Physics 224: Paper Discussion 3
Winter 2020

Mathis, Rumpl & Nordsieck 1977:

- If the fit were to be done today, what routine could do it and could it be improved? My favorite sentence in this paper "Most of the problems arise from the bump", how would the fit change and how would the problems resolve if the fit was not to the 2160 bump?
- What is the dominant source of differences in extinction for various dust species? How significant are properties such as albedo, index of refraction etc in comparison to size distribution?
- This is more of a technical question, but, why is okay for the author to force a fit to the data. They state that in order to fit the width of the 2160 bump, they had to artificially lower the values of the uncertainty parameters. Is there a justification for doing this?
- When studying polarization, it seems like they graphite particles are spherical and then lump all the other materials together into cylinders. Why is it okay to do that? I feel like the actual shape/charge distribution of the different types of dust grains would have an affect on polarization. The actual procedure they're following for this part is also a bit unclear to me.
- I don't really understand the logic for making the errors around the lambda-2160 bump artificially small. The stated reason is to "force the computed extinction to provide an excellent fit to the lambda-2160 bump, both of which are well determined". If they are very well determined, shouldn't the OAO and TD-1 measurements, and therefore the uncertainty, reflect that? Are the authors saying they somehow understand that bump better than the OAO and TD-1 data show?
- They note in this paper that for wavelengths shorter than 1700 angstroms, that results from mie theory begins to diverge from the experimental results. In this paper, they calculate the scattering through the albedo they say. Where is the error they are worried about coming up in this calculation for the albedo/ application of the albedo? Their fits seem to be very good, so why were they worried about this source of error in their fits?
- While the authors go to lengths to express the fact that none of the models work without a significant fraction of dust being graphite, they do not touch upon any theories regarding why it is there in the first place. What are some of

the possible astrophysical causes of such a high prevalence of graphite? Does it come down to it being the simplest possible grain that can be assembled given the abundances of heavy elements?

- I find the lower limit on the size distribution for "other" materials quite interesting. Though it is only a factor of 5 larger than the lower limit on the range for graphite, it would imply that it makes the smallest dust grains of the other materials about 100 times more massive than the smallest sized graphite grains. In addition to this it sort of implies that the timescale for aggregation from smaller grains to larger grains is faster than the timescales associated with creating the smallest grains. That is to say suppose the smallest grain with size a1 is about the limit where it's interaction with EM waves becomes more dust-like than molecule-quantumy-like. What size that is, I'm not sure, do we know what that transition size is? Whatever that scale is, if it is below 25nm, then it seems like the processes that supply those sized grains does so at a rate much slower than it takes for those grains to grow up to 25nm. Is there some theoretical explanation for this?

- Would it be possible to have non-cylindrical dust grains that could produce polarization? Obviously the spherical grains cannot, but are there other shapes allowed for the dust grains (based on their chemistry, that is likely) that would produce a polarized signal? If not, which of the hypotheses they present for why their polarization fits are not consistent is most likely? It seems like a combination is likely: we know there are dust grains that align with the magnetic field and thus produce polarization in this way, but it seems feasible that some grains would have dielectric coatings like they describe. What fraction of the grains would have to be in these states to explain the observed polarization spectral behavior?

- In section III, they mention that the crystalline structures of these particles can be modified by cosmic rays. My guess would have been that cosmic rays can still scatter off these particles but with a different cross-section, is this a correct assumption?

- I'm a bit confused about the "coating" of the grains. Does a "coated grain" mean it is coated by the dense gas or something else? Why would the coated grain be more easily aligned in the magnetic field? Also, what is the physical reason for the bump near 2160 angstrom?

Sellgren et al. 1984:

- The author proposed that the near-infrared emission of three reflected nebulae may be due to thermal emissions from small grains being briefly heated, and the numbers of these grains are consistent with Mathis et al. (1977). If the grain size distribution of Mathis et al. (1977) is correct, does it mean that most reflected nebulae should contain such small grains? If so, does all observed reflected nebulae to date show smooth continuum with similar color temperatures?
- I'm curious if any work has been done since on justifying the extension of the MRN size distribution to the grain sizes used in this analysis. While the extrapolation down to 10 Angstroms doesn't seem unreasonable, the bin sizes used in the MRN distribution were 25 Angstroms. Is there anything important features that may be smoothed out in these relatively coarse bins?
- How does the measured spectrum depend on factors such as foreground extinction, type of stars present in the reflection nebula, and optical density, and could these significantly change the dust grain size distribution or the proposed mechanism for the infrared emission?
- The model they present seems to fit the observed inconsistencies with the previous understanding of the reflection nebulae. How else can you support the model they present? Have there been follow-up studies and complementary observations that confirm their hypothesis, or is it still just the best explanation of all the phenomena described?
- My question is about the broader impact of this model (along with the other paper): did this idea of 10 Angstroms grains being briefly excited by absorbing individual UV photons turn out to be correct? Was someone able to extend the measurements of the grain size paper down to this size and confirm the population density there, showing that the $a^{-3.5}$ relation holds?
- In the implication section, the author state that "These Nebula represent a select sample...where the amount of UV radiation is sufficient to produce near infrared emission yet inefficient to ionize an HII region which masks the near infrared". Does this mean that the Nebula is optically thin, and that Case A recombination should be assumed, instead of Case B?
- What is the typical energy scale for gas-grain collisions assuming a size distribution from the previous paper? This was ruled out in favor of absorption of UV photons but it'd be nice to know. Section (IV b)
- I'm confused about why the "low values of observed radio continuum emission" rule out free-free emission as a source of NIR continuum emission. I would've

thought that at high temperatures you would expect more free-free emission. Is this because at the temperature of these nebulae, free-free emission would peak in radio wavelengths if it were to occur significantly?

- The paper demonstrates that ∼10 Å dust grains are good candidates to explain the 1000 K emission from the nebula; however, it is unclear to me why the emission would peak at this particular temperature. The dust population must contain grains of similar but different sizes that can be subjects to the same mechanism, but output a different brightness temperature. As such, I would expect the observed emission temperature to be "fuzzy" and distributed across a much wider range of values.

- My question is somewhat related to the formation of such a region of small dust particles. It would make sense if the Carbon particles came from a supernova remnant, but is it just because of the dynamic time scales involved in the problem that the particles observed are so small? Or is there some other reason for the origin of such a vast region of small dust grains? Or are these dust grains just common but the fact that they are in vicinity of certain sources of UV radiation that they have these spectral properties?

- In earlier calculations by Allen and Robinson 1975, they found the temperatures of these molecules to be around 200-500K, so they used a specific heat that was not temperature independent. In this paper they use a high temperature limit of the specific heat for the particles. They also say that there may be chemical reactions on the surface and collisions. How would molecular species changing from reactions alter this result? the specific heat scales as the degrees of freedom, so I does changing the molecules chemical composition or structure (i.e. degrees of freedom) have a large impact on these results?

- What's the timescale for a 10 angstrom sized grain heated to 1000K to return to the average temperature of the surrounding gas? Is it appropriate to use the Stefan-Boltzmann formula, P = A*sigma*T**4 to calculate this relaxation timescale?