A New Era in Bioastronomy
ASP Conference Series, Vol. 213, 2000
G. Lemarchand, K. Meech (eds.)

High Circular Polarization in the Star Forming Region NGC 6334: Implications for Biomolecular Homochirality

François Ménard

Canada-France-Hawaii Telescope, P. O. BOX 1597, Kamuela, HI 96743, USA

Antonio Chrysostomou, Tim Gledhill, James H. Hough

Dept. of Physical Science, Univ. of Hertfordshire, Hatfield, UK

Jeremy Bailey

Anglo-Australian Observatory, Epping, N.S.W., Australia

Abstract. The amino-acids which form the building blocks of biological proteins are all left-handed molecules. By contrast, when these molecules are made in the laboratory equal numbers of the right and left-handed versions are made. This homochirality found in biological material may well be a prerequisite for the origin of life and a number of processes have been proposed to produce the required enantiomeric excess in prebiotic organic molecules. We report here on the detection of high degrees of circular polarization in the star forming complex NGC 6334, in the constellation Scorpius. This important finding suggests the widespread nature of a potentially efficient process to produce biomolecules with large chiral excess, namely selective (asymmetric) photolysis by circularly polarized light. The mechanism, well known in the laboratory, was first suggested to take place in a star forming region by Bailey *et al.* (1998) following the discovery of high degrees of near-infrared circular polarization in the Orion molecular cloud, OMC-1. NGC 6334 is a giant HII region and molecular cloud similar to Orion. These two detections of large circular polarization, among the small number of sources surveyed so far, lead us to suggest that the conditions needed for selective photolysis by circular polarization to take place may be quite widespread in massive star formation regions.

1. Introduction

The origin of the homochirality of biological molecules, the fact that living organisms use almost exclusively L-amino acids, has been a mystery since homochirality was discovered in the 19^{th} century. Many mechanisms have been proposed to produce the effect on prebiotic molecules soon after the formation of Earth, but none seems efficient enough. They would all require amplication by extremely large factors to account for the chiral excess observed today. Because of that, an extra-terrestrial origin for the chiral excess has been proposed

(Bonner 1991). This view is supported by the discovery of an excess of L-amino acids in the Murchison meteorite (Cronin & Pizzarello 1997; Engel & Macko 1997).

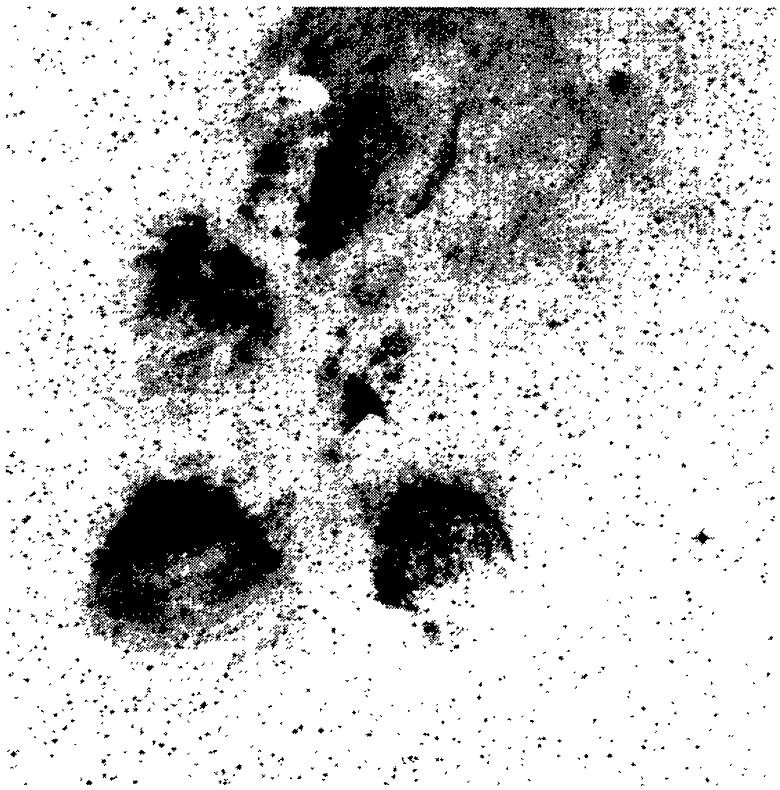

Figure 1. Optical image of the star forming complex NGC ~ 6334. North is up and East to the left. The image size is 45′ on a side. The zone under study in this contribution, NGC 6334-V, is located in the dark patch near the center of the field. Adapted from the Palomar Sky Survey.

Although circularly polarized light from the daylight sky is not efficient enough to produce the observed excess, efficient selective photolysis by 100% circularly polarized light that resulted in a large chiral excess has been demonstrated in the laboratory (e.g., Balavoine *et al.* 1974). It is therefore tempting to suggest that astronomical sources of highly circularly polarized light may be responsible for the homochirality we observe on Earth today.

In the course of an ongoing circular polarization mapping survey of star forming regions (e.g., Chrysostomou *et al.* 1997, Gledhill *et al.* 1996, Ménard *et al.* 2000) we discovered strong infrared circular polarization in reflection nebulae in the Orion OMC-1 star-forming region (Chrysostomou *et al.* 2000). The implications of this discovery for the origin of biomolecular homochirality were discussed by Bailey *et al.* (1998) in a paper to *Science*.

