11. Interstellar Extinction (very simplified)

11.1 Magnitudes

The interstellar extinction has traditionally been measured in magnitudes rather than optical depth. This made the comparison to observations easier.

The magnitude of an object with flux density I is:

$$m = -2.5\ log_{10}(I)$$

The difference in magnitude between two objects is:

$$m - m_0 = -2.5\ (logI\ - logI_0) = -2.5\log(\frac{I}{I_0})$$

For example, a star 100 fainter than I_0 would have a magnitude of (m = +5).

Notes:

If two objects are at the same distance and have the same spectral type, then the interstellar extinction is

$$A_\lambda = -2.5\,\log(\frac{I_\lambda}{I_{\lambda,0}})$$

where $I_{\lambda,o}$ is the flux density of the object without extinction.

Expressed as an optical depth, we have $I_\lambda = I_{\lambda,0}e^{-\tau_\lambda}$ where τ_λ is the optical depth. Then

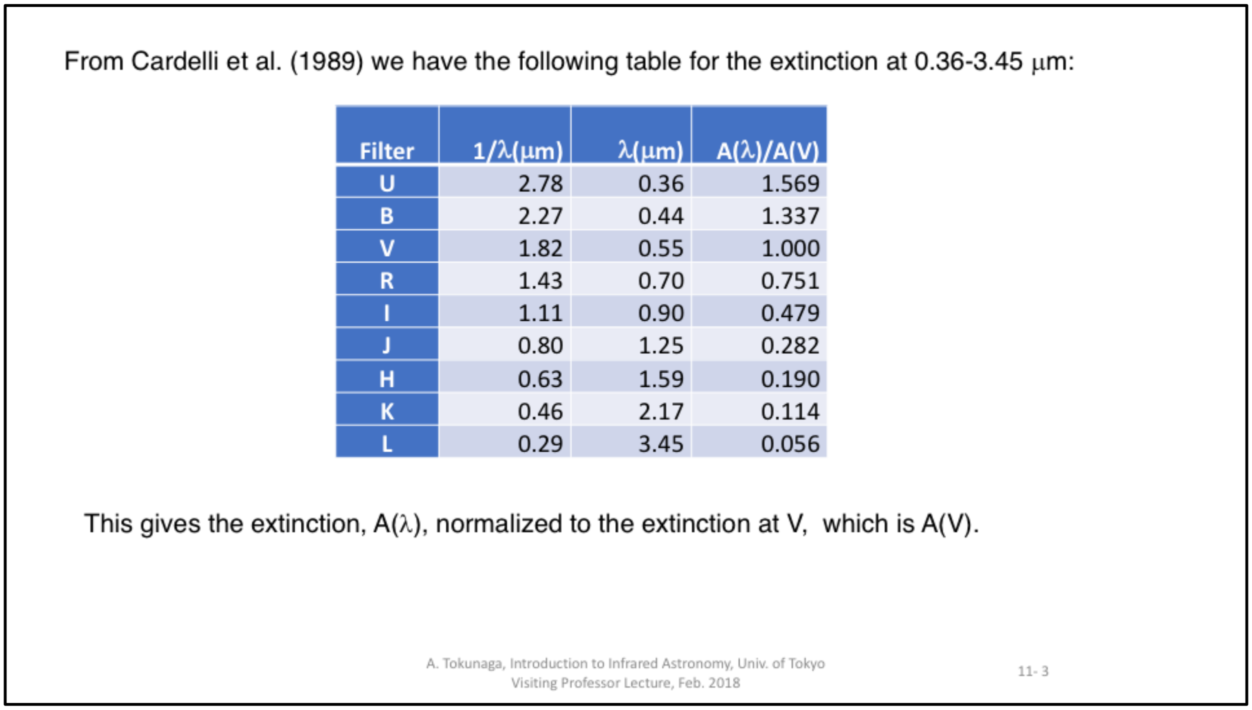
$$A_\lambda = -2.5\log(e^{-\tau_\lambda}) = 1.086\,\tau_\lambda$$

To keep this discussion simple, I will not discuss the total to selective extinction,

$$R = \frac{A_V}{E(B-V)} = \frac{A_V}{A_B - A_V}$$

This ratio is usually assumed to be 3.1 for the interstellar medium but it can be 5-7 in dark clouds. B and V are the Johnson filters at 0.44 and 0.55 μm.

Notes:

