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Longterm multi-wavelength variability of 3C 273

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We present a summary on the update of 3C 273's Database and on the analysis of the longterm multi-wavelength variability of this bright quasar. The on-line database is now covering more than 40 years of observations from radio to gamma-rays offering a unique view on the complex variability properties of this active galactic nucleus. The amplitude and the maximum time scales of the variations depend strongly on the frequency and show trends that are characteristic of the underlying emission processes. The variability properties of the X-ray band imply the presence of either two separate components (possibly a Seyfert-like and a blazar-like) or at least two parameters with different timing properties to account for the X-ray emission below and above $\sim$20 keV. The dominant hard X-ray emission is most probably not due to electrons accelerated by the shock waves in the jet as their variability does not correlate with the flaring millimeter emission, but seems to be associated to long-timescale variations in the optical. This optical component is consistent with being optically thin synchrotron radiation from the base of the jet and the hard X-rays would be produced through inverse Compton processes (SSC and/or EC) by the same electron population. We show evidence that this synchrotron component extends from the optical to the near-infrared domain, where it is blended by emission of heated dust that we find to be located within about 1 light-year from the ultraviolet source.

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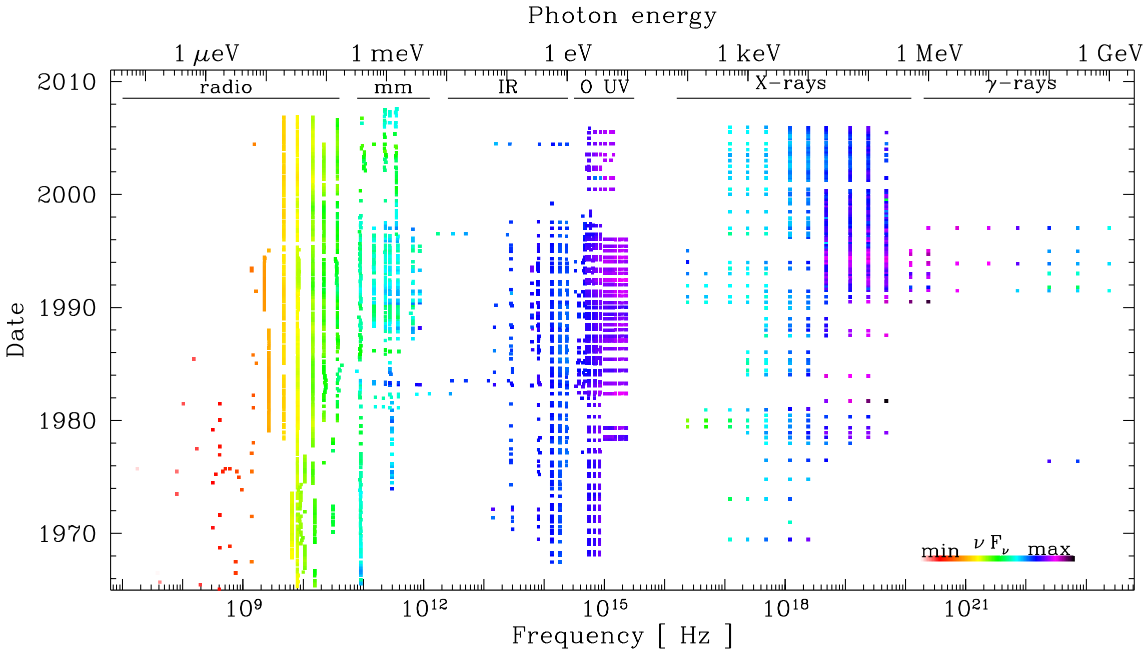

Figure 1: Time coverage of all 3C 273 observations of the database as a function of the frequency, colour-coded to represent the νF_ν intensity of the measured fluxes.

