Stellar Photometry: II. Transforming

Ast 401/Phy 580

Fall 2015

Summary

We've learned how to measure instrumental magnitudes for a star using aperture photometry or PSF-fitting:

(a) Add up all of the counts within an aperture of a certain radius. Call this Sum_total

(b) Estimate the sky value per pixel ("Sky") from an annulus far removed from the star

(c) Subtract off the sky contribution: Sum_total-Sky x number of pixels in measuring aperture. Call this Sum_above_sky

(d) instrumental mag is just -2.5 log (Sum_above_sky)+C, where C is usually 20.0 or 25.0 just for convenience.

But our work here is not done

We must transform our instrumental magnitude to the standard system. This means:

(1) Correcting for atmospheric extinction

(2) Correcting for color terms

(3) Correcting for the instrumental zero-point.

Photometry transformation

Let X = airmass = sec (z)

Let U, B, V, R, I stand for the magnitude in the standard system.

Let u, b, v, r, i stand for the instrumental magnitudes in the observed system. In general, then:

u = Const_u + U + color_term_U x (U–B) + extinct_U x Xu

b = Const_b + B + color_term_B x (B–V) + extinct_B x Xb

v = Const_v + V + color term_V x (B–V) + extinct_V x Xv

r = Const_r + R + color_term_R x (V–R) + extinct_R x Xr

i = Const_i + I + color_term_I x (R–I) + exintct_I x Xi

UBV System

THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME 117 MAY 1953 NUMBER 3

FUNDAMENTAL STELLAR PHOTOMETRY FOR STANDARDS OF SPECTRAL TYPE ON THE REVISED SYSTEM OF THE YERKES SPECTRAL *ATLAS**

H. L. JOHNSON AND W. W. MORGAN
Yerkes and McDonald Observatories

Received November 29, 1952

ABSTRACT

A system of photoelectric photometry is outlined which utilizes the revised zero point of the visual magnitude scale of the North Polar Sequence and which returns to the original definition for the zero point of color indices in terms of main-sequence stars of class A0; the interval A0–gK0 is 1 mag. The revised Yerkes *Atlas* system (MK) of spectral classification is taken as standard. The latter is described

UBV System

Photographically, one could determine magnitudes to about 5-10% (i.e., 0.05-0.10 mag). The International Astronomical Union had adopted magnitudes and colors for stars on a photographic system for stars near the north pole (the "North Polar Sequence"). However, when photoelectric photometers came into play, with much greater precision (<1%, or <0.01 mag), problems became apparent.

