Dust Maps
Robert Trumpler first confirmed the existence of interstellar dust (1930; see syllabus link and, in particular, point 5 of the Summary on page 187).

Trumpler noticed that open star clusters of the same general apparent size had different brightnesses.

Either the real size of clusters increases farther from the Earth (i.e. the Earth is in a special location), or stars become progressively fainter at larger distances.

Absorption by interstellar dust would make stars progressively fainter with distance from the Earth.
Now, the most cited journal paper in astronomy deals with the careful mapping of interstellar dust

Schlegel et al. (1998; see syllabus links)

The paper is well-cited because any measurement of the flux (or magnitude) from extragalactic sources must correct for foreground absorption by dust in our Galaxy

To correct a magnitude for dust, subtract the extinction ($A$) in that band ($m_{true} = m_{observed} - A$; additional equations for interstellar reddening are linked from the syllabus)
We have the Schlegel et al. dust maps installed locally in `/d/scratch/Archives/SFDmaps/` and we can use the `sfdmap` package and `astropy.coordinates` to access them:

- Convert (RA, Dec) to Galactic coordinates:
  - `ra, dec = '00h42m30s', '+41d12m00s'`
  - `c = SkyCoord(ra, dec).galactic`

- Obtain the reddening at this position from the dust maps
  - `import sfdmap`
  - `dustdir = '/d/scratch/Archives/SFDmaps/'`
  - `m = sfdmap.SFDMap(dustdir, scaling=1)`
  - `ebv = m.ebv(c.l.value, c.b.value, frame='galactic')`
• Note that it is also possible to obtain the reddening without first converting to Galactic coordinates, e.g.

  
  - $ra, dec = '00h42m30s', '+41d12m00s'$
  - $c = SkyCoord(ra, dec)$
  - $ebv = m.ebv(c.ra.value, c.dec.value)$

• Finding extinction requires wavelengths and a dust-law from the extinction package. To find rough extinctions for the SDSS $ugriz$ filters (more on $ugriz$ later):

  
  - import extinction
  - $wave = np.array([3543., 4770., 6231, 7625., 9134.])$
  - $A = extinction.fitzpatrick99(wave, 3.1*ebv)$
Python tasks

1. The objects at \((\alpha, \delta) = (246.933^\circ, 40.795^\circ)\) and \((236.562^\circ, 2.440^\circ)\) are both quasars near a redshift of \(z = 1.08\)

   • Use the *SDSS Navigator Tool* linked from the syllabus to obtain the magnitudes of these quasars and plot \(g - r\) versus \(r - i\) for both quasars in the same plot

   • Do the quasars have similar colors? Should they?

   • Correct the quasars’ magnitudes for Galactic extinction and re-plot them. Do their colors now agree better?

2. Let’s visualize the dust in the region of each quasar

   • Use `numpy.meshgrid` to make a 2-dimensional 100 x 100 array (i.e. a grid) centered near \((236.6^\circ, 2.4^\circ)\) with \(1^\circ\) bins. Create another set centered at \((246.9^\circ, 40.8^\circ)\) for RA in \(1.3^\circ\) bins and for DEC in \(1^\circ\) bins.
3. Convert your RA/DEC 100 x 100 arrays to Galactic \((l, b)\)

4. Using matplotlib’s *contour* procedure (linked from the syllabus), let’s plot dust maps

- Find the amount of reddening \(E(B-V)\) for each *pair* of positions in your 100 x 100 arrays, *i.e. for each of* \((l[0], b[0]), (l[0], b[1]) ... (l[99], b[0]), (l[1], b[0]) ... \text{etc.}\)

- Make a contour plot:
  
  $$CS = plt.contour(RA, Dec, ebmv)$$

5. On your plots, also show the position of each quasar and a line in RA/Dec depicting the Galactic Plane (a line from \(l = 0^\circ\) to \(360^\circ\); \(np.arange(360)\); at \(b = 0^\circ\); \(np.zeros(360)\)]