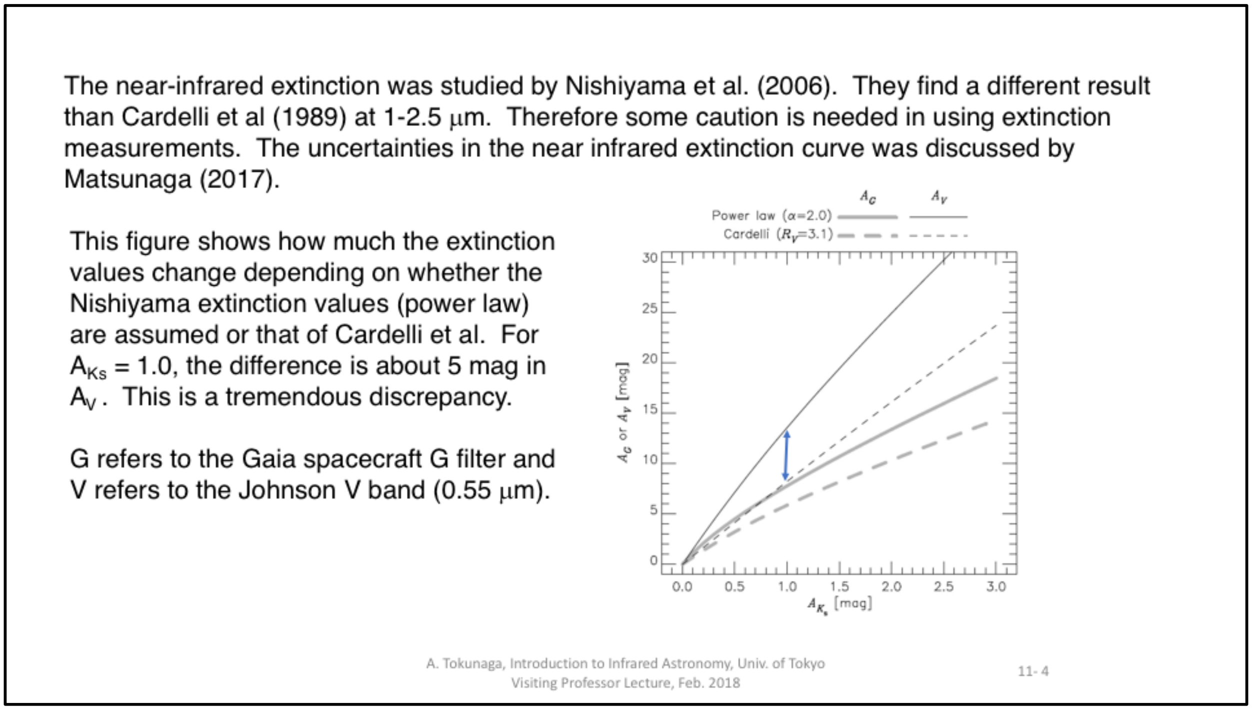


From Cardelli et al. (1989) we have the following table for the extinction at 0.36-3.45 μm:

Filter	1/λ(μm)	λ(μm)	A(λ)/A(V)
U	2.78	0.36	1.569
B	2.27	0.44	1.337
V	1.82	0.55	1.000
R	1.43	0.70	0.751
I	1.11	0.90	0.479
J	0.80	1.25	0.282
H	0.63	1.59	0.190
K	0.46	2.17	0.114
L	0.29	3.45	0.056

This gives the extinction, A(λ), normalized to the extinction at V, which is A(V).

Notes:
Cardelli, J. A., G. C. Clayton and J. S. Mathis (1989). "The relationship between infrared, optical, and ultraviolet extinction." The Astrophysical Journal **345**: 245-256.



The near-infrared extinction was studied by Nishiyama et al. (2006). They find a different result than Cardelli et al (1989) at 1-2.5 μm. Therefore some caution is needed in using extinction measurements. The uncertainties in the near infrared extinction curve was discussed by Matsunaga (2017).

This figure shows how much the extinction values change depending on whether the Nishiyama extinction values (power law) are assumed or that of Cardelli et al. For A_{Ks} = 1.0, the difference is about 5 mag in A_V . This is a tremendous discrepancy.

G refers to the Gaia spacecraft G filter and V refers to the Johnson V band (0.55 μm).

Notes:
Nishiyama, S., T. Nagata, N. Kusakabe, N. Matsunaga, T. Naoi, D. Kato, C. Nagashima, K. Sugitani, M. Tamura, T. Tanabé and S. Sato (2006). "Interstellar Extinction Law in the J, H, and Ks Bands toward the Galactic Center." The Astrophysical Journal **638**: 839-846.

Matsunaga, N. (2017). Time-series surveys and pulsating stars: The near-infrared perspective. European Physical Journal Web of Conferences. **152**.

Figure from Matsunaga (2017) showing how the extinction affects the observed spectral energy distribution of a star like the sun.

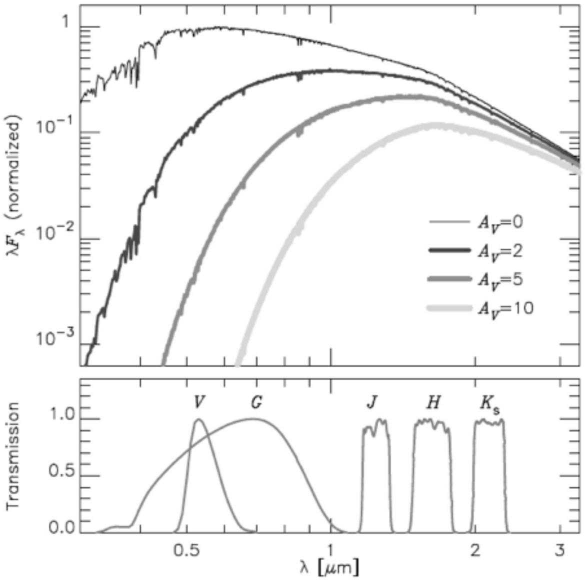


Figure 1. (Top) The synthetic spectrum of the Sun based on ATLAS9 by Kurucz and Castelli and those affected by the power law extinction, $\sim \lambda^{-2}$. (Bottom) Filter transmission curves, normalized to the peak of each bandpass.

Notes: