Early results from Planck: SEDs and radio continuum spectra of blazars

Metsähovi-Tuorla Planck team

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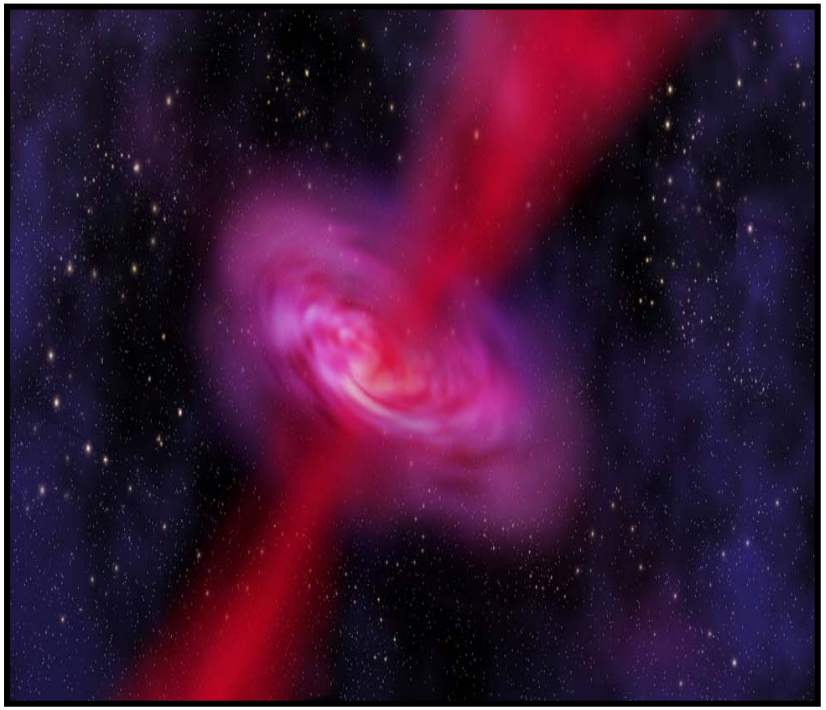
Planck Collaboration

Planck satellite

- Launch: May 2009
- First all-sky survey started: Aug 2009
- Second all-sky survey started: Feb 2010
- ”Early Release Compact Source Catalog” (ERCSC) and other early data for point sources (1+ surveys) published: Jan 2011
- Observing until end-2011 (LFI+HFI), into 2012 (LFI only)
- Intermediate papers to be published: Feb 2012
- Cosmology and products first year data to be published: Jan 2013, second year data: Jan 2014.

Planck science projects on extragalactic point sources

- **The Astrophysics of Quasars and BL Lac Objects**
- Extreme GPS and Other Strongly Inverted-Spectrum Radio Sources
- Statistical properties of radio sources



Active Galactic Nuclei (AGN)

Extragalactic point sources –why Planck?

- Planck produces the most complete radio source catalogs ever at high radio frequencies (30 - 857GHz)
  - complete samples of all classes of radio sources
  - simultaneous data (Planck + mf campaigns)
  - high-frequency radio data important for studying the early stages of flares
  - variability at several time scales
  - ToO, new sources…

Science goals: AGN & Planck

- ”Complete” SEDs, properties of the synchrotron and the IC peaks, AGN model parameters
- Structure and physics of radio jets, developing and testing models of shocked relativistic jets, separation of jet components
- Testing unification models (& blazar sequence)
- Modelling and testing the high energy emission production scenarios
- Variability of AGN at various time scales
- Comparison with microquasars and LLAGN

Planck Early Results

- Building Spectral Energy Distributions (SEDs) for a complete northern 1 Jy sample of approx. 100 radio sources (AGN) using simultaneous Planck, Fermi and other multifrequency data
- Planck-collaboration, Aatrokoski et al.: ”*Spectral energy distributions and radio continuum spectra of northern extragalactic radio sources*” (contact person: A. Lähteenmäki, Metsähovi). Submitted to A&A, available at astro-ph.

