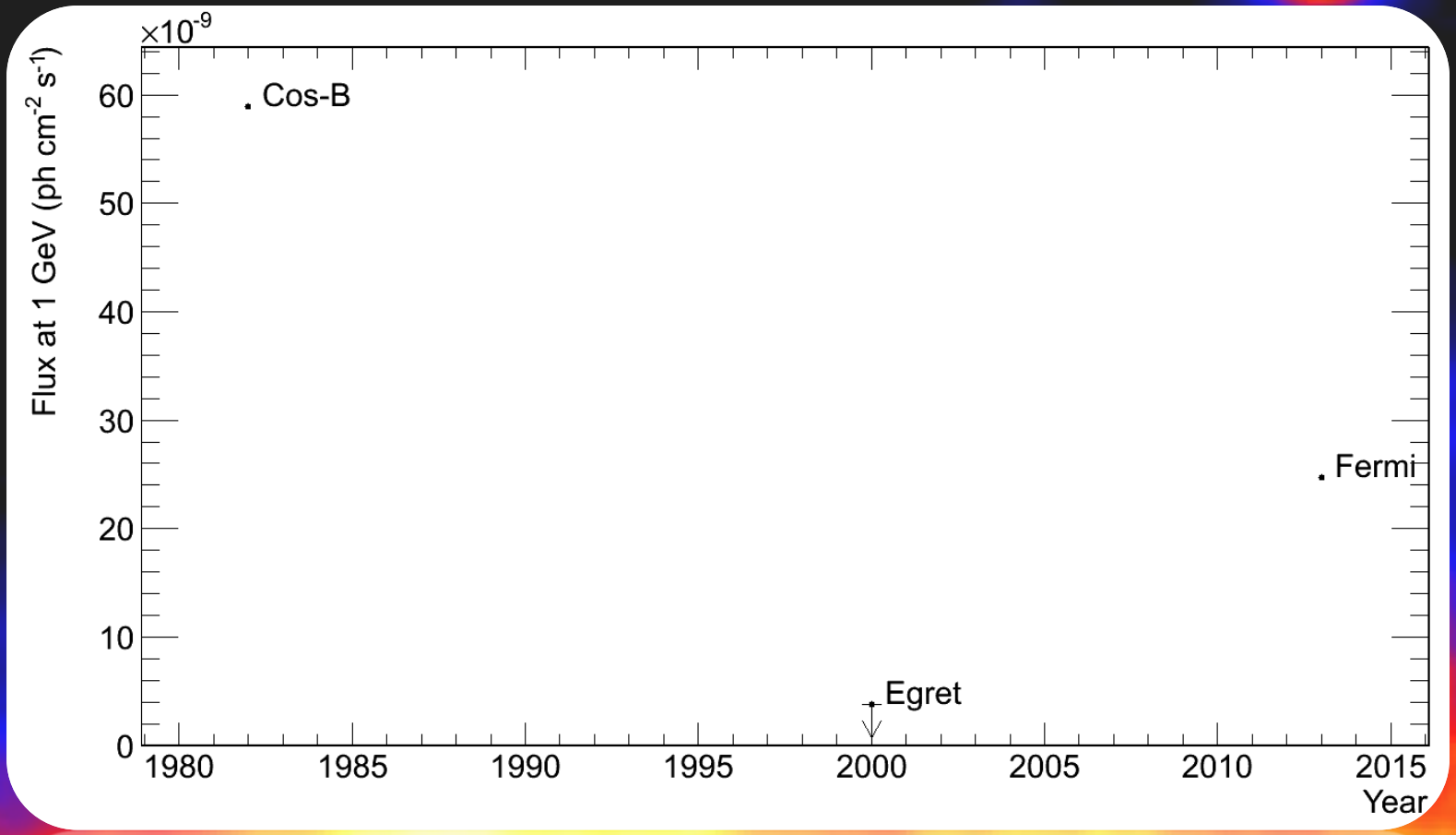
$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu \rightarrow e^- + \bar{\nu}_e + \nu_\mu + \bar{\nu}_\mu$$