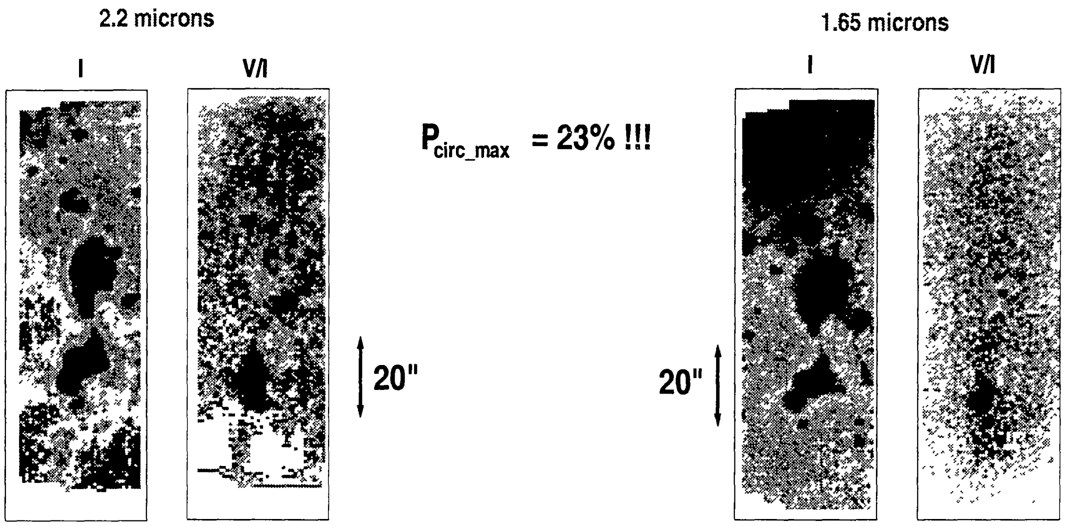

Figure 2. Intensity (I) and circular polarization (V/I) maps of NGC ~ 6334-V in the H (1.65 μm) and K (2.2 μm) near-infrared bands. On each image North is up and East to the left. The plate scale is 0.″6 pixel^{-1}. The seeing was measured to be between 1.5 and 2.0 arcsec during the observations. Large positive (negative) circular polarization is coded in black (light grey) in the V/I images. Notice the very different scale between Fig. 2 and Fig. 1.

Although the observations were carried out at near-infrared wavelengths, numerical simulations showed the possibility to find similarly large values of circular polarization in the UV range. Bailey *et al.* (1998) therefore proposed that an enantiomeric excess in organic molecules in the proto-solar nebula was generated by circular polarization as a result of scattering of UV light from a nearby star not at the center of the nebula. For a more complete description of these results, the readers are referred to Bailey *et al.* (1998).

2. Observations and Results

The data presented here were obtained on 1997, May 25 at the *Anglo-Australian Telescope* (AAT), Siding Springs, Australia. The instrument used was the Infrared Imaging Spectrograph (IRIS) with the polarimeter module (IRISPOL) upstream. IRISPOL was designed and built at the University of Hertfordshire, UK. The instrumental setup is identical to the one used by Chrysostomou *et al.* (2000) and Bailey *et al.* (1998) for the observation of Orion OMC-1.

The observations of NGC 6334-V were obtained in the H- and K-bands (1.65 and 2.2 μm respectively). The intensity maps (I, left panel of each set) and circular polarization maps (V/I, or right panel of each set) are presented in Figure 2. The main result in the context of this conference is the detection, in both filters, of large regions of high circular polarization. Large positive (negative) circular polarization is coded in black (light grey) on the images. In the K-Band (2.2 μm), up to 23% circular polarization is detected in the southernmost reflection nebula. The results presented here were fully confirmed on 1998, August 7 using a different imaging polarimeter on UKIRT, the *United Kingdom Infrared Telescope*.

The distance to NGC ~ 6334 is ~ 1.7kpc and the zones where the circular polarization is large are many arcseconds across (equivalent to 10^4 AU), i.e., much larger than the actual solar system. They are also part of a molecular cloud complex, rich in organic species. This is very similar to what is observed in Orion OMC-1.

3. Discussion

The results presented in Figure 2 (§2) show that the occurence of high circular polarization is not unique to Orion OMC-1. Rather, given the small number of high-mass star formation regions we probed so far, it might well be a common feature of these regions. Assuming that a similarly large polarization is found at ultraviolet wavelengths, where amino acids can be photo-destroyed selectively, and given the large area over which this large polarization is found, we propose that a chiral excess may have been produced in the prebiotic organic molecule pools located within these reflection nebulae. This material may subsequently have form comets or small bodies that fell on the early planets, providing the original homochiral molecules possibly needed to form life.

A more thorough analysis of the data and a more extensive description of the implications of our results will be presented in a forthcoming paper (Ménard *et al.* 2000). More details on the implications of the discovery of large circular polarization for the origins of life can be found in Bailey *et al.* (1998).

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