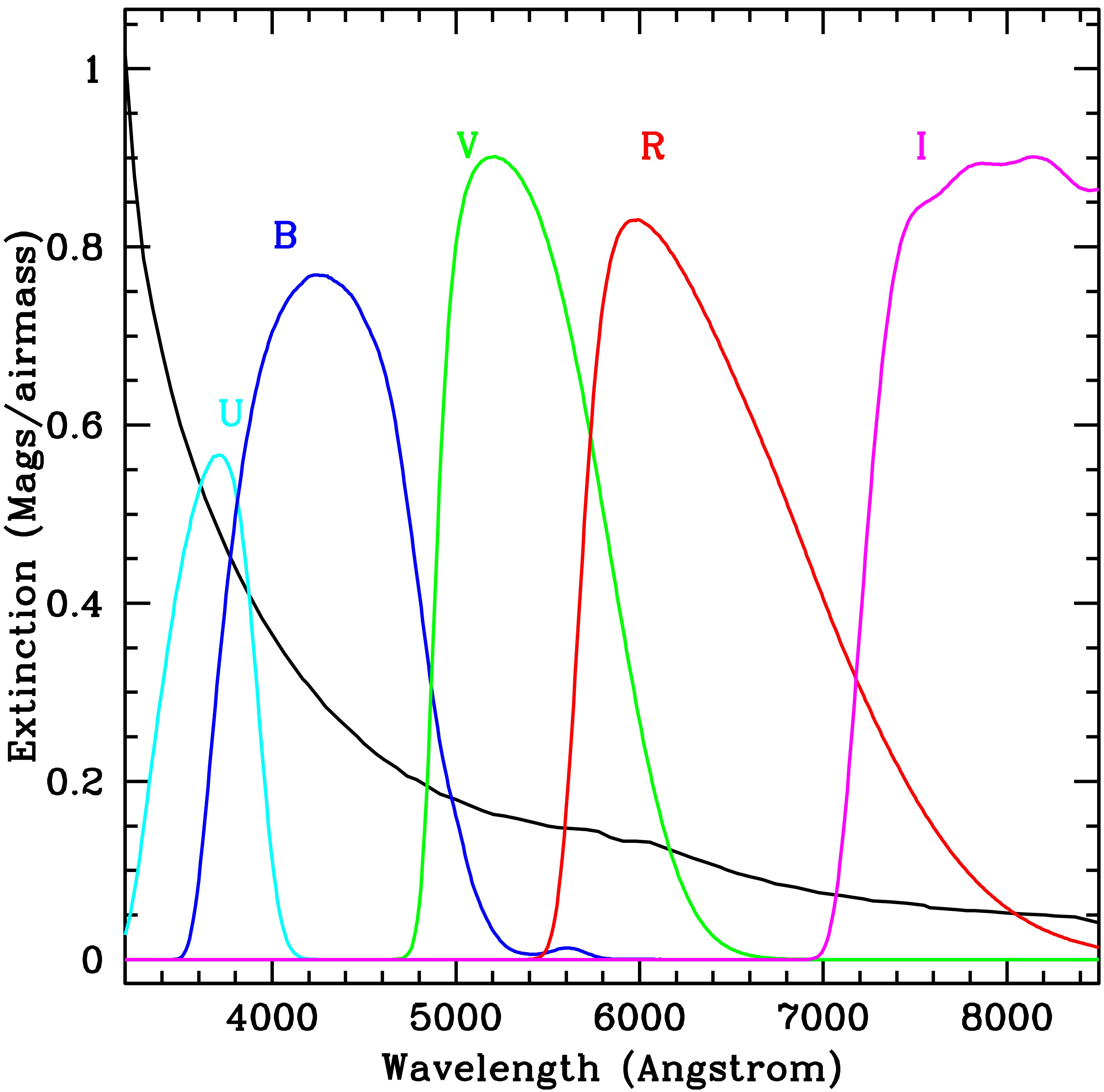
UBV Sytem

These problems weren't that the photographic magnitudes were "bad." Instead, the problem was that the stars in the North Polar Sequence didn't cover a broad enough range of spectral types, reddenings, and luminosity classes.

UBV System

Why does any of this matter?

We saw in Lecture 7 that the filter bandpasses are very broad compared to changes in the extinction.