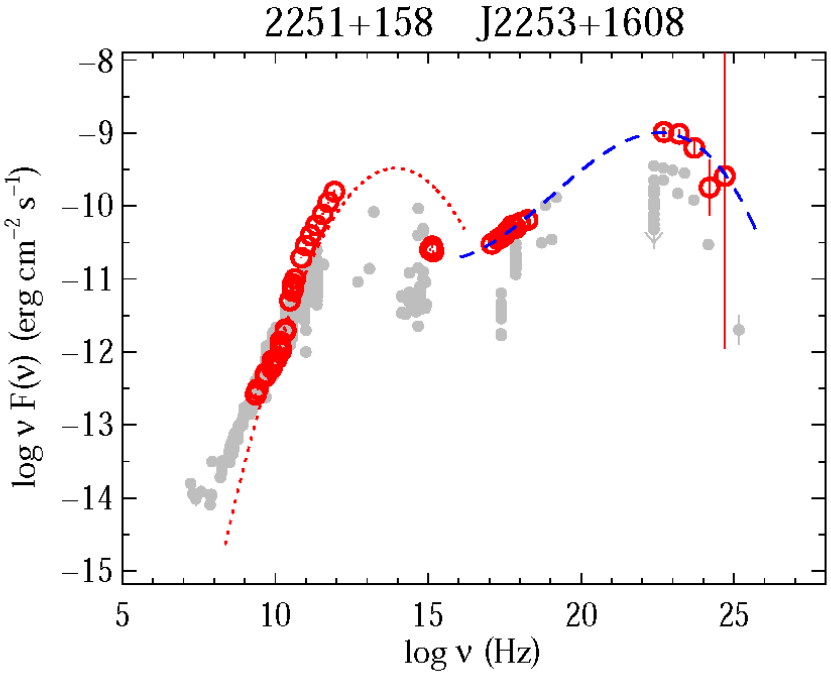
The sample

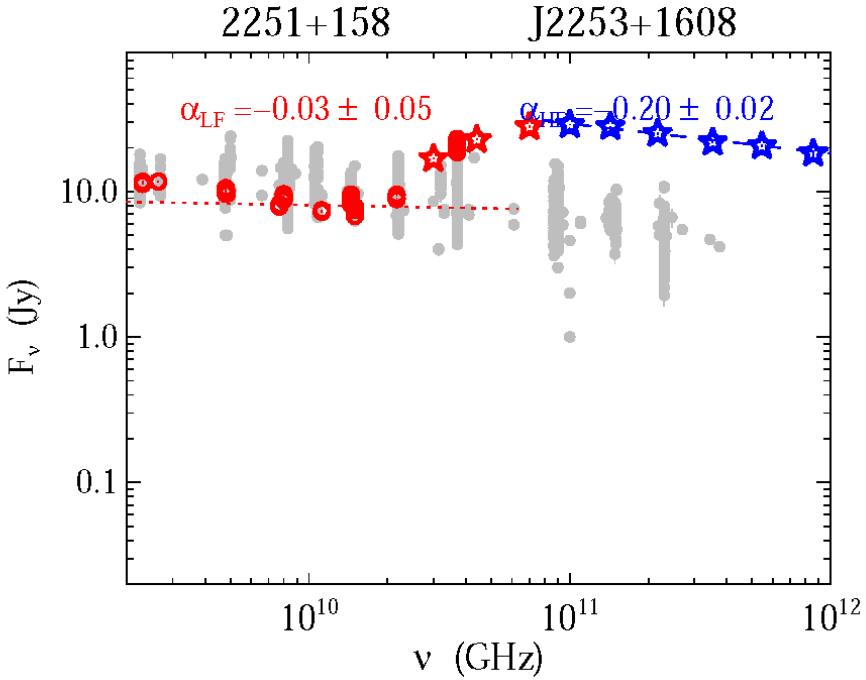
- The Complete 1 Jy northern sample
  - average radio flux at 37 GHz > 1 Jy
    (for some sources 30 years of data), δ > -10
- Radio-selected sample of various AGN classes
  - High polarization quasars (HPQ)
  - Low polarization quasars (LPQ)
  - BL Lac objects (BLO)
  - Radio galaxies (GAL)
- 104 sources

The data

- Planck, 9 frequencies
- Radio
  - Metsähovi, RATAN-600, UMRAO, VLA, ATCA, Effelsberg, IRAM, APEX, OVRO, Medicina
- Optical
  - Tuorla + KVA (La Palma), Xinglong (+ Liverpool 2m)
- X-rays (+optical+UV)
  - Swift
- Gamma-rays
  - Fermi
- (ToO TeV
  - MAGIC, VERITAS)

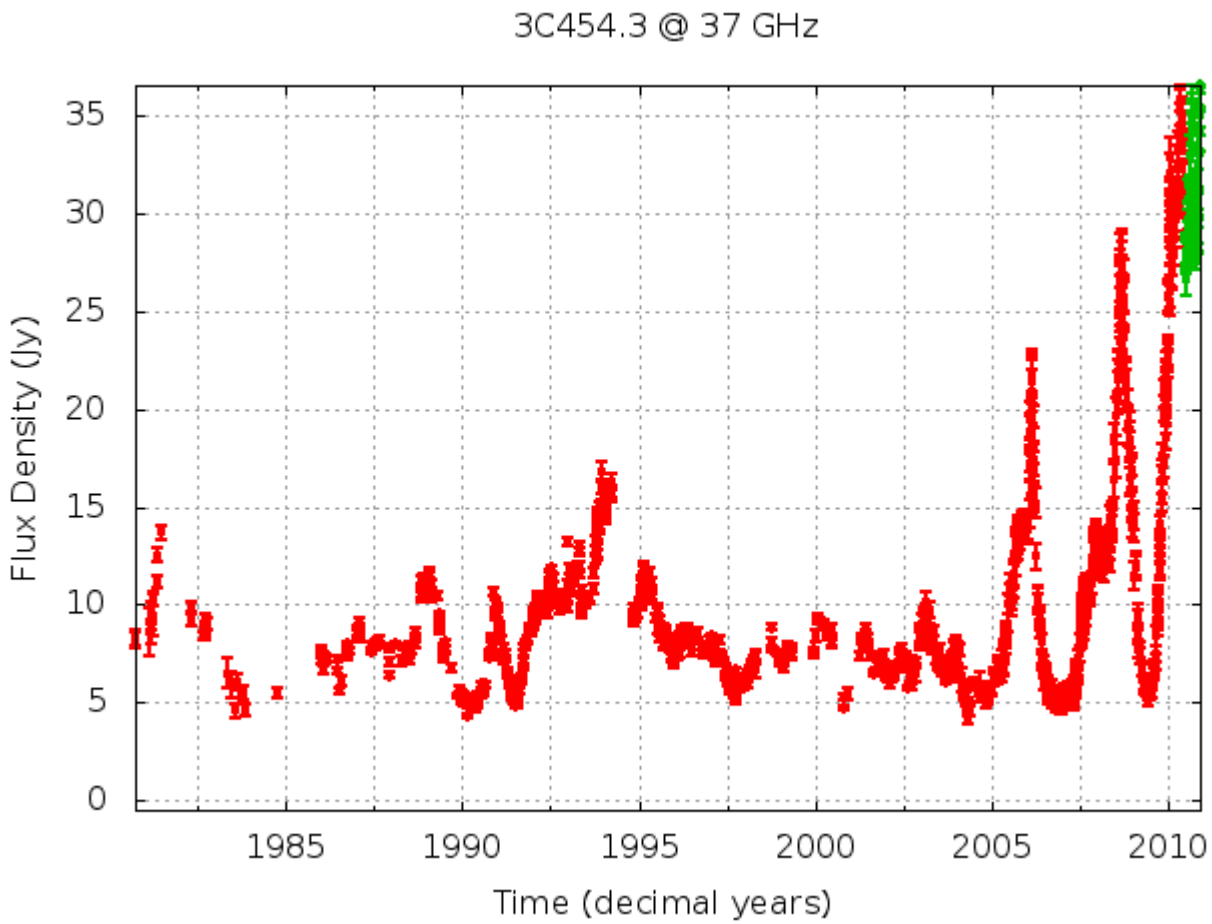
Examples of SEDs and radio spectra: 2251+158 (3C 454.3)



