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LETTER

Letter to the Editor

Variability and a vanishing YSO in the Serpens cloud core

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Abstract. This letter compares data from a recent near-IR study of the Serpens cloud core with data from previously published studies. It is found that one object, irs 81 has completely vanished, fading by more than 3.8 magnitudes at K, while a total of 10 of the observed objects have varied by over 0.5 magnitudes in H or K, with little change in colour. We have also discovered 13 new objects in the cloud core which were below the magnitude limit of previous studies.

Key words: Stars: formation – Stars: variables

1. Introduction

The small–amplitude photometric variability of T Tauri stars has been studied for some years, and appears to be caused by hot and cold starspots (e.g. Bouvier et al. 1988; Fernandez & Eiroa, 1996), while larger amplitude variations might be attributable to the circumstellar environment, as in RY Lup (Gahm et al 1989). However, much less is known about the variability of embedded young stellar objects (YSO's) because these require studies to be made at infrared wavelengths, for which instrumentation is still relatively uncommon - at least on small telescopes. Yet evidence for quite strong variability in the near infrared has been found in NGC1333 SSV 13 (Aspin & Sandell 1994) and B5 irs1 (Moore & Emerson 1994) for example. Some variability appears to be in the form of outbursts, as in the companion to T Tauri (Kobayashi et al. 1994). Indeed embedded YSOs, with their larger quantities of circumstellar gas and dust, might be expected to show large photometric variations. Fortunately, with the development of infrared detector arrays, and given the compact nature of many embedded clusters, studies of infrared variability can now be conducted efficiently.

The Serpens molecular cloud core is a well studied star forming region, 310 pc distant (de Lara et al 1991), containing many YSO's at various evolutionary stages. In a recent study by Eiroa and Casali (1992, hereafter EC) over 160 objects were found in the near-IR, 51 of which were identified as being members of the cluster. Recently, Hodapp (1995) discovered a dramatic brightening of one of the young stars in the cluster, and associated it with an FU Ori type of event. In an attempt to search for variability in other YSO's we decided to re-image the area around the main nebulosity in the near-IR, and compare the results with EC (taken 6 years previously).

2. Observations and results.

The new observations were made on May 1, 1995 on the United Kingdom Infrared Telescope (UKIRT) using IRCAM3 which uses a 256 × 256 InSb array, at $0''.3$ per pixel resolution. The observations consisted of 5 frames in each of the H and K bands; 4 of which were overlapping. The results presented in EC were obtained with the same telescope, but using the first generation infrared camera (IRCAM), during April 1988 and May 1989. The new data cover roughly 7.5 arcmin^2, which corresponds to a subset of the field covered in EC. In total, 35 stellar objects were seen by both studies.

Data reduction proceeded in the normal way. Flat-fields were obtained on a nearby sky position. Since there was bright structured reflection nebulosity in the regions of overlap between frames, we were able to carry out both a zero-point and transparency correction for four of the frames. Final photometric reduction of point sources was achieved using the STARLINK package PHOTOM with a software aperture of $5''$. Standard star observations were used to calculate apparent magnitudes. The magnitude limits of the new observations are 18.0 at J and 16.0 at K.

A histogram of the K magnitude differences between the old and new data set was calculated and showed that most sources had minimal variability. However, the median of the magnitude differences was not zero, but 0.1 magnitudes. Since it seems unlikely that any variability would be coordinated over the cluster, it was concluded that this probably represented a systematic er-

ror in the photometry. With this assumption, the magnitudes of the YSOs in the new data were calibrated by making their median magnitude the same as that for the photometry in EC. Use of the median (rather than a mean) ensures that a few strongly variable sources do not significantly effect the photometric calibration. The histogram of K data resulting from this calibration is shown in fig. 1.

