Astronomical Techniques MKEP5 (SS 2016)

Homework # 9
(to be submitted on Wednesday June 29)

Exercise A. The near-infrared spectrum of a typical massive elliptical galaxy is characterized by the stellar absorption of NaI at 1.14 µm (at rest frame). This feature is astrophysically rather important as it is used together with other spectral indices to estimate the Na abundance and the IMF slope in ellipticals.
As you can see in Fig. 1, the atmosphere is rather opaque at the wavelength of this feature. At which redshift should this galaxy be if we want to observe this stellar feature with an atmospheric transmission > 0.9? (3 points)

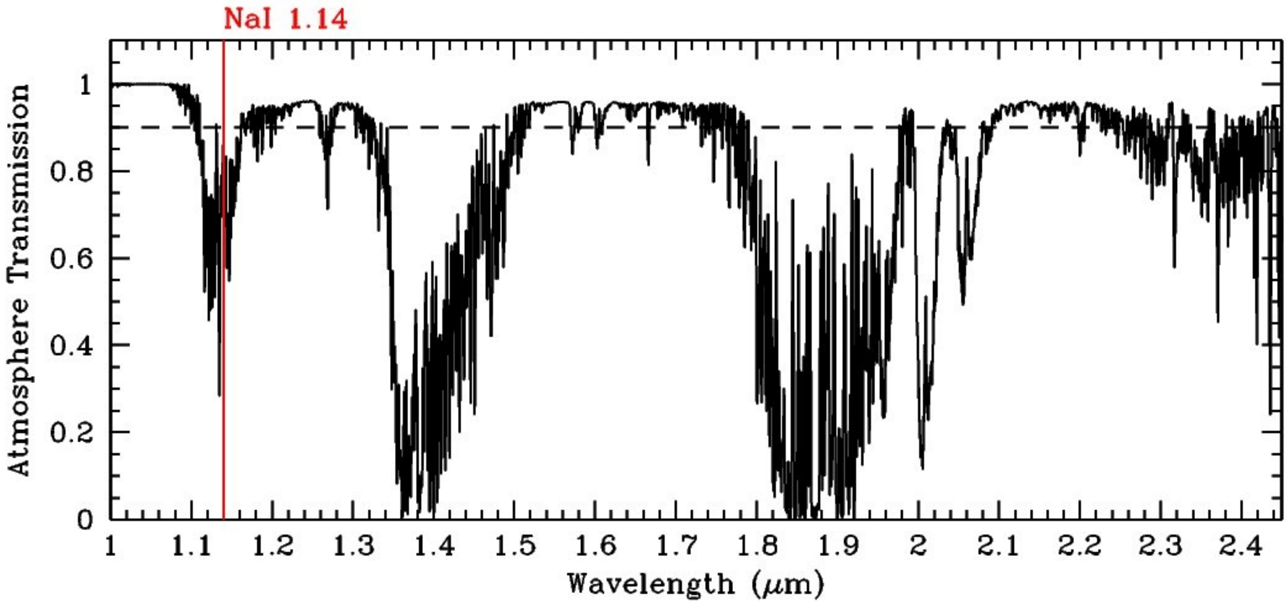

Fig. 1: the restframe wavelength of the NaI absorption feature in red compared with the transmission spectrum of the atmosphere.

Exercise B. The Initial Mass Function (IMF) is an empirical function describing the distribution of initial masses for a population of stars (i.e. the number of stars with masses in the range *m* to *m* + d*m*). In 1955 Salpeter derived an IMF of the form: $dN(m) = C \times m^{-2.35} dm$, where C is a constant. According to this IMF, we expect the stellar population of a galaxy to be dominated (in number) by stars less massive than 0.3 solar masses, which have an effective temperature lower than 3000 K. At which wavelengths should we observe this galaxy in order to reliably estimate its total mass (in stars)? (2 points).

Exercise C. Figures 2 and 3 show the Horsehead Nebula in Orion imaged at optical and near-infrared wavelengths, respectively. Notice that the images have a different spatial scale.
Compare the two images and briefly and qualitatively explain:

1. Why is the Horsehead feature much darker in the optical than in the near-infrared? (2 points)

2. Why can we see more stars through the Horsehead Nebula when this is imaged at near-infrared wavelengths? (2 points)

Fig. 2: the Horsehead Nebula imaged from the ground in the [OIII]λ5007Å (green), Hα λ6563 Å (red) and [SII]λ6717 Å filters.

Fig. 3: the Horsehead Nebula imaged by HST through the J and H filters.

Exercise D. We acquire images of a stellar field in the standard filters in the same night, while the ambient temperature is 12^{o} C. At which wavelength is the thermal emission of the telescope strongest, if the sky conditions do not change across the night and it's new moon, and how does it affect your images? (3 points)

Fig. 4: A false-colour composite image of the Large Magellanic Cloud observed at 24, 70, 100, 160 and 250 µm by Spitzer and Herschel.

Exercise E. Figure 4 shows the Large Magellanic Cloud galaxy in mid-infrared light as seen by the Herschel Space Observatory (ESA+NASA) and the Spitzer Space Telescope (NASA). The image is a false-colour composite of 5 images acquired at 5 different wavelengths, as explained in the table below:

Colour	*Wavelength in micron*
Blue	24.0
Cyan	70.0
Green	100.0
Green	160.0
Red	250.0

The colours listed above indicate temperatures in the dust that permeates the galaxy. Colder dust, in red, is placed in correspondance with regions where star formation is at its earliest stages, while the hotter dust, in blue, indicates where fully-formed, main sequence and/or post-main sequence stars are located.
What is the temperature range of the dust in Figure 4? (3 points)

Exercise F. Imagine you use the 100m telescope at Effelsberg, and observe a source of 5 Jy. The receiver has a bandwidth of 4.6 – 5.1 Ghz. Assume an efficiency of 0.55.
What is the total radiative energy collected by the receiver in 10 s? (3 points)

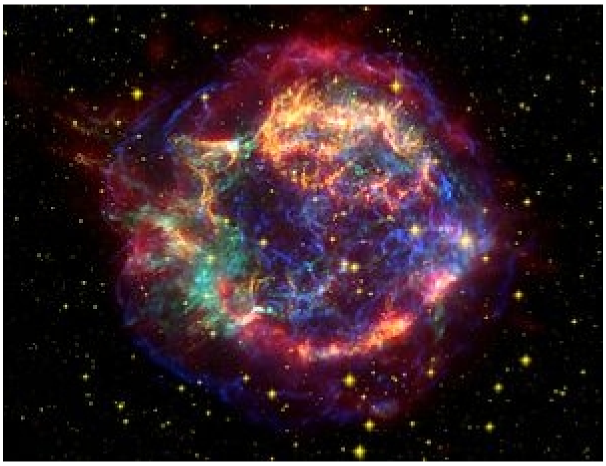

Fig. 5: colour-composite of Cassiopeia A (SNR): red is infrared, orange visible and blue+green X-rays.

Exercise G. Cassiopeia A in Fig. 5 is a supernova remnant in the Milky Way. Its apparent magnitude is V = 6 mag, while its absolute magnitude is M_V = -6.66 mag. This nebula has a diameter of 3 pc.

1. Which baseline should a radio array cover in order to resolve substructures in the Cassiopeia nebula as small as 1/10 of the nebula diameter at 1.4 GHz? (4 points)

2. What would be the likely cause of radio emission in such a supernova remnant? (3 points)