A simulation study of Scattered Light due to Cirrus Clouds in our Galaxy

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Abstract

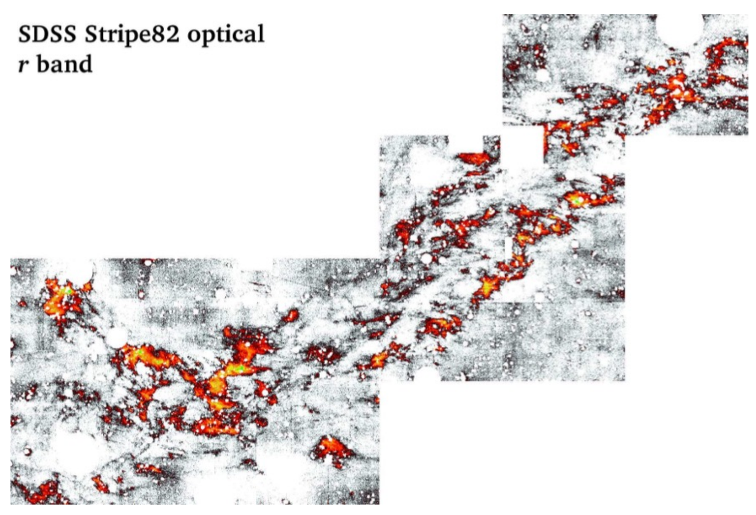
The extragalactic low surface brightness (LSB) objects are challenging to study due to systematic errors of sky subtraction and scattered light in the atmosphere and the telescope. Among the systematic errors, the widespread presence of Galactic cirrus clouds is one of the major obstacles in studying the LSB features of extragalactic sources. Interstellar dust clouds are also fundamental to understanding many interesting issues, including dust properties and the interstellar radiation field. Radiative transfer models in a clumpy/turbulent dust cloud, in which photons are incident from the ambient interstellar medium (ISM), are calculated to investigate the properties of the scattered light and compared with the observational results.

I. Introduction

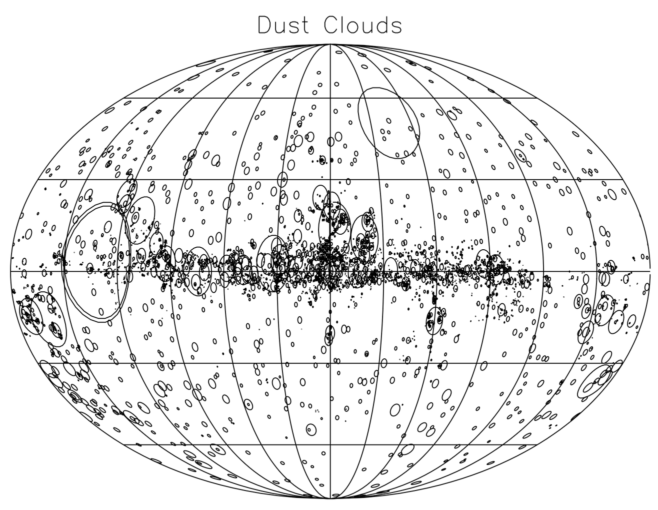
○ Low Surface Brightness (LSB) Objects

- Modern deep optical surveys allow us to investigate critical issues regarding the hierarchical evolution of galaxies, which are intrinsically associated with LSB features surrounding galaxies.
- Despite the present day's observational and technical advances concerning LSB features, the presence of interstellar dust reflecting starlight poses an unavoidable obstacle, thereby impeding the study of the faint outskirts of galaxies.
- ***It is, therefore, crucial to distinguish cirrus clouds from extragalactic LSB features.***

○ Cirrus Clouds are ubiquitous!



