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Research Note

Cn 1-1: a bipolar type I planetary nebula

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Summary. Polarization measurements of Cn 1-1 are interpreted as due to scattering by nebular dust. It is suggested that the nebula has a bipolar morphology. This, together with the enhanced nitrogen abundance in the nebula, supports the view that Cn 1-1 is a type I protoplanetary nebula.

Key words: planetary nebulae – dust – polarization – morphology

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Cn 1-1 (= HDE 330036 = PK 330+4°1) is a peculiar emission-line object that has been classified in the literature both as a symbiotic star (Glass and Webster, 1973) and as a planetary nebula (Lutz, 1977, 1984). It was detected by the Infrared Astronomical Satellite (IRAS) as a strong source of far-infrared radiation (Pottasch et al., 1984) indicating the presence of cool dust in the system. Bhatt and Mallik (1986) discussed the nature of the dust in Cn 1-1 and suggested that the object is a type I protoplanetary nebula in a binary system.

Polarization measurements of Cn 1-1 have been made recently by Schulte-Ladbeck and Magalhaes (1987). A high degree of linear polarization (~3%) was observed. However, they regarded Cn 1-1 as a symbiotic star and considered the observed polarization to be of purely interstellar origin. We argue here that the observed polarization, at least in part, is intrinsic to Cn 1-1 and is due to scattering by dust grains in the protoplanetary nebula asymmetrically distributed around the central star. A bipolar morphology for the nebular dust distribution is suggested.

The wavelength (λ) dependence of the observed percent polarization $P(\lambda)$ for Cn 1-1 ($P(0.36\,\mu\mathrm{m}) = 1.96 \pm 0.18$, $P(0.44\,\mu\mathrm{m}) = 2.58 \pm 0.22$, $P(0.55\,\mu\mathrm{m}) = 2.79 \pm 0.12$, $P(\mathrm{H}\alpha) = 2.84 \pm 0.23$, $P(0.79\,\mu\mathrm{m}) = 2.97 \pm 0.08$ and position angle $\theta = 29 \pm 3°$ for all wavelengths; Schulte-Ladbeck and Magalhaes, 1987) shows that $P(\lambda)$ increases with λ and the wavelength of maximum polarization $\lambda_{\max} \gg 0.55\,\mu\mathrm{m}$, the mean interstellar value. A least square fit to the empirical relation: $\ln(P_{\max}/P(\lambda)) = K \ln^2(\lambda_{\max}/\lambda)$ (Serkowski et al., 1975), gives $K = 0.74$, $\lambda_{\max} = 0.74\,\mu\mathrm{m}$ and $P_{\max} = 2.98\,\%$ with associated errors 0.09, 0.05 µm and 0.06% in K, $\lambda_{\max}$ and $P_{\max}$ respectively. In Fig. 1 the polarization properties of Cn 1-1 are compared with those of other stars in its neighbourhood. Within ~5° of Cn 1-1, at distances less than ~1 kpc from the Sun, there are 9 stars (HD 137709, 138769, 139129, 141168, 141318, 142529, 142919, 143101 and 143546) for which polarization measurements (in the blue filter) are available (Mathewson and Ford, 1970). In Fig. 1a the observed percent polarization P is plotted against the distance modulus in magnitudes Δm (= 5 log $D - 5$, where D is the distance in pc), while the polarization position angle θ is plotted against Δm in Fig. 1b. For 3 of these stars (HD 137709, 141318 and 142919) within ~5°, and 5 more stars (HD 136003, 146323, 147977, 150135 and 150421) within ~10°, of Cn 1-1 and less distant than ~1 kpc, the wavelength of maximum polarization $\lambda_{\max}$ is available (Serkowski et al., 1975). In Fig. 1c $\lambda_{\max}$ is plotted against Δm.