U
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1
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7000
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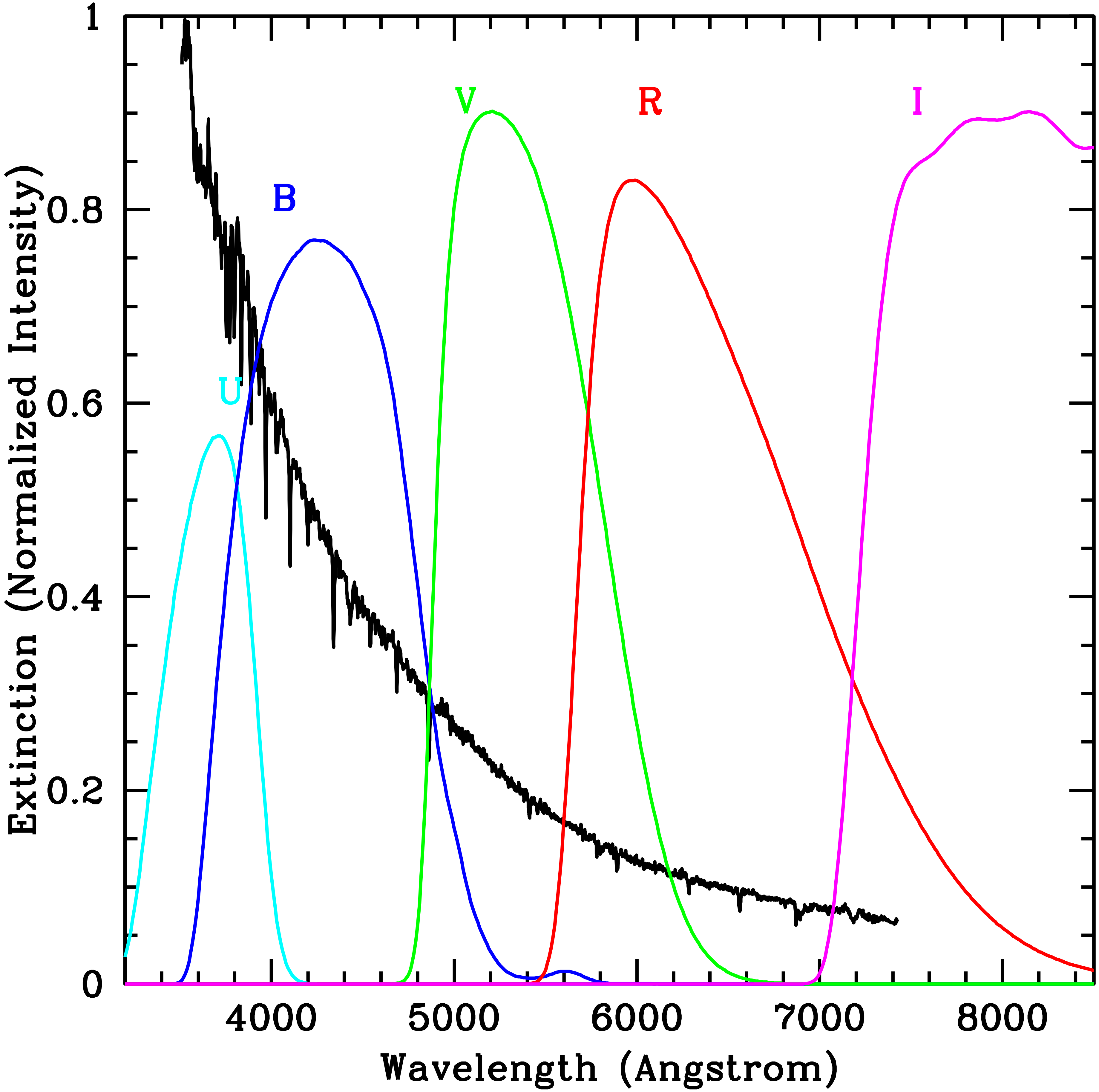
Extinction (Mags/airmass)
Wavelength (Angstrom)

UBV System

Now consider three different stars...



