SOLAR SYSTEM SIZE PROTO-STELLAR SOURCES EMBEDDED IN THE ρ OPH DARK CLOUD

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High spatial resolution infrared observations (mostly at L, some at K) of several young stars in the ρ Oph dark cloud were obtained with the specklegraph at the ESO 3.6m telescope in Chile in July 1985. Sources included EL29, EL21, EL14 and EL9 (Elias 1978, Table 2), and were all measured in two orthogonal directions, W-E (PA=90°) and N-S (PA=180°). Here we shall present visibility functions for EL29 and EL21 and indicate the spatial structure and dimension of these objects. We refer to Elias (1978, p.468/69) for earlier studies of EL29 and EL21.

Figures 1 and 2 show the results to be discussed below. The fitting model is always a combination of two concentric Gaussian profiles (core-halo structure)

$$V(f) = (1-V_h)e^{-(f/f_1)^2} + V_h\, e^{-(f/f_2)^2}$$

V denoting the visibility function, f the spatial frequency in arcsec^{-1}, and V_h is the fraction of the visibility contributed by the halo. This expression Fourier transforms back into the object plane as

$$O(\alpha) = (1-V_h)e^{-(z\alpha/\alpha_1)^2} + V_h\, e^{-(z\alpha/\alpha_2)^2}$$

where $z = 2(\ln 2)^{\frac{1}{2}}$ and therefore $\alpha_{1,2}$ are full widths at half maximum in arcsec (α_1 for the core, α_2 for the halo); $\alpha_{1,2}=z/(\pi f_{1,2})=0.53/f_{1,2}$.

A similar procedure was used by Beckwith et al. (1984) in their pioneering infrared speckle work on HL Tau and R Mon done at the IRTF and UKIRT which resulted in the first discovery of solar system-size haloes around young stars. Our detections of similar structure around EL29 and EL21 are the first detections of that kind in the southern hemisphere, and were achieved despite poor seeing (generally 2.5-3 arcsec). The scan speed was adjusted to be fast enough (50 msec) to "freeze" the seeing pattern. The point source for calibration was o Sco (= IRC-20311), a star of type A5II. More observational details will be given elsewhere. The same ESO specklegraph had been used previously by Chelli et al. (1984) to resolve the sub-arcsecond structure of IRc2 in the KL-nebula.

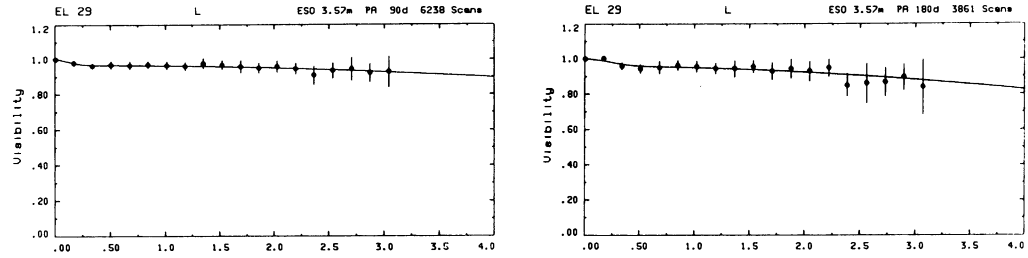

Fig. 1

Fig. 1. Visibility functions of EL29 at λ = 3.6 μm, W-E on the left, N-S on the right.

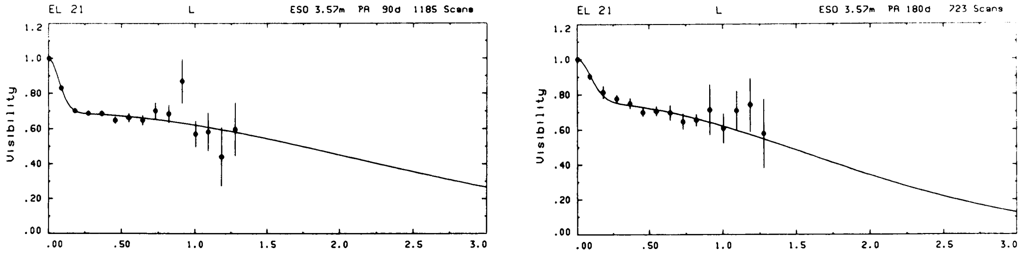

Fig.2a

Fig. 2a. Visibility functions of EL21 at λ = 3.6 μm, W-E on the left, N-S on the right.