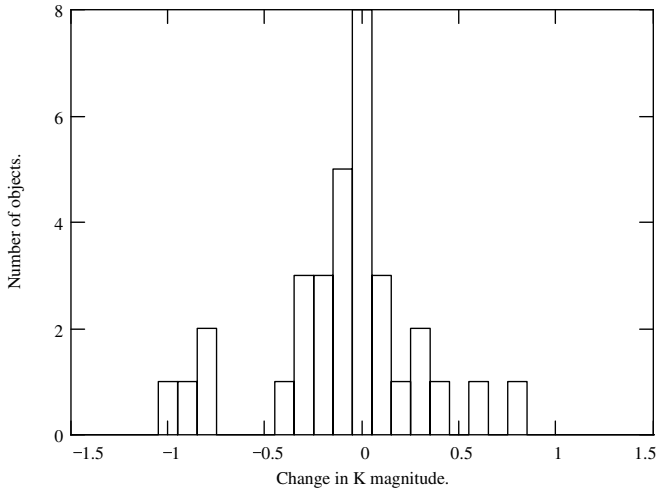

Fig. 1. The histogram of ΔK for the comparison between the new data and that from EC, for a sample of 35 stellar objects.

The estimated random errors in the new photometry were 0.03 magnitudes for the fainter sources (given by PHOTOM), while EC quote an accuracy of 0.1 magnitudes. Unfortunately, most of the sources lie on fairly bright background nebulosity, and it is difficult to determine if the local background used for a source in this survey is the same as that used in EC due to centroiding differences and differences in pixel size. We therefore chose to be conservative and defined variable objects as those that showed a difference of greater than 0.5 magnitudes (5σ) between the old and new photometry. Table 1 shows the list of varying objects under this criterion, where source numbers refer to the classification in EC. Tests using different sky and sources apertures allow us to be very confident that these are indeed variable sources.

14 previously uncatalogued objects were also discovered in the new data, all but one of which have magnitudes fainter than the survey limit of EC. Unfortunately, with only H and K data it is not possible to say with certainty whether or not they are connected with the cloud core. Most are not very red which, given the extinction through the core, may mean they are foreground objects. For the sake of future studies, including ongoing ISO observations, we give their positions and magnitudes in Table 2. Many of these objects are at the magnitude limit of this study, so their magnitudes will have random errors approaching 0.2 mags.

Irs81 is the most interesting object in this study. Despite being a bright source in the EC survey, it has completely disappeared in the new data - a dimming of at least 3.8 mags. in K. Figure 2 shows an image of the surrounding field - irs81 is clearly absent in the new data. A further K frame was taken on March 11 1996 through the UKIRT service programme, and confirms the disappearence. All that is seen in the new image is an area of nebulosity no brighter than nearby parts of the main reflection nebula. Three other objects, listed as YSOs by EC (irs101, irs102 and irs104) also seem to have vanished as point sources although they are clearly associated with small areas of nebulosity in the new data, with no apparent bright central sources.

An interesting object seen in both the new data and in EC is irs88, one of the sources in the SVS4 Southern sub-cluster. Originally only K data was available, but the new data give K=11.9 and H-K=5.5, making it more than twice as red as anything else in this study.

Table 1. Old and new photometry of varying sources

Source	K_{EC}	$(H-K)_{EC}$	K	H-K	Notes
irs53	10.9	1.8	11.75	1.53	a
irs73	12.5	1.6	11.76	1.30	a
irs75	15.9	> 0.1	15.01	1.87	
irs76	15.3	> 0.7	14.50	2.87	
irs81	12.2	0.6	> 16	> 1	a
irs82	8.8	1.5	9.34	1.49	a
irs101	13.4	> 2.6	> 16	> 1	
irs102	15.4	> 0.6	> 16	> 1	
irs103	12.3	1.9	11.31	1.87	a
irs104	14.8	> 1.2	> 16	> 1	

Notes: a - objects associated with Serpens cloud core by EC.

Table 2. New sources

Source	R.A. 18^h27^m	Dec. 1°	H	K	
irs164	$21\overset{s}{.}6$	$12'28''$	16.8	16.8	
irs165	21.7	$12'33''$	16.5	15.8	
irs166	21.9	$12'40''$	16.4	15.6	
irs167	22.7	$10'31''$	17.5	16.3	
irs168	22.9	$10'36''$	17.8	16.6	
irs169	24.2	$13'27''$	17.9	16.5	
irs170	24.4	$11'13''$	> 18	16.4	possible
irs171	24.4	$11'17''$	> 18	16.5	binary
irs172	24.5	$13'40''$	17.3	16.4	
irs173	24.7	$13'36''$	17.1	15.7	
irs174	24.8	$10'55''$	> 18	16.7	
irs175	26.6	$10'20''$	> 18	15.6	
irs176	27.3	$13'47''$	17.2	15.8	
irs177	28.1	$11'42''$	> 18	16.6	