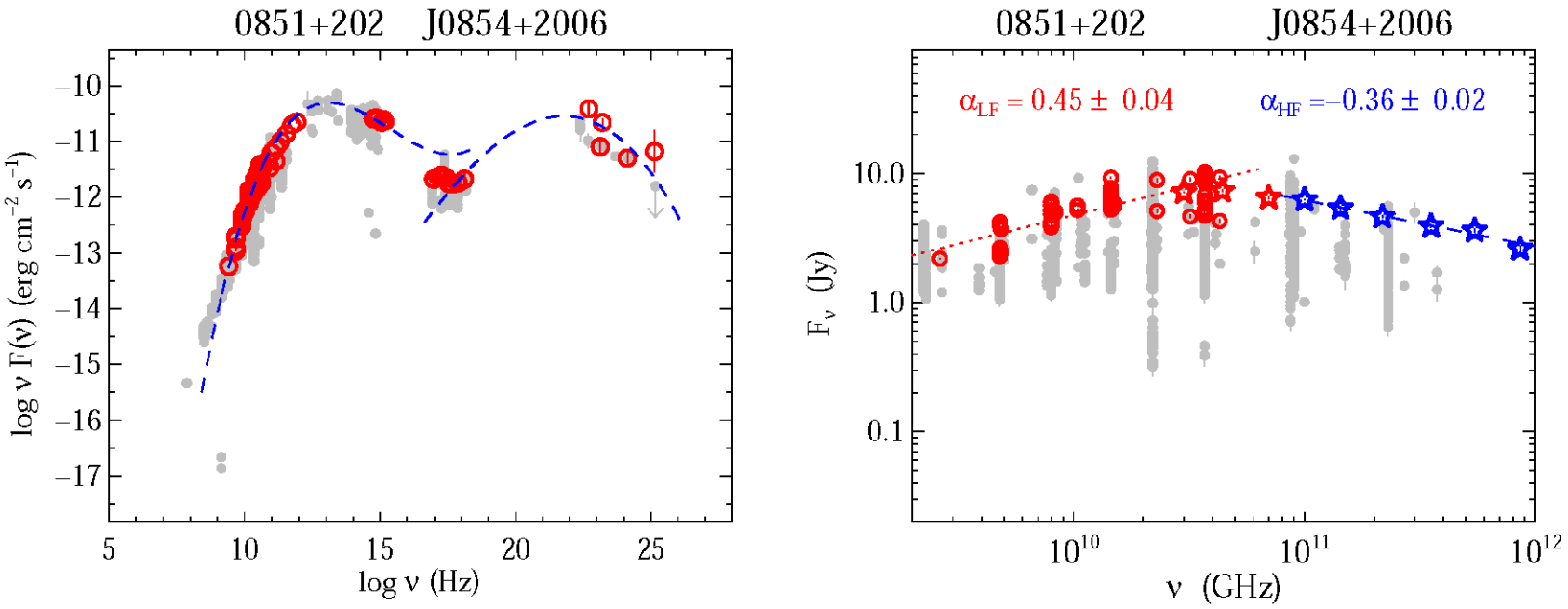


A well studied object, e.g., Villata et al. 2007, 2009, Raiteri et al. 2008 (WEBT/GASP), also Hovatta et al. 2007, 2008 (longterm behaviour + flares)

Variability of 2251+158 (3C 454.3) at 37 GHz for the last 30 years

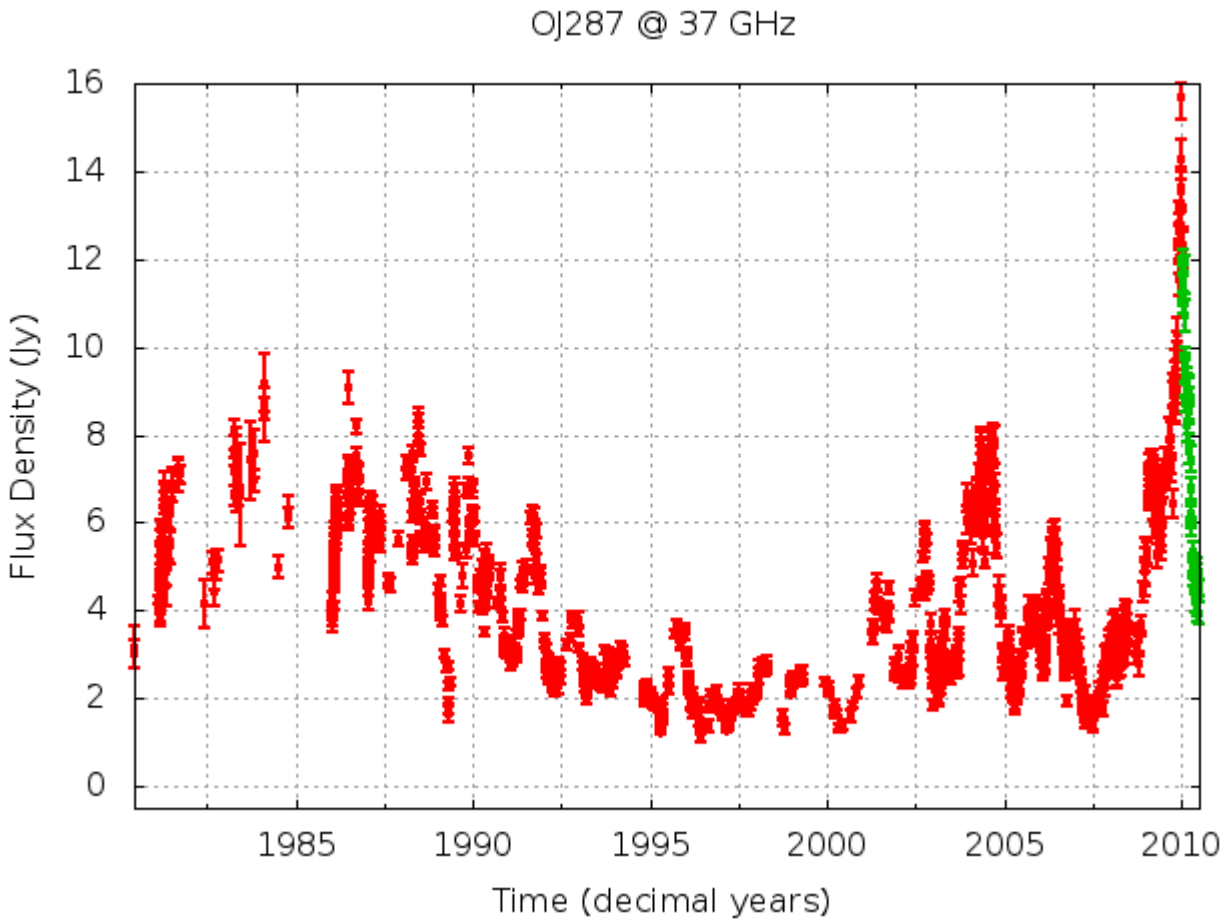


Examples of SEDs and radio spectra: 0851+202 (OJ 287)

