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A REMARKABLE STRUCTURAL CHANGE IN A FAINT COMETARY NEBULA

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ABSTRACT

A newly discovered cometary nebula is noted as having undergone a remarkable change in appearance in the last 20 years. The major part of the nebula has disappeared, to be replaced by a much smaller fan, and the associated star has brightened by a few magnitudes in the same period.
Subject headings: nebulae: general — stars: formation

One of us (M. C.) has undertaken a systematic perusal of the entire *National Geographic Society–Palomar Observatory Sky Survey* in a search for faint nebulous objects that may be relevant to pre–main-sequence evolution. This search has not been confined to dark clouds but is certainly more complete in such areas. Several closely nebulous stars have been found in the dense dark clouds associated with NGC 7023. This letter describes our investigation of one of these objects which lies at (1950) $20^h45^m30^s$, $+60°47'$.

Figure 1*a* (Plate L11) is reproduced from the Sky Survey red print and reveals a striking linear nebula which also appears on the blue print. There is an extremely faint, very red star removed some 25″ from the southern extremity of this nebular streak. During spectroscopic studies undertaken with the 3 m reflector at Lick Observatory on 1976 December 1 this streak could not be seen with the television acquisition system. However, a faint, fan-shaped nebula was visible, with the star marked in Figure 1*a* at its apex. Figure 1*b* is reproduced from a 40 min Crossley plate obtained 1976 December 22 with preflashed 103a-E emulsion plus RG1 filter, so that the response reasonably matches the Sky Survey red passband. The original linear nebula is clearly not visible at the present epoch, whereas a fan nebula has appeared, associated with the red star which is currently much brighter than in 1955.

Klemola has kindly allowed us to examine the collection of plates covering the region of NGC 7023 taken with the Lick 20 inch (51 cm) astrograph. There are five plates of relevance, four blue plates taken on 1950 October 4, 1951 August 9 and 29, and 1975 August 3, and a yellow plate taken on 1975 August 3. The best seeing occurred for the oldest plate, which shows a trace of the streak but no clear sign of the star. Neither is seen on the 1951 plates. In 1975 a fan nebula is clearly seen, some 30″ in length, with a bright triangular core at its southern tip. The star is visible only on the yellow plate, where its magnitude has been visually estimated to be 18.5.

A spectrum of the star was obtained on 1976 December 1 using the Lick image-tube scanner (Robinson and Wampler 1972) on the 3 m telescope and covering the region 4250 to 6700 Å with a resolution of ~7 Å (see Fig. 2). It shows an extremely steep continuum, rising toward the red, above which appear emission lines of Hα, Hβ, and [O I]. Lines of Fe II also are represented, especially in the red, where multiplets 40, 74, and 46 are seen, and very weakly in the yellow (multiplets 48 and 49). The emission-line content of the spectrum is like that of the canonical young star. An impression of extreme reddening is conveyed by the large Balmer decrement, the shape of the continuum, and the weakness or absence of the yellow and blue multiplets of Fe II compared with the obvious visibility of the red. The Na I D-lines appear in deep absorption with an equivalent width of ~5 Å, far too large to be accounted for by interstellar sodium along the 600 pc distance of NGC 7023 (Aveni and Hunter 1967) and its associated dark clouds.

The photospheric spectral type is hard to determine, but the absence of perceptible He I absorption, coupled with narrow-band continuum indices (cf. Cohen and Kuhi 1976), suggests a type close to A5 V, with $A_V = 7.9 \pm 0.2$ mag. If we locate the star within the surrounding small dark cloud and associate the cloud with NGC 7023, then the observed V magnitude of 16.9 implies $M_V \approx 0$, which is consistent with its being an early A dwarf. The observed ratio of Hα to Hβ is over 200. If the region where the Balmer emission lines arise is selectively reddened by comparison with the stellar continuum, then this extreme decrement, corresponding to $M_V \approx 12$, is explicable. Alternatively, allowance for underlying photospheric absorption at Hβ and a very large optical depth in Hα could reconcile the continuum and emission-line extinctions.

From our spectrophotometry of the star on 1976 December 1, we would estimate a yellow magnitude (~5100 Å) of about 17.7. From the 1975 August 3 yellow astrograph plate the corresponding magnitude is about 18.5. This suggests that the brightening of the