Cirrus Clouds in the SDSS Stripe82 field (Roman et al. 2020)



Dust Clouds Catalog (Dutra & Bica, 2002)

○ Motivation: Limitations of the Far-IR maps & Use of optical colors as a probe of cirrus clouds

- The poor spatial resolution of far-infrared and submillimeter data makes them inefficient for studying small angular scale features.
- Therefore, ***it is desirable to use the optical data itself to identify the presence of cirri*** without the need for complementary data at other wavelengths.
- Roman et al. (2020) demonstrated the optical colors of Galactic cirri differ significantly from those of extragalactic sources, highlighting the high potential of deep multi-band optical photometry for identifying the presence of cirri at a higher spatial resolution than those provided by FIR observations.
- ***This work presents a theoretical exploration of how the colors of cirrus clouds differ from those of galaxies.***
- ***These colors also provide clues about the properties of dust and the surrounding interstellar radiation field (ISRF) to which cirrus clouds are exposed.***

II. Model Settings

○ Aim: Monte Carlo Radiative Transfer Model

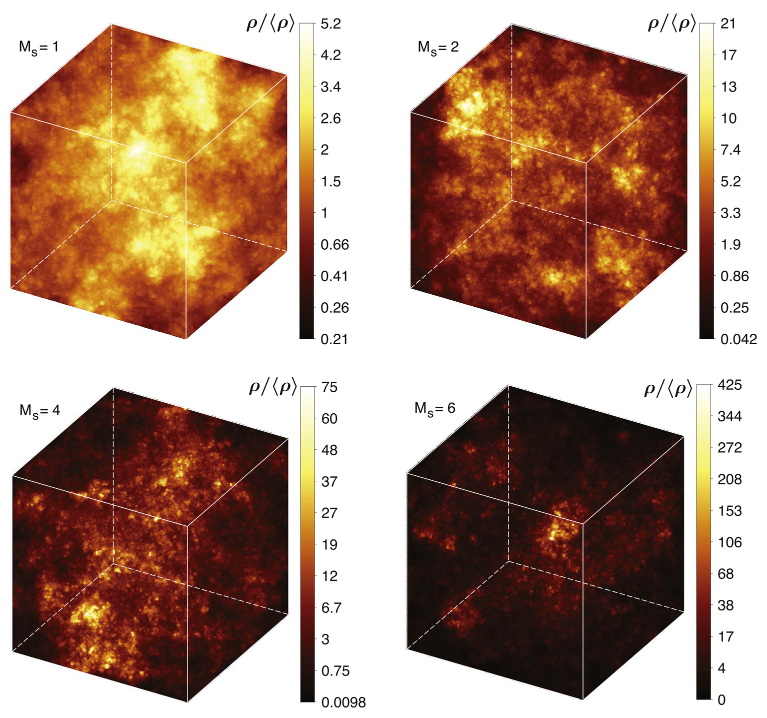
- ***To make theoretical color maps from cirrus clouds and compare them with the observational results for the SDSS Stripe82 region*** (Roman et al. 2020).

○ Clumpy/Turbulent Medium

- The medium is created to have a log-normal density distribution, which is consistent with the observations of the turbulent interstellar medium (ISM), using a fractal algorithm (Seon 2012; Seon & Draine 2016).

