Realistic synthetic photometry

Due date: Feb 17, 2021

In the previous assignment we convinced ourselves that stars are far from being blackbody radiators; instead, their spectral energy distribution (SED) is quite complex. At the same time, we studied *model* atmospheres; you can imagine that *real* stellar atmospheres are even more complex. We will ignore the intrinsic complexity and add a few important ingredients into our synthetic photometry simulation: noise, interstellar extinction, Earth's atmosphere, and telescope/detector efficiency. If you find yourselves twiddling your thumbs by the end, there's also a *very* cool extra-credit opportunity. So let's get going!

1. Even constant stars aren't truly *constant* – they are *noisy* in the sense that their SED changes as a function of time. Time to turn to google and figure out two things: (1) what types of noise are there (i.e. white, red, pink, brown, . . .) – what does that mean? (2) What type of noise is most typical for stars? What physical mechanism causes that noise?

2. Take a $T = 6000\,\mathrm{K}$, $\log g = 4.5$ SED template and add *temporally variable* red noise to it. Play with parameters and come up with something that seems reasonable. Then synthesize a lightcurve (light as a function of time) in Johnson B and V passbands. Take ∼100 timestamps. Comment on lightcurve variability.

3. Now add interstellar extinction to the mix. Interstellar extinction causes *reddening* of the spectra. The most frequently used is the Cardelli-Clayton-Mathis 1993 formula (yes, the Villanova Cardelli!), and there is even a slightly improved Fitzpatrick (1999) formula (yes, the Villanova Fitzpatrick!). Incorporate the extinction model and explain why we say that it causes *reddening* of the spectra.

4. Next, add atmospheric extinction due to Earth's atmosphere. Rayleigh scattering causes most of the commotion. Read up on it, find a good extinction formula, and comment how it affects the spectrum.

5. Finally, make your observing system realistic: find a typical optical response and a typical CCD quantum efficiency response, and apply them to the spectrum. If you feel particularly adventurous, you can add one more thing to the mix: photon counting noise – a Poissonian noise that scales with the square root of the signal. Re-synthesize your

lightcurves and comment on different effects that you have included in the simulation.

6. *Extra credit:* Observing circumstances change – mostly as a function of zenith distance, also known as airmass. It essentially tells you how much “atmosphere” you have between the observatory and the observed star. Account for airmass in your lightcurve synthesis. First semester celestial astronomy can help here.