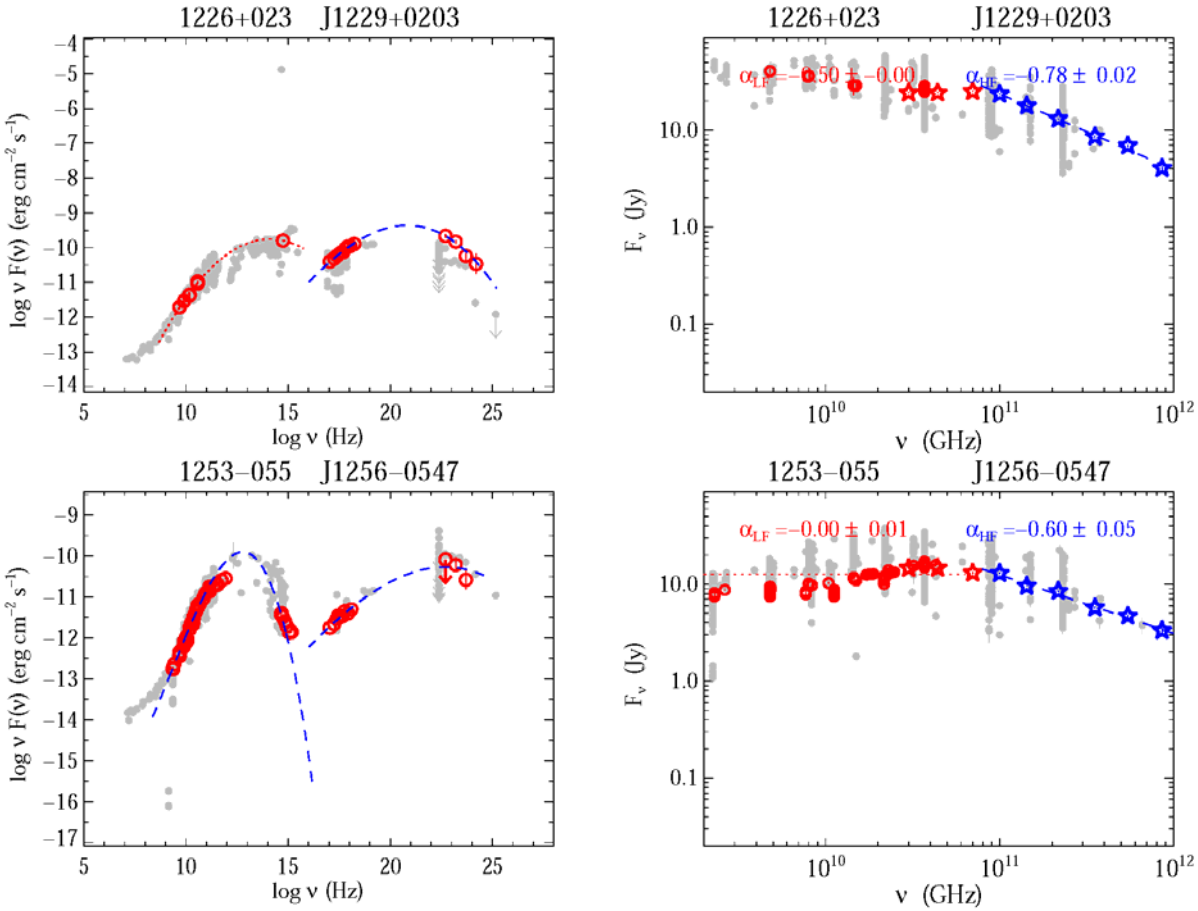


Another old, well-studied friend, e.g., Hovatta et al., Nieppola et al., several recent papers

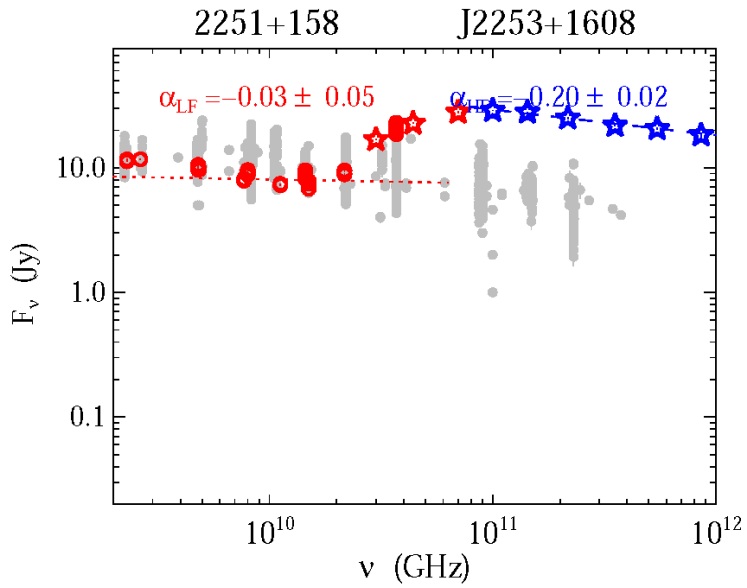
Variability of 0851+202 (OJ287) at 37 GHz

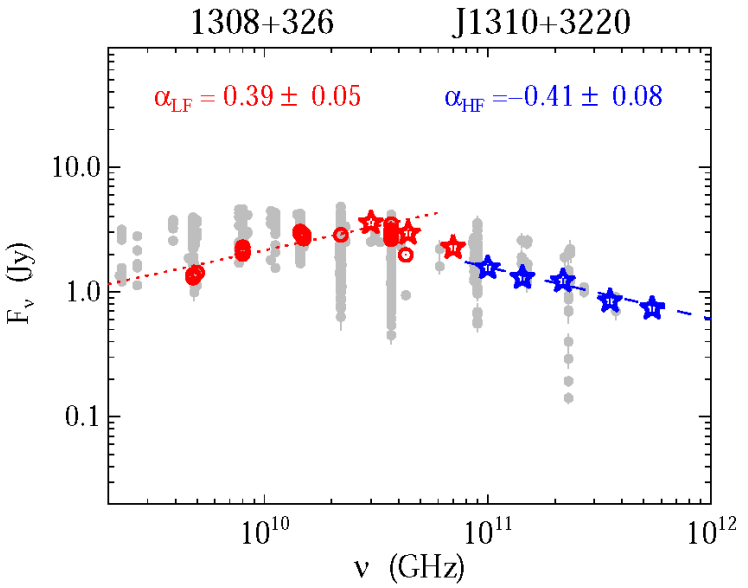


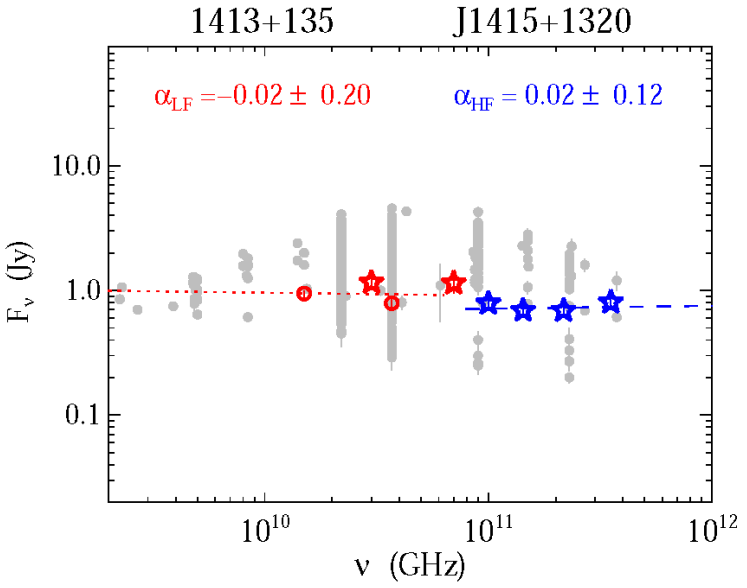
Examples of SEDs and radio spectra: 3C 273 and 3C 279