From the graphs we obtained the following results (note that 1 arcsec at the distance of the ρ Oph cloud (160pc) corresponds to 160AU):

EL29 at L has two symmetric components, a compact core ($\alpha_1 \leqslant 0.05$ arcsec) and an extended halo ($\alpha_2 \sim 2$-4 arcsec) contributing $\sim 4\%$ of the total flux. [This halo contribution goes up to $\sim 40\%$ at K (much like in the case of HL Tau), which is consistent with the expected behaviour of an infrared reflection nebula where light from an inner source is scattered by circumstellar grains. In this connection it is interesting to note the finding of solid CO absorption at 4.6μm towards EL29 (Zinnecker et al. 1985), possibly related to circumstellar grains.]

EL21 at L is a spectacularly complex, conical object elongated to the NE by several arcsec. A two component model is almost not sufficient. The halo component decreases less abruptly than a Gaussian, but the fit is still rather good. The core component ($\geqslant 0.2$ arcsec) is quite large, possibly also asymmetric. EL21 (=GSS30) appears to be a bi-lobed (?) asymmetric infrared reflection nebula surrounding an accretion disk (see Castelaz et al. 1985, especially their K map in Figure 5).

As for EL14 (= Do-Ar 21) and EL9 (= HD 147889), we merely mention that both sources are resolved, the former having two components (at K) and the latter (at L) having only one component. Finally, we mention that none of the four sources under study turned out to be a binary object at the separations and contrast that we can probe, but we plan to extend our search in the near future.

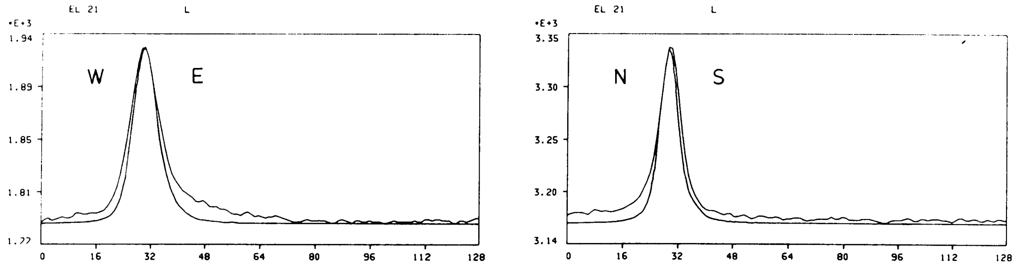

Fig.2b

Fig. 2b. Coadded scans of EL21 at $\lambda = 3.6$ μm.
Note the broad wings towards E and N. The lower line is the calibration star. The unit on the x-axis is 0.17 arcsec. The signal between 64 and 128 is sky.

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INFRARED CO EMISSION FROM WL 16

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The Rho Ophiuchi source WL 16 is the second Young Stellar Object (YSO) found to have infrared CO emission bands. IRAS observations show that WL 16 is far less luminous (∿ 14 $L_\odot$) than the first source of infrared CO emission, BN (> 5000 $L_\odot$). Also in contrast to BN, the CO emission from WL 16 represents a significant fraction of the total luminosity. The 2.3 μm first overtone CO emission bands were observed with the Steward Observatory Fourier Transform Spectrometer at the 2.3 m telescope.

The infrared spectrum of WL 16 shows both first overtone CO band emission and emission from the Br γ line of atomic hydrogen. No evidence of emission from molecular hydrogen is present. Analysis of the spectral features indicates that the size of the emission region is ∿ 1 AU or greater, the excitation temperature of CO is greater than 4000 K, and the density of the emission region is greater than 10^{11} cm^{-3}. If the additional constraints of LTE and chemical equilibrium are imposed the density, excitation, and size of the emission region become a function of the temperature. Solutions matching the size of emission region with the blackbody radius and matching the average density of a 1 $M_\odot$ protostellar model of Stahler, Shu, and Taam (1981) have been calculated. In both models the emitting gas is predominantly atomic, rather than molecular. The protostellar solution has a temperature of 4150 K, a density of 5×10^{11}, a mass of 9.1×10^{-5} $M_\odot$, and a radius of 3.7×10^{13} cm.

Although the observed CO emission matches the predicted flux from an accreting spherical protostellar model, other interpretations are