Cn 1-1, at distance modulus $\Delta m = 8.27$ (distance 450 pc; Lutz, 1984), is represented by open circles in Fig. 1 and stands out from rest of the stars. For Cn 1-1 $\lambda_{\max} = 0.74 \pm 0.05\,\mu\mathrm{m}$; much larger than $\lambda_{\max} = 0.56 \pm 0.01\,\mu\mathrm{m}$ for stars in its neighbourhood (Fig. 1c). The polarization position angle θ (blue filter) $= 26 \pm 2°$ for Cn 1-1 (Schulte-Ladbeck and Magalhaes, 1987) is very different from $\theta = 49 \pm 3°$ for the neighbouring stars (Fig. 1b). Also, the percent polarization of Cn 1-1 is higher than that of all other stars (Fig. 1a). The high degree of polarization at a position angle very different from that for the neighbouring stars and, most importantly, the large $\lambda_{\max}$ ($0.74 \pm 0.05\,\mu\mathrm{m}$) compared with the value of $\lambda_{\max}$ ($= 0.56 \pm 0.01\,\mu\mathrm{m}$) for other stars in the region indicate that the polarization characteristics of Cn 1-1 are peculiar. In addition to the normal interstellar polarization appropriate to its distance, there must be a component of polarization that is intrinsic to Cn 1-1. The strength, the position angle and the wavelength dependence of the intrinsic component should be such that when added to the interstellar component it changes the position angle and shifts the wavelength of maximum polarization to the values observed.

The interstellar distance to Cn 1-1 was estimated by Lutz (1984) to be 450 pc ($\Delta m = 8.27$). Within ~5° of Cn 1-1 the closest space neighbours for which polarization measurements are available are: HD 142919 ($\Delta m = 7.4$, $P_{\max} = 1.98\,\%$, $\lambda_{\max} = 0.57\,\mu\mathrm{m}$, $\theta = 46.2°$) and HD 141318 ($\Delta m = 8.5$, $P_{\max} = 2.42\,\%$, $\lambda_{\max} = 0.57\,\mu\mathrm{m}$, $\theta = 51.0°$). For Cn 1-1 the observed values are: $\Delta m = 8.27$, $P_{\max} = 2.98\,\%$, $\lambda_{\max} = 0.74\,\mu\mathrm{m}$, $\theta = 29°$.

To make a conservative estimate we assume an interstellar component characterized by $P_{\max} = 2.4\,\%$, $\lambda_{\max} = 0.57\,\mu\mathrm{m}$ and $\theta = 49°$ in the polarization of Cn 1-1. To reproduce the observed polarization, Cn 1-1 is then required to have an intrinsic polarization characterized by:
$P(0.36\,\mu\mathrm{m}) = 1.32 \pm 0.10\,\%$, $P(0.44\,\mu\mathrm{m}) = 1.67 \pm 0.12\,\%$,
$P(0.55\,\mu\mathrm{m}) = 1.81 \pm 0.06\,\%$, $P(\mathrm{H}\alpha) = 1.83 \pm 0.12\,\%$,
$P(0.79\,\mu\mathrm{m}) = 1.92 \pm 0.04\,\%$
and $\theta = 1 \pm 4°$ for all wavelengths. Cn 1-1 thus has a significant (~1.8%) intrinsic polarization, at a position angle $\theta \sim 1°$, which rises towards the longer wavelengths.

