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Modeling New Spectropolarimetry Data for the BN Object

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Abstract. New spectropolarimetry data taken for the BN object include many previously unobserved features. Among these are a possible polarization reversal at the short wavelength end of the ice feature and a rotation in the position angle across this feature. These are modeled using the dipole approximation to calculate the properties of the grain ensemble and a simple radiative transfer model of the Stokes parameters to determine the observed polarization. By matching these models to the new and better data, we will better constrain the grain properties and morphology along this line of sight than has previously been done.

1. Introduction

The BN object has long been studied in great detail. It is a bright infrared source located in the dense molecular cloud OMC-1. The observed polarization of the ice band was first modeled by Lee & Draine (1985 [LD85]). They reproduced both the 3.1 μm water-ice feature and the 9.7 μm silicate feature in polarization and extinction. However, much work has since been done in grain composition and alignment as well as new observations taken with much higher spectral resolution (see Chrysostomou et al. 1996). This line of sight warrants further study.

With the new high-resolution spectropolarimetry data, detailed structures can be observed in the polarization feature as well as the extinction feature. This can lead to information about the composition, shape, and temperature of the grains responsible for polarizing the light. The observed rotation of the position angle across the ice feature suggests a grain population with two spatially separated components, each with a slightly different alignment direction. Modeling these aspects of the data will lead us to a better understanding of both the grain population and the morphology of this line of sight.

2. Model

The model that has been constructed is similar to that in LD85. In order to compute the polarization due to a particular grain population, one must first calculate the grain cross sections for that population. This is done by assuming grain shapes, sizes, and compositions. The cross sections are then calculated using any one of a number of different methods. We have used the Rayleigh approximation (long wavelength approximation) to calculate these cross sections. Once these are obtained, a simple one dimensional integration of the radiative transfer equation for the Stokes parameters allows one to calculate the observed polarization for light passing through a "slab" containing this particular grain population (LD85). In addition, one can model multiple grain populations using a multiple slab model (Martin 1974).

The parameter space for the unknowns describing the grain population is quite large. The grain parameters include grain shape (oblate, prolate), size, composition (bare cores, core/mantle), and mantle thickness. We have chosen a model that is similar to LD85 by using core/mantle grains consisting of graphite cores with ice mantles as well as silicate cores with ice mantles. The dielectric functions for the graphite and ices were taken from the literature (Draine & Lee 1984; Hudgins et al. 1993) while the silicate dielectric was constructed using a Lorentz oscillator model to reproduce the observed silicate features (Messinger & Roberge 1996). The silicate dielectric function is essentially constant in the region of interest for this work.

The grains were chosen to be oblate rather than prolate as recent work suggests that it is the oblate grains that are aligned (Hildebrand 1988). The size of the grains was held constant for simplicity. The effects of a size distribution are to be studied in detail in the future. The mantle thickness was varied to adjust the strength of the feature and the ice composition was also varied to better fit the feature. Ice temperatures were allowed to range between 10 K and 140 K to account for different temperature ices in the line of sight (Smith, Sellgren & Tokunaga 1989). The ice compositions used were water ice with impurities. A pure ice mantle provides a feature that is too narrow to account for the observations. The primary ices used were the "STRONG" and "WEAK" mixtures from Hudgins et al. (1993), which contained H_2O:CH_3OH:CO:NH_3 in the ratios 100:50:1:1 and 100:10:1:1, respectively.

In an attempt to better understand the effects of the various parameters on the polarization feature, an investigation of the parameter variations was done. It has been found that the core axis ratio for oblate grains affects the wavelength of the peak of the polarization. Flattening the grains moves the peak to longer wavelengths. This is important as the shift between the peak in the optical depth and the peak in the polarization can now be measured accurately and may be a good diagnostic of the grain population characteristics. The temperature of the ice has an effect on the polarization feature as well as the extinction feature. Warmer ices tend to narrow the feature in polarization and shift the peak to slightly longer wavelengths (see Fig. 1). Such detailed modeling of the extinction features has been done to estimate the temperature ranges of ices in the past (Smith, Sellgren & Tokunaga 1989). These results combined with new models of the polarization with high resolution can lead to better constraints on the grains.