1. Introduction

The quasar 3C 273 is one of the best observed active galactic nuclei (AGN) at all wavelengths, due to its brightness and to its numerous interesting features both typical of blazars (high variability, a jet with superluminal motion, polarization) and of Seyfert galaxies (a blue-bump, variable broad emission-lines). We continue the effort of updating 3C 273's Database by collecting and including all available multi-wavelength observations from radio to gamma-rays. This project has been initiated in 1999 by Türler et al. [1] and has now been updated by Soldi et al. [2] with the inclusion of the last 10 years of data. As an illustration, we show in Fig. 1 the time and frequency coverage of the database organized as lightcurves in various frequency bands, whereas Fig. 2 shows the average spectral energy distribution and the range of variability. All individual lightcurves are publicly available in graphical and data format at `http://isdc.unige.ch/3c273/`. We present here a summary of the main results of the variability analysis of this dataset that is currently being published in [2].

2. Variability amplitude and timescale

For lightcurves with sufficient observations and adequate time sampling, we derive the amplitude of the variations relative to the mean flux, F_{var}, and the maximum time scale of variability, τ_{max}, estimated with a structure function analysis. The results are given in Fig. 3 and show that both variability parameters depend strongly on the frequency of the radiation. The following interesting trends can be observed:

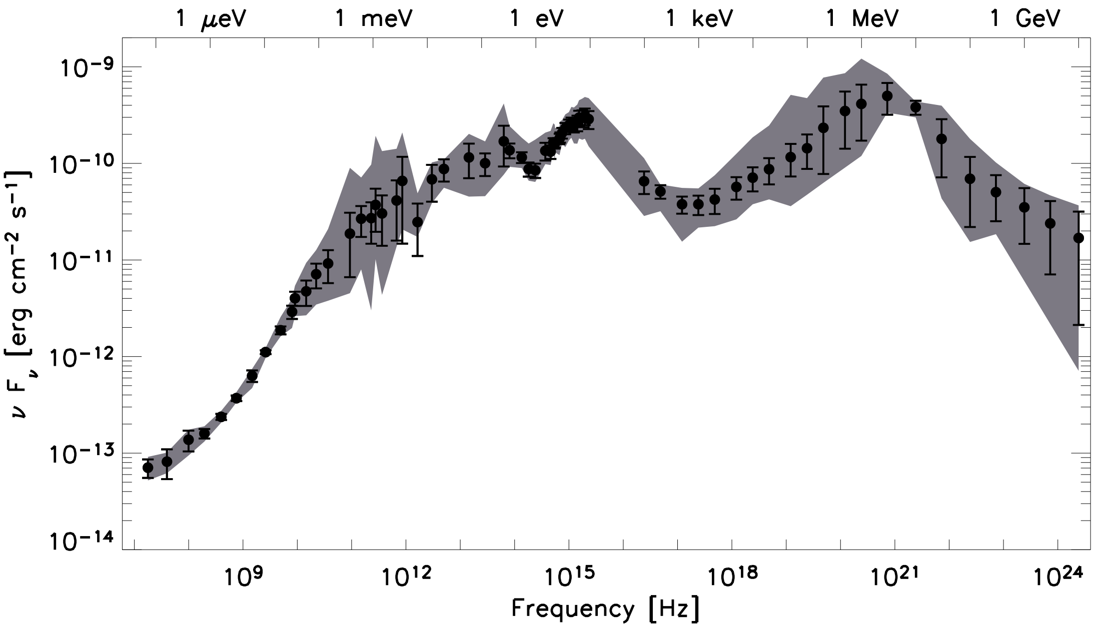

Figure 2: Average spectral energy distribution of 3C 273. The error bars represent the standard deviation from the mean values and the grey area indicates the observed range of variations.

- **X- and gamma-rays**: F_{var} is increasing steeply with energy above 20 keV, whereas at lower X-ray energies the increase is rather shallow. In addition, significantly longer variability time scales are observed above 20 keV than below. This suggests the presence of either two separate components (possibly a Seyfert-like and a blazar-like one) or at least two parameters with distinct variability properties to explain the different characteristics of the variations below and above 20 keV.
- **optical-ultraviolet**: the F_{var}-decrease from ultraviolet to optical is due to the increasing dominance of the $\mathscr{R}$ component, i.e. the longer-wavelength blue-bump component identified by Paltani et al. [3] and showing smaller variations on longer time scales, compared to the ultraviolet component.
- **infrared**: after the removal of synchrotron flares, a less variable component appears. The similarity of the infrared F_{var} trend with that found in the optical-ultraviolet suggests that the $\mathscr{R}$ component is still significantly contributing to the near-infrared emission.
- **radio-millimeter**: the F_{var}-increase and τ_{max}-decrease from the radio to the millimeter band can be well understood as due to the superposition of synchrotron flares in the jet, starting as short flares at high frequencies and propagating to lower frequencies while evolving on longer time scales [4].