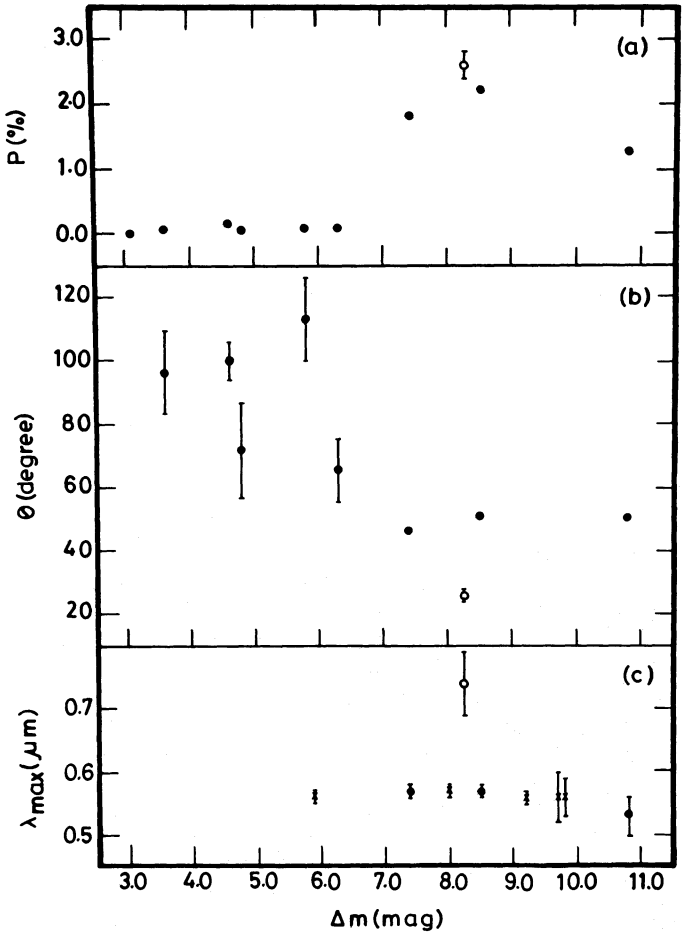

Fig. 1a–c. Plot of percent polarization P, position angle θ and wavelength of maximum polarization $\lambda_{\max}$ against the distance modulus Δm for stars in the region of Cn 1-1. The symbols are: ○ Cn 1-1, ● stars within ~5° of Cn 1-1, × other stars within ~10° of Cn 1-1. When error bars are not shown, the errors are less than the symbol size

It is unlikely that the intrinsic polarization in Cn 1-1 is due to aligned dust grains in the nebula. Following the analysis in Greenberg (1968) we find that for grain alignment by Davis-Greenstein mechanism, under the conditions existing in the nebula (number density $n \sim 10^6\,\mathrm{cm}^{-3}$, gas temperature $T \sim 10^4$ K, dust grain temperature $T_g \sim 200$ K; Lutz, 1984; Pottasch et al., 1984), the magnetic field needed $B \sim 10^{-3}$ Gauss. Such a high magnetic field cannot be produced in Cn 1-1 by amplifying the interstellar field ($\sim 10^{-6}$ Gauss) by compression because, during the evolutionary phase to which Cn 1-1 belongs, the nebula is ejected from the central star and is expanding, rather than collapsing from the interstellar medium. Also, the magnetic field direction would have to change from the local interstellar magnetic field direction, because the polarization position angles are different. An alternative mechanism for the intrinsic polarization is the scattering by dust grains in the nebula.

In view of the evidence from the IRAS measurements for the existence of dust in Cn 1-1, we suggest here that this dust is the cause of the intrinsic polarization. To be able to produce a net polarization, the dust must be asymmetrically distributed around the central star. The situation here may be similar to that in many other bipolar nebulae (e.g. Cohen, 1983) and infrared sources in bipolar molecular outflow regions (e.g. Sato et al., 1985) for which the strong polarization has been interpreted to be due to scattering by dust grains in a non-spherical circumstellar shell. Although their corresponding evolutionary phases are different, Cn 1-1 may resemble these objects in having a bipolar morphology. The large polarization even longward of $\lambda = 0.55\,\mu$m could be caused by the large (compared to the normal interstellar) dust grains in Cn 1-1 for which evidence was found by Bhatt and Mallik (1986).

The bipolar morphology is quite common among type I planetary nebulae (Peimbert and Torres-Peimbert, 1983). The large abundance ratio N/O ($\simeq 1$) for Cn 1-1 (Lutz, 1984) and the position of its central star on the HR diagram (Bhatt and Mallik, 1986) are consistent with the type I classification. Polarization observations thus support the suggestion that Cn 1-1 is a bipolar type I planetary nebula.

We also note here in passing that a sharp rise in the degree of polarization (Fig. 1a) and a corresponding change in the position angles (Fig. 1b) at around $\Delta m \simeq 7.0$ (distance ~250 pc) may indicate the presence of an interstellar cloud at this distance in the direction of Cn 1-1. A similar jump in reddening in this region is apparent in Fig. 3 of Lutz (1984).

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