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# Interstellar grains in the regions of anomalous extinction

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**Abstract.** We have evaluated the interstellar extinction curve and the ratio $R$ of the total to the selective extinction using exact computations of extinction efficiencies for various grain models. The computed results are compared with the observations in the star forming region, Orion, where the observed $R \sim 5.2$. Grains of sizes larger than the normal seem to fit the observed extinction in these regions.

*Key words* : interstellar extinction—star forming regions

## 1. Introduction

An important parameter characterizing the interstellar extinction is the ratio $R$ of the total to the selective extinction given by $R = A_v/E\ (B - V)$. The average value of $R$ is ~ 3.1 (e.g. Savage & Mathis 1979) though regions of lower and higher $R$ values exist (Serkowski *et al.* 1975; McMillan 1978; Breger *et al.* 1981; Mathis 1990), known as the regions of anomalous extinction which are associated with recent star formation (Breger *et al.* 1981; Cordelli & Clayton 1988). In our earlier publications (Vaidya *et al.* 1984; Vaidya & Desai 1987) we had considered grain models incorporating spherical, non-spherical, absorbing as well as non-absorbing particles. The purpose of the present study is to investigate the properties of the grains in the regions of anomalous extinction by invoking the models which incorporate core-mantle particles. In each case, we have evaluated the interstellar extinction curve (i.e. $E(\lambda - V)/E(B - V)$ versus $\lambda^{-1}$) and the value of $R$. We have compared our results with the observations for stars in the nearby HII region, the Orion nebula where the observed $R \sim 5.2$ (Breger *et al.* 1981).

## 2. Results

The details of the evaluation of the interstellar extinction curve and the computations of $R$ are given earlier (Vaidya *et al.* 1984). Table 1 shows the ratio $R$ of the total to the selective extinction for various values of the size parameter $r_0$ in the size distribution function (Greenberg 1968). Table 1 also shows the (last column) required value of $r_0$ to reproduce the observed value of $R \sim 5.2$. When we plot the extinction curve for these models we find that most of them fit the observed extinction curves reasonably well in the wavelength range that we have considered (≥ 3000 A). An illustrative extinction curve is given in figure 1 for the case of core-mantle particles (model 8 in table 1).

**Table 1.** Results for the ratio $R$

| Grain model | Refractive index $n$ | $r_0$ 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | For $R$ = 5.2 |
|---|---|---|---|---|---|---|---|
| Sphere | 1.33-0.05 i | 2.05 | 2.64 | 3.64 | 5.38 | 8.86 | 0.59 |
| Cylinder | 1.33-0.05 i | 2.95 | 3.70 | 5.28 | 8.95 | — | 0.49 |
| Oblate a/b = 5 | 1.33-0.05 i | 2.19 | 2.91 | 3.75 | 4.71 | 5.59 | 0.64 |
| Prolate a/b = 5 | 1.33-0.05 i | 2.19 | 2.85 | 3.48 | 4.56 | 9.06 | 0.63 |
| Sphere | 1.50-0.0 | 2.42 | 4.07 | 9.29 | — | — | 0.44 |
| Cylinder | 1.50-0.0 | 3.31 | 6.65 | — | — | — | 0.37 |
| Prolate a/b = 2 | 1.50-0.0 | 2.48 | 15.51 | — | — | — | 0.36 |
| Sphere Core/mantle | 1.33-0.05 i/ 1.50-0.0 | 2.34 | 2.95 | 3.94 | 5.70 | 9.30 | 0.58 |
| Core/mantle | 1.50-0.0/ 1.33-0.05 i | 2.35 | 3.96 | 8.86 | — | — | 0.44 |
| Core/mantle | 1.50-0.05 i/ 1.33-0.05 i | 2.77 | 3.30 | 4.28 | 6.90 | — | 0.55 |
| Core/mantle | 1.50-0.0/ 1.33-0.0 | 2.11 | 3.59 | 7.96 | — | — | 0.44 |

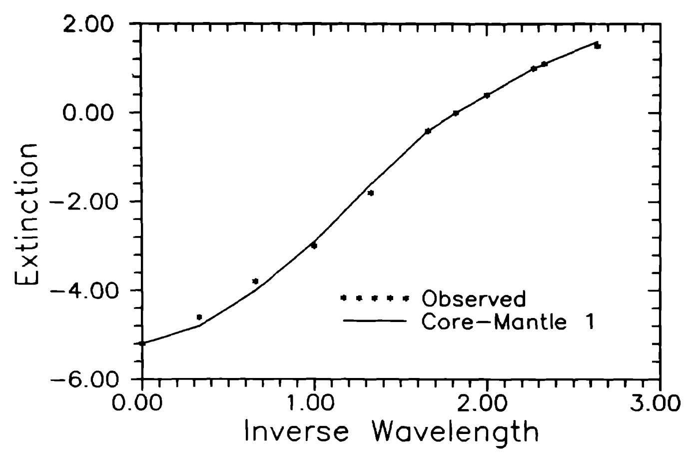


**Figure 1.** Extinction curve for core-mantle particle (Model 8 in table 1). The stars are the observed values.

## 3. Discussion

It is seen from table 1 that for each model the value of $R$ in general increases with $r_0$ and it is possible to find a value of $r_0$ that will yield $R$ = 5.2. Thus it is clear from these results that grains larger than the normal grains ($\geq 0.2 - 0.3$ μm) are required to match the observed curves in these regions. As suggested by Cardelli & Clayton (1988), in Orion and other HII regions the grains have grown larger than normal through coagulation and accretion. Hence, we have included in the present study the core-mantle particles as grain models. It is found that these models also fit very well with the observed data in the Orion (figure 1). Comparison of these models with other HII regions is in progress. Also, the comparison with the observed polarization data in these regions would help to put greater constraints on these models.

## 4. Conclusion

The model curves show that the grains of sizes larger than the normal are required to match the observed curves for the stars in the Orion, the region of anomalous extinction. These larger sizes could be due to accretion of the material on the average sized particles.

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