3. Cross-correlation results

To identify possible correlations and time delays between radiation emitted at different wavelength, we cross-correlate lightcurves at different frequencies. The results are summarized below:

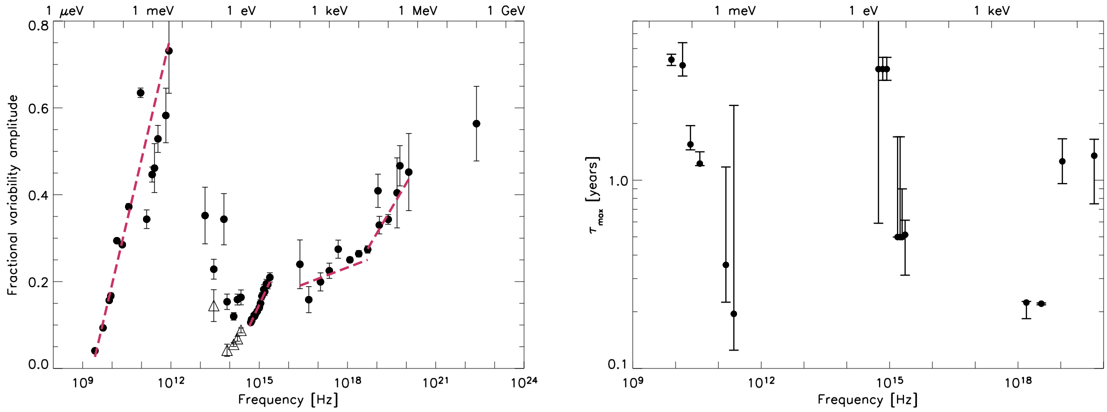

Figure 3: *Left panel:* Spectrum of the fractional variability amplitude, F_{var} (circles). Triangles have been obtained after removal of synchrotron flares in the infrared band. Dashed lines highlight the trends. *Right panel:* Maximum variability time scale, τ_{max}, as a function of the frequency.

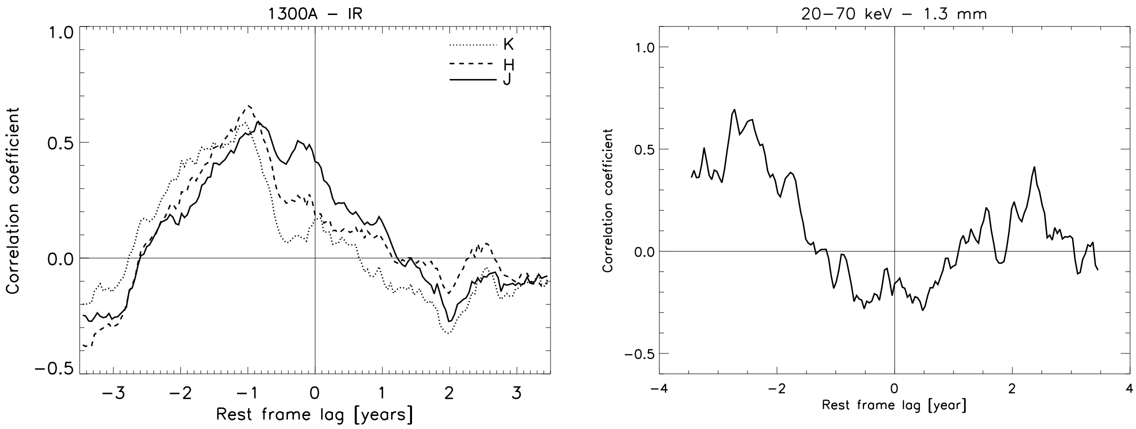

Figure 4: *Left panel:* Correlation between the 1300 Å and the near-infrared (J, H and K band) lightcurves. Delays of 0.8–1.2 years are observed in the near-infrared emission with respect to the ultraviolet one. *Right panel:* Correlation between the 20–70 keV and the 1.3 mm lightcurve.

