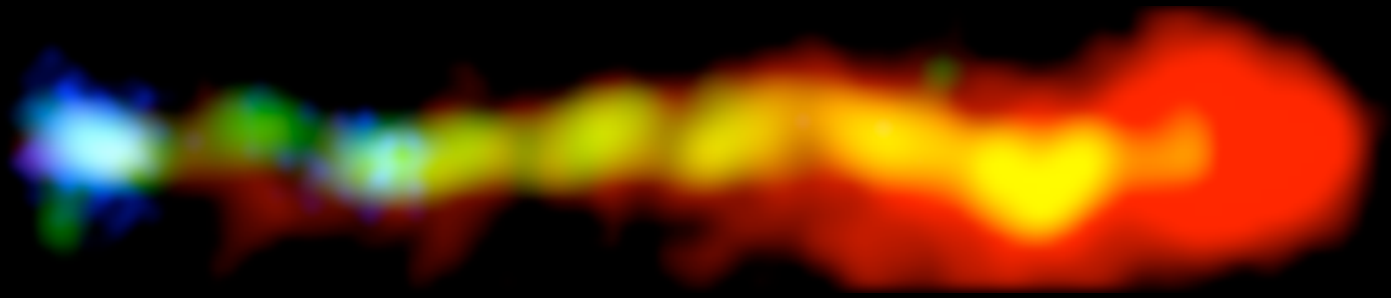
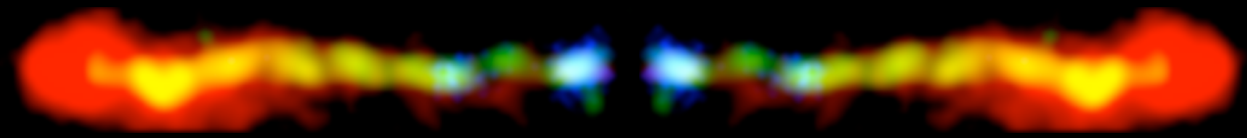


Optical observations of extragalactic jets

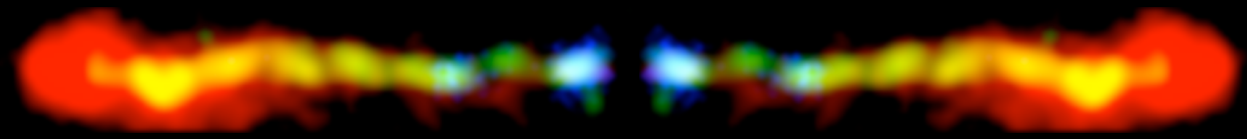
Sebastian Jester
University of Southampton

Outline



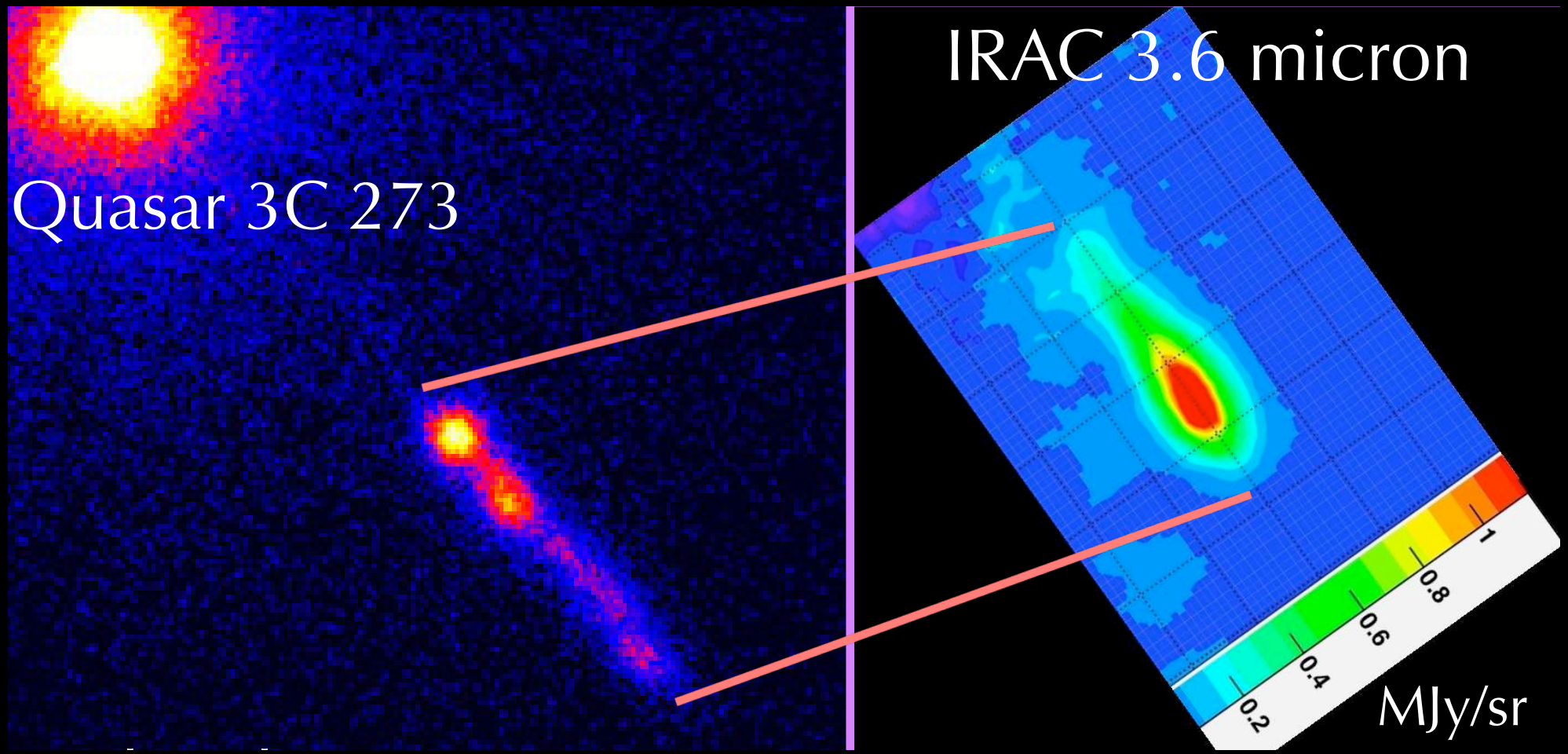
- Motivation: Why o(ptical) why?
- 3C273 with Spitzer and Chandra
  - Support for synchrotron X-rays rather than IC/CMB (Uchiyama; Jester)
- Searches for new jets with Chandra/HST
  - A few new optical jets, detailed data on 2
  - Cen A with Spitzer (Hardcastle; Brookes)
- HST polarimetry of 6 low-power (FRI) jets (Perlman et al. 2006)
- Open Questions
- The future

Motivation



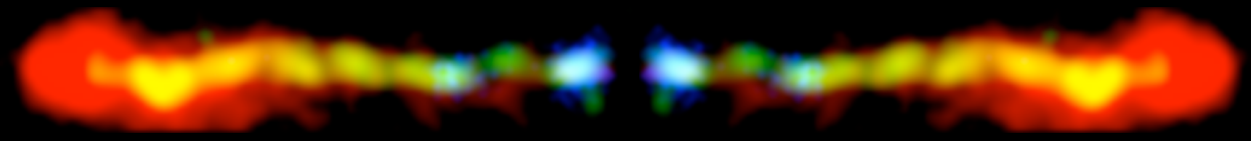
- Optical synchrotron ⇒ local acceleration
- Low-power (FR I) jets:
  - X-ray synchrotron common,
    Optical synchrotron must be there, too
- High-power (FR II) jets:
  - X-rays: IC-CMB or synchrotron?
  - Constraints on bulk Γ and electron low-energy cutoff from SEDs (AGN feeback!)
- Study B-field traced by highest-energy particles via optical polarisation
- Constrain particle acceleration mechanism