Motivation – NGC 1275 in the Radio





Motivation – NGC 1275 in γ rays

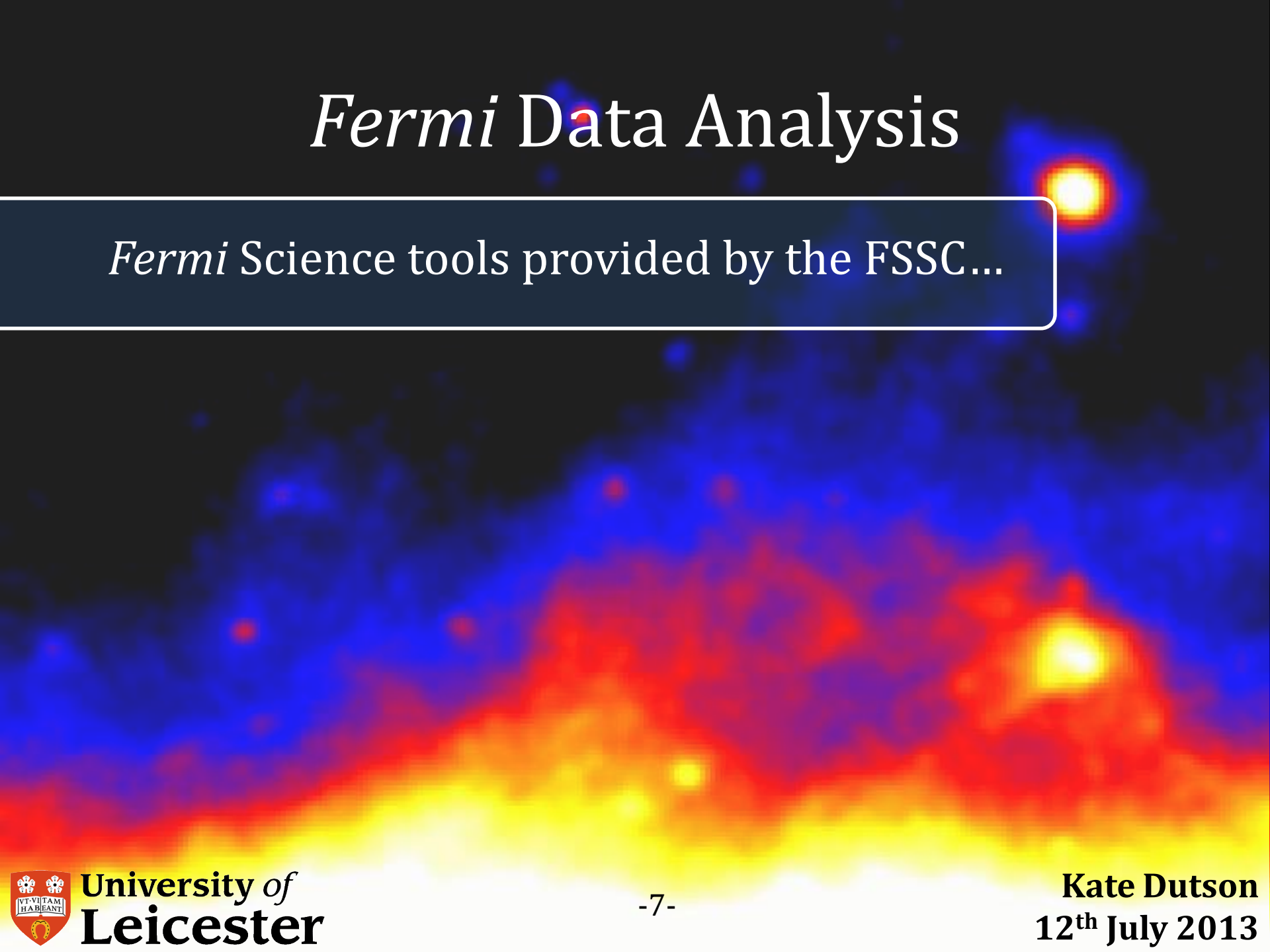


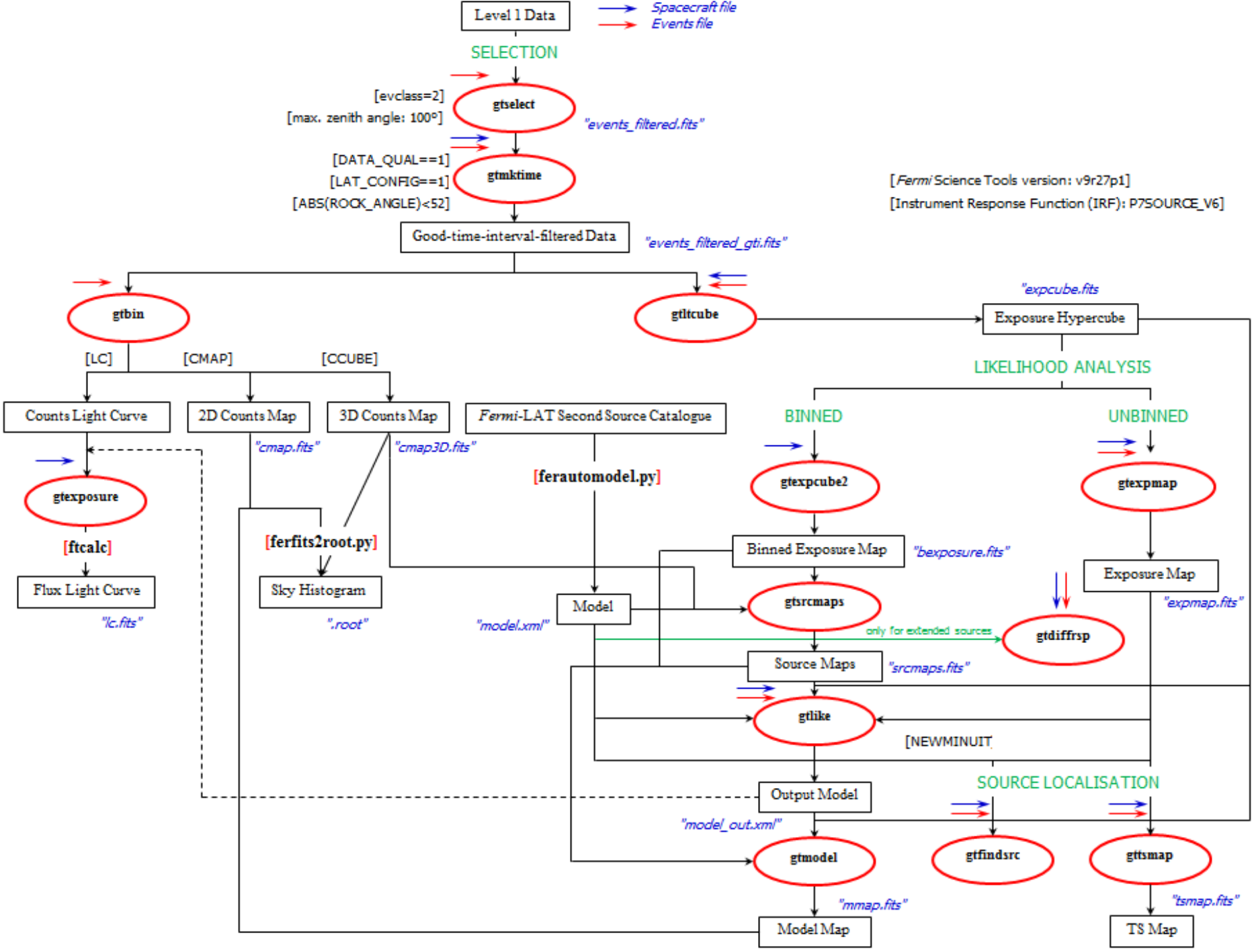
The *Fermi Gamma-ray Space Telescope*

- Launched in 2008
- Carries the **Large Area Telescope** (LAT), which is sensitive to γ-rays of energy **20 MeV – 300 GeV**
- Surveys whole sky every ~3 hours (two orbits)