Extinction (Normalized Intensity)
Wavelength (Angstrom)
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7000
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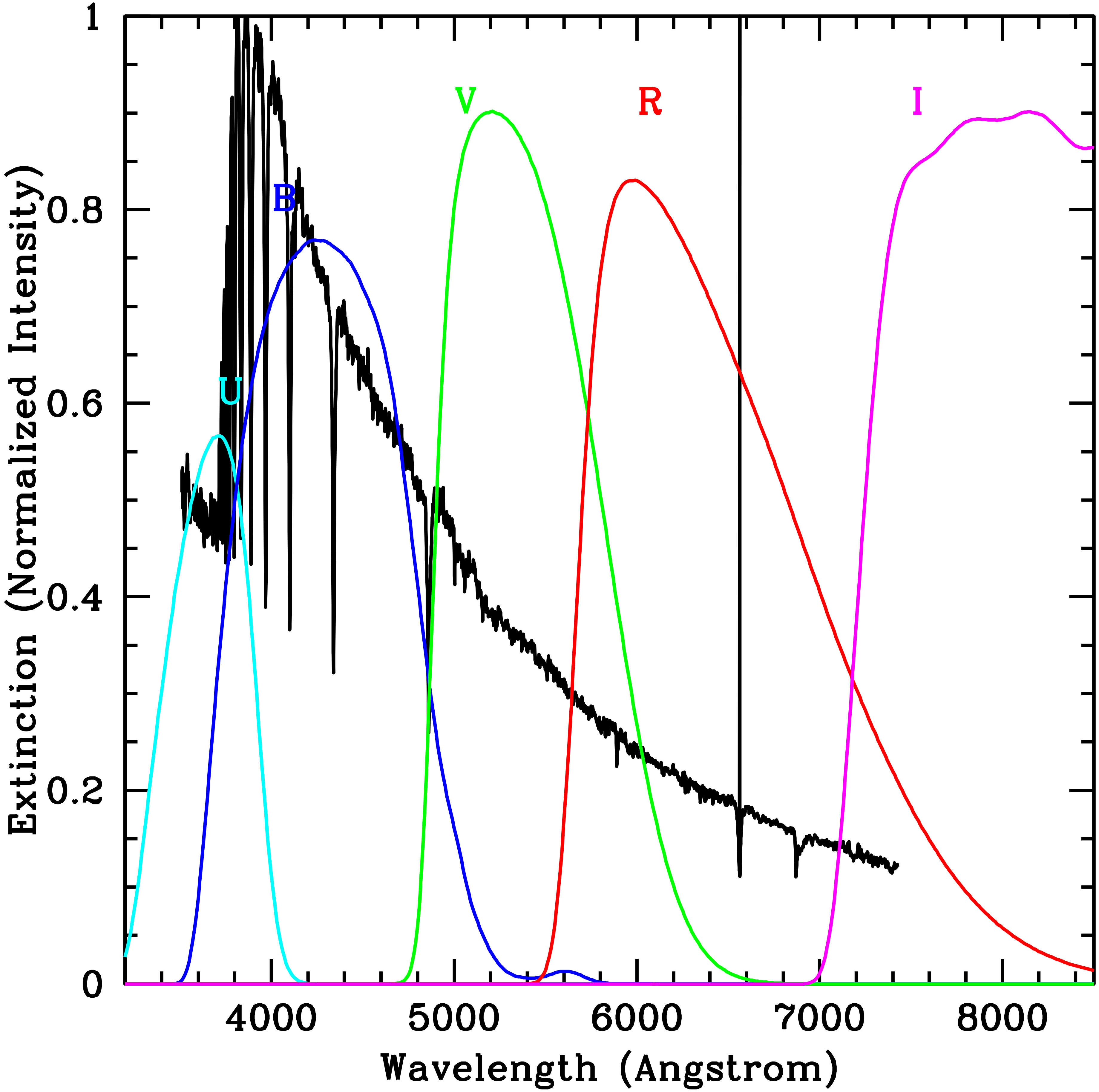

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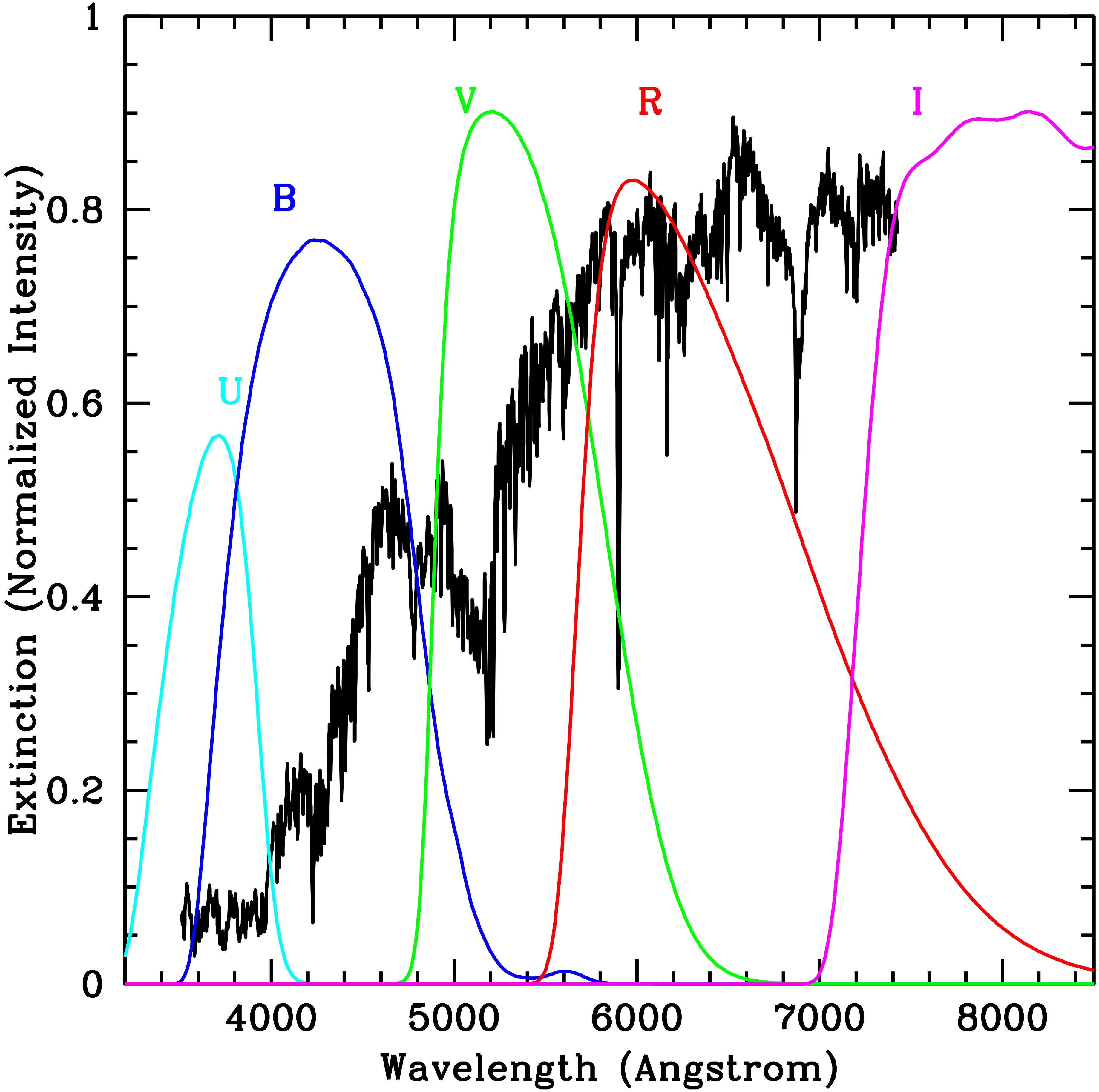