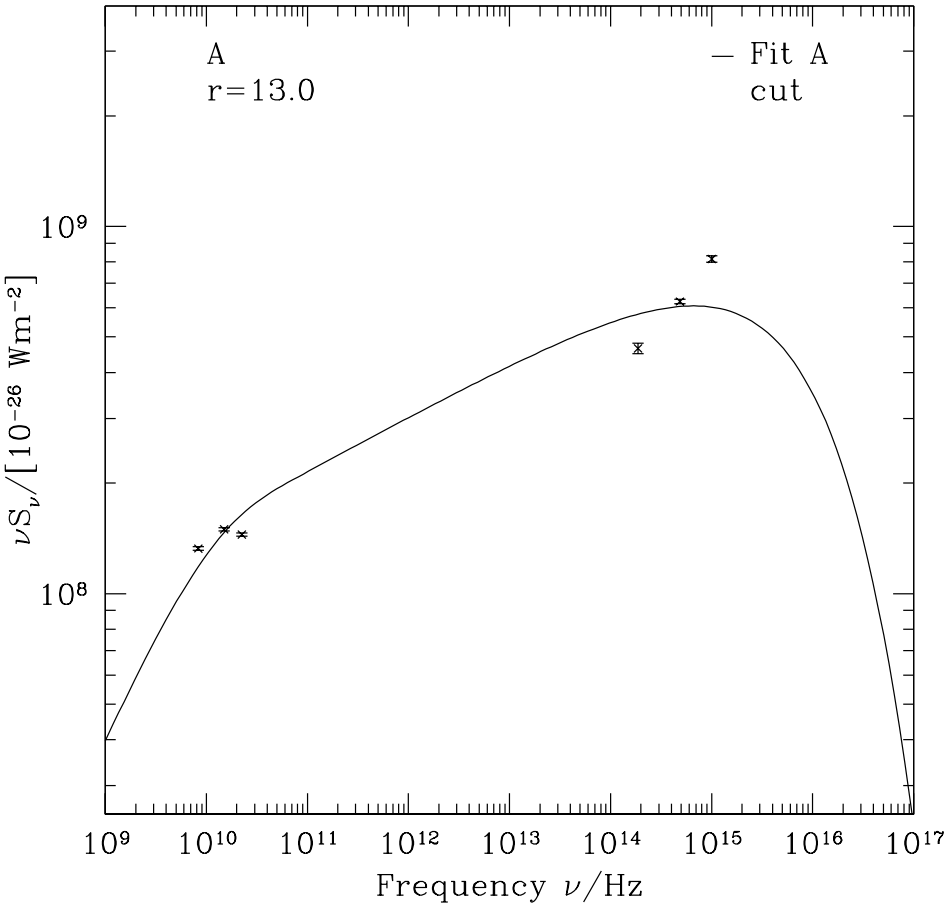
3C273 with Chandra & Spitzer

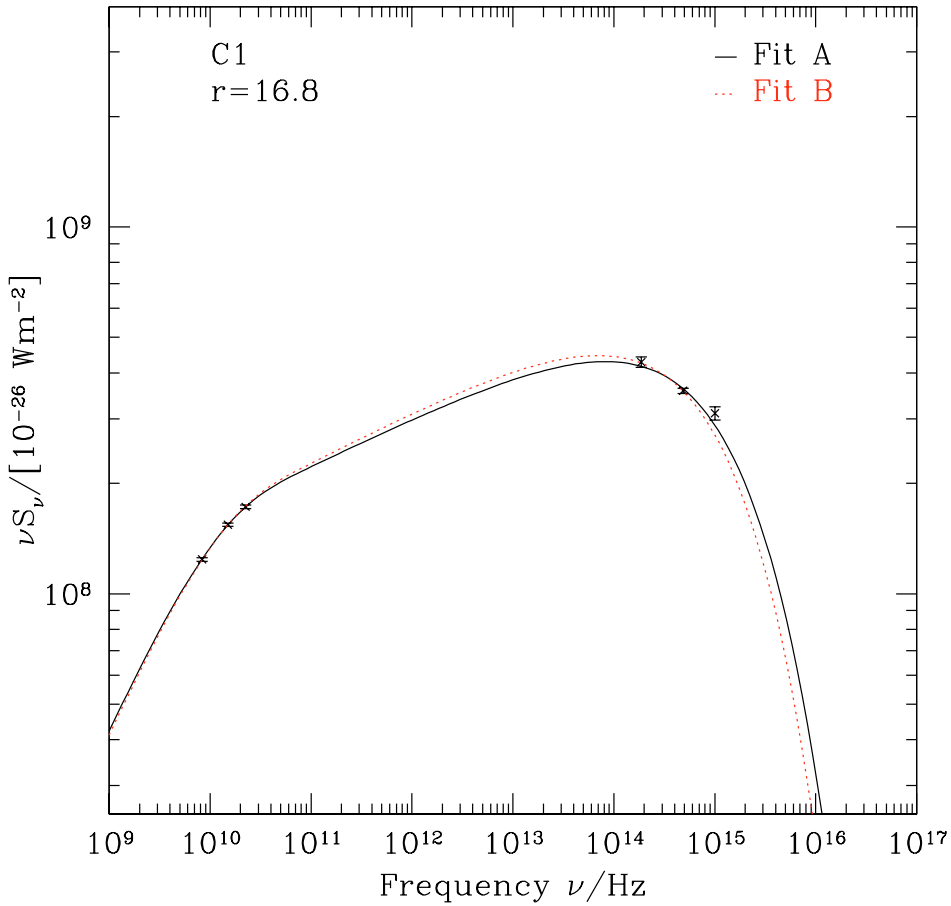


Y. Uchiyama et al., ApJ accepted [astro-ph/0605530]

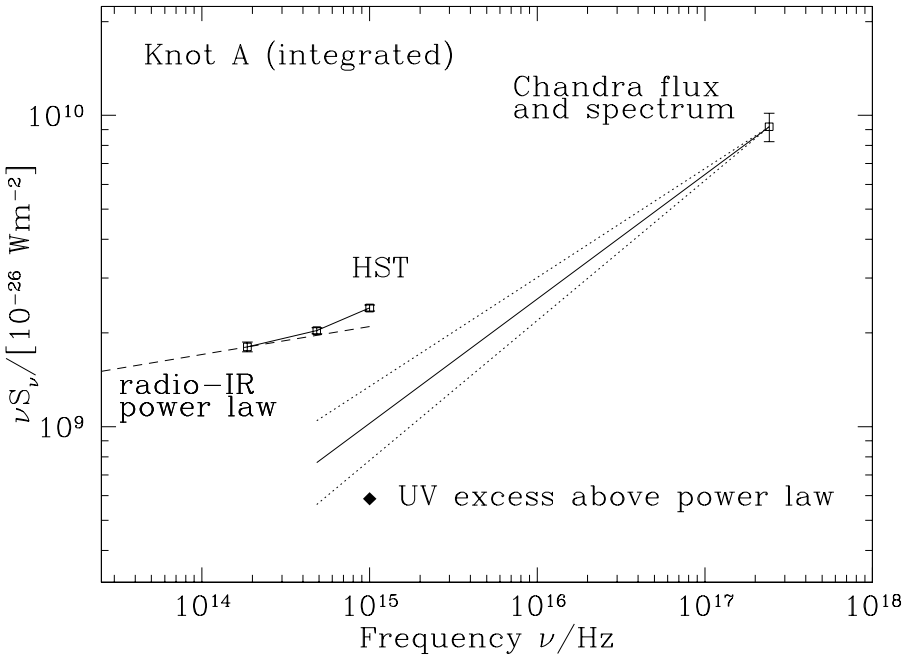
Interesting change to SEDs!