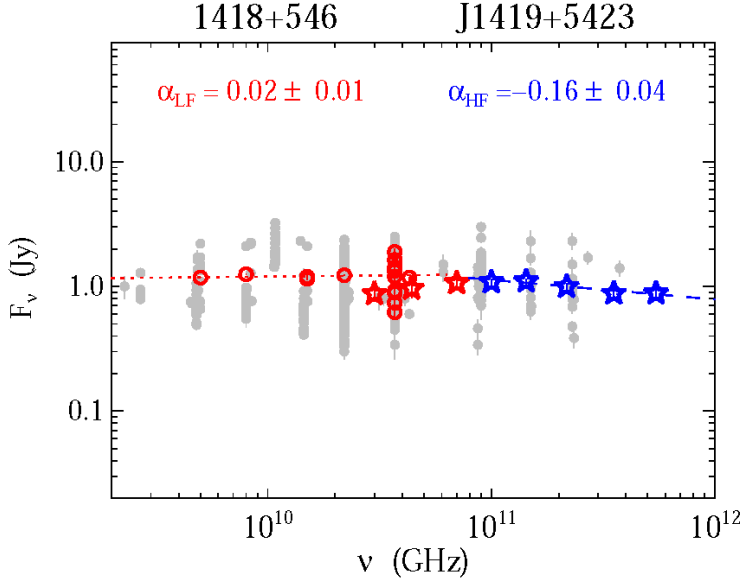


No room for mid-IR component, indicating that the IC emission also comes from the synchrotron component.

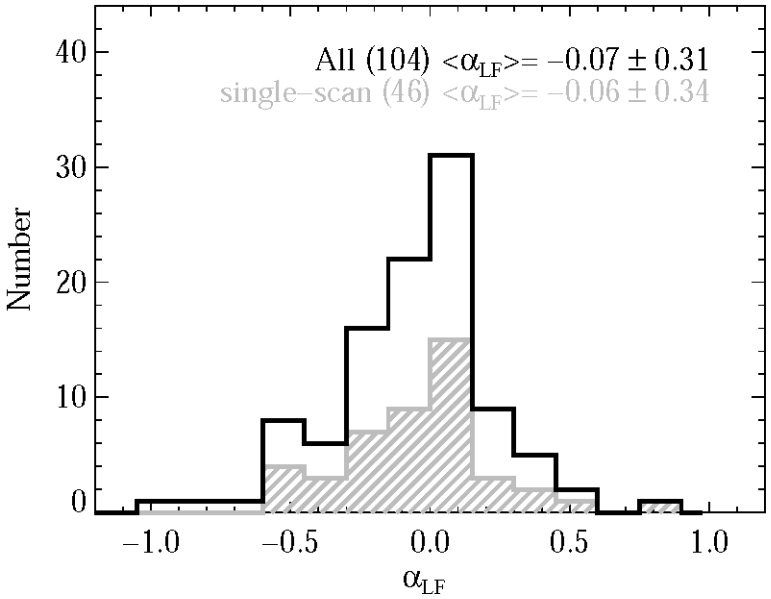

2251+158
J2253+1608
α_{LF} =–0.03 ± 0.05
α_{HF} =–0.20 ± 0.02
10.0
1.0
0.1
F_ν (Jy)
10^{10}
10^{11}
10^{12}
ν (GHz)

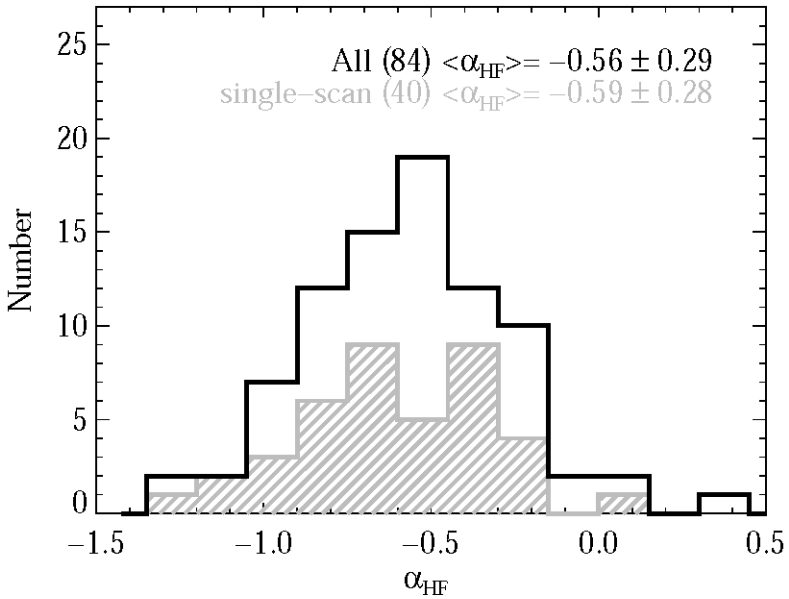

1308+326
J1310+3220
α_{LF} = 0.39 ± 0.05
α_{HF} =–0.41 ± 0.08
10.0
1.0
0.1
F_ν (Jy)
10^{10}
10^{11}
10^{12}
ν (GHz)


1413+135
J1415+1320
α_{LF} =–0.02 ± 0.20
α_{HF} = 0.02 ± 0.12
10.0
1.0
0.1
F_ν (Jy)
10^{10}
10^{11}
10^{12}
ν (GHz)


1418+546
J1419+5423
α_{LF} = 0.02 ± 0.01
α_{HF} =–0.16 ± 0.04
10.0
1.0
0.1
F_ν (Jy)
10^{10}
10^{11}
10^{12}
ν (GHz)

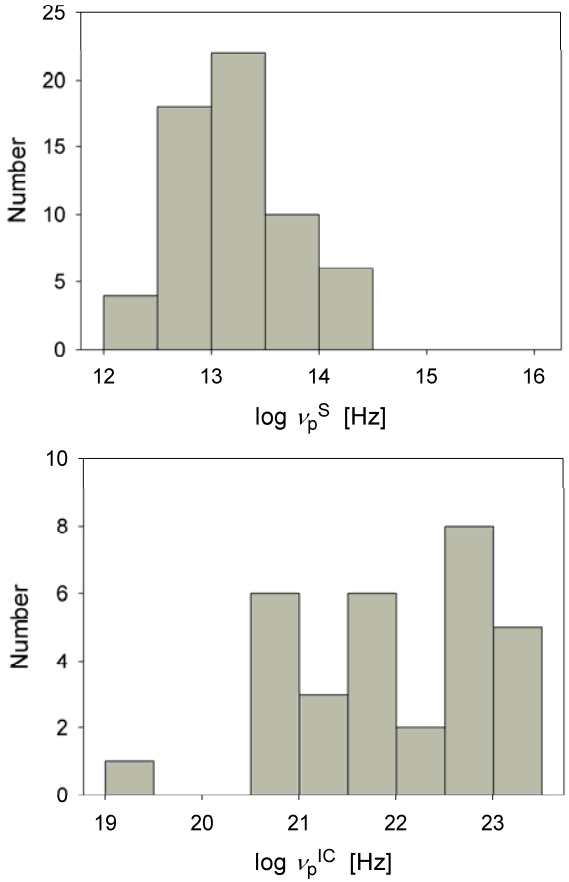
Flat high radio frequency spectra?

