# Large-scale Jet in Quasar 3C 273

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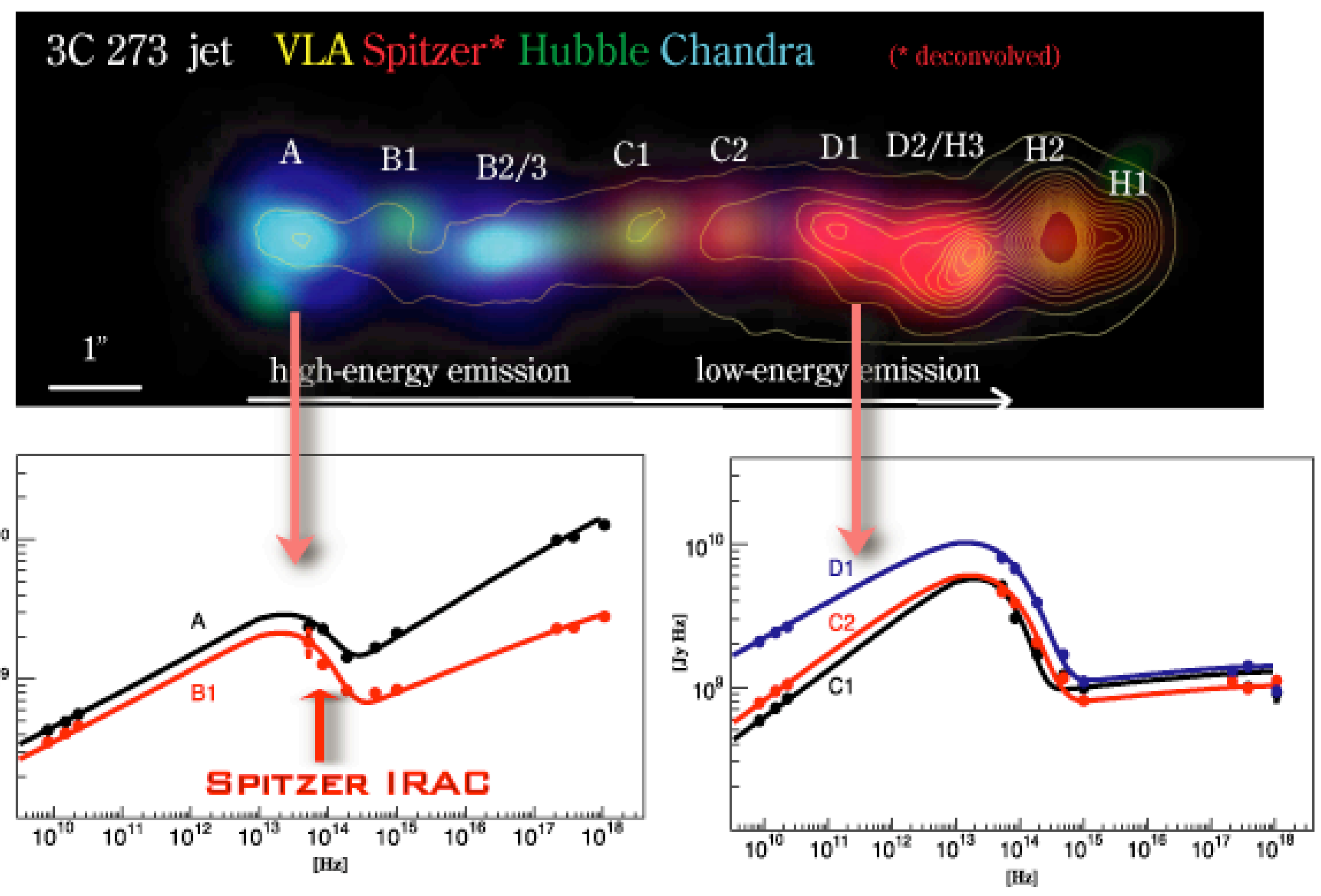
## Abstract

**We have measured, for the first time, infrared fluxes of the kpc-scale jet of the quasar 3C 273 with IRAC on board the Spitzer Space Telescope (Uchiyama et al., astro-ph/0605530). When combined with the multi-frequency data, this allows us to clearly identify two spectral components along the jet: the low-energy synchrotron (radio-to-infrared) and the high-energy component (optical-to-X-ray). The latter may be due to a second synchrotron component or due to "beamed" inverse-Compton scattering. The present polarization data would favor the synchrotron interpretation of the high-energy component. If so, particle acceleration in the jet knots would be fast enough to accelerate protons to very-high-energies, which may be interesting in the context of the origin of cosmic-rays.**

## *Spitzer* Infrared Observations

The *Spitzer* IRAC observations at 3.6 and 5.8 microns of the jet of 3C 273 have been carried out on 2005 June 10 as part of our GO-1 program. In Fig. 1, we show the 3.6-micron jet image, as well as the radio (*VLA*), optical (*HST*), and X-ray (*Chandra*) images.