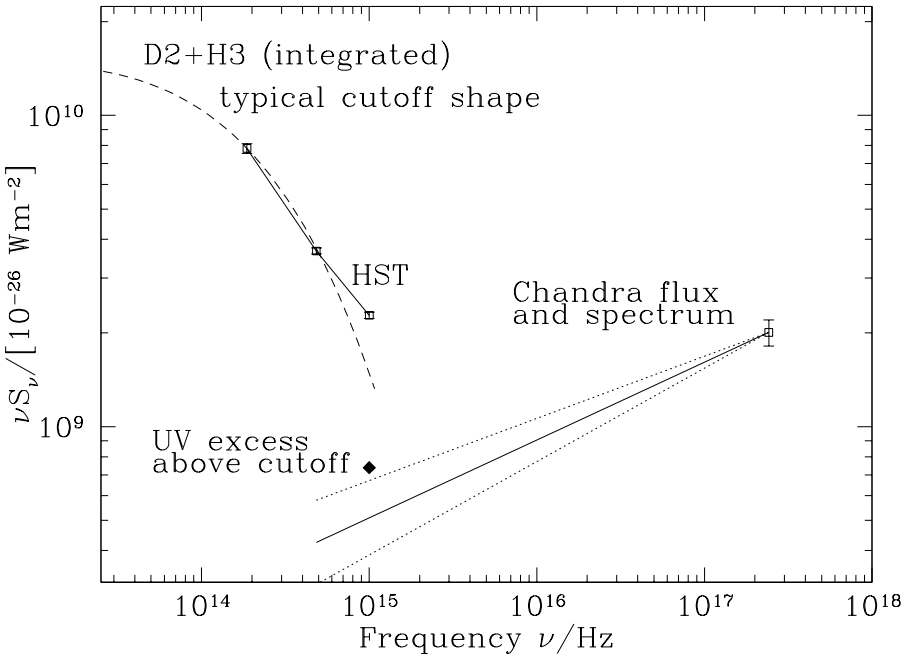






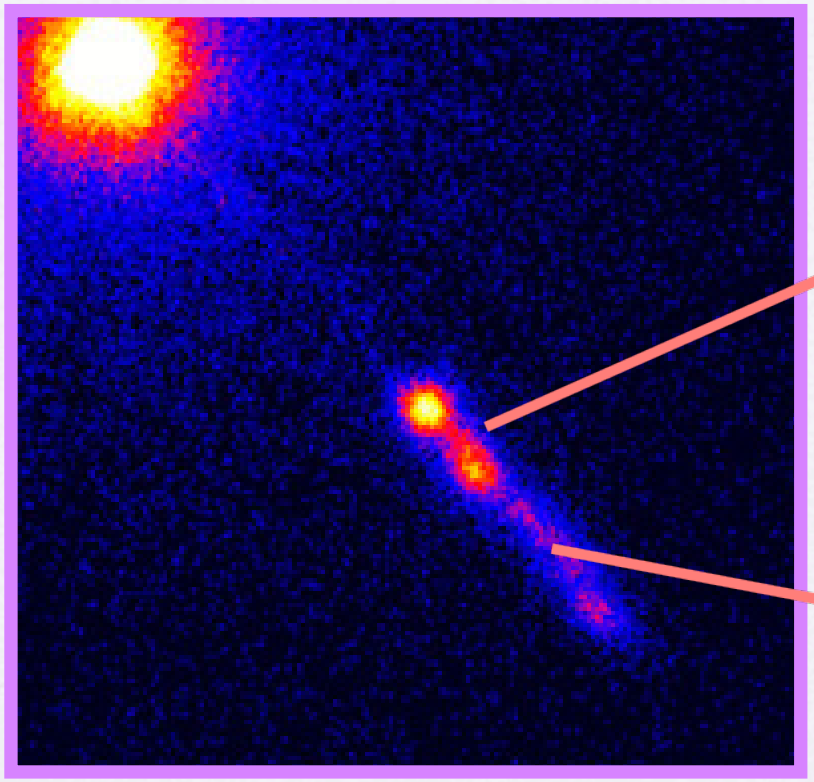
VLA+HST SEDs from Jester et al. 2005





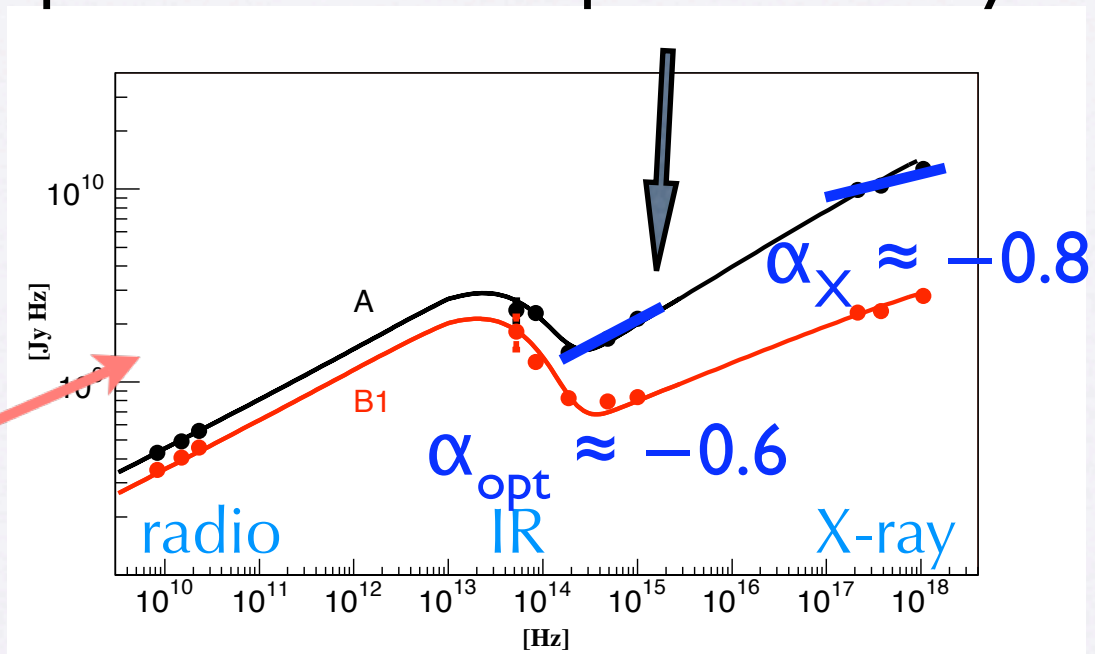
Jester et al. 2002 suggestion: UV excess linked to X-rays

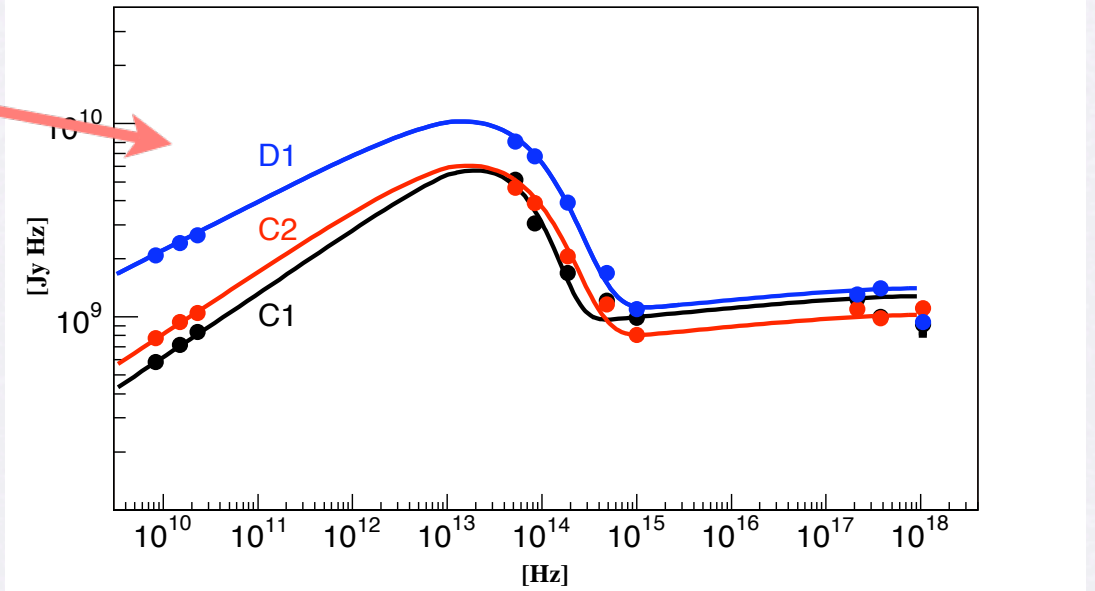
Multiwavelength Spectra



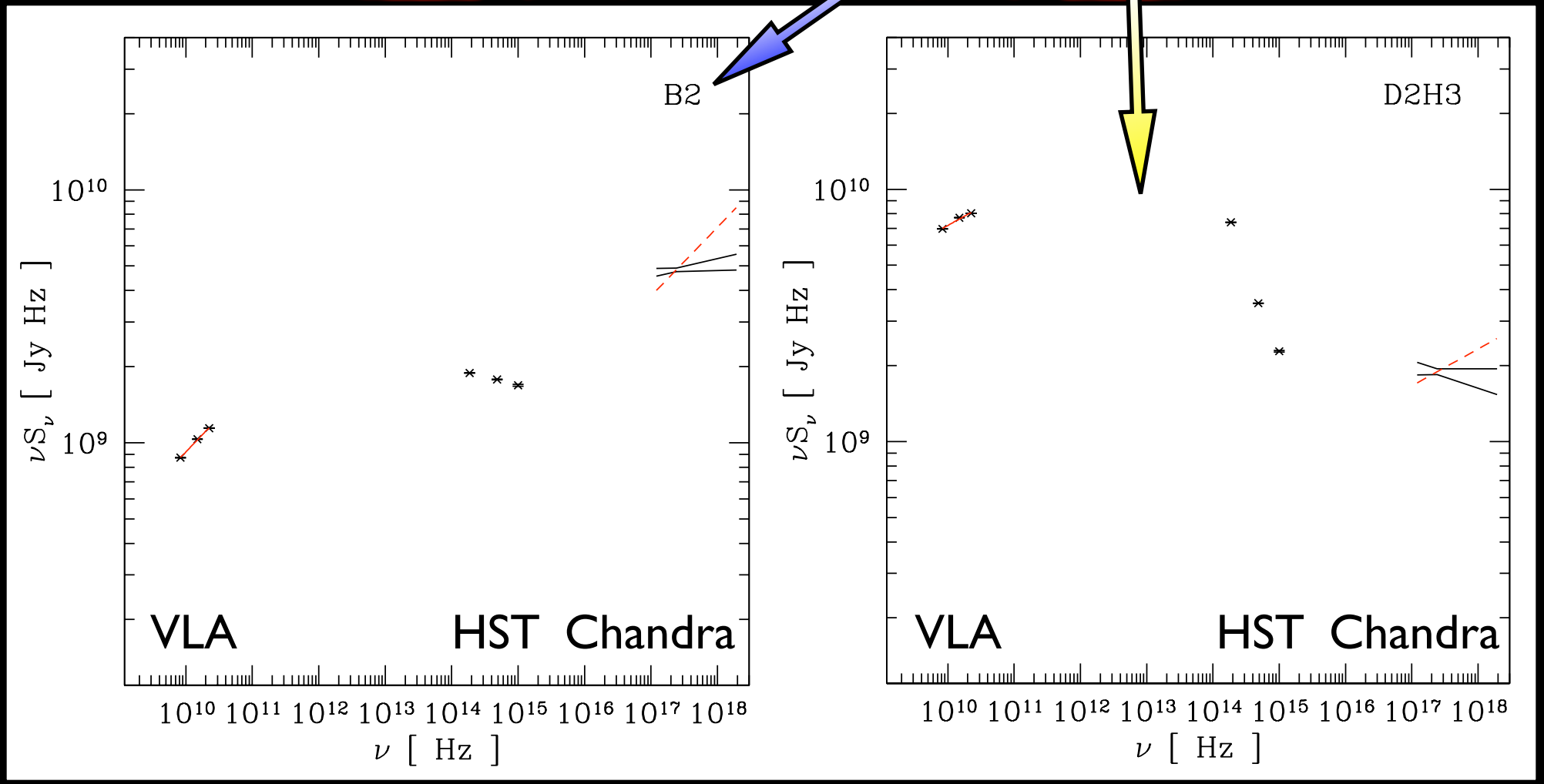
Two-component:
synchrotron + synchrotron !!
(radio/optical polarization)

Spitzer SED links optical to X-rays!



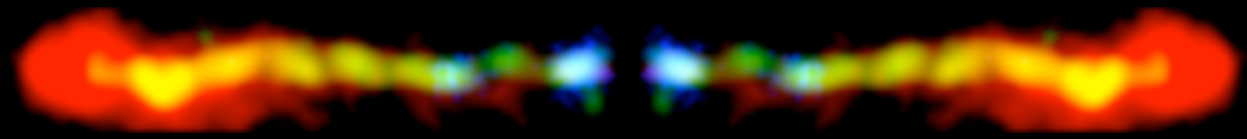


3C273 with Chandra



X-rays too soft for 1-zone IC-CMB! [astro-ph/0605529]

3C273: all synchrotron?!