3.1 The ultraviolet–infrared relation

A correlation is observed between the ultraviolet and the near-infrared lightcurves (see Fig. 4 *Left panel*), suggesting that the near-infrared emission is radiated by dust heated up by the ultraviolet continuum. The 0.8–1.2 year delays we find could represent the travel time of the photons from the ultraviolet source to the dust location. The delays increase with increasing infrared wavelength suggesting an extended dust region with a temperature gradient.

3.2 The hard X-ray emission

Cross-correlating the hard X-ray and millimeter lightcurves (Fig. 4 *Right panel*), we do not find a correlation at short lags that would be expected if the same electron population was responsible for both the synchrotron and the inverse Compton emissions. Therefore, it seems that the dominant

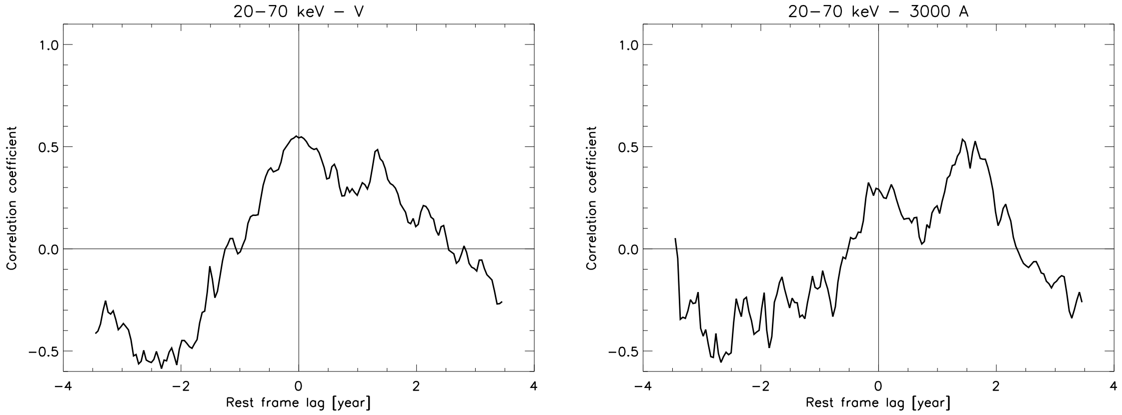

Figure 5: *Left panel:* Correlation between the 20–70 keV and the optical V-band lightcurves. *Right panel:* Correlation between the 20–70 keV and the ultraviolet lightcurve at 3000 Å. The secondary peak at 1.5 years indicates a possible delay of the hard X-ray emission with respect to the blue-bump.

hard X-ray emission is produced by a different electron population than that emitting the radio-to-millimeter radiation.

On the other hand, a correlation without delay is observed between the hard X-rays and the optical – $\mathscr{R}$-component dominated – component (Fig. 5 *Left panel*). A secondary peak in the correlation at 1.5 years becomes dominant when the hard X-rays are correlated with the ultraviolet (Fig. 5 *Right panel*). Considering the measurement of slightly polarized emission in the optical domain, the spectral shape and the variability properties of the $\mathscr{R}$ component, we propose that it could be synchrotron emission from the base of the jet. This emission would have to be relatively unrelated with the outburst activity in the radio-millimeter domain that would arise further downstream. In this case, the hard X-rays could be produced by the same electron population emitting the $\mathscr{R}$/synchrotron component. In addition, if the ultraviolet provide the seed photons for the Compton processes producing hard X-rays, the correlation at 1.5-year delay could indicate the distance covered by the photons from the ultraviolet to the X-ray source.

4. Conclusion

Multiwavelength data sets spanning many years are of fundamental importance for studying the physics of AGN. The more data we add, the more evident it becomes that our view of AGN is still too simplistic to describe and understand the complexity of these objects. Nevertheless, the worldwide observational effort on 3C 273 during decades, allows us to progress in the characterization of its variability properties across the electromagnetic spectrum and to identify relations between the emission from one spectral range to the other. The last decade provided us a much clearer picture of the X-ray variability, whereas future facilities like the GLAST satellite will enable the extention of this analysis in the gamma-ray domain.

References

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