Determination of the solar limb-darkening coefficient through the analysis of intensity profiles derived from solar imaging data

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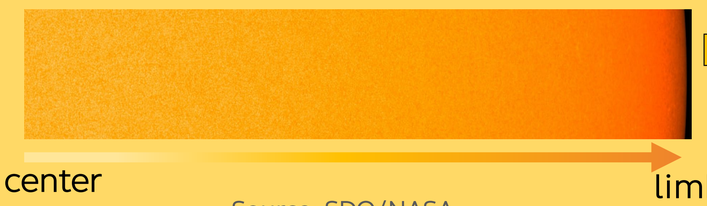
Abstract

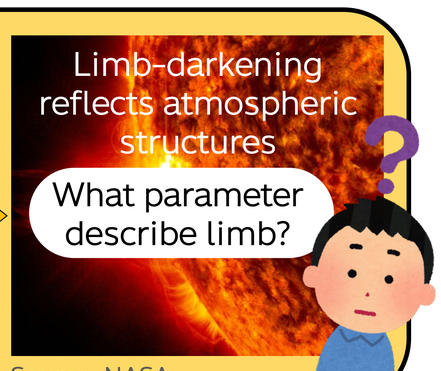
This study determines the solar limb-darkening coefficient using DSLR imaging coupled with a 6-inch Dobsonian telescope. Solar intensity profiles were extracted and analyzed using ImageJ, after which the limb-darkening coefficients were derived through both linear and nonlinear regression based on the least-squares method. The analysis employs commonly used limb-darkening formulations, including the linear, quadratic, and logarithmic laws. The results indicate that the averaged coefficients differ across the adopted models. For the linear law, the limb-darkening coefficient u yields an average value of 0.44. Under the quadratic law, two coefficients are obtained: u_1 with an average of 0.64 and u_2 with an average of 0.53. Finally, the logarithmic law also produces two coefficients, yielding average values of 0.69 for u_3 and 0.67 for u_4. These findings reflect the model-dependent nature of limb-darkening characterization derived from observational solar imaging.

Introduction

solar images consistently exhibit a gradual darkening toward the edge of the disk, known as solar limb-darkening.



Source: SDO/NASA



Source: NASA

Methodology

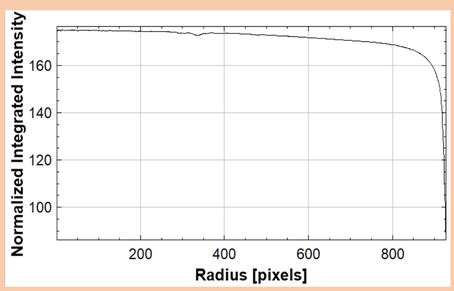
Part I : Observing and Collecting Solar Imaging Data