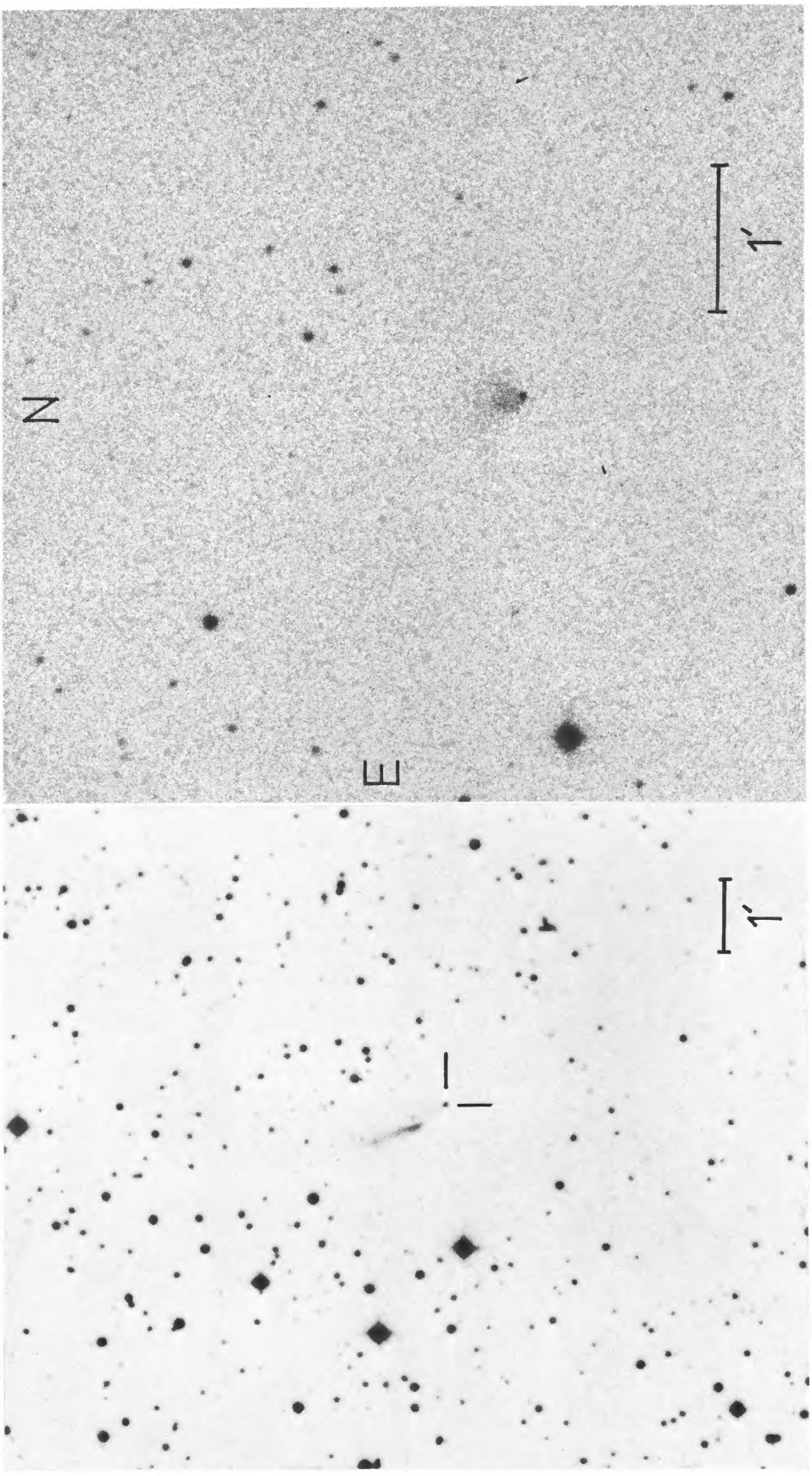

FIG. 1(*a*).—Reproduction of the Red Palomar Sky Survey plate taken on UT 1952 August 8, showing the original linear nebula.
FIG. 1(*b*).—Lick Crossley red plate taken on UT 1976 December 22, showing the brighter star and the fan but no streak.

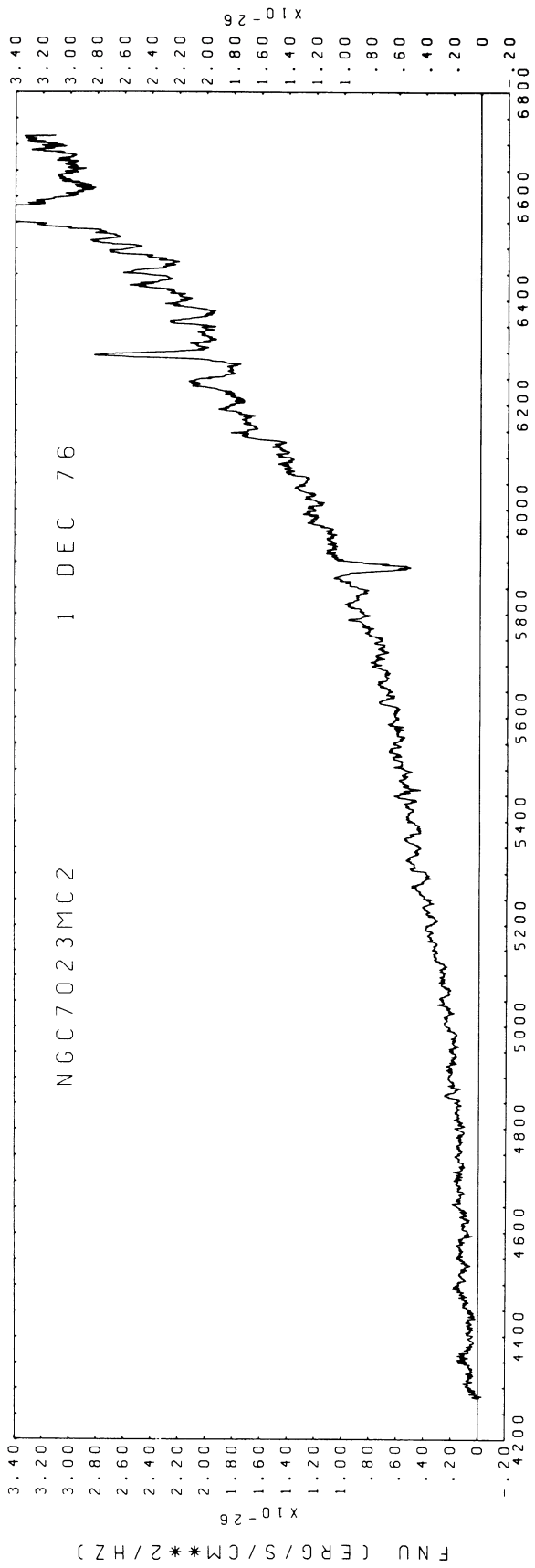

FIG. 2.—Lick 3 m scanner spectrum of the star associated with the fan nebula. The strongest lines are those of Hα, [O I], and Na I.

star was still taking place in 1975, and must have occurred on a time scale of the order of a few years. The fact that both blue and yellow astrograph plates show the fan to an equal extent, while the star appears only on the yellow, implies that the fan is a reflection nebula illuminated directly by the star, whereas the star is seen through heavy obscuration in the line of sight.

There are three outstanding phenomena to explain in this object: the disappearance of the streak, the appearance of the fan, and the brightening of the star. It is of interest to note that both streak and fan occur in the same hemisphere, and this may be a clue that the three phenomena are not independent. Several possible explanations for the streak suggest themselves: (*a*) a special geometric configuration in a circumstellar shell which permits a beam of starlight to escape and scatter in a uniform medium, or impinge upon some scattering inhomogeneity; (*b*) a preexisting density fluctuation in the ambient medium illuminated by a light pulse, produced by a previous flare-up of the star; (*c*) a physical ejection of material by the star. Any model with beaming into a uniform medium requires that the star lie on the axis of the light beam. This is not the case. In the inhomogeneous model, the disappearance of the streak requires the dissipation or motion of the illuminated material. However, the typical velocity dispersion in dark, dense clouds is of the order of only a few km s^{-1}, making such dissipation or motion unlikely on a time scale of no more than 20 years. For an adopted distance of 600 pc, the time required for light to travel from the star to the linear nebula is of the order of 4 months. One might attempt to identify the present increased brightness of the star and the instability of the fan nebula with the onset of a new light pulse. However, the Lick astrograph plates taken in 1975 show the fan but no streak, exactly as the Crossley plate of 1976 December (Fig. 1b). Therefore, an explanation in terms of a light pulse seems extremely unlikely. The third possibility is that the streak represents remnant material from a massive stellar flare. The almost neutral color of the streak on the Sky Survey photographs indicates that the brightness of this nebula is not due to a recombination-line spectrum, which would be dominated by Hα. Consequently, it must have been a reflection nebula. However, it must have become invisible within 20 years. This demands a very high velocity of ejection ($\sim$5000 km s^{-1}) which has caused the material to disperse and its reflected brightness simultaneously to decrease. This picture is not unreasonable in view of the large velocities ($\sim$2000 km s^{-1}) of some solar flares.

The likeliest possibility for the brightening of the star (amplitude $\sim$2 mag) is that a dusty circumstellar cocoon has collapsed into a toroidal configuration inclined to the line of sight, rendering the star more visible than in 1955 although it is still heavily reddened. There is no other explanation for the fan than to appeal to the general picture of cometary nebulae (Cohen 1974). A time scale of some years is not inconsistent with the free-fall time for the prestellar cocoon of an early-type star.

Quantitative calculations for this model must await further observations that might reveal spectral changes. However, so little is known about the precise time scales for the disappearance of the streak and the brightening of the star that we appeal to astronomers having access to plate collections covering the NGC 7023 region for any observations in the 20 year period during which these remarkable changes have occurred.

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