Learning about Mie Scattering PhL 2.8-14.03

I am wondering whether Mie used the Jackson multipole expansion, or some other method.

I made a return visit to the water drops website I found, and it is leading to many new things. First, I downloaded the guy's software package and it runs beautifully and quickly. It claims to use the algorithms of Mie and/or Debye invented in 1908 but which were not computable until the last 20 years when machines became fast enough.

Here are some references from this Help system:

The Mie scattering algorithm used in MiePlot is based on the BHMIE code published in Appendix A of the book **"Absorption and Scattering of Light by Small Particles" by Craig Bohren and Donald R. Huffman**, published by Wiley-Interscience (ISBN 0-471-29340-7). This book is readily available from booksellers, such as Amazon.com. Various versions of the **BHMIE source code** may be downloaded from the library of scattering codes in Piotr Flatau's "Scatterlib" at http://atol.ucsd.edu/~pflatau/

I would also like to thank Professor Raymond Lee for his stimulating paper **"Mie theory, Airy theory, and the natural rainbow," Applied Optics 37, 1506-1519 published in 1998**. A PDF version of this article may be downloaded from http://www.usna.edu/Users/oceano/raylee/RLL_cv.html. The "Lee diagrams" generated by MiePlot are based on his work.

The Debye series algorithm has been derived from Chapter 5 of the book **"Scattering of waves from large spheres" by Walter T. Grandy, Jr. published in 2000** by Cambridge University Press (ISBN 0-521-66126-9). As there are very few published results of Debye series calculations, it has been difficult to verify the accuracy of this algorithm. However, there appears to be good agreement between MiePlot results and the graphs shown in the paper "Assessing the contributions of surface waves and complex rays to far-field Mie scattering by use of the Debye series" by Edward A. Hovenac and James A. Lock published in the Journal of the Optical Society of America A Vol. 9 (5), pp. 781 – 795, May 1992. Nevertheless, my initial tests suggest that the phase of the Debye series may be incorrect. This error does not affect the amplitudes of the contributions from individual ray paths, but it may give incorrect results when the contributions of different ray paths are combined as a vector sum. Any independent confirmation of MiePlot's accuracy or inaccuracy will be appreciated.

Marcel Wernand (http://www.nioz.nl/en/deps/fys/wernand/Welcome.html) of the Royal Netherlands Institute for Sea Research has generously supplied **comprehensive measurements of the spectrum of sunlight.**

Les Cowley (http://www.sundog.clara.co.uk/atoptics/phenom.htm) provided many invaluable suggestions, feedback and support during the creation and testing of the MiePlot program.

I looked at the Lee paper, and it is focussed on comparing Airy theory and Mie theory, and does not review Mie theory, but does give the reference.

5. G. Mie, "Beiträge zur Optik trüber Medien, speziell kolloidaler Metallösungen," Ann. Phys. **25,** 377–445 (1908). An English translation is available as G. Mie, "Contributions to the optics of turbid media, particularly of colloidal metal solutions," Royal Aircraft Establishment library translation 1873. (Her Majesty's Stationery Office, London, 1976).

More from the web,

Gustav Mie:
Beiträge zur Optik trüber Medien, speziell kolloidaler Metallösungen.
Annalen der Physik, Vierte Folge, Band 25, 1908, No. 3, S. 377-445.

Contributions to the optics of turbid media, especially colloidal metal suspensions.
English translation no. 79-21946, National Translation Center,
John Crerar Library, Chicago, IL 60616, USA

Here is a listing from another site of classic papers, all in German!

- [1] **Alfred Clebsch:** Ueber die Reflexion an einer Kugelfläche. Journal für Mathematik, Band 61, 1863, Heft 3, p 195-262.
- [2] **Ludvig Lorenz:** Lysbevaegelsen i og uden for en af plane Lysbolger belyst Kugle. Det Kongelige Danske Videnskabernes Selskabs Skrifter, 6. Raekke, 6. Bind, 1890,1, p 1-62.
- [3] **Ludvig Lorenz:** Sur la lumière réfléchie et reéractée par une sphère (surface) transparente. in Oeuvres scientifiques de L. Lorenz. revues et annotées par H. Valentiner. Tome Premier, Libraire Lehmann & Stage, Copenhague, 1898, p 403-529.
- [4] **Gustav Mie:** Beiträge zur Optik trüber Medien, speziell kolloidaler Metallösungen. Annalen der Physik, Vierte Folge, Band 25, 1908, No. 3, p 377-445.
- [5] **Peter Debye:** Der Lichtdruck auf Kugeln von beliebigem Material. Annalen der Physik, Vierte Folge, Band 30, 1909, No. 1, p 57-136.
- [6] **Arnold Sommerfeld:** Über die Ausbreitung der Wellen in der drahtlosen Telegraphie. Annalen der Physik, Vierte Folge, Band 28, 1909, No. 4, p 665-736.