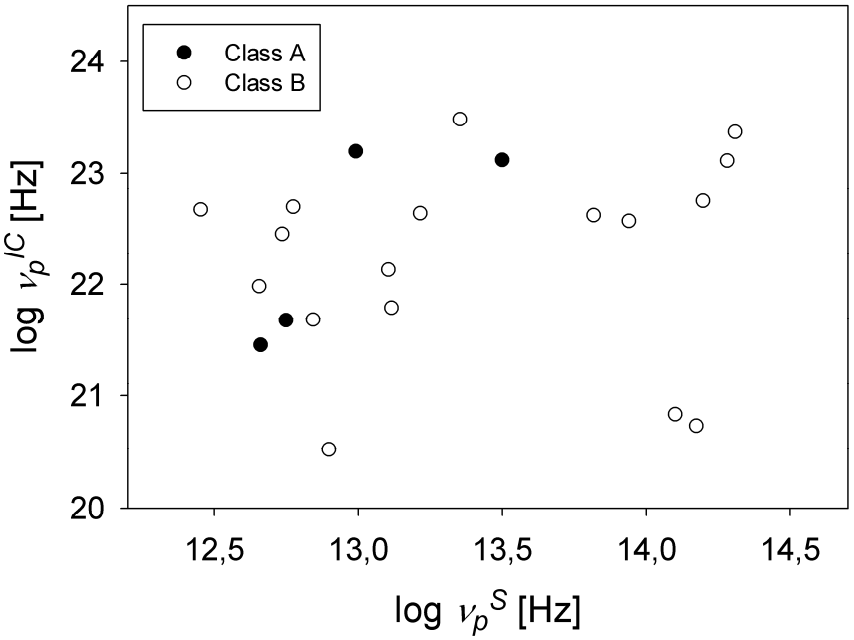




Smallest values of α_{thin} around -0.2 to -0.4 and a maximum around -0.7 indicate electron energy index s ≈ 1.5.

Synchrotron and IC peak frequencies

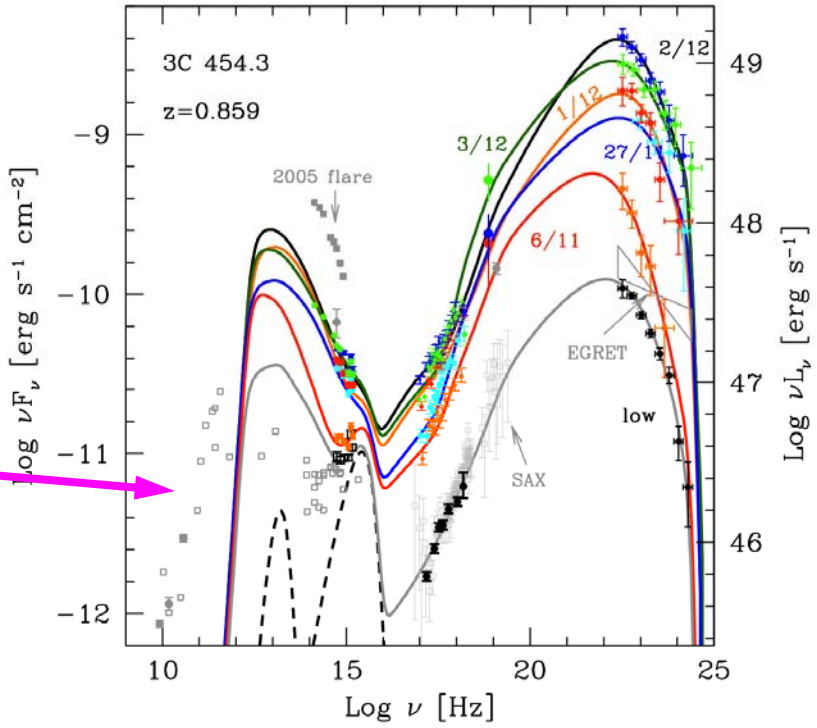




No correlation between peak frequencies, but there is a tendency for the sources with high synchrotron peak to have a high IC peak.

SED modelling

- Contemporary models fit the high-energy inverse Compton (IC) part rather nicely, but (still) almost completely ignore the synchrotron (=radio) part which most likely is the source for the high-energy emission



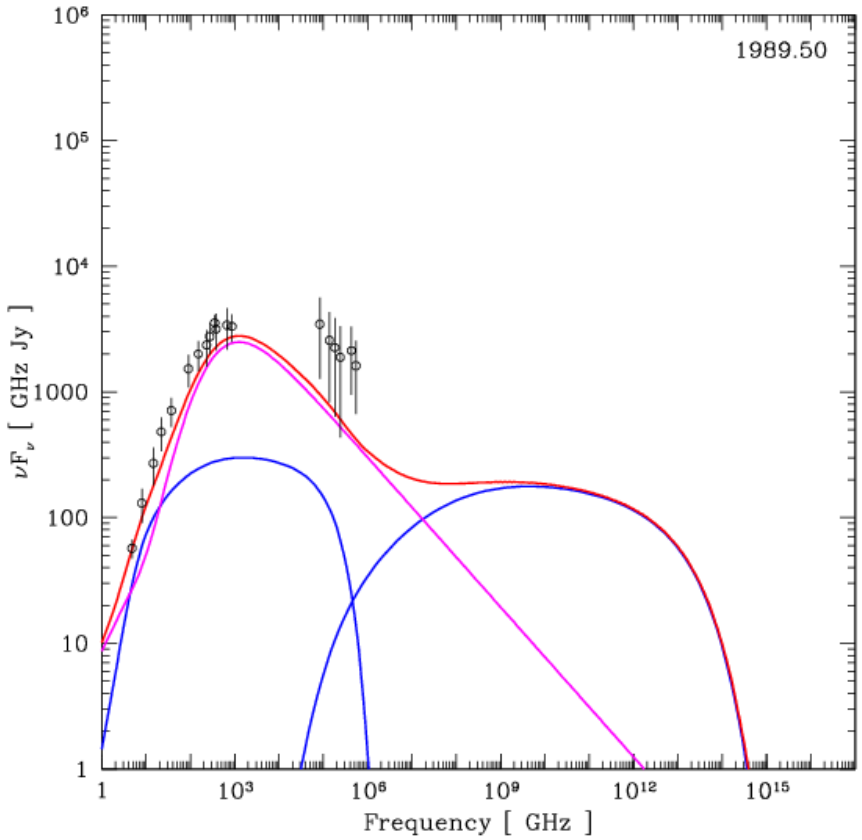
Bonnoli et al. 2010

Multicomponent SED modelling

- Start with the underlying physics and fit the primary photons (i.e. synchrotron, also at low frequencies!) first.
- Use multicomponent fitting
  - Underlying jet flow + individual shocks moving in the jet
  - possible because Planck LFI+HFI extend the radio SED way beyond the usual