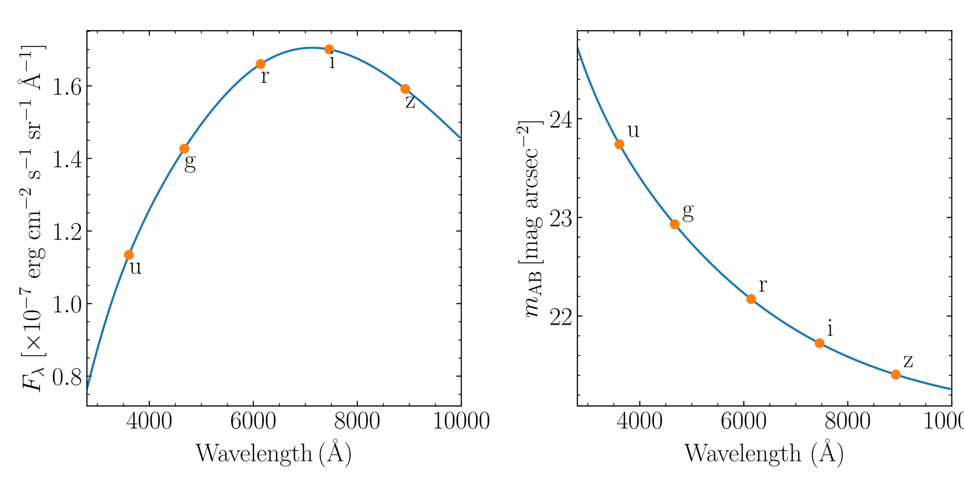
○ Dust & Optical Depth

- The dust albedos and asymmetry factors for the u, g, r, i, and z bands are obtained from the Weingartner & Draine (2001) model.
- The optical depth of the medium is varied from $\tau \approx 0.1$ to 2 in the SDSS g-band.

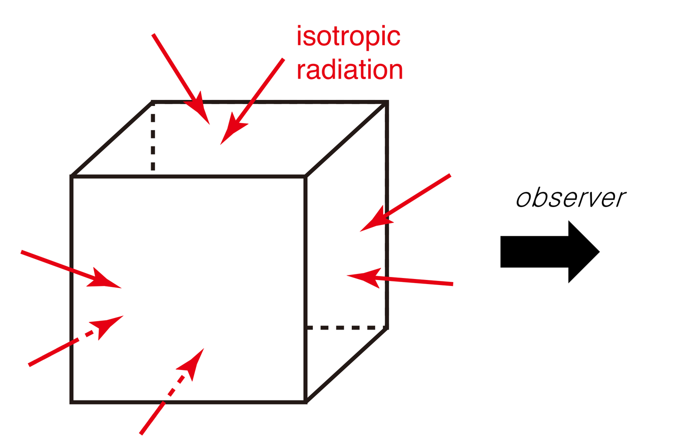


Realizations of lognormal density fields

○ Interstellar Radiation Field (ISRF)



SED of the ISRF (Mathis et al. 1983; Draine 2011)



Isotropic ISRF

- The ISRF is isotropically incident upon the surfaces of the turbulent medium.
- The spectral energy distribution of the ISRF is assumed to be that of Mathis et al. (1983), which has later been modified by Draine (2011) to improve agreement with the COBE-DIRBE photometry.

