EVIDENCE FROM OPTICAL POLARIMETRY FOR SPIRAL STRUCTURE IN THE MAGNETIC FIELD AND CLOUD DENSITY AROUND NEWLY-FORMED STARS

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ABSTRACT. Deep CCD imaging of the Serpens bipolar nebula shows it to be surrounded by molecular cloud material having spiral density structure. Polarization mapping indicates that the magnetic field in this material also exhibits spiral structure and we interpret this as the remains of the magnetically-braked collapse of a protostellar cloud. A binary star system has formed in the cloud core.

1. INTRODUCTION

We have performed deep CCD imaging and polarimetry of the Serpens bipolar nebula (RA=18:27:24, Dec=1°12'40") in an investigation of remnant protostellar cloud material and magnetic field structure around newly-formed stars. Our purpose is to clarify the detailed geometry of protostellar collapse and to investigate the role which magnetic fields may play in this process. We also aim to assess the suitability of the resulting circumstellar density and magnetic field structure for the acceleration and collimation of bipolar outflows.

The Serpens nebula is located in an active star-forming molecular cloud, and it is the site of a pre-main-sequence star IRS2 (age $\leq 10^5$ yr), which illuminates the surrounding cloud optically through cavities produced by a bipolar outflow. Density and field structure in the accreting cloud which existed during the formation of IRS2 should still be observable in regions as yet undisturbed by this bipolar outflow.

2. OBSERVATIONS

Our CCD images (Plate 1) show that the nebula is partly encircled by a radially extensive dark spiral filament, which provides clear evidence of spiral structure in the accreting material. High linear polarization is also seen in the scattered light, forming the expected approximately circular pattern around the illuminator IRS2. However (as in similar objects elsewhere), substantial deviations from

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circularity are also present which can be attributed to selective extinction by magnetically aligned foreground dust in the circum-nebular medium. Details of the surrounding field structure may be deduced from these deviations from circularity in the polarization pattern.

3. INTERPRETATION

Substantial deviations which form a band of parallel polarization around the centre of the nebula can be attributed to an approximately toroidal magnetic field in a circumstellar disk. A small but significant spiral distortion is also seen throughout the polarization map, appearing to mimic the spiral structure in the underlying cloud density. We interpret this as due to the outer field structure of a non-axisymmetric magnetically-braked collapse in a cloud whose rotation was initially inclined to the magnetic field (Fig 1).

The centre of the polarization pattern, which is dominated by magnetically aligned grains (rather than scattering), lies to the NE of IRS2, implying that IRS2 does not lie at the centre of the magnetic structure of the nebula. A nearby faint red star appears to have formed as a companion to the NE of IRS2 due to fragmentation of the cloud core, with the resulting magnetic structure enveloping both stars.

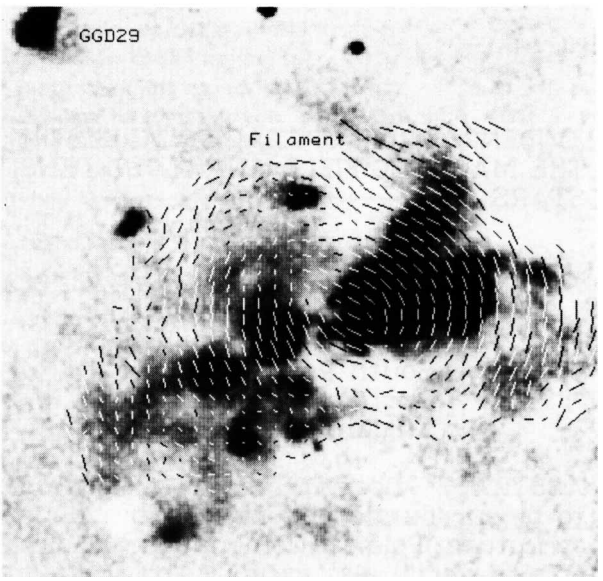

Plate 1. A 780nm wavelength linear polarization map of the Serpens nebula with a 670nm CCD image.

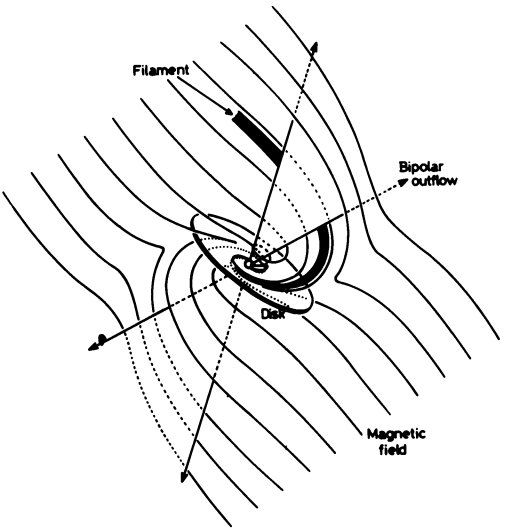

Figure 1. The proposed field structure around the nebula, resulting from magnetically-braked star formation.

A fuller account of these observations will be submitted to MNRAS.

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