- Spitzer SED links optical & X-ray emission
- Röser et al. 1996:
  - Optical polarisation is high ⇒ synchrotron
  - Similar in radio & optical at 1.3”

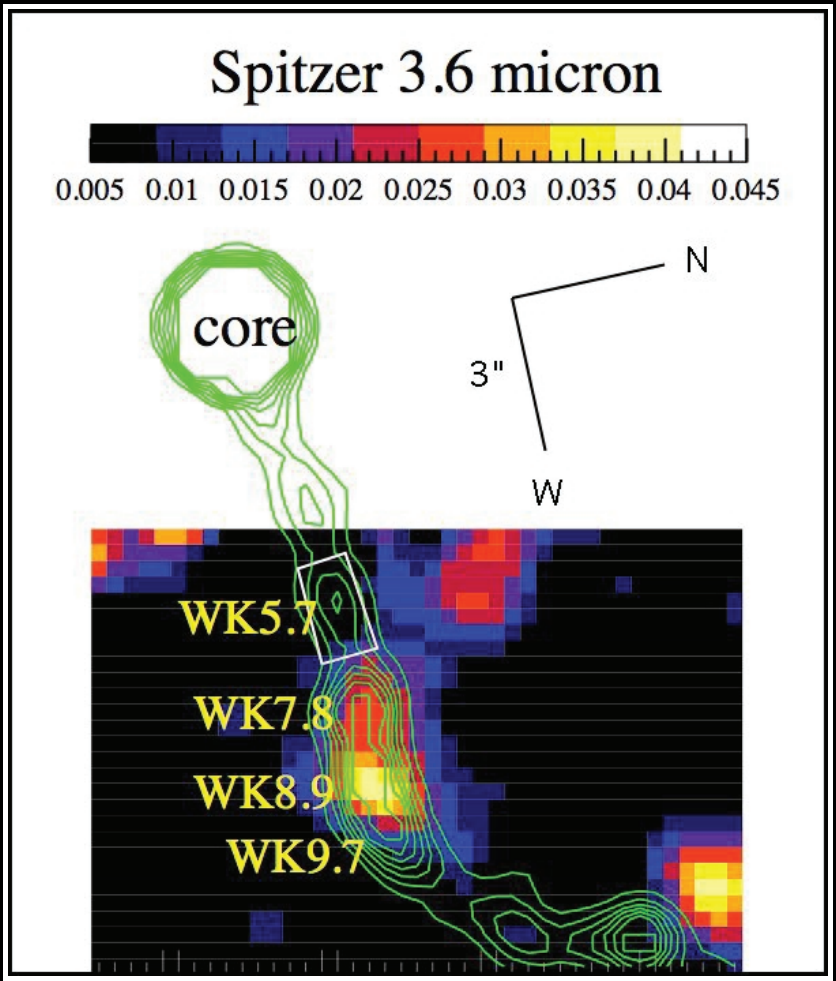
⇒ X-ray synchrotron, too

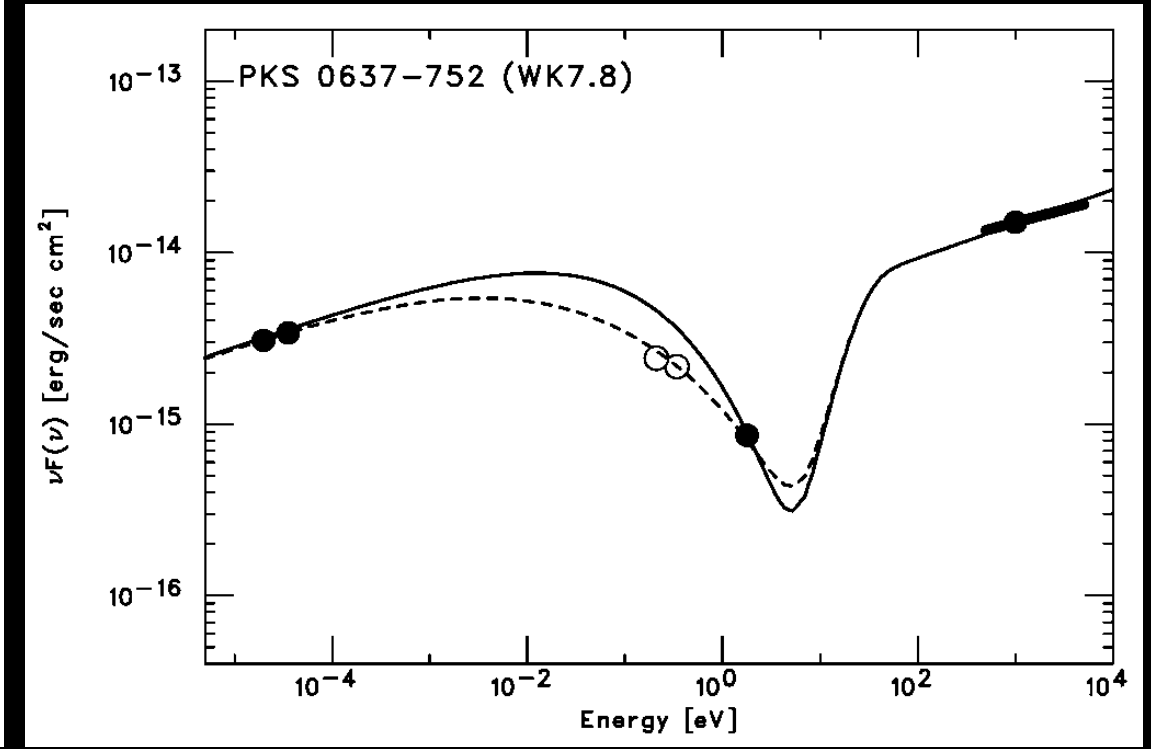
- Chandra SED: X-rays are (mostly) too soft for 1-zone CMB-IC

⇒ Need inhomogeneous flow (shear layer)

  - Synchrotron from shear acceleration?
  - What about other jets?
    - More Spitzer!