Fermi Data Analysis

Fermi Science tools provided by the FSSC…

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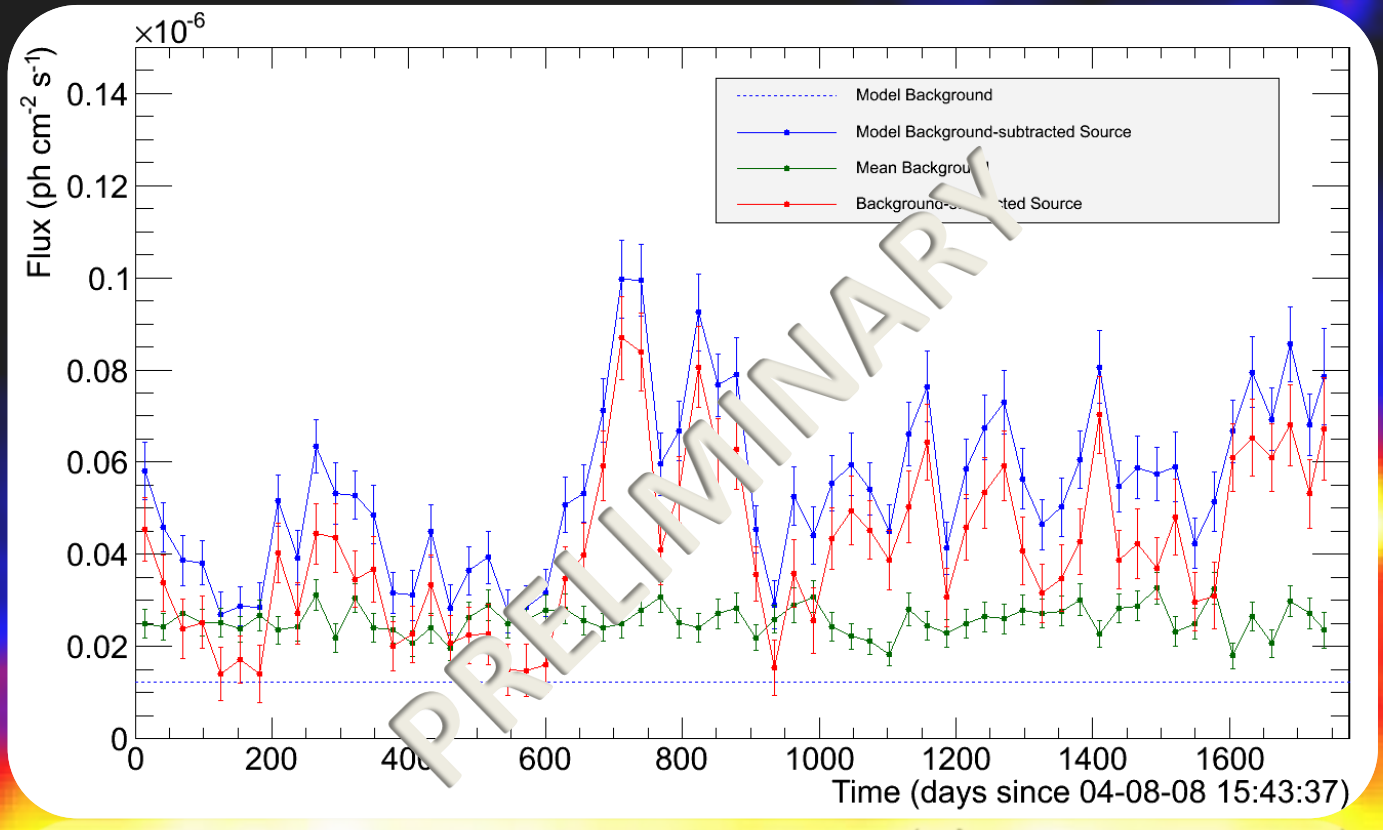
TS Map

