Journal of Quantitative Spectroscopy & Radiative Transfer 113 (2012) 2310–2320

Contents lists available at SciVerse ScienceDirect

Journal of Quantitative Spectroscopy & Radiative Transfer

journal homepage: www.elsevier.com/locate/jqsrt

Review

The nature of interstellar dust as revealed by light scattering

C. Cecchi-Pestellini [a,*], M.A. Iatì [b], D.A. Williams [c]

[a] INAF-Osservatorio Astronomico di Cagliari, Strada N. 54, Loc. Poggio dei Pini, I-09012 Capoterra, CA, Italy
[b] Istituto per i Processi Chimico-Fisici, CNR, Viale F. Stagno d'Alcontres 37, I-98158 Messina, Italy
[c] University College London, Department of Physics and Astronomy, Gower Street, London WC1E 6BT, UK

ARTICLE INFO

Available online 12 March 2012

Keywords:
Interstellar dust
Models
Light scattering
T-matrix

ABSTRACT

We discuss the important roles played by interstellar dust in the evolution of the interstellar medium of the Milky Way and other galaxies. We show the mathematical techniques that enable the optical properties of spherical grains and clusters of spheres to be computed. We describe two current approaches to modelling the properties of interstellar dust. Finally, we consider some possible limitations of these approaches and suggest that revised models may be required to take account of these concerns.

Contents

1. Introduction

Sir William Herschel (1738–1822) in his astronomical surveys of rich star fields noted that in some locations there appeared to be a "hole in the sky" (he wrote: *ein Loch in Himmel*), i.e., small regions of the sky in which stars seemed to be absent. He was not able to tell whether there were true absences of stars from these "holes" or whether something was obscuring the light of the stellar background. An example of what Herschel might have considered to be a "hole in the sky" is shown in Fig. 1. This is a well-known optical image of B68, a well-confined dark cloud

* Corresponding author.
E-mail address: ccp@ca.astro.it (C. Cecchi-Pestellini).

0022-4073/$ - see front matter © 2012 Published by Elsevier Ltd.
doi:10.1016/j.jqsrt.2012.02.039

(first catalogued by Barnard in 1919) which is viewed against the background light of a very rich star field. Certainly, no stars are evident in this image at the centre of the cloud; however, a look at the edges of the object shows that the edge is not really abrupt but a gradual diminution of the intensity and increasing reddening of the background stars. Indeed, infrared images of the object (see Fig. 2) show that many stars can be detected in the infrared through B68. Evidently, B68 and objects like it are regions where considerable extinction and reddening of starlight is occurring. It is unclear from these images alone, however, whether the extinction and reddening of starlight are confined to objects like B68, or are a more general phenomenon.

That question was addressed by Wilhelm Struve in 1847. He noted that the apparent number of stars per unit volume of space declined with distance. He rejected the implication that the Earth was in a special position and argued instead that starlight must suffer absorption in proportion to the distance travelled through the interstellar medium, in other words, that there is an agent in the interstellar medium causing a general extinction and reddening. From 1910 E.E. Barnard made deep photographic studies of regions like B68 and showed that they also contain agents scattering and absorbing starlight, and by 1930 R.J. Trumpler had shown that the absorption is wavelength-dependent. The theory of light scattering developed by L.V. Lorenz and by G. Mie led to the conclusion that this wavelength-dependent extinction was caused by dust particles of a size comparable to the wavelength of optical light. The discovery by J.S. Hall and independently by W.A. Hiltner in 1949 that optical starlight can be polarised during its passage through the interstellar medium led to the deduction that this was a consequence of differential extinction caused by partially aligned asymmetric dust grains. Evidently, the interstellar medium contained gas and dust mixed together; in some locations the number density of dust grains was so great as to create the effect of "holes in the sky".

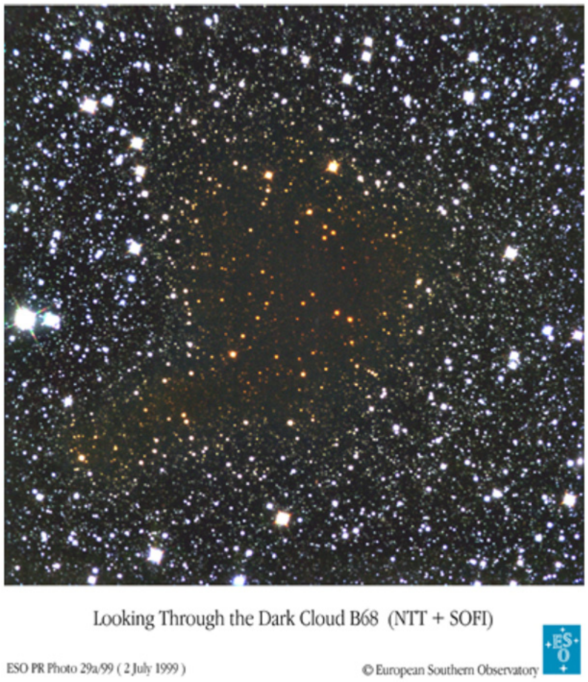

Fig. 2. A infrared false-colour image of Barnard 68. Evidently, infrared radiation penetrates this molecular cloud more readily than visible light, and many background stars can be seen. Barnard 68 is not a "hole in the sky". Courtesy of ESO.

Fig. 1. A concentration of dust and gas in an interstellar cloud absorbs the visible light of background stars, apparently creating a "hole in the sky". The molecular cloud Barnard 68 is about 500 light years from Earth, towards the Ophiuchus constellation. Courtesy of FORS team, 8.2 m VLY Antu, ESO.

Since the seminal work of van de Hulst, interstellar dust has long been an important application of techniques of light scattering. In this article we shall briefly review the information about the nature and composition of interstellar dust that can be obtained from the application of light scattering theory to astronomical observations of dust. We shall also consider some recent speculations about the various components of dust.

2. Why is dust important in modern astronomy?

For most of the 20th century the presence of interstellar dust, mixed with the gas, has been an accepted concept in astronomy. However, the dust was regarded mainly as an irritating "fog" that prevented a clear view of the stars; it was regarded as irritating because stellar astrophysics was a very important area of astronomy at that time. Most of the early effort was therefore to find simple ways of allowing for dust extinction, so that the true intensity and spectrum of the unshielded star could be estimated from the observed obscured star. However, over the last half century it has become increasingly accepted that dust has many very important roles to play in astronomy, and that dust is a crucial component of the