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7000
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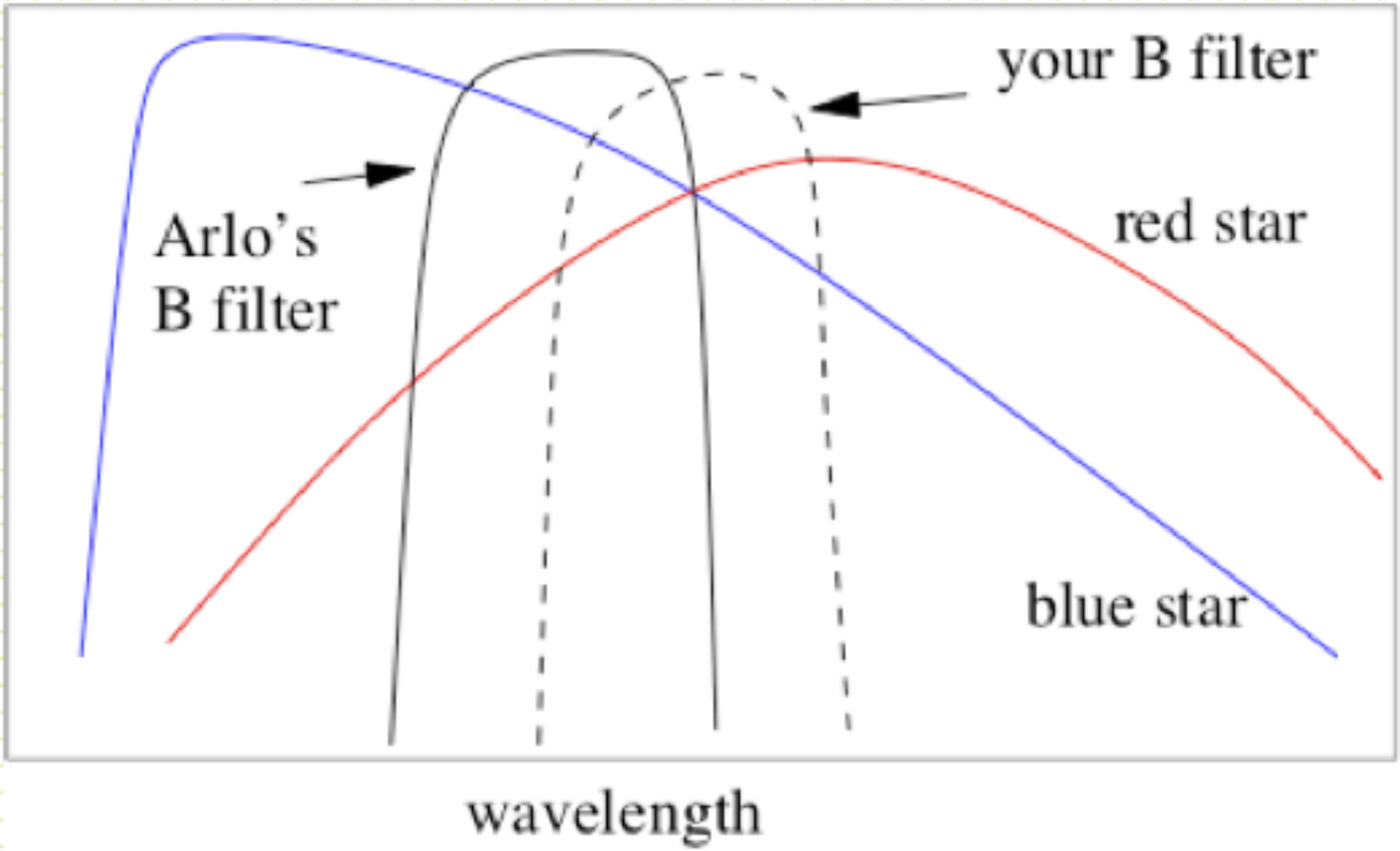
UBV System