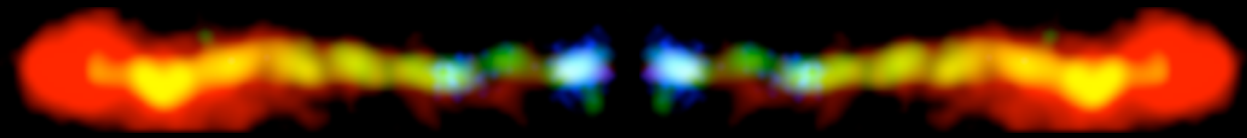
PKS 0637-752 with Spitzer





Uchiyama et al. 2005: constraints on kinetic energy flux

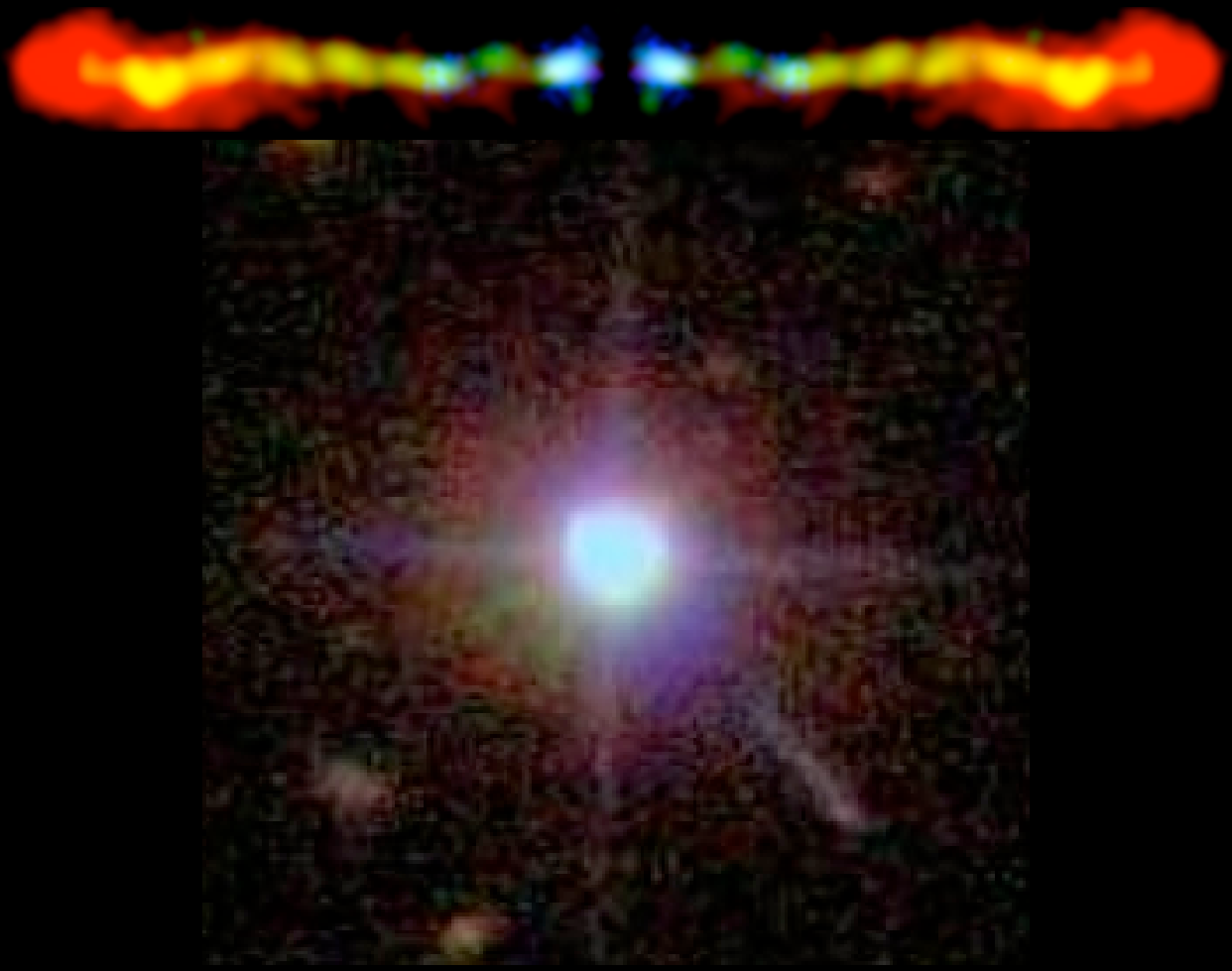
Searches for optical/IR jets



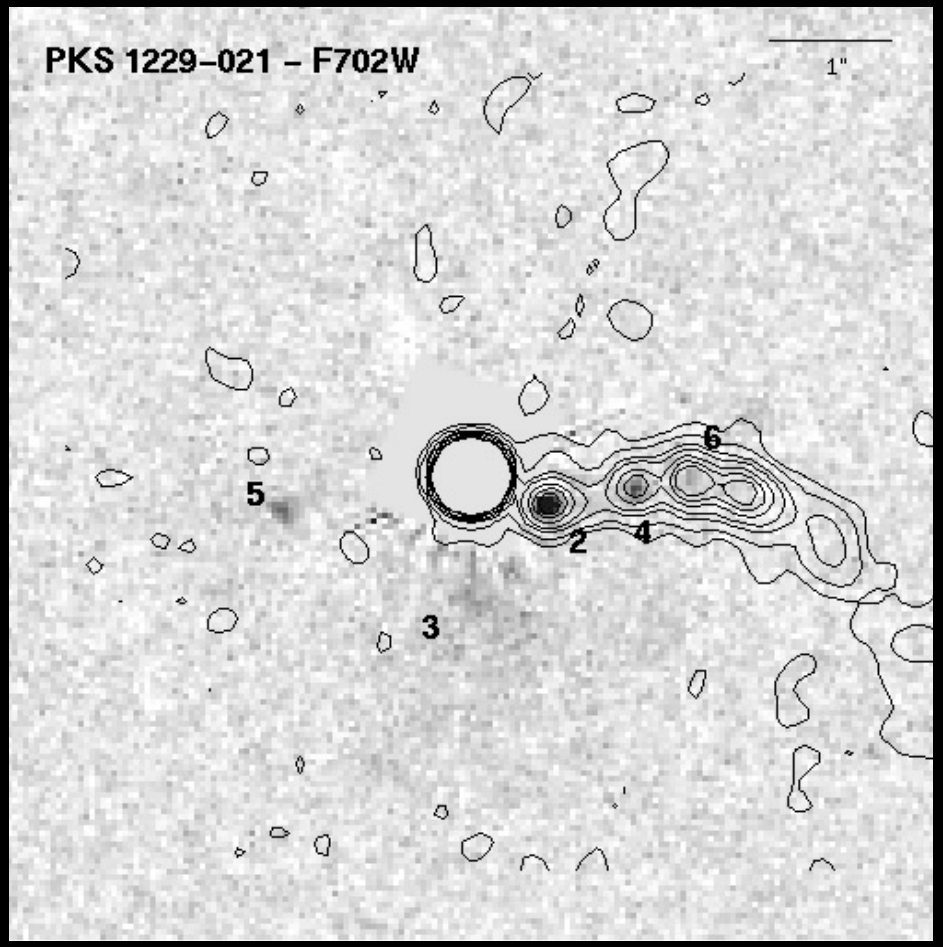
- http://home.fnal.gov/~jester/optjets/ lists 39 confirmed objects; 2-3 more to be published soon (Gelbord/Perlman/Marshall)
- History:

Pre-HST	B2/3C snapshots	HST/CXO surveys	Cheung archival	Other HST
11	9	12	2	7

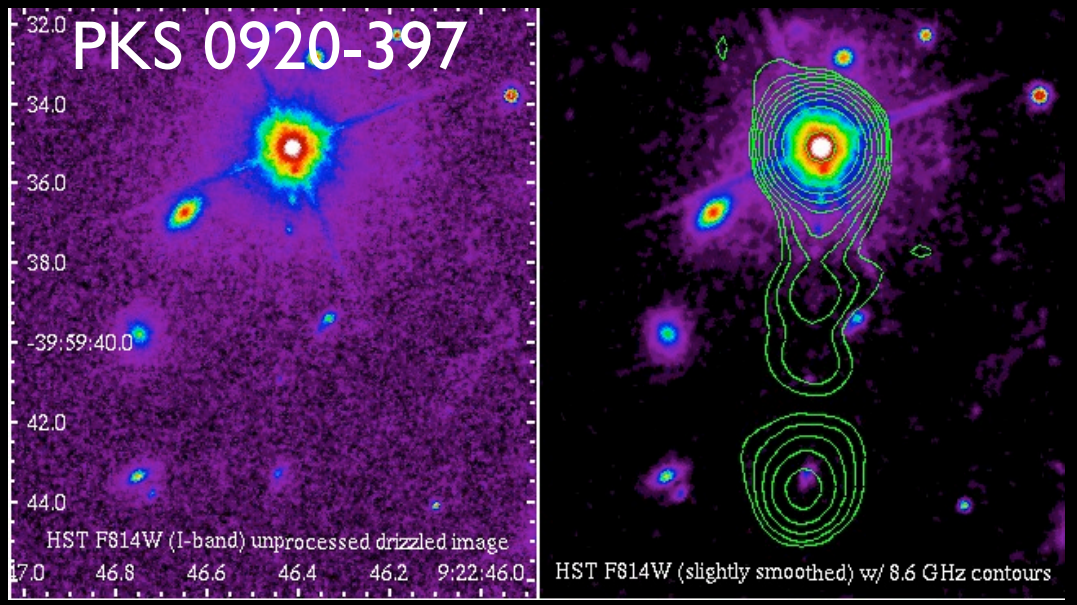
Could find 3C273 with SDSS...



Some jets, old and new



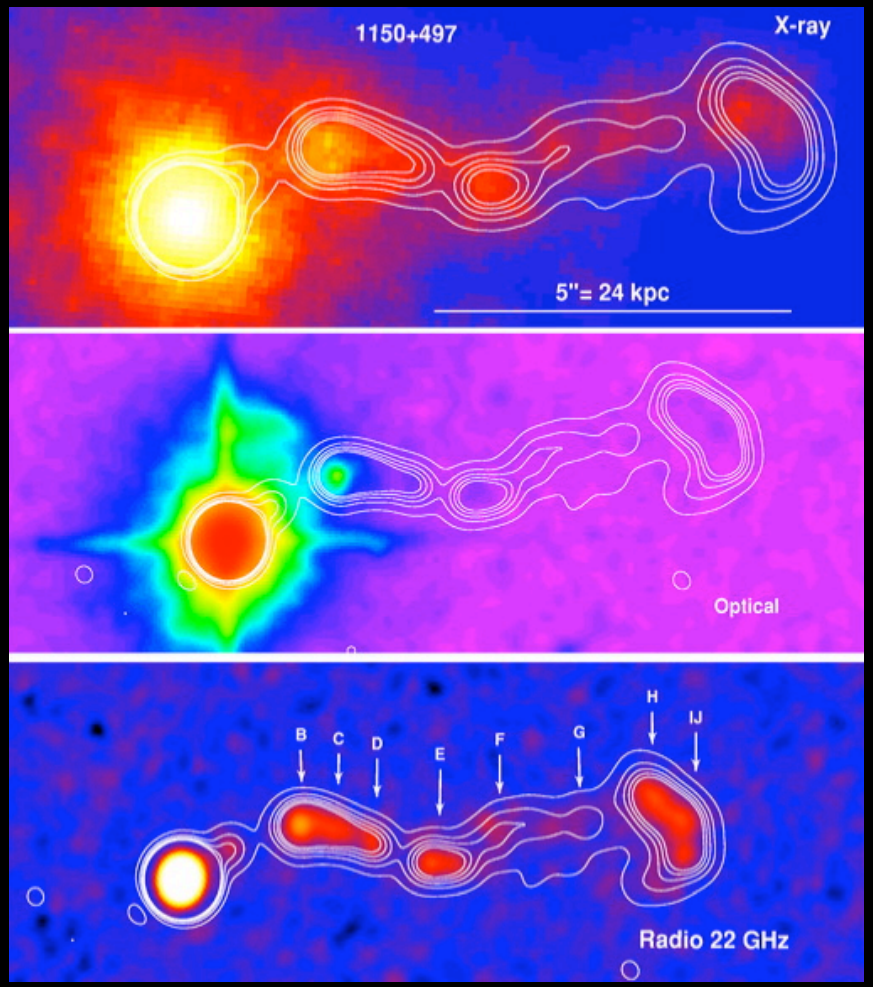
Le Brun et al. 1997 (3.6 ksec)
Re-found by C. C. Cheung