SSC modelling of 3C 279

(Lindfors et al. 2005, 2006, Türler et al. 2000)



Animation:
http://isdc.unige.ch/~turler/jets/

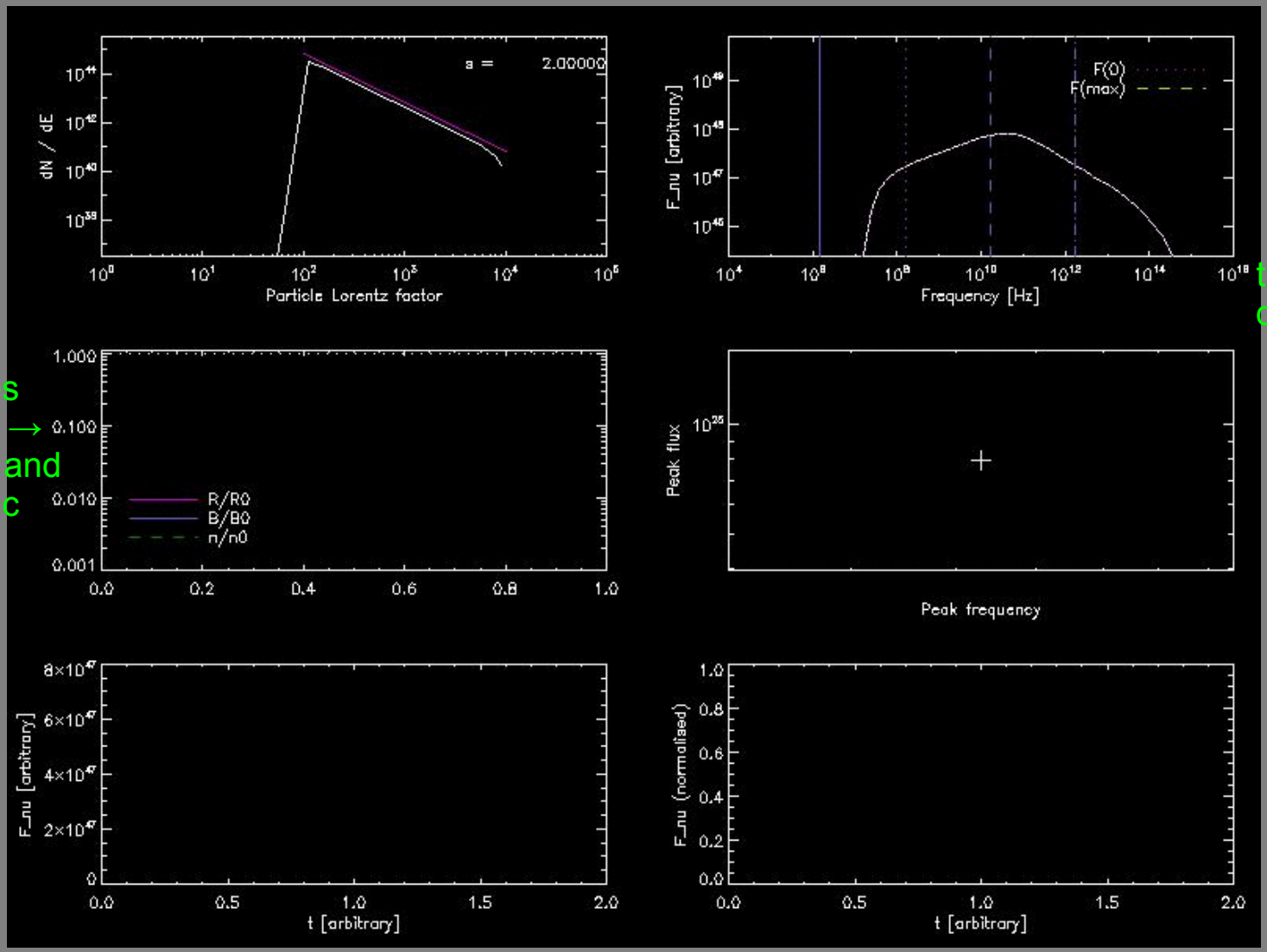
Modelling work in progress (Tammi et al.):

J. Tammi: A real-life example: A flare in jet. Shocks accelerates particles in a moving blob.

Particles get accelerated initially, and cool down.

Radiated spectrum: Rises when the number of radiating particles increases and the cloud grows; decreases when magnetic field decreases and particles lose their energy.