Spectral lines and energy distribution matters! If your bandpass is just a little bit off...



Stolen from Mike Bolte

UBV System

No two astronomers were likely to use the identical telescope with the identical filters and detectors. Each photographic plate, photomultiplier, and CCD are a little different from each other. Even if you're using the same equipment, the amount of dust on the mirror will change, or the atmospheric conditions will change slightly. One needs to be convert one's measurements to a standard system.

UBV System

Harold Johnson and coworkers had been using a 1P21 multiplier and a new set of UBV filters to observe stars in clusters.

In 1953 Johnson & Morgan (1953) urged that astronomers adopt their UBV system.

UBV System

Johnson (1955) suggested some fules to minimize the transformations:

(1) Use the same type of filters. All were glass filters made by Corning.

(2) Aluminized reflecting telescopes, not refractors.

(3) Use a large number of standard stars of all kinds to derive the transformation.

(4) Use photoelectrically determined standards.

UBV

The zero-point of the UBV system was tied to Vega: Vega has U=B=V=0.00. There were then ten "primary" standards and 108 secondary standards. Many of these were observed by Johnson with the 21-inch telescope at Lowell Observatory.

UBV—>UBVRI

Johnson et al. (1966) suggested adding R and I at 7000Å and 9000Å, respectively. Kron et al. (1953) had defined another R and I bandpass centered at 6800Å and 8250Å. The latter was modified by Cousins (1976), who observed a zillion stars, and eventually the modified RI was adopted. Today it's known as UBVRI "Johnson/Kron-Cousins system".

Arlo Landolt

"In every revolution there is one person with a vision."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THE ASTRONOMICAL JOURNAL VOLUME 88, NUMBER 3 MARCH 1983

UBVRI PHOTOMETRIC STANDARD STARS AROUND THE CELESTIAL EQUATOR[a]

ARLO U. LANDOLT[b]
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Received 8 November 1982

ABSTRACT

UBVRI photoelectric observations have been made of 223 stars mostly in an approximate two degree band centered on the celestial equator. The observing program was planned to provide new *UBVRI* standard stars, available to telescopes of a variety of sizes in both hemispheres, on an internally consistent homogeneous system around the sky. Most of the stars are in Selected Areas 92–115. The stars average 20.7 measures each on 12.2 different nights. The stars in this paper fall in the range $7 \lesssim V \lesssim 12.5$ and $-0.3 \lesssim (B-V) \lesssim +2.0$.

223 standard stars near the equator, with an average of 21 measurements each!

This paper forced the Kron-Cousins RI to become THE standard system.

Question

Why stars within a 2^o band near the equator?

A) Observable from both northern and southern hemispheres.

B) Avoids the Milky Way

C) Something else silly.