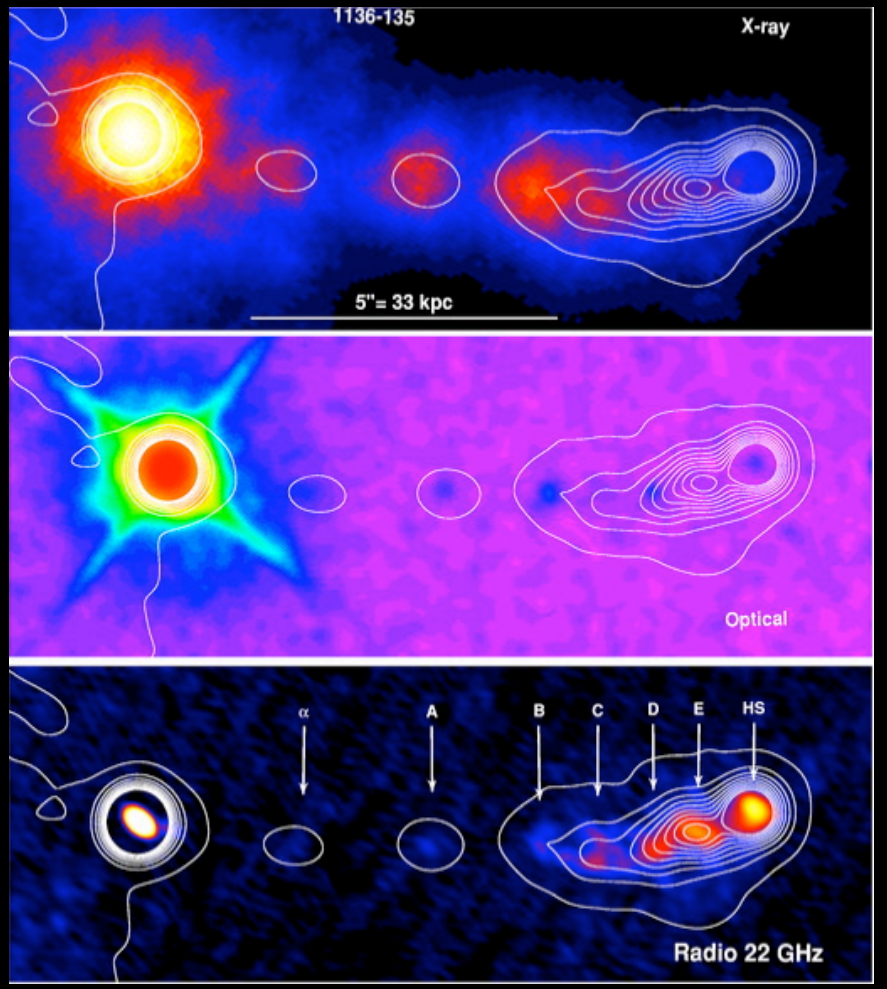
Gelbord/Perlman/Marshall
in prep. (+ 1-2 jets and 2-3 HS)
see poster!

PKS 0812+020?

Follow-up of Sambruna survey

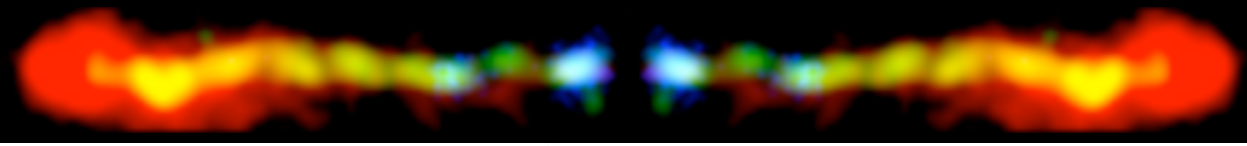


1150+497
(Sambruna et al. 2006)

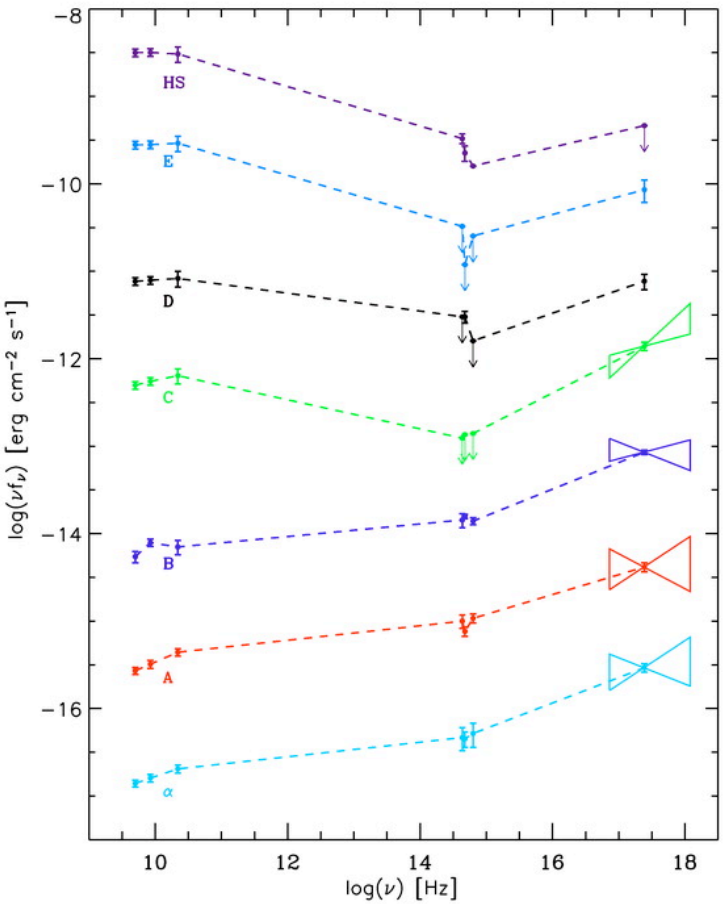


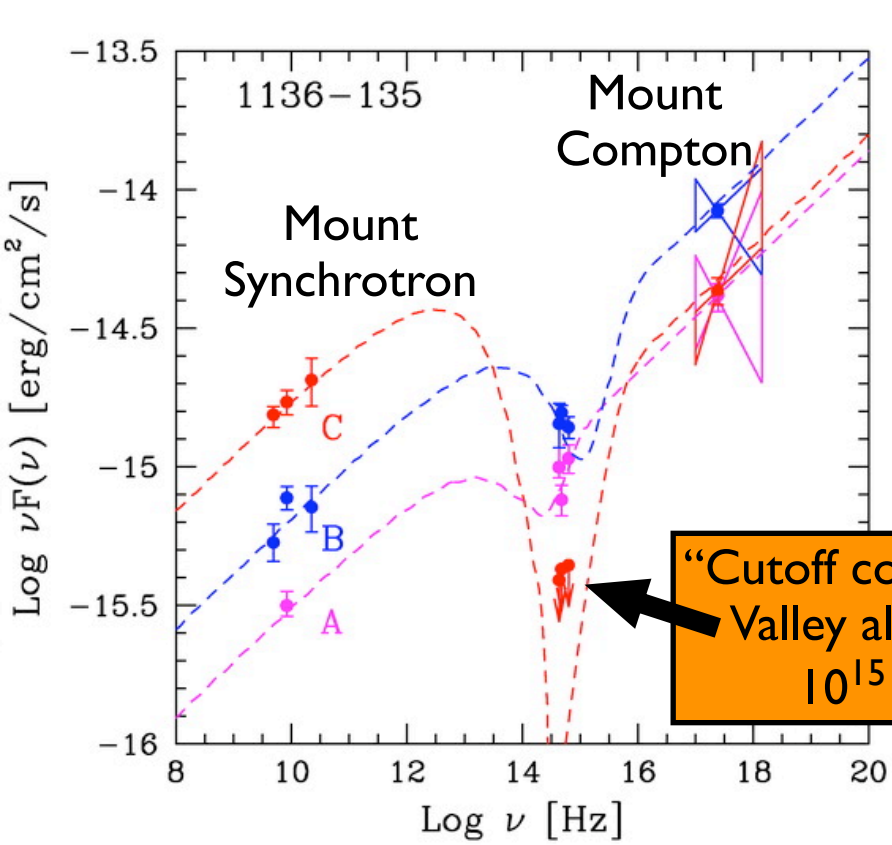
1136-135
Another 3C273?