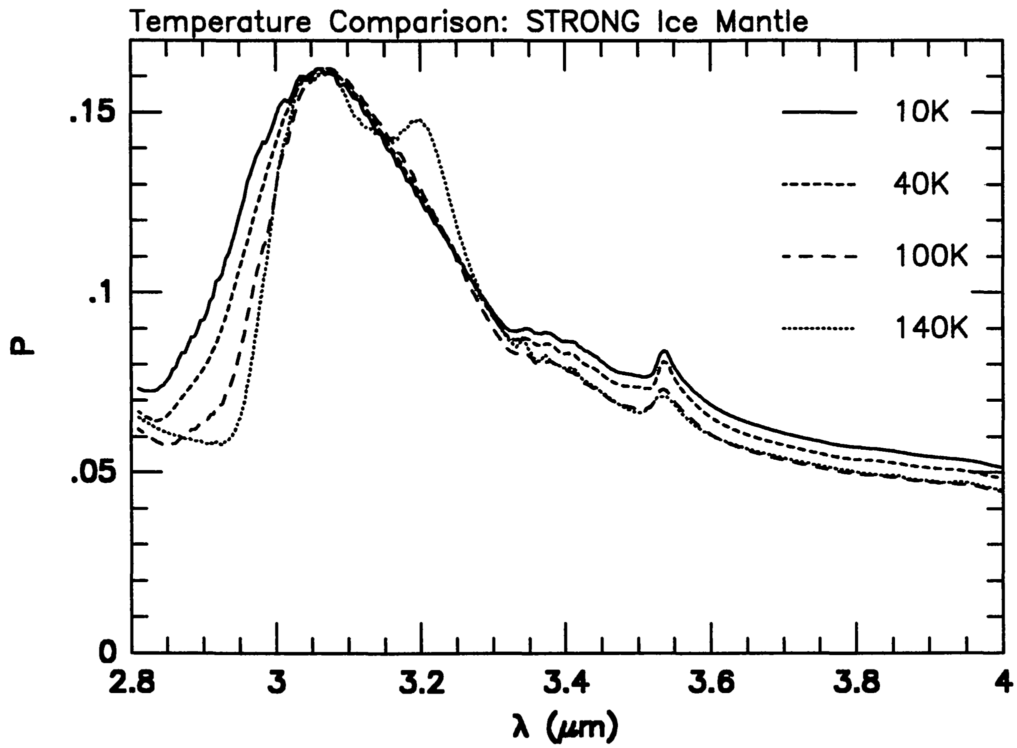

Figure 1. Effect of mantle temperature variation on the polarization profile.

3. Results

The preliminary results of our model are shown in Fig. 2. The best fit to the data we have achieved so far involves a two component grain model. We have used graphite grains coated with a 100 K ice mantle and silicate grains coated with a 40 K ice mantle. This is in general agreement with Smith, Sellgren & Tokunaga (1989), who require a mixture of different temperature ices to reproduce the water ice extinction towards BN. The grains were modeled as oblate spheroids with semiaxes a parallel to the symmetry axis and b perpendicular to the symmetry axis. Our best fit has $b/a = 1.2$ for the graphite grains and $b/a = 1.5$ for the silicate grains. The ice used was the STRONG mixture of Hudgins et al. (1993). This mixture contains a large amount of methanol as indicated by the feature at 3.6 μm. This feature is not seen in the data. We believe that the methanol is "simulating" some impurity in the ice which causes the feature to be broadened out, in better agreement with the observations. The feature was much too narrow for ices with less impurities.

As can be seen, the polarization feature is moderately well reproduced. The closeness of fit is strongly dependent on the mantle material. Our absorption feature model reproduces the general shape of the feature above an assumed

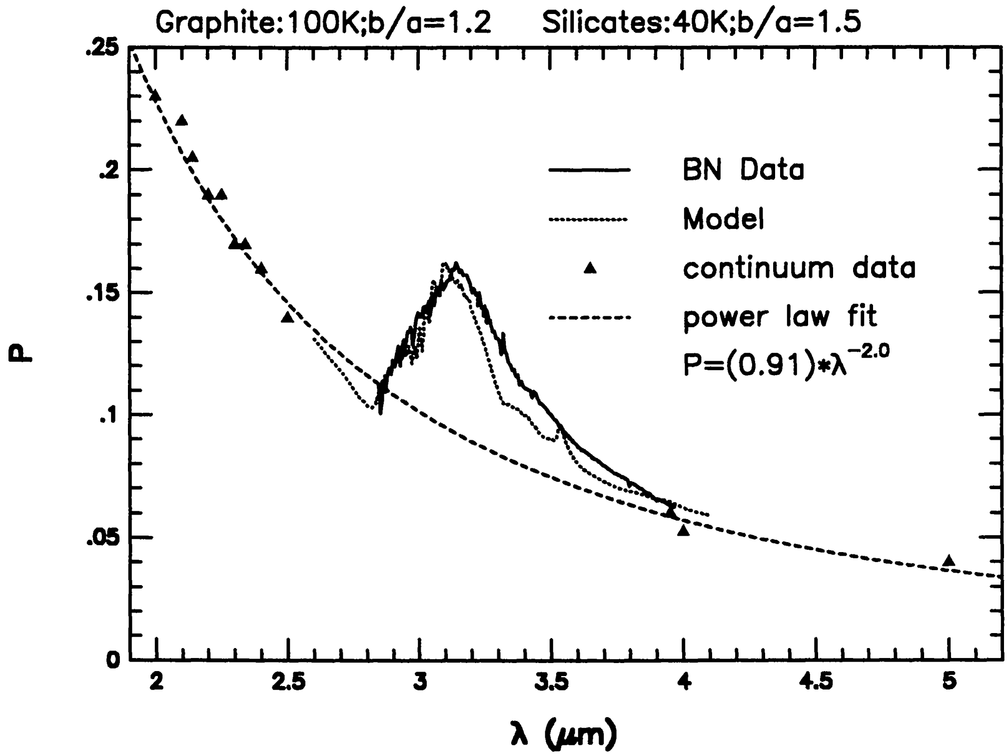

Figure 2. Model fit to the data assuming a power law continuum with an absorption feature added on top of continuum. Core compositions used are shown with temperature of mantle ice indicated.

power law continuum polarization. We have not yet included any modeling of the continuum polarization.

This is part of a work in progress with the ultimate goal of successfully modeling the spectropolarimetry of the water ice and silicate features towards the BN object. It is hoped that information about the morphology and grain population will be gained from our results.

4. Summary

1. There are new high-resolution spectropolarimetry data of the BN object that can be modeled in greater detail than before.

2. A simple absorption profile model has been constructed to reproduce the data using graphite and silicate oblate cores covered with ice mantles.

3. To successfully reproduce the data, water ice at different temperatures with impurities in it is needed.

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