DSLR Camera attached to a Dobsonian telescope

Source: Jirachai Jariya

Daily images were captured during 14:00 P.M to 15:00 P.M. local time

Converting images using "ImageJ" software into grayscale

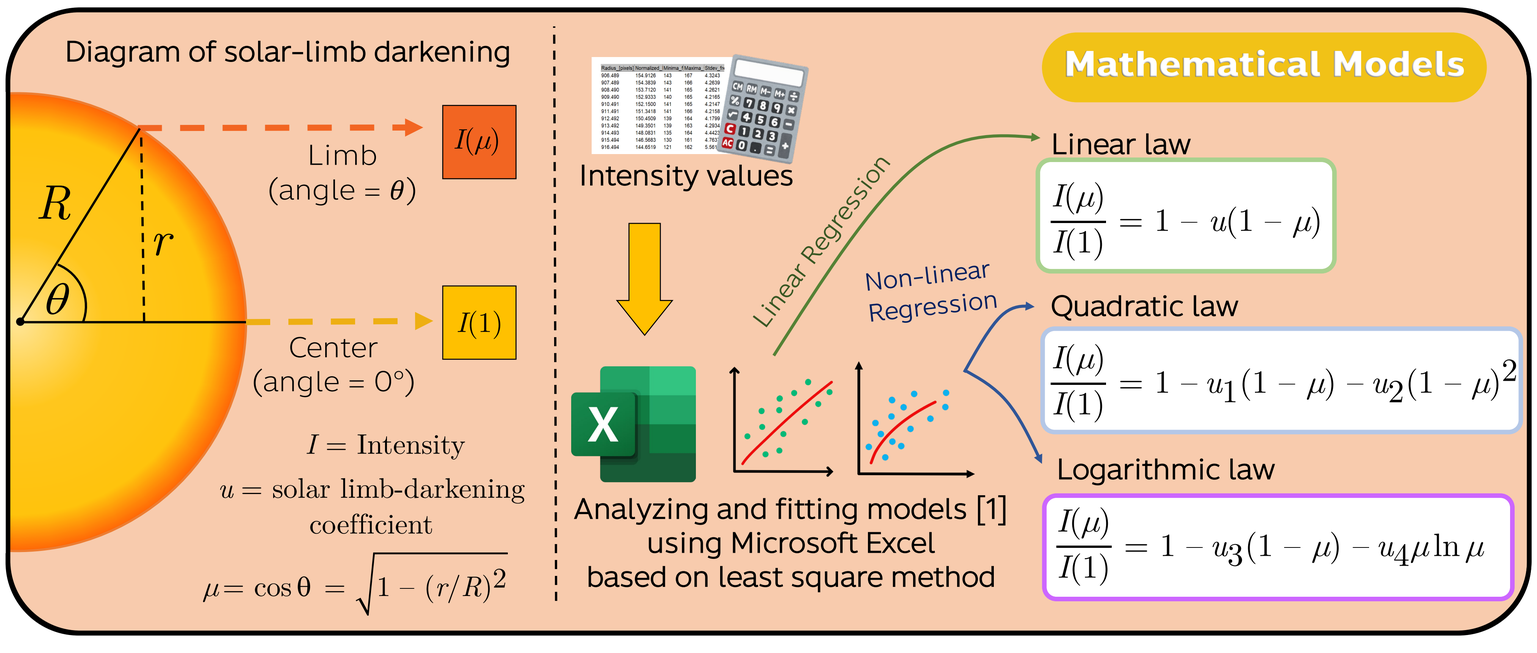


Radius_[pixels]	Normalized_I	Minima_fr	Maxima_	Stdev_fr
906.489	154.9126	143	167	4.3243
907.489	154.3839	143	166	4.2639
908.490	153.7120	141	165	4.2621
909.490	152.9333	140	165	4.2165
910.491	152.1500	141	165	4.2147
911.491	151.3418	141	166	4.2158
912.492	150.4509	139	164	4.1799
913.492	149.3501	139	163	4.2934
914.493	148.0831	135	164	4.4423
915.494	146.5683	130	161	4.7637
916.494	144.6519	121	162	5.5619

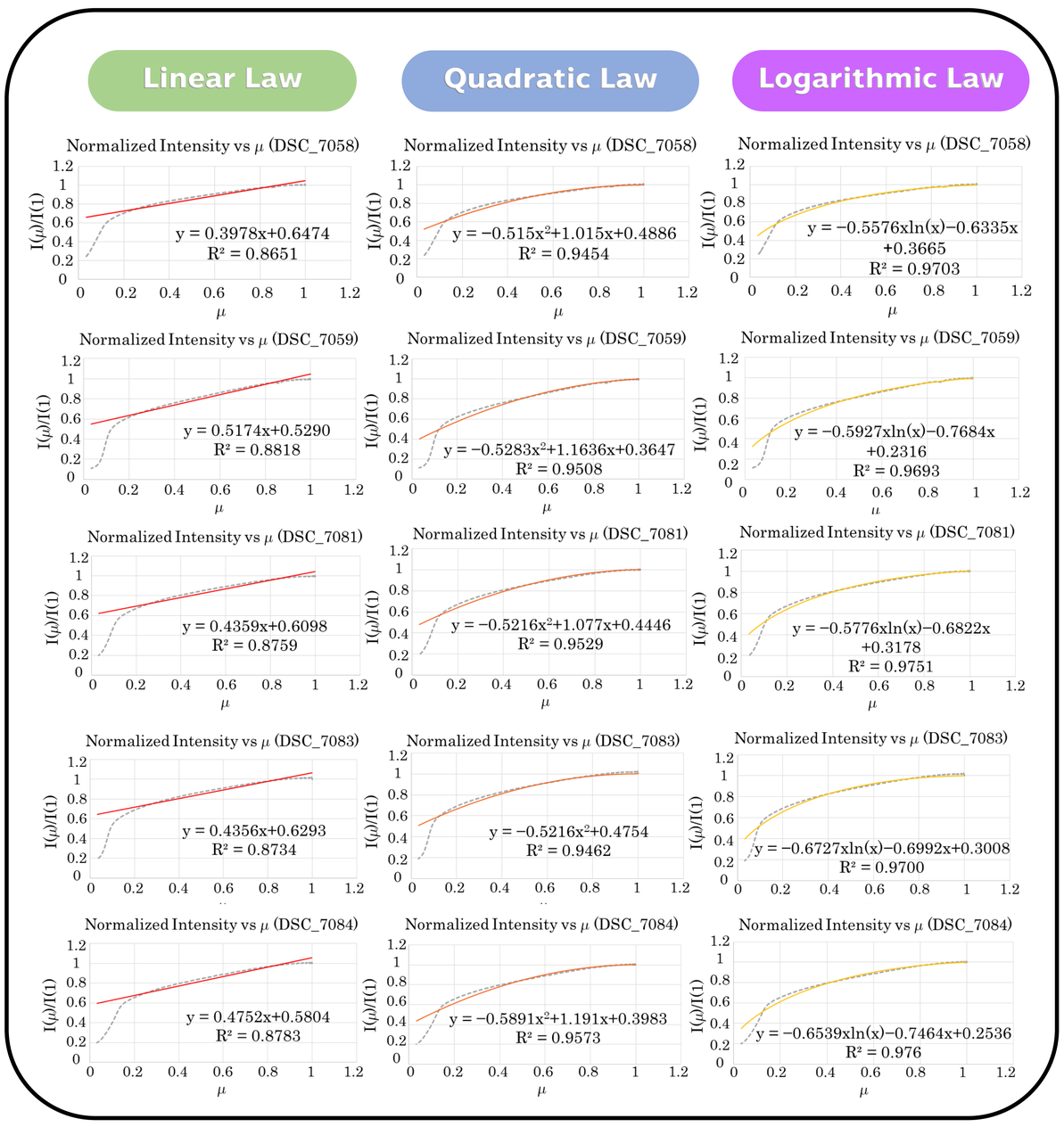
Applying the plugin "Radial Profile Angle" *(plugin need to be installed first)

the intensity graph (Left) and intensity values (Right)

Part II : Data Analysis



Results & Conclusion



The averaged results indicate that, for the linear model, the coefficient u is approximately 0.44. For the quadratic model, u_1 and u_2 average 0.64 and 0.53, respectively. For the logarithmic model, u_3 averages 0.69 and u_4 averages 0.67.

Although these experimental values may be affected by measurement or processing inaccuracies, equipment limitations, or atmospheric and dust interference, they remain valuable for further studies of stellar atmospheres, including the Sun and other stars.

Reference

[1] A. Claret, D. Dragomir, J. M. Matthews. Theoretical gravity and limb-darkening coefficients for the MOST satellite photometric system. A&A 567 A3 (2014). Retrieved April 15, 2025, from https://doi.org/10.1051/0004-6361/201423515