*Figure 2: (Top) false-color image of the 3C 273 jet, illustrating spectral evolution along the jet. (Bottom) broadband SEDs of the jet knots.*



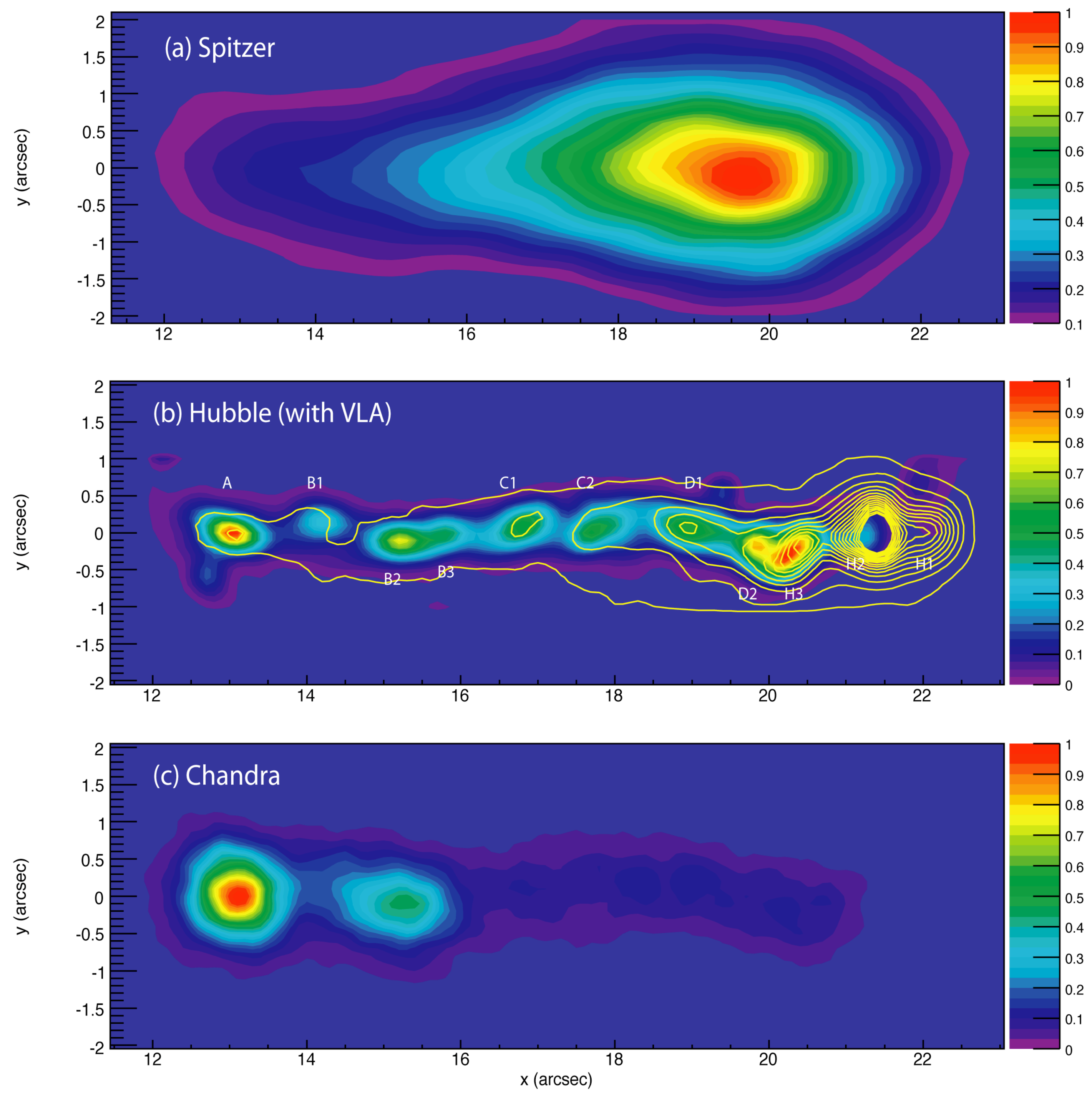

## Synchrotron vs Inverse-Compton

In many quasars jets, some jet knots (like knot A in 3C 273) radiate their power predominantly in X-rays. Despite extensive work, the dominant X-ray emission mechanism remains unsettled---"is it relativistically beamed inverse-Compton (IC) or synchrotron radiation?"

An important finding in our study is that the optical and X-ray fluxes must be explained by the ***same*** emission mechanism. Then the fact that both the radio an optical jet emission are linearly polarized to a similar degree of about 15% (Roeser et al. 1996), suggests both the low- and high-energy components are of synchrotron origin. Also, steeper spectra in X-rays (than in radio) in "outer" knots (see Fig. 2) would disfavor the beamed IC origin for X-rays (see Jester et al. 2006).

However, we note that the polarization in optical alone does not easily rule out the IC model since the ***optical*** IC emission by mildly-relativistic electrons may show some degrees of linear polarization (Fig. 3, Uchiyama et al. in prep). We need more sensitive measurements of polarization to draw firmer conclusions about the origin of the high-energy radiation component in quasar jets.

**Figure 1**: **Multi-frequency Images of the 3C 273 jet. (a) Spitzer IRAC 3.6 micron (b) Hubble 620 nm from Jester et al. (2005) (c) Chandra 0.4-6 keV.**




## Multi-frequency Analysis

We derived the flux densities of individual knots at various wavelengths (Fig. 2). Since the PSF widths of *Spitzer* IRAC are comparable to the angular separation of adjacent knots (typically 1"), we have performed 2D PSF fitting to obtain the infrared fluxes. Two distinctive spectral components become apparent: (1) low-energy synchrotron from radio to infrared and (2) high-energy component from optical to X-rays. Note that the SEDs of "inner" knots (A and B1) are strikingly different from those of "outer" knots (C1,C2, and D1). Importantly, the optical emission is dominated by the high-energy component, not by the radio synchrotron, as had been widely assumed to date in the modeling of quasar jets. This finding offers new clues as to the controversial origin of the X-ray emission seen in many quasar jets.

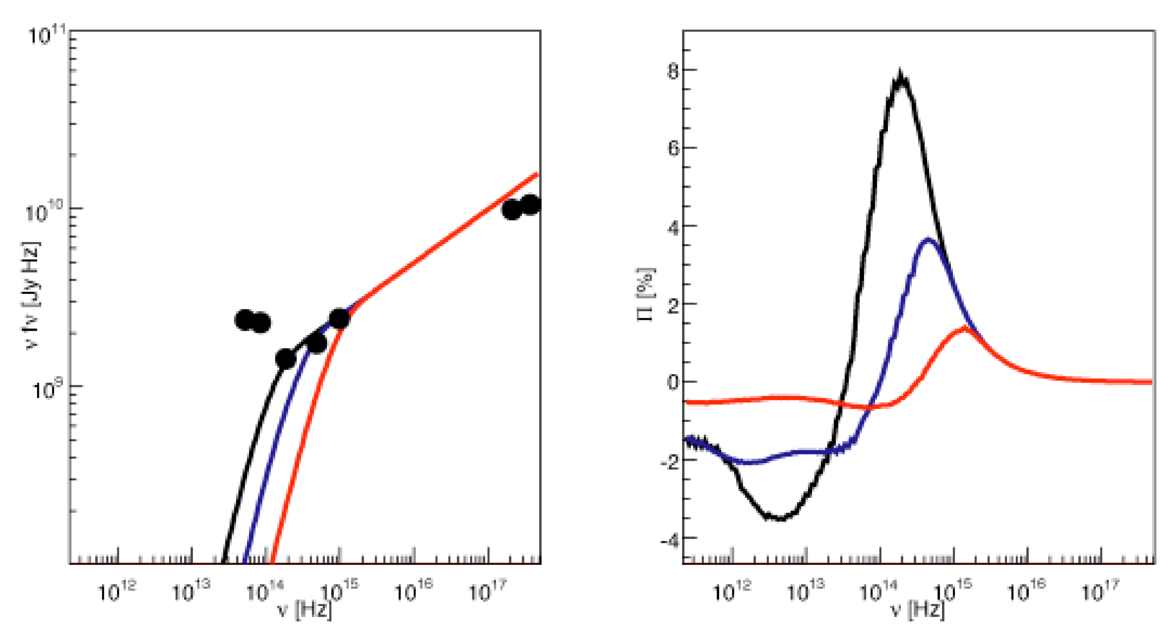



*Figure 3: Spectra (left) and polarization degrees (right) of the beamed IC radiation on CMB. The values of minimum electron energy determine the degree of polarization. Emin/511 keV = 2 (black), 3 (blue), and 5 (red)*

Intriguing implications of interpreting the X-ray emission as due to a synchrotron process are: (1) very fast cooling of X-ray-emitting electrons (< 100 yr) requires ***in-situ*** particle acceleration in the jet knots; (2) long-lived protons can in principle be accelerated to very high energies, say $10^{19}$ eV, making quasar jets interesting sites for the origin of extragalactic cosmic-rays.