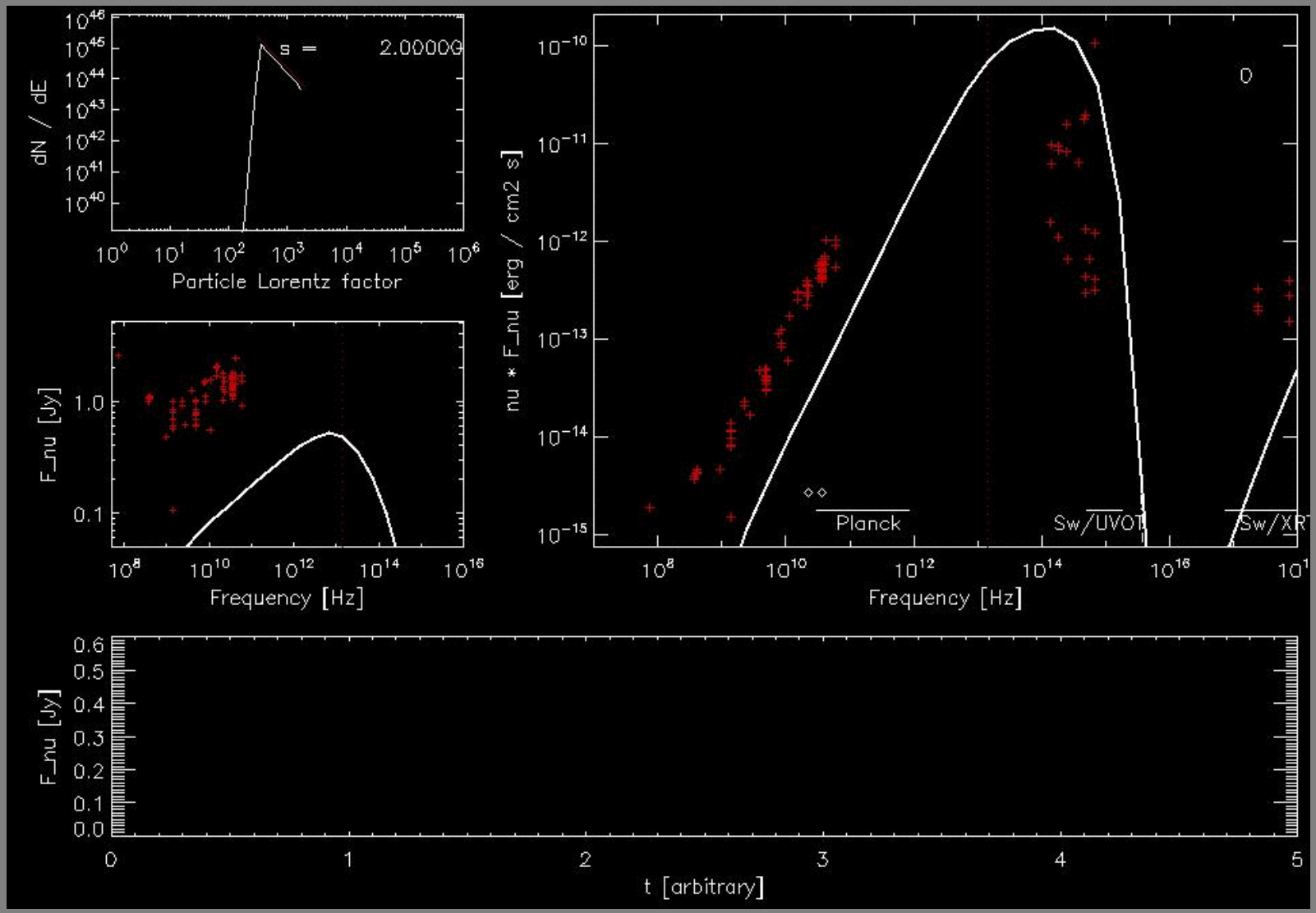
Jet becomes broader → Density and magnetic field drop.



The rise and decay times and the shape of the flare depend on observing frequency. At some frequencies the flare is seen half a year later.

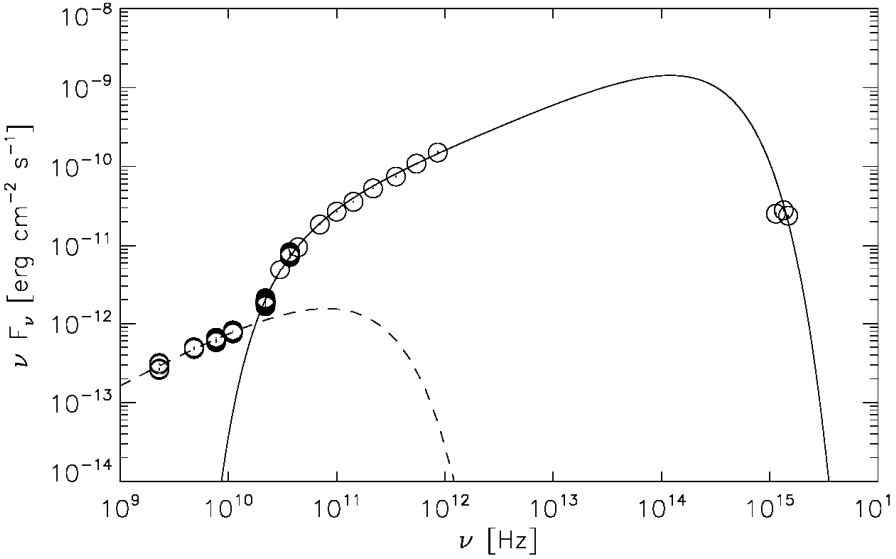
J. Tammi: A real-life example: Multiple shocks in the jet.

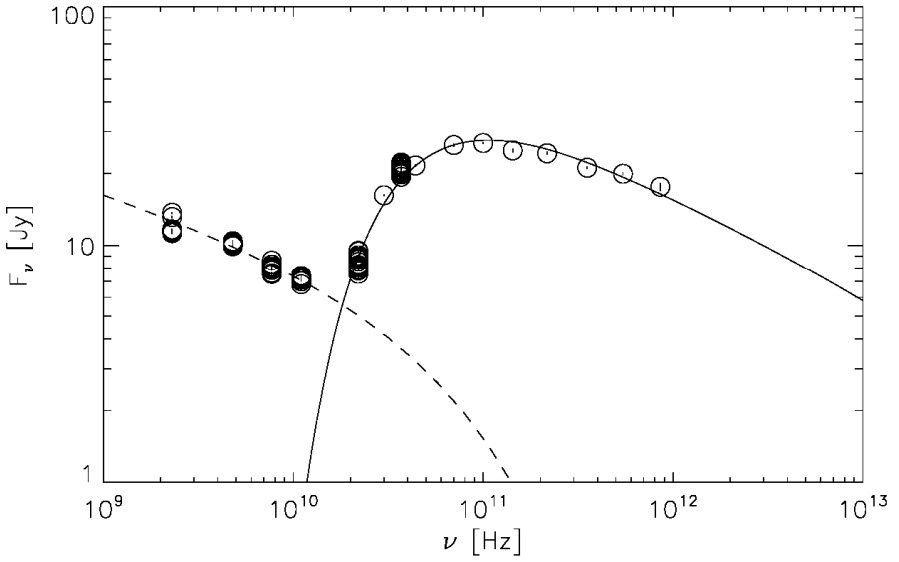
Spectrum: Strong variation at high frequencies, little at radio.



Lightcurve: Each shock creates a new flare.

Example of multicomponent modelling: 3C 454.3 (Tammi et al.)





Conclusions…

- 104 SEDs and radio continuum spectra of AGN
  - Rarely smooth, several components contribute
  - Variability!
- Synchrotron and IC peak frequencies do not correlate
- Low frequency spectral indices flat as expected
- High frequency spectral indices remarkably flat, indicating hard electron spectral energy index s, clearly below ≈2

…Conclusions

- In many cases there is no room for additional mid-IR component
  - IC gamma-ray emission originates in the synchrotron (i.e. shock) components
- A lot remains to be done with future Planck data and the individual all-sky scans
  - For example, multicomponent fitting starting from the synchrotron photons

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 50 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency -- ESA -- with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.