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

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I. 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 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.

II. Motivation

○ Cirrus Clouds

Fig1. **A Diagram of the CGM,** Tumlinson et al (2017)

- The CGM is the gas outside the disk and the interstellar medium(ISM), but inside their virial radius.
- Essential for understanding galaxy evolution
- The inflowing gas extend star formation
- Ejection of the baryons through galactic winds
- Circulation of baryons in & out of galaxies
- Kinematic studies of the CGM are critical in understanding baryon cycle and feedback processes.

○ Question

○ Observations of CGM

Fig5. Energy Levels of Atomic Hydrogen

- Lyα line results from an electron transition from n = 2 to n = 1
- The spectrum exhibits **double peaks** in the static medium.
- **Gas kinematics** and **spatial information** are imprinted in the scattered photons.
- **Radiative transfer (RT) modeling** studies are necessary to interpret the observational data

III. Model Setting

○ Interstellar Radiation Field (ISRF)

Fig7. Reproduction of the result from Garavito-Carmargo et al (2014)

- They investigated the effects of rotation velocity(RV), viewing angle, and column density when the medium rotates
- The peaks get broader as the RV, viewing angle, and column density increase.

○ Purpose of our study

Distinguishing the impact of rotation, random motion, and viewing angle on the characteristics of the line profiles

IV. Geometry

R_i : Inner radius
R_o : Outer radius
R_i=0.1 R_o

Fig8. Rotation curve of CGM from Mg II absorption study
Ho et al. (2017)

Fig9. Geometry of the medium

- Rotation curve increases **linearly** in the inner part, remains **flat** in the outer part

V. Results

○ Peak shift by viewing angle & Column density(CD) effect

$N_H = 10^{18} cm^{-2}$ $N_H = 10^{21} cm^{-2}$ $N_H = 10^{18} cm^{-2}$

Fig10. Peak shift when viewing angle changes
RM = 12.8 km s^{-1}, RV = 300 km s^{-1}

Fig11. Comparing RM & RV effect

- The **peak shift** increases as the **viewing angle** increases.
- This effect gets **weaker** as the **column density** increases.
- Effect of **random motion(RM)** is **larger** than that of the **rotation effect.**
- The **morphology** of the rotation effect is **different** from the random motion effect.

○ Effects of Rotation velocity & column density

$N_H = 10^{18} cm^{-2}$ $N_H = 10^{21} cm^{-2}$ $N_H = 10^{18} cm^{-2}$ $N_H = 10^{21} cm^{-2}$

Fig12. Column density effect at viewing angle 0°

Fig13. Column density effect at viewing angle 90°

- Even at viewing angle 0°, peak shift exist when **column density** increases.
- Peaks get broader and the shift increases as **rotation velocity** increases.

○ Velocity profile

Fig14. Velocity profile of static (left), and rotating medium (middle, right)

- The velocity profile of rotating medium at viewing angle 0° is similar to the static case
- Both the static and rotating media exhibit double peaks.
- However, the rotating medium displays distinguishable redshifted and blueshifted line profiles when examining spatially resolved spectra.

Summary and Future Work

- ❖ We investigated the effects of **viewing angle, column density, rotation velocity**, and **random motion** on the Lyα spectra of rotating CGM.
- ❖ **Spatially resolved Lyα** can distinguish between the double peaks of the static medium and those of the rotating medium.
- ❖ **Both outflow and rotation** should be considered in Lyα spectrum analysis.
- ❖ **Future work** : Clumpy medium, intrinsic line(ISM effect), inflow & outflow of the medium

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