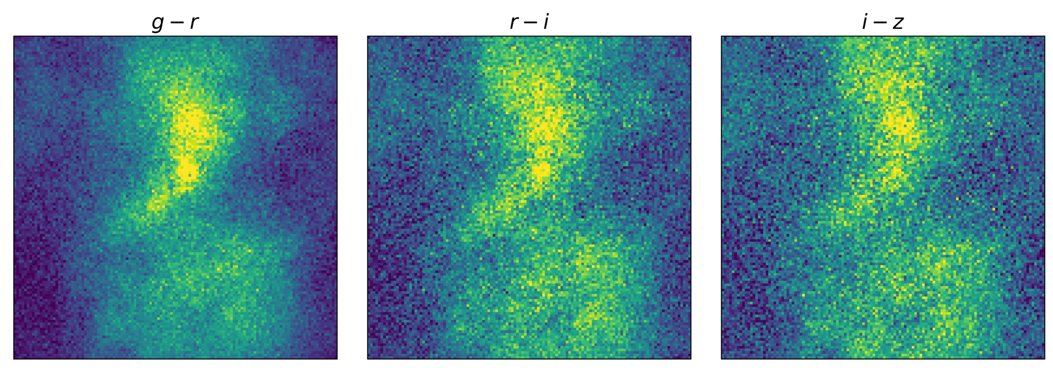
III. Results

○ Definitions

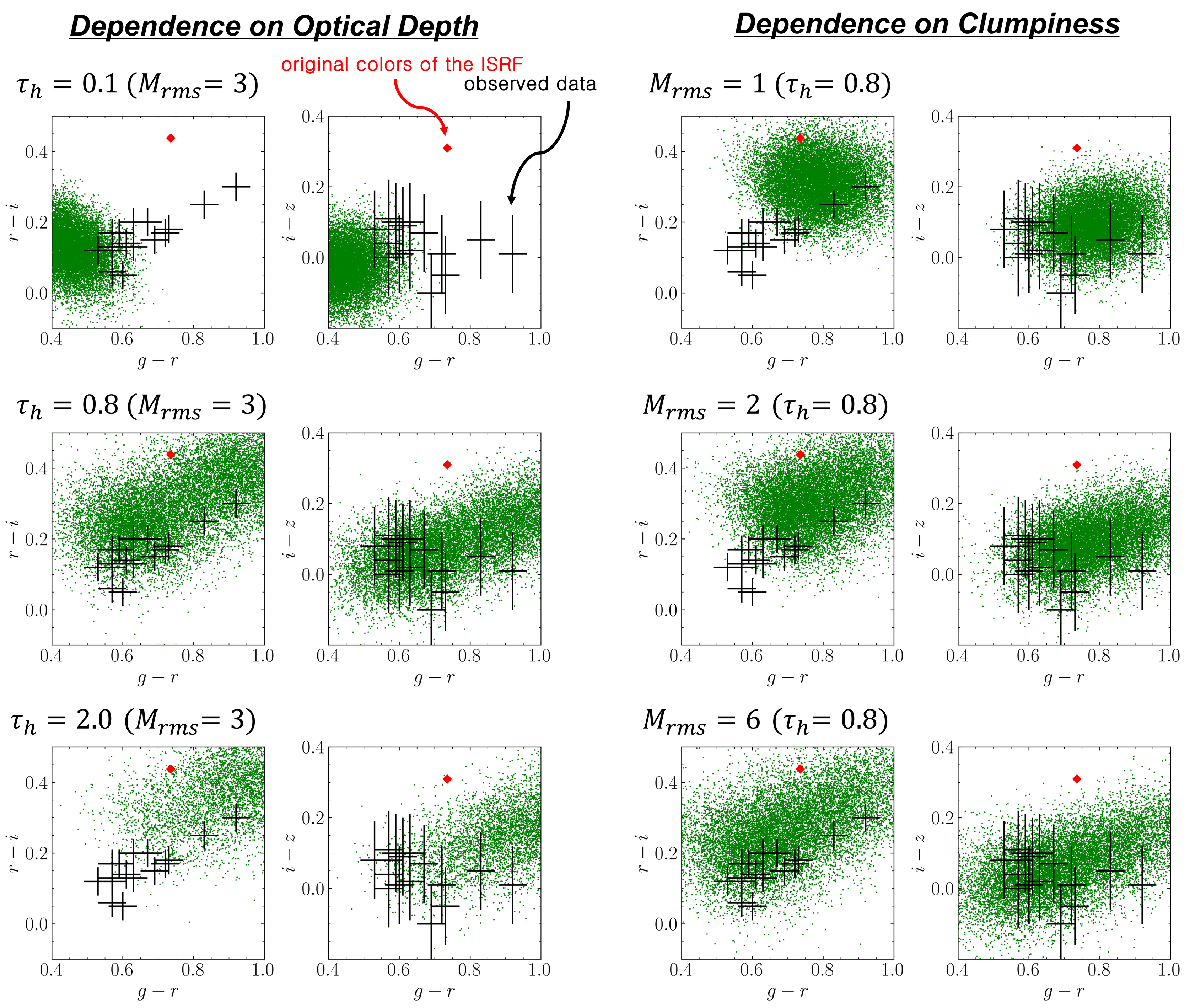
- τ_h = homogeneous optical depth for g band defined by the center-to-edge optical depth of a cloud with a constant density, but with the same dust mass as the lognormal density cloud.
- M_{rms} = the root-mean-square (rms) Mach number representing the clumpiness of medium.