I see a huge number of available programs, but no one yet is giving me a summary of Mie theory! One site in Germany is promoting the T-Matrix Method. There are also tons of books on scattering theory on this web site.

My conclusion is that you have to buy an English translation from the John Crerar library, or learn to read German. Best then to get this from a secondary source!

So now I start over searching on just "Mie scattering". I see some good stuff at Wolfram.

Continue 2/14/03.

Marriott Trip. I found the exact Born and Wolf I will be getting soon, I see it was $47 direct from A1, I was dumb. It does the Mie stuff, but not in the elegant formalism I have grown to like. I found better descriptions in other books, but I was pressed for time. I did copy 3 pages out of a book by Barber and Chang which seems to echo the same stuff I saw in my 4 page Mie Theory paper, including the strange expansion for the plane wave which is (3.8) in this paper. The biggest contribution of this paper really is its bibliography references 52-55 where it claims to be obtaining all its theory! Naturally they were all checked out, being important references. These books bridge the gap between the present 2003 and the original 1908 work of Mie and Debye.

Bohren & Huffman 1983. This seems to be the principle reference everyone uses and refers to. It is a $66 paperback on amazon, you can view the contents. It also has computer programs, and I think people are using these now. A1 price is $53.

van der Hulst 1981 "Light Scattering by small particles" Dover $15, amazon $11, next order maybe/

M. Kerker 1969.

Kim & Lee 1983 paper -- applies Mie theory to Gaussian Beams

Perhaps it is time to let the dead dog lie.

I did my own multipole solution for Mie, I was hoping to check my results against some other source, but that has not proven possible without spending more time and/or money. So let's pause to see what we have learned so far, and maybe I am really done. There are other pressing matters such as L3.

The Mie notes I have read have shown that the coefficients have poles where the dielectric sphere has resonances, and you tend to see resonant peaks on your Mie scattering differential cross section. You can naively think of these as occurring when an integral number of wavelengths fits inside the sphere, but in fact these are the resonances that one can compute as I did for Carleton's cavity. Books note that the resonances are in the same place no matter how you stimulate the sphere, does not have to be a plane wave but can be. There are many formalisms for doing the same scattering problem, keep that in mind.

My original interest was in dealing with partially transparent floaters. My model was a sphere of index something like 1.37 sitting inside a medium of 1.33, so a small difference. I have a nice Mie scattering program, but I think it is only computing results in the radiation zone. I wanted the close-in results as well, which is why I was computing those coefficients. No one cares about the close-in results because most applications involve what happens far from the scatterers. Smoke, volcanoes, atmospheric moisture, stellar dust, blood cells in motion. No one cares about the near-zone but me. I was interested in this because I was not getting super-dark tiny black spot shadows.

So what do I think the near-zone might look like? The floaters are about 8 wavelengths in diameter. I think there will be some Mie scattering. However much energy is scattered is removed from the plane wave and we end up with a "shadow" for that reason. In addition, there could be some absorption. So I do expect some kind of shadow, but not very strong. Since I don't really know the index differential, it is hard to do any quantitative calculations along the lines of my earlier efforts with the opaque disks. When all is said and done, if I did know the exact answer, it would be some characteristic diffraction smooth pattern with the expected diffraction angle width, and the central peak could still be whiter than the surroundings due to interference with the plane wave. We know that as the indices gradually match, the entire effect goes away smoothly, so I can imagine a weak result. Too bad I cannot do more that just make this conjecture.

So why don't we put this project to bed. I could read about the $j = \ell \times 1$ version of the VSH functions and all that, but I think other things are more important right now. So let's at least get a good filing system for all the stuff we have amassed so far.