Question

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THE ASTRONOMICAL JOURNAL VOLUME 104, NUMBER 1 JULY 1992

UBVRI PHOTOMETRIC STANDARD STARS IN THE MAGNITUDE RANGE $11.5 < V < 16.0$ AROUND THE CELESTIAL EQUATOR[1]

ARLO U. LANDOLT[2]

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Received 7 January 1992; revised 6 March 1992

ABSTRACT

UBVRI photoelectric observations have been made on the Johnson–Kron–Cousins photometric system of 526 stars centered on the celestial equator. The program stars within a 298 number subset have sufficient measures so that they are capable of providing, for telescopes of intermediate and large size in both hemispheres, an internally consistent homogeneous broadband standard photometric system around the sky. The stars average 29 measures each on 19 nights. The majority of the stars in this paper fall in the magnitude range $11.5 < V < 16.0$, and in the color range $-0.3 < (B-V) < +2.3$.

Now 526 standards with 29 measures each!
Much fainter than the previous sample.

Fainter standards

Why?

a) Avoids saturating with large telescopes and sensitive CCDs.

b) Allows one to integrate longer and thus avoid scintillation issues.

c) Fainter stars means that there are more subdwarfs so better coverage in luminosity.

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#	Bibcode / Authors	Cites / Title	Date	List of Links / Access Control Help
1	1992AJ....104..340L Landolt, Arlo U.	3690.000 UBVRI photometric standard stars in the magnitude range 11.5-16.0 around the celestial equator	07/1992	A F G D R C S O U H
2	1983AJ.....88..439L Landolt, A. U.	1404.000 UBVRI photometric standard stars around the celestial equator	03/1983	A F G D R C S O U
3	1973AJ.....78..959L Landolt, A. U.	660.000 UBV photoelectric sequences in the celestial equatorial Selected Areas 92-115	11/1973	A F G D R C O U
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6	2009AJ....137.4186L Landolt, Arlo U.	92.000 UBVRI Photometric Standard Stars Around the Celestial Equator: Updates and Additions	05/2009	A E F X D R C S U
7	1983AJ.....88..853L Landolt, A. U.	83.000 UBVRI photometry of stars useful for checking equipment orientation stability	06/1983	A F G D R C S U

Reminder

Why do we even care about "standard" photometry?

Want to know physical properties of stars, such as effective temperatures. Can calibrate colors with temperatures.

Other systems

Extension to near-IR: JHK. 2MASS survey covered the entire sky.

Sloan: After 8 years covered a quarter of the sky. Used their own filter system, u′, g′, r′, i′, and z′. The zero points were tied to spectrophotometric system, i.e., stars with constant f_ν would have the same colors.

Wait, where were we?

But our work here is not done

We must transform our instrumental magnitude to the standard system. This means:

(1) Correcting for atmospheric extinction

(2) Correcting for color terms

(3) Correcting for the instrumental zero-point.

Photometric transformations

Let X = airmass = sec (z)

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r = Const_r + R + color_term_R x (V-R) + extinct_R x Xr

i = Const_i + I + color_term_I x (R-I) + exintct_I x Xi

Photometric transformations

Want to observe standard stars at airmasses that bracket the observations of your program objects.

Want to observe standard stars with colors that bracket the expected color range of your program objects.

Photometric transformations

The closer your instrumental system (filter+detector) is to the "standard system" the closer the color terms will be close to zero.

Typical values for extinction (from Lecture 7)

U: 0.50 mag/airmass

B: 0.25 mag/airmass

V: 0.15 mag/airmass

R: 0.10 mag/airmass

I: 0.07 mag/airmass

Photometric transformations

The way we've stated the transformation equations, we'd have to solve them iteratively:

b = Const_b + B + color_term_B x (B-V) + extinct_B x Xb

v = Const_v + V + color term_V x (B-V) + extinct_V x Xv

Homework_10 due 12/3

We observe three standard stars, and want to know the color-term, zero-point, and extinction term for the B filter.

StarA: V=12.0, B-V=0.10. At an airmass of 1.3 we find b=13.489.

StarB: V=13.0, B-V=2.00. At an airmass of 1.3 we find b=16.864.

StarC: V=12.5, B-V=0.00. At an airmass of 1.7 we find b=13.976.