Sambruna SEDs: 1136



increasing r

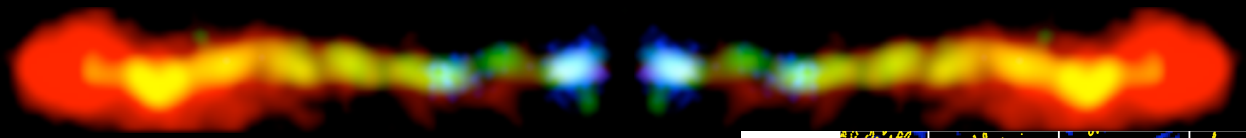


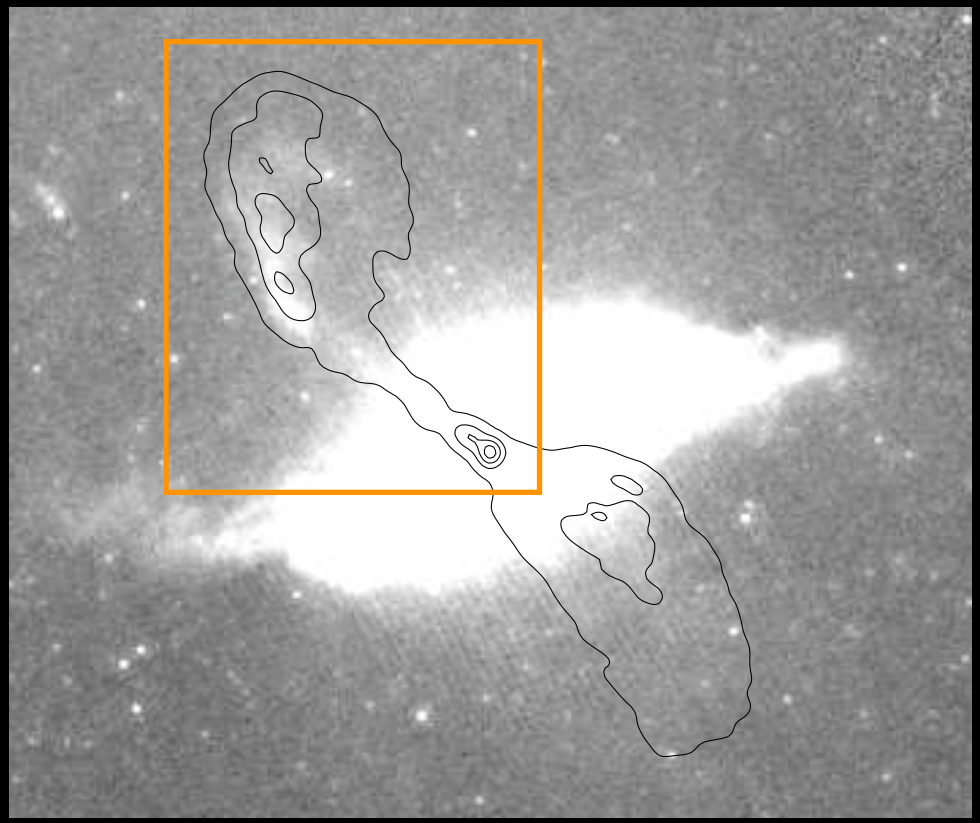


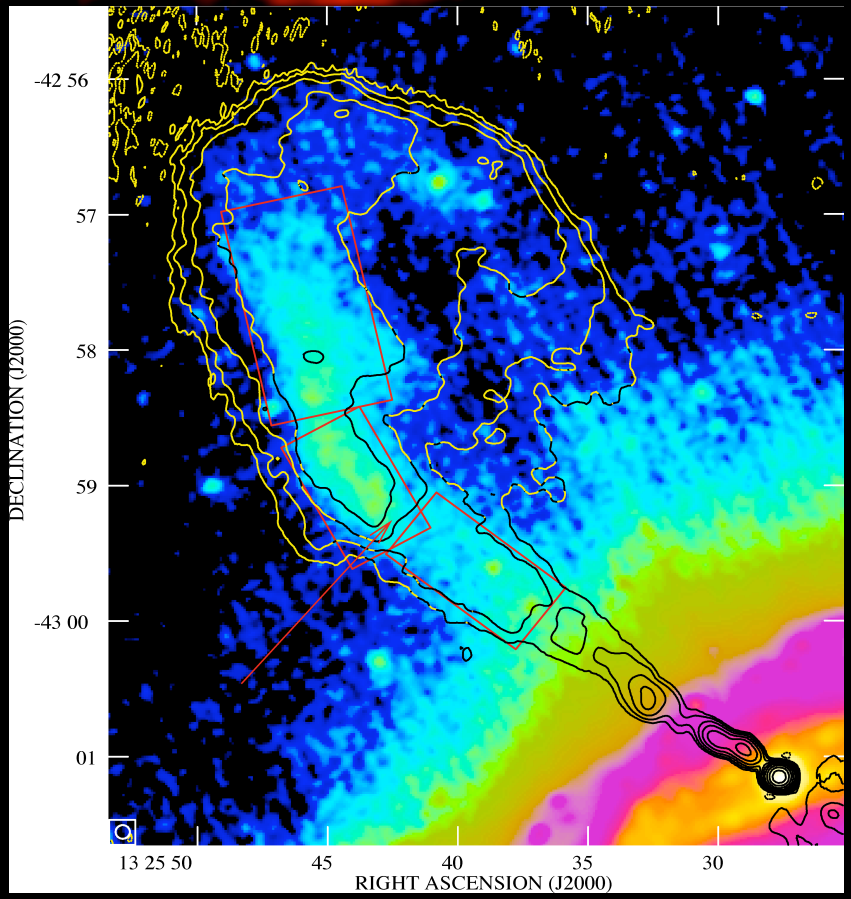
"Cutoff conspiracy"
Valley always at
10^{15} Hz?

Again, need Spitzer/ALMA to check IC-CMB
⇒ location of valley (cutoff and IC cut-on)

Cen A with Spitzer (24μ)





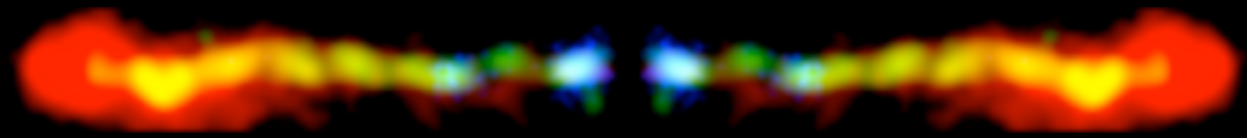


Brookes et al. 2006

Hardcastle et al. 2006

Radio, IR, UV, X-ray synchrotron; multi-component spectra!

New polarisation results

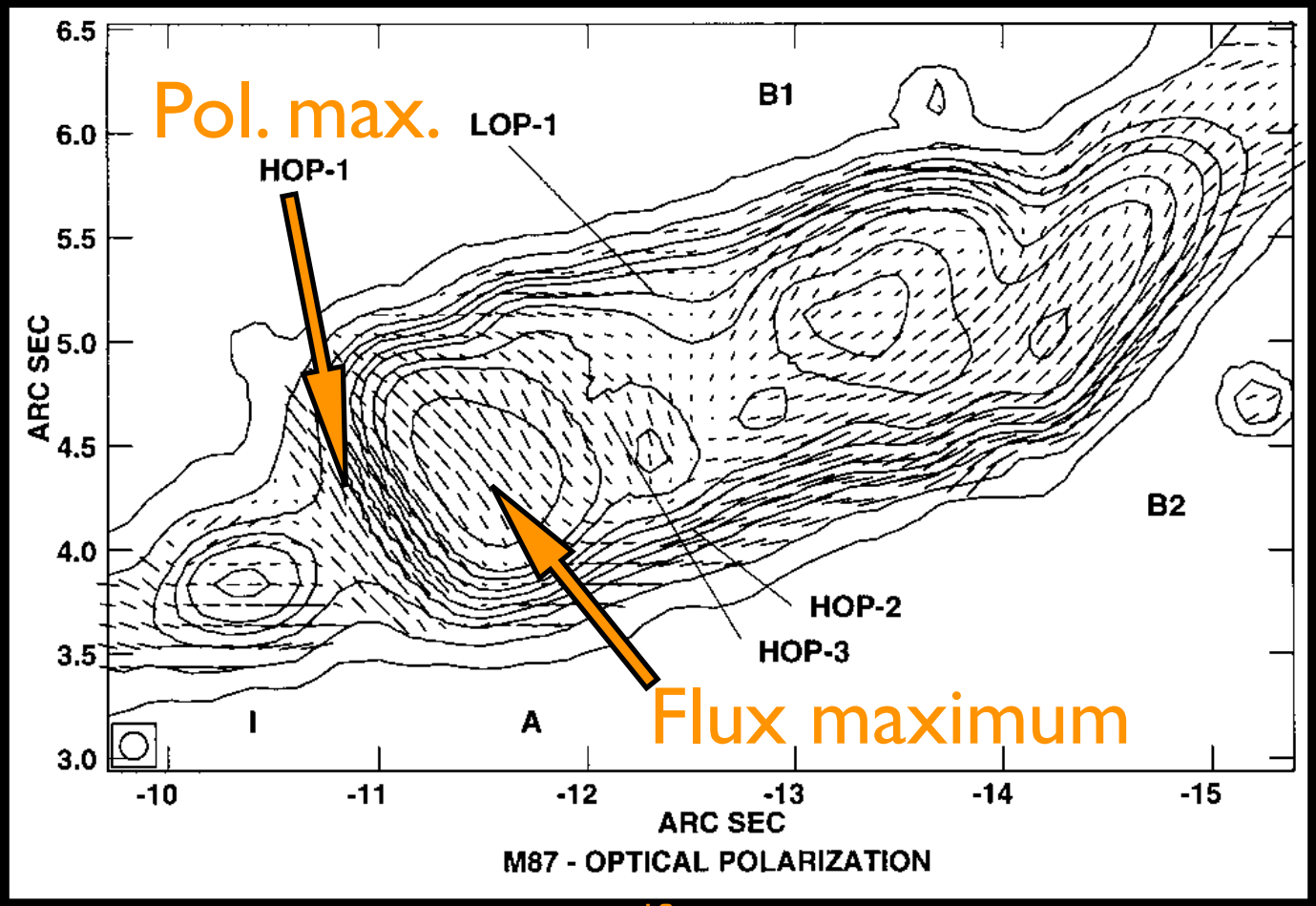


- Perlman et al. 2006 [astro-ph/0606119]: HST/WFPC2, ACS optical polarimetry atlas of 6 nearby FRI jets
  - 3C 15, 66B, 78, 264, 346 and 371
  - High optical polarisation, 10%-50%
  - M87 showed radio/optical differences (Perlman et al. 1999)
  - Results: similar differences in new jets, but no universal patterns
- Compare Lyutikov et al, Laing et al. modeling