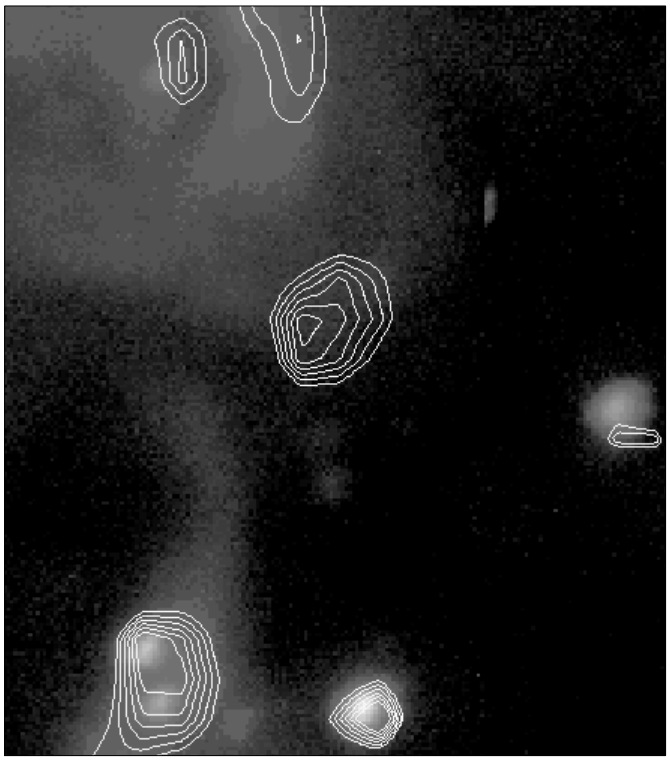

Fig. 2. The area centred on irs81. The greyscale image is from the service observations of this year and the contours are from the original data of EC. Irs81 has vanished in the recent greyscale image.

3. Discussion

If the photometric changes represent changes in circumstellar extinction, then a normal reddening law would also result in changes in H-K colour given by $\Delta(\mathrm{H}-\mathrm{K}) = 0.7A_{\mathrm{K}}$ where A_{K} is the K band extinction. But of the variable YSOs that have H and K photometry in both studies (irs53, 73, 82 and 103), the variability is consistent with being grey within the errors ($\Delta(\mathrm{H}-\mathrm{K}) \approx 0$). Thus the changes are not simply the result of changes in reddening. Grey variability has been observed before, with several different models being proposed to explain it. Voshchinnikov and Grinin (1991) have observed large grey variability in the Ae/Be star WW Vul; they suggested that this was in the main part due to large opaque dust clouds ($\approx$0.01 AU) obscuring the star. The variability seen in this study is on a smaller scale, corresponding to a 30% change in the flux from the object in the line of sight, so if clouds are to serve as an explanation they would have to be smaller than those suggested by Voshchinnikov and Grinin, while remaining optically thick in the H and K bands (to ensure greyness). Moore and Emerson (1994) have also observed grey variations from J to K, although there were colour changes in the L,L' and nbM bands. They explain their results as due to a depletion of small dust grains (compared to the interstellar medium), resulting from coagulation. Either of these models could explain the variability we observe in the four YSOs with H-K data from both studies.

The disappearance of irs81 is more difficult to explain. In the original EC survey it appears as an extended object $\approx 5''$ across, on the edge of the nebulosity associated with SVS20. It is also worth noting that irs81 lies only $18''$ from the sub-mm source SMM4 (Casali et al 1993), but we have no evidence that the two are physically associated. We know of no other example of a nebulous YSO in a star forming region fading as dramatically as this one, although other nebulae have been observed to vary. Hubble discovered that the fan nebula NGC 2261, now known to be associated with the young star R Monocerotis, varies significantly. Lightfoot (1989) suggests that this variability is due to clouds around the young star casting shadows on the nebulosity. If this model were to apply in the case of irs81, it would mean that the central source has now become completely obscured.

4. Conclusion

We have found that 28% of observed YSO's in Serpens have varied by $>$0.5 mags. in the near–IR over a timescale of six years. In those objects with both H and K data, the variations are consistent with being grey. In one object in particular, irs81, a fading by over 3.8 magnitudes has made it vanish altogether.

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