LONG-TERM EVOLUTION OF FU ORI-TYPE STARS AT INFRARED WAVELENGTHS

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Abstract. We investigated the brightness evolution of 7 FU Ori systems in the 1 – 200 µm wavelength range using observations from the Infrared Space Observatory (ISO), 2MASS and MSX data. The SEDs were compared with earlier ones derived from the IRAS photometry and ground-based observations around the epoch 1983.

Key words: stars: pre-main sequence – stars: circumstellar matter – infrared: stars – stars: individual: V1057 Cyg

1. INTRODUCTION

FU Orionis objects are low mass pre-main sequence stars undergoing outburst in optical light of 5 mag or more. The fading phase after the outburst is well documented in the optical/near-infrared, but no data have been available so far at far-infrared wavelengths. The ISO (1995 – 98), provided new photometric data in the 4.8 – 200 µm range: 5 FU Ori-type stars were observed with ISOPHOT, the infrared photometer on-board ISO. The goal of our study is to compare far-infrared SEDs based on IRAS photometry (1983) with SEDs compiled from ISOPHOT, MSX, and 2MASS (1996 – 2000), and check for long-time variations of the infrared flux during a period of 15 years.

2. OBSERVATIONS AND DATA REDUCTION

Table 1 lists the infrared photometric data used in this study. We compiled a list of all confirmed/candidate FU Orionis objects

*Based on observations with ISO, an ESA project with instruments funded by ESA member states (especially the PI countries France, Germany, the Netherlands and the United Kingdom) with participation of ISAS and NASA.
Fig. 1. SEDs of FU Orionis objects at the two different epochs (1983 with open symbols and 1996 – 2000 with filled symbols).

from the literature and selected those 7 objects for further study where sufficient data were available at both epochs (1983 and 1996 – 2000) to create a complete mid/far-infrared SED.

Table 1. Overview of infrared photometric data of FU Ori objects.

| Instrument      | Wavelengths [µm] | Aperture | Date       |
|-----------------|------------------|----------|------------|
| ground-based    | J H K L M N Q     | ≤ 6''    | 1970s –    |
| IRAS            | 12, 25, 60, 100   | 1 – 3'   | 1983       |
| MSX             | 4.25, 4.29, 8.28, 12.13, 14.65, 21.34 | 18''     | 1996 – 1997 |
| 2MASS           | J, H, Ks         | 1997 – 2001 |
| ISOPHOT         | 4.8, 12, 25, 60, 100, 120, 200 | 43” – 180” | 1995 – 1998 |

The ISOPHOT data reduction was performed using the ISOPHOT Interactive Analysis Software Package V10.0 (PIA, Gabriel et al. 1997) following a standard scheme (for details see Abraham et al.) As an error estimate we adopted an absolute calibration uncertainty of 25%, which represents well the sum of the random and systematic uncertainties. Colour corrections were applied for each measurement by convolving the observed SED with the ISOPHOT filter profiles in an iterative way.

3. RESULTS

Our main results, the comparison of SEDs at the two different epochs, are summarized in Figure 1 and Figure 2. From the figures
one can draw the following conclusions:

**Near-IR ($\lambda \leq 5 \mu m$):** the sources show various trends: Parsamian 21, V1331 Cyg and Z CMa are unchanged, V1057 Cyg, V1515 Cyg and V1735 Cyg have faded, V346 Nor have become slightly brighter.

**Mid-IR ($5 \leq \lambda \leq 20 \mu m$):** only V1057 Cyg shows systematic flux change: it faded by a factor of 2 during the period.

**Far-IR ($\lambda \geq 60 \mu m$):** the majority of the sources does not show any variation within the measurement uncertainties. The only possible exception is V346 Nor exhibiting $2\sigma$ drop at 100 $\mu m$. (For V1331 Cyg there are no FIR data other than IRAS.)

4. DISCUSSION: THE CASE OF V1057 CYG

We interpret the V1057 Cyg observations in the framework of the accretion disk model of Kenyon & Hartmann (1991, hereafter KH).

**At $\lambda \leq 5 \mu m$:** according to KH between 1971 and 1983 a general decay of the flux density was observed, with the lowest amplitude at 5 $\mu m$. The emission comes from the inner hot part of the accretion disk, and the flux decrease is due to the dropping accretion rate after the outburst.

The flux decay was continuing between 1983 and 1997. However, no clear wavelength dependence can be observed in this period, suggesting that the energy budget of the inner part of the disk is now dominated by reprocessed light rather than by the release of accretion energy.

**At $5 \leq \lambda \leq 20 \mu m$:** according to KH between 1971 and 1983 a flux decay was observed which was wavelength independent and followed the same rate as in the optical. The emission probably originates from an extended envelope which reprocesses the optical radiation of the central source.

In the period 1983 – 1997 the wavelength independent fading was still going on and its rate remained synchronised with the rate of the optical decay (about a factor of 2 at all wavelengths). The
results continue supporting the envelope model.

At $\lambda \geq 20 \mu$m: according to KH in the lack of real measurements it was assumed that the far-infrared emission originates also from the envelope and its radiation drops with time due to the decreasing irradiation from the central source.

Our data however show no flux variation at all. This result suggests that either the far-infrared flux comes from a different cold component of the system whose energy budget is independent of the central source; or the temperature of the outer part of the envelope – where the long wavelength emission may come from – follows the change of irradiance only on a significantly longer timescale than the 15 years period we covered.

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