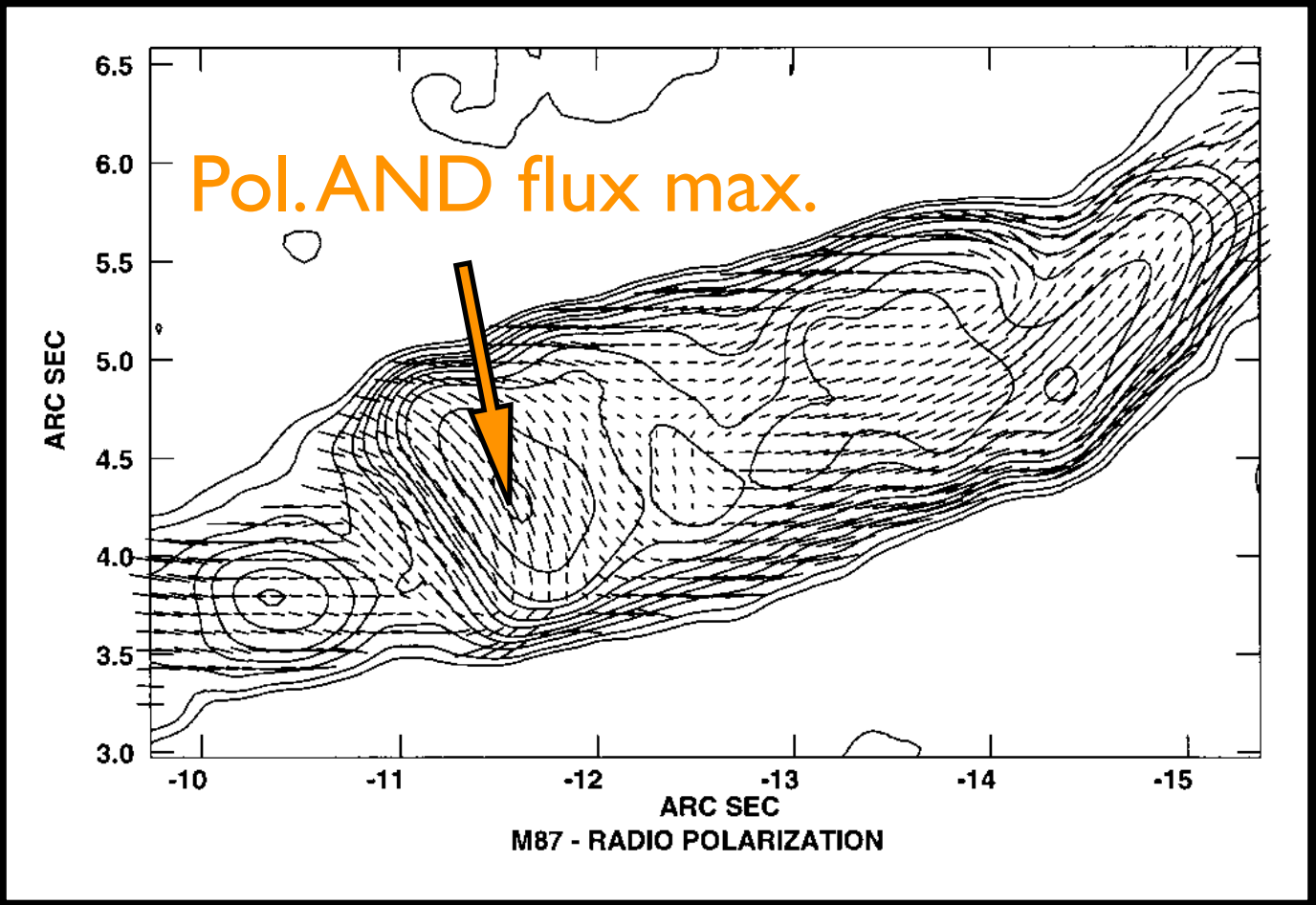
High-polarisation regions I

- Polarisation maximum in jet interior; often upstream of flux maximum

e.g. M87



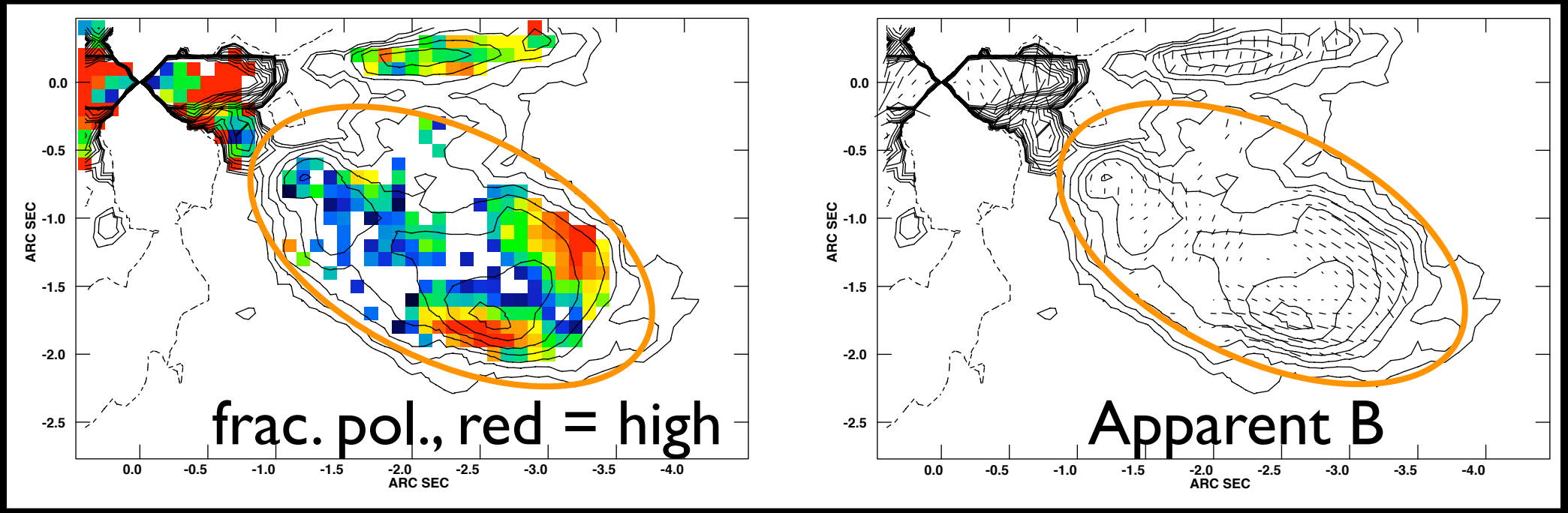
Comparison to radio: M87



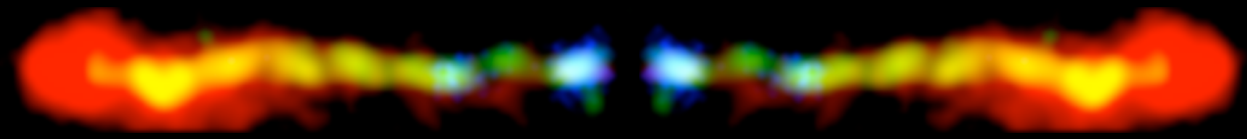
Radio and optical polarisation peaks and troughs often not in same place

High-polarisation regions II

- Near edge of jet (also seen in radio)
  - B aligned with jet edge
  - Unpolarised valley in jet centre
  - e.g. 3C15, 3C 346, 3C 371

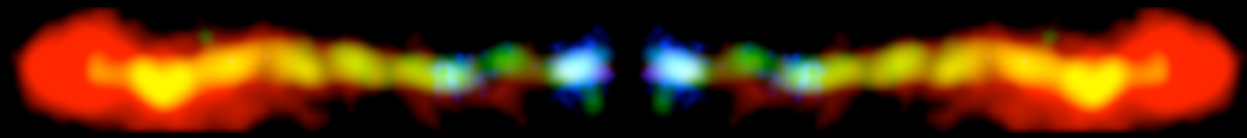


What have we learned?



- 3C 273 with Spitzer/Chandra:
  - SED+Spitzer links X-ray and optical
  - High optical polarisation implies synchrotron, hence X-ray synchrotron
  - Flow is inhomogeneous, forget 1-zone models!!! (already Jester et al. 2002)
- Beginning to get
  - detailed optical SEDs for other jets
  - good HST polarimetry for low-power jets
- Still need polarimetry for high-power high-z jets like 3C 273, 0637-752, 1229-021

Open Questions

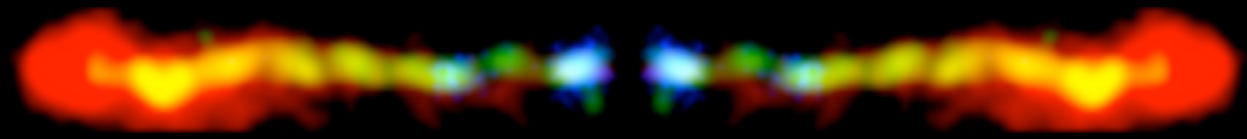


- Why are locations and sizes of "knots" mostly wavelength-independent?
- What creates polarisation features?
- Does IC-CMB work?
  - Need more SEDs including Spitzer/ALMA, more comparisons radio↔X-ray spectrum
  - Test bulk deceleration models using polarisation properties (Laing et al.)
  - Cutoff conspiracy: why is Compton valley apparently always near optical?

More questions

- Optical hot spots seem understood:
  - Shock-accelerated particles (Fermi)
  - Low-power hot spots have lower B-field, hence smaller losses and more optical em. (Meisenheimer et al. 1997, Prieto et al. 2002, Brunetti et al. 2003)
- In jets:
  - What is the acceleration mechanism?
  - Is there a similar "Loss sequence"?
  - Again: need more detailed SEDs!

The future



- Post-HST space-based optical jet astronomy:
  -
  - Instead:
    - Ground-based AO polarimetry?
    - A real optical/UV HST replacement?
  - Do "X-ray polarimetry" in optical band!
- LOFAR: map low-energy end of electron population directly in radio band
  - Test IC/CMB model predictions in optical (cutoff conspiracy)

www.astro.soton.ac.uk/~jester/3C273.html