○ Color-Color Maps

Color maps for $\tau_h = 0.6$, $M_{rms} = 3$

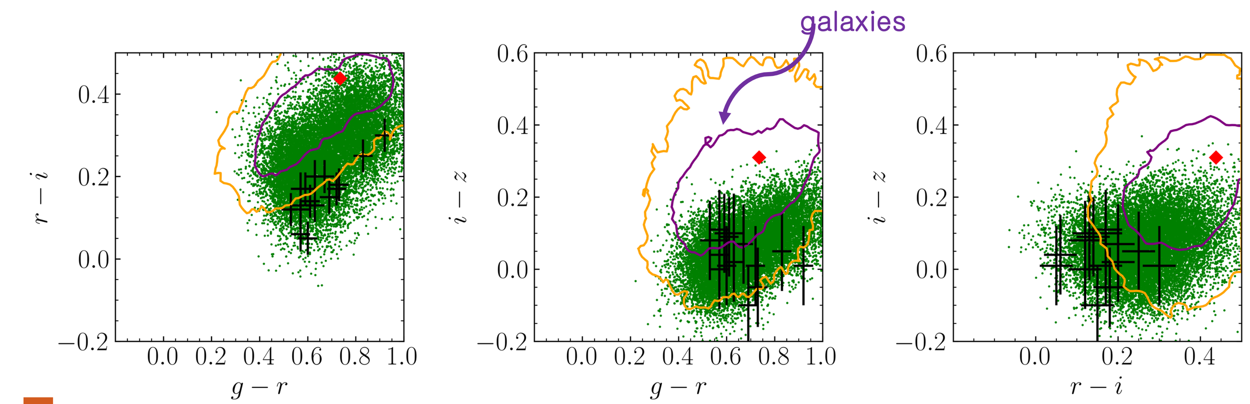


○ Color-Color Diagrams

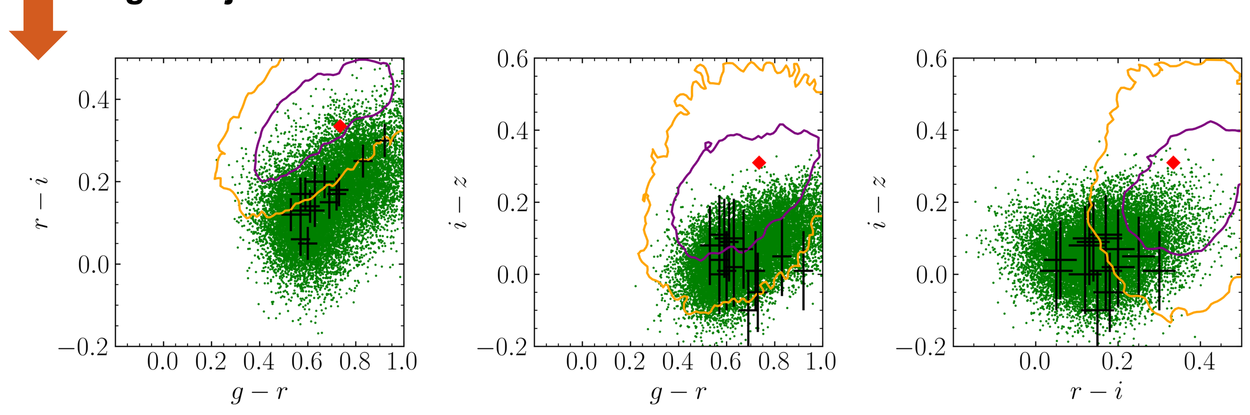


○ Best Model & Slight Adjustments of the ISRF

- ***The observed color-color diagrams are well reproduced by models with $\tau_h \approx 0.6$ and $M_{rms} \approx 2-4$.***
- ***However, the ISRF should be lowered by a factor of 1.1 in the i- and z-bands or increased by a factor 1.1 in the g- and r-bands.***



Slight adjustment of the ISRF



- **Red diamonds** denote the colors of the ISRF.
- **Black crosses** represent the observed results from Roman et al. (2020).
- **Purple** and **orange** lines denote the 1σ and 2σ contours for the colors measured from galaxies in the Stripe82 regions (Roman et al. 2020).
- **Green dots** are from the simulations.

Summary

❖ ***The Galactic cirrus clouds reflect the Galactic starlight, thus making them bluer. In contrast, external galactic SEDs are dominated by attenuation and, as a result, appear redder.***

❖ ***The SED of the ISRF needs to be slightly modified or an anisotropic radiation field may be considered.***

Illuminating the Dusty Universe: A Tribute to the Work of Bruce Draine (Oct. 30 – Nov. 03, 2023, Florence, Italy)