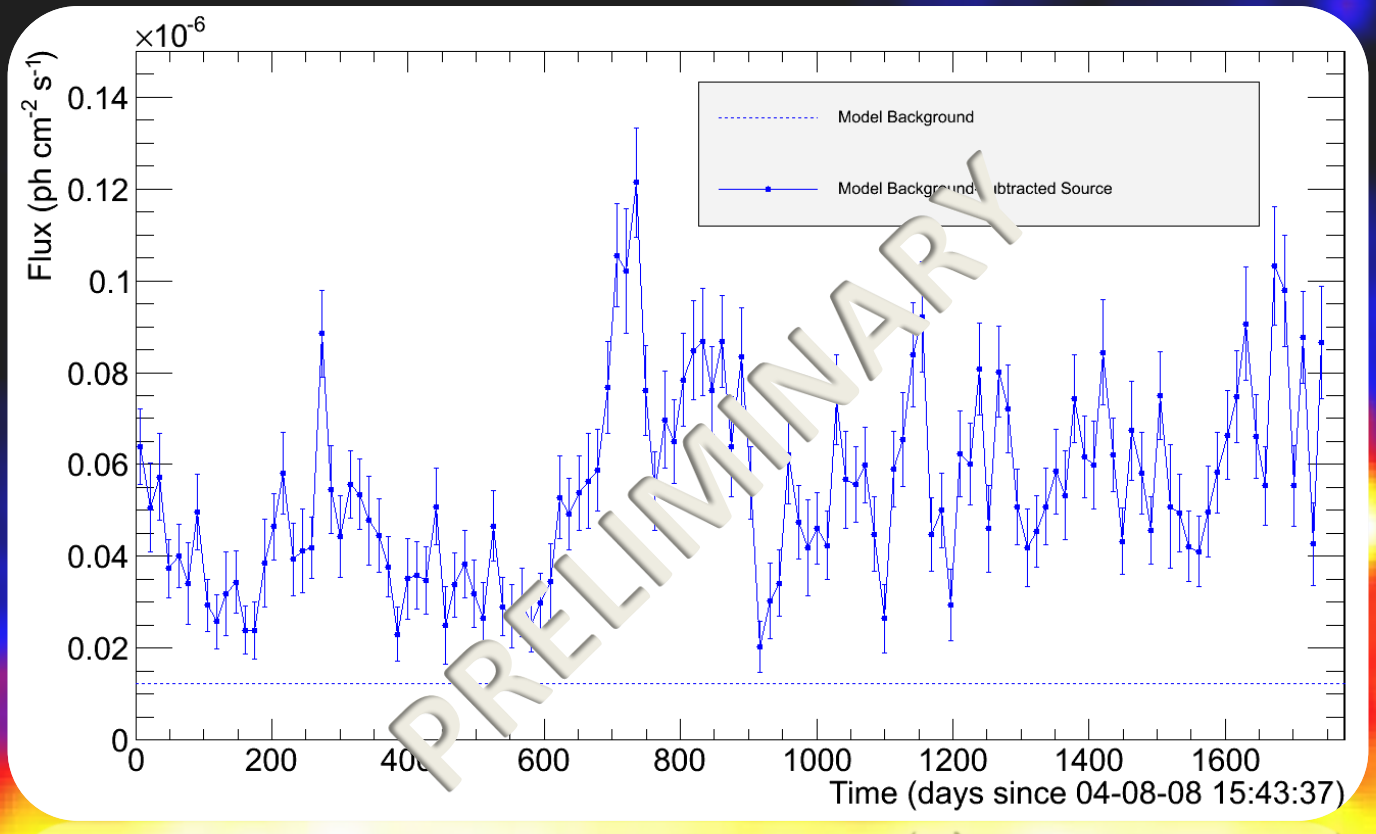
Light Curves - *Fermi*

- Monthly bins:



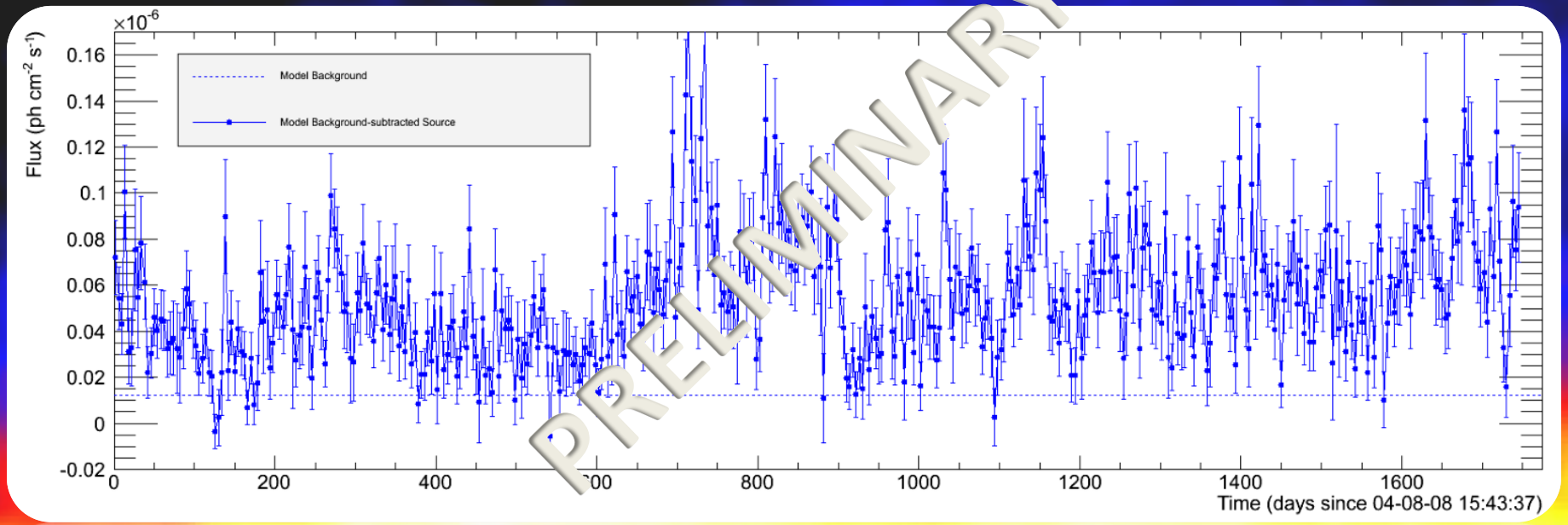
Light Curves - *Fermi*

- 2-week bins:



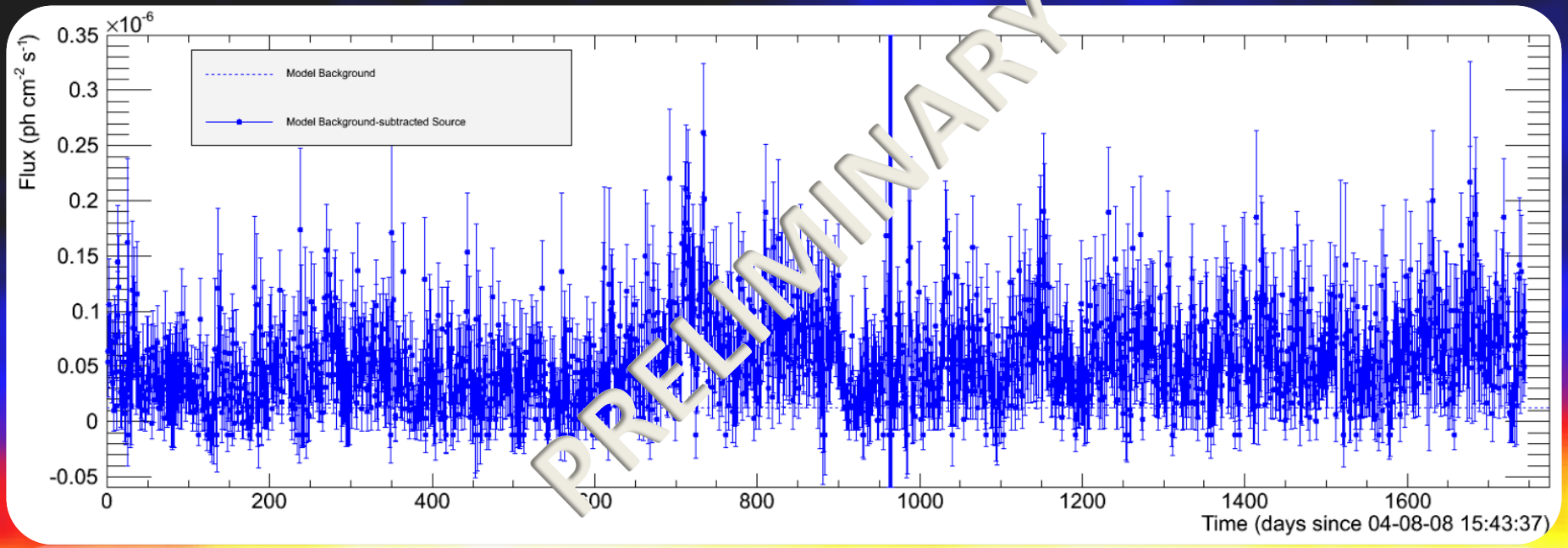
Light Curves - *Fermi*

- 4-day bins:

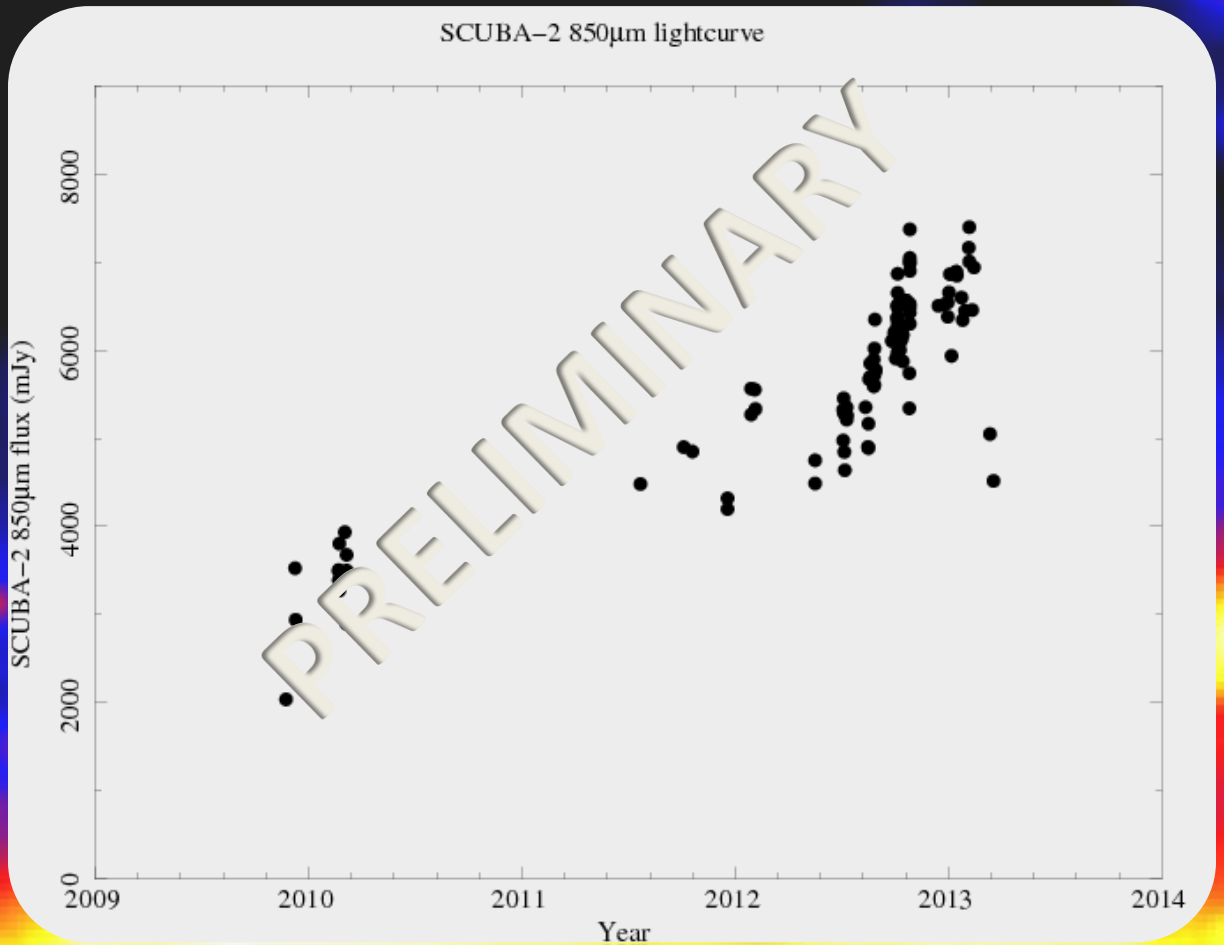


Light Curves - *Fermi*

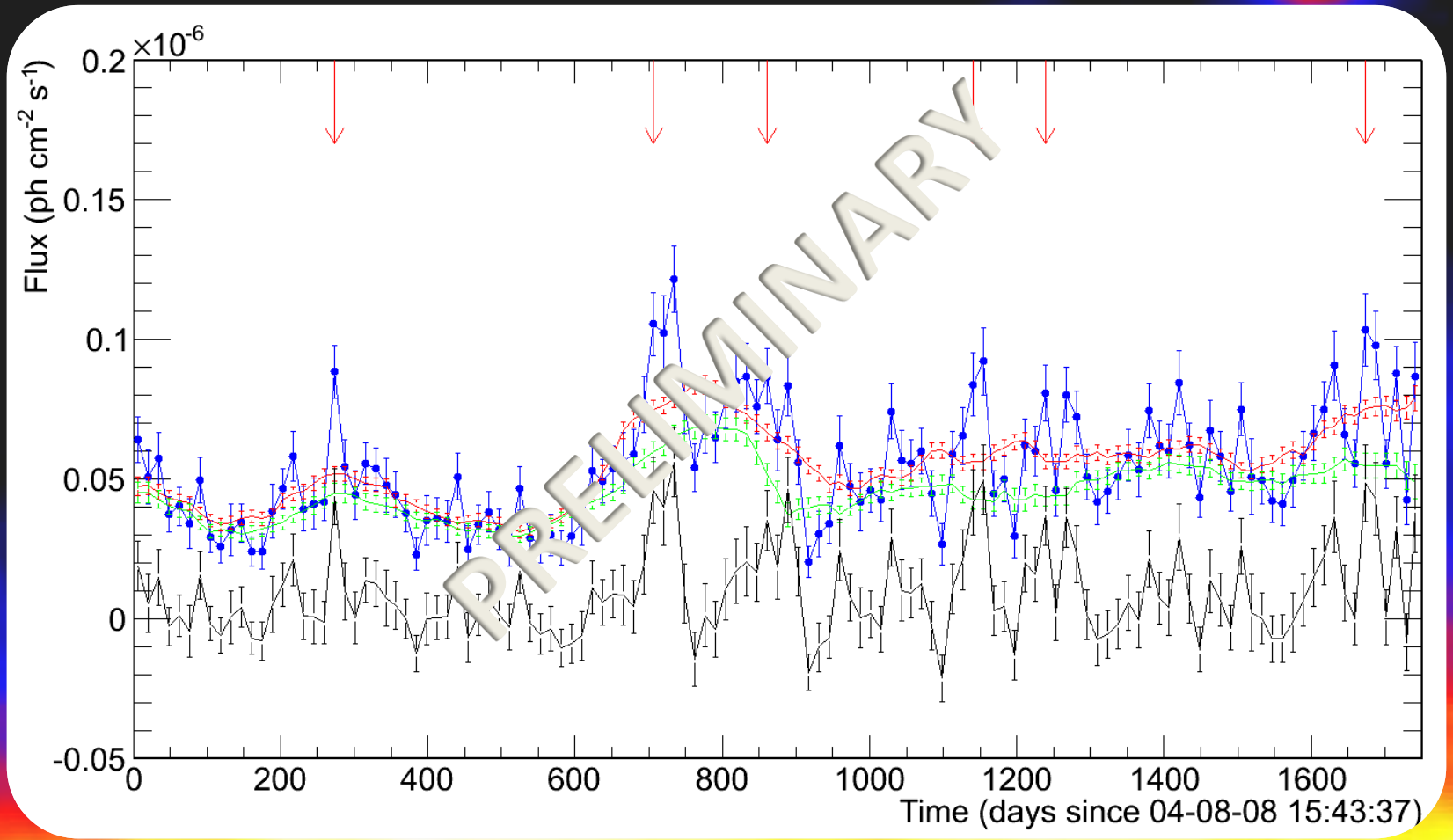
- daily bins:



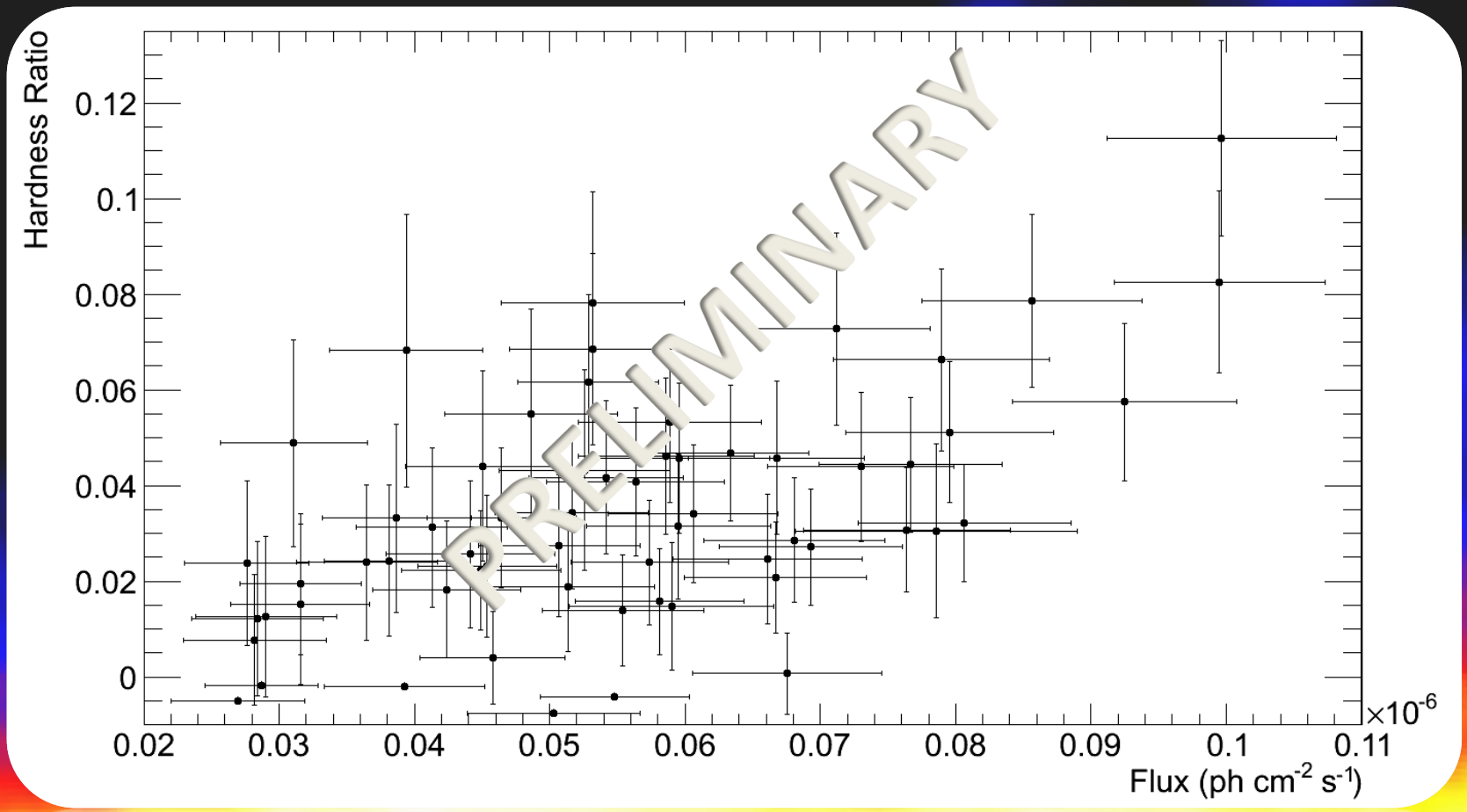
Light Curves – SCUBA-2



Finding Flares…

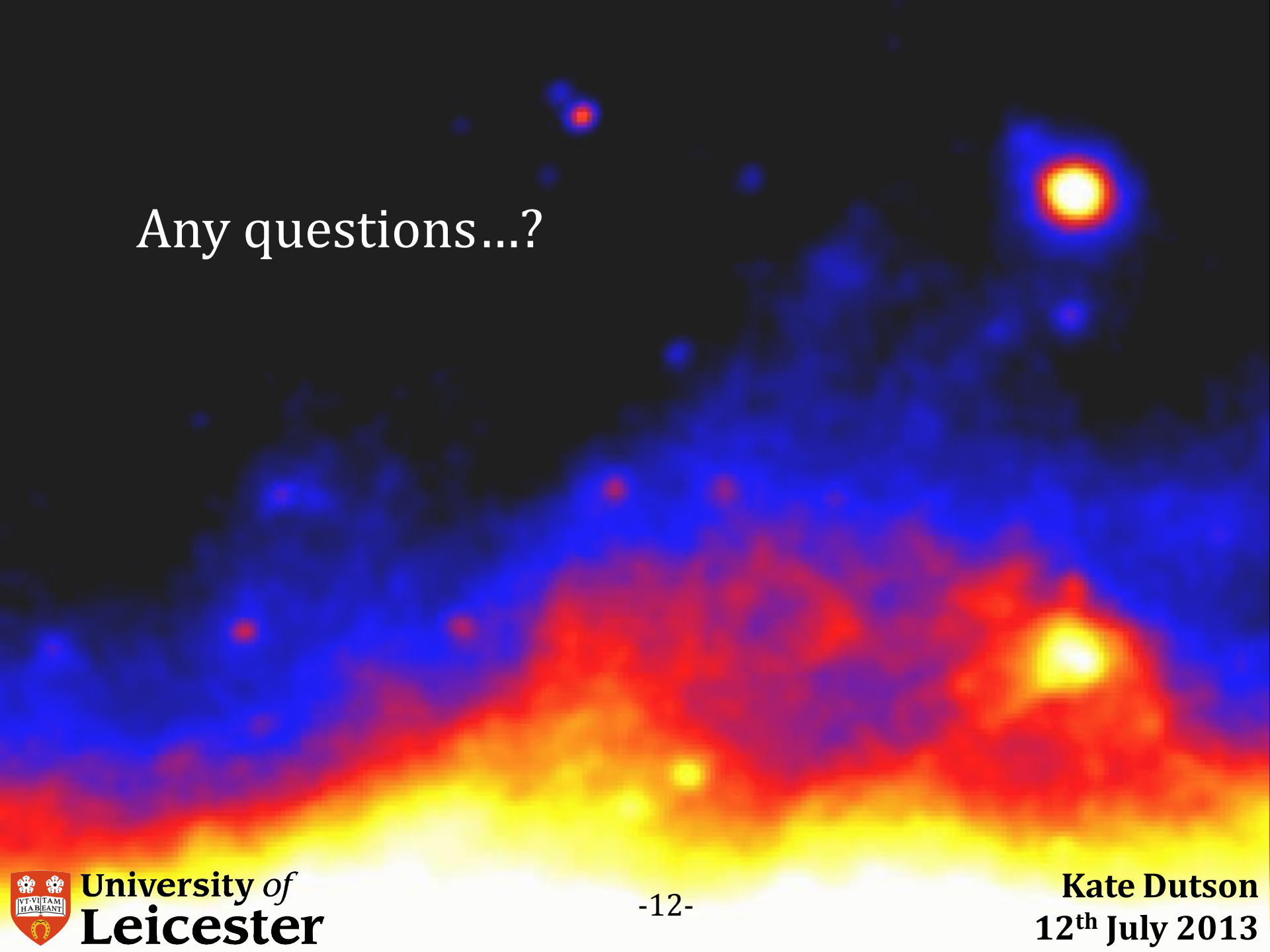


Hardness Ratio-Flux Correlation

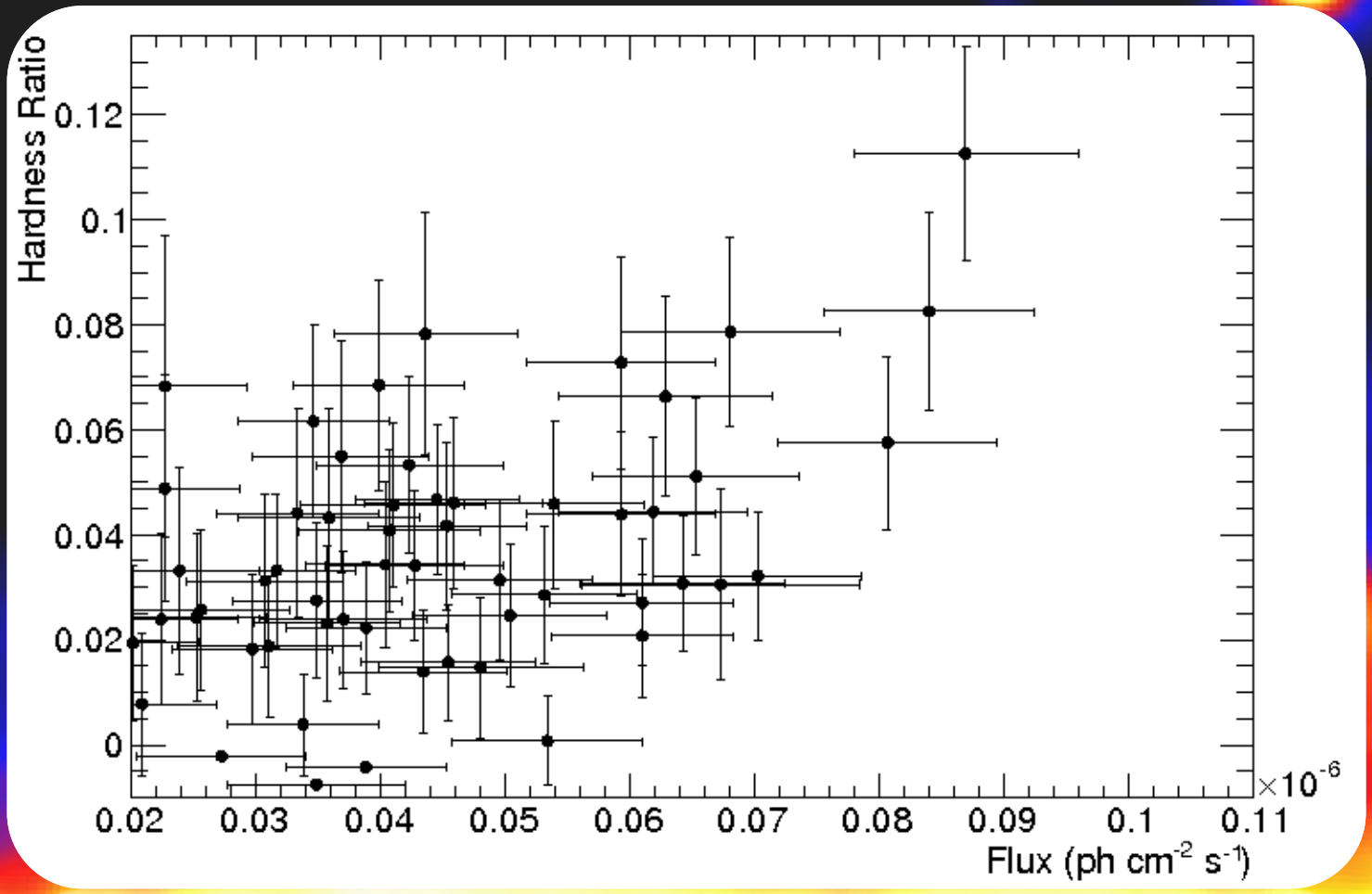


In Summary

- Historical motivation for observations of NGC 1275
- Highly variable source at radio wavelengths and in γ rays
- Correlation between overall flux and hardness ratio?
- Hints of a radio-gamma connection – to be further investigated!


Any questions…?

Diagnostic Plots



Diagnostic Plots