Extragalactic Astronomy 2
Assignment 1

Due: 1700 hours, June 11th, 2021 (*Total: 300 Points, Weightage : 30%*)

General Instructions

(1) You should obtain solutions to these questions by yourself. Any suspicion of plagiarism will warrant deduction of points (2) The deadline for submission of the answers is fixed. No credit for late submissions. Having said this, given the pandemic situation, if there is a genuine issue that prevents on-time submission, please email me. (3) The number of points allotted for each question are given in square brackets at the end of the question. (4) A few of these questions involve making plots. Please attach a print-out of the most relevant plot(s) and the code you used to make the plot(s). Make sure all plots are clearly labeled and use sensible units. (5) I hope that the pandemic situation will improve by the submission date, so that you can submit the assignment in person at NCRA. I will give you separate instructions on submission closer to the submission date.

1. Using the data available at the NASA Extragalactic Database (NED) http://ned.ipac.caltech.edu/ identify which of these objects host an AGN. Explain in a couple of sentences why you believe each object to be an AGN or not.

   Cygnus A, 3C84, NGC4151, NGC253, NGC1266, Mrk231, IC5063, M51, PKS1322-42, BL Lac.

   [30 points]

2. For a realistic mass of a Schwarzschild SMBH, calculate the minimum time period of a tiny planet (so that you need not worry about tidal disruption) in a stable orbit around the SMBH.

   [20 points]

3. If the number density of the relativistic electron population as a function of energy is given by $n(E)dE = CE^{-p}dE$, then show that the emitted synchrotron spectrum also has a power law form. Derive an expression relating the power law index p with the power law index α of the emitted synchrotron spectrum.

   [20 points]

4. Superluminal motion: Plot the $\beta_{app} = v_{app}/c$ of a source component moving with Lorentz factor γ at an angle ψ with the line of sight for four different values of $\gamma = 2, 5, 10, 15$.

   [20 points]

5. Consider an optically thick accretion disk with a temperature profile given by:

$$T(r) = \left(\frac{3GM_{BH}\dot{m}}{8\pi\sigma_{SB}r^3}\right)^{1/4}$$

   Neglecting any boundary effect (i.e. the fact that a real accretion disk extends only over a finite range in radii), show that the emitted spectrum is a power law $L_\nu \propto \nu^{1/3}$. Comment: The true spectrum of an accretion disk deviates from this simple power law, mainly due to the existence of an inner boundary.

   [30 points]

6. The Gaia space mission is obtaining multi-epoch photometry and astrometry for more than a billion stars. Explain how you can use this dataset to discover new quasars.

[10 points]

7. The total energy stored in the radio lobes of a galaxy is estimated to be 10^{60} erg. If the total mechanical luminosity (energy that is effectively transported upto the lobes) of this galaxy is $10^{12} L_{\odot}$, estimate the minimum jet lifetime for this galaxy.

[10 points]

8. Optical spectra of blazars do not show emission or absorption lines. Explain why these lines are missing from blazar spectra.

[10 points]

9. Figure 1 shows the visible spectrum of a distant quasar. Five prominent spectral lines can be seen in the spectrum. Determine the redshift of the quasar and identify the five emission lines that are seen in the spectrum.

[20 points]

10. If a star of mass m_s and radius R passes a black hole of mass $M_{BH} (\gg m_s)$ at a distance D ($D \gg R$), what is the minimum value of D inside which the star will be tidally disrupted? If a sun-like star approaches the black hole at the centre of the Milky Way, at what distance would it be disrupted?

[30 points]

11. Assume that the optical galaxy associated with the radio source Centaurus A is the same size as our Galaxy and draw a scale diagram of the radio and optical emission regions of Centaurus A. Clearly indicate the dimensions and the relative positions of the various components.

[20 points]

12. Estimate the accretion rate on to a black hole needed to account for the luminosity of a Seyfert nucleus that has a bolometric luminosity of $4 \times 10^{10} L_{\odot}$. Express your answer in solar masses per year.

[20 points]

13. Calculate the dust sublimation radius, in metres and parsecs, for an AGN of luminosity 10^{38} W. Assume that dust cannot exist above a temperature of 2000 K. [20 points]

14. Shown in Fig.2 are histograms of quasars discovered by the SDSS I/II, SDSS III and SDSS IV projects. Clearly, each project discovered new quasars in different regions of redshift space. Explain how the candidate selection criteria were changed in each of the surveys to achieve this.

[30 points]

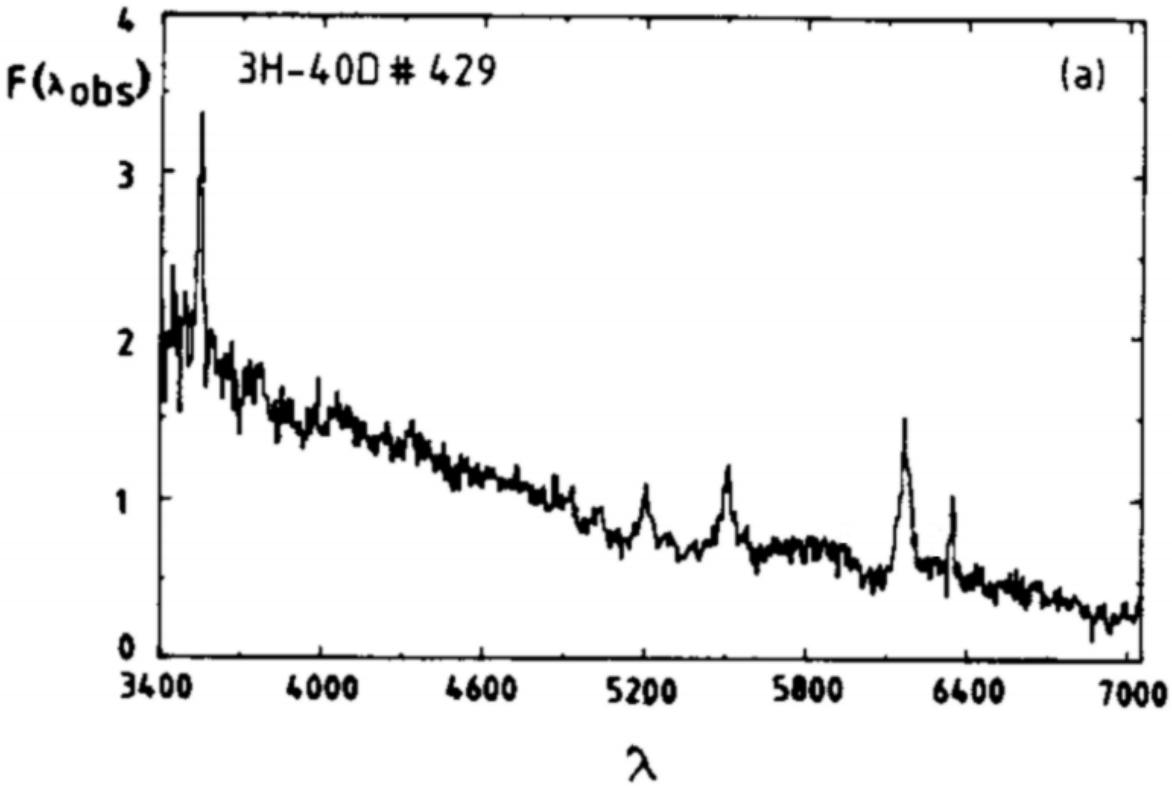

Figure 1: A observer-frame spectrum of a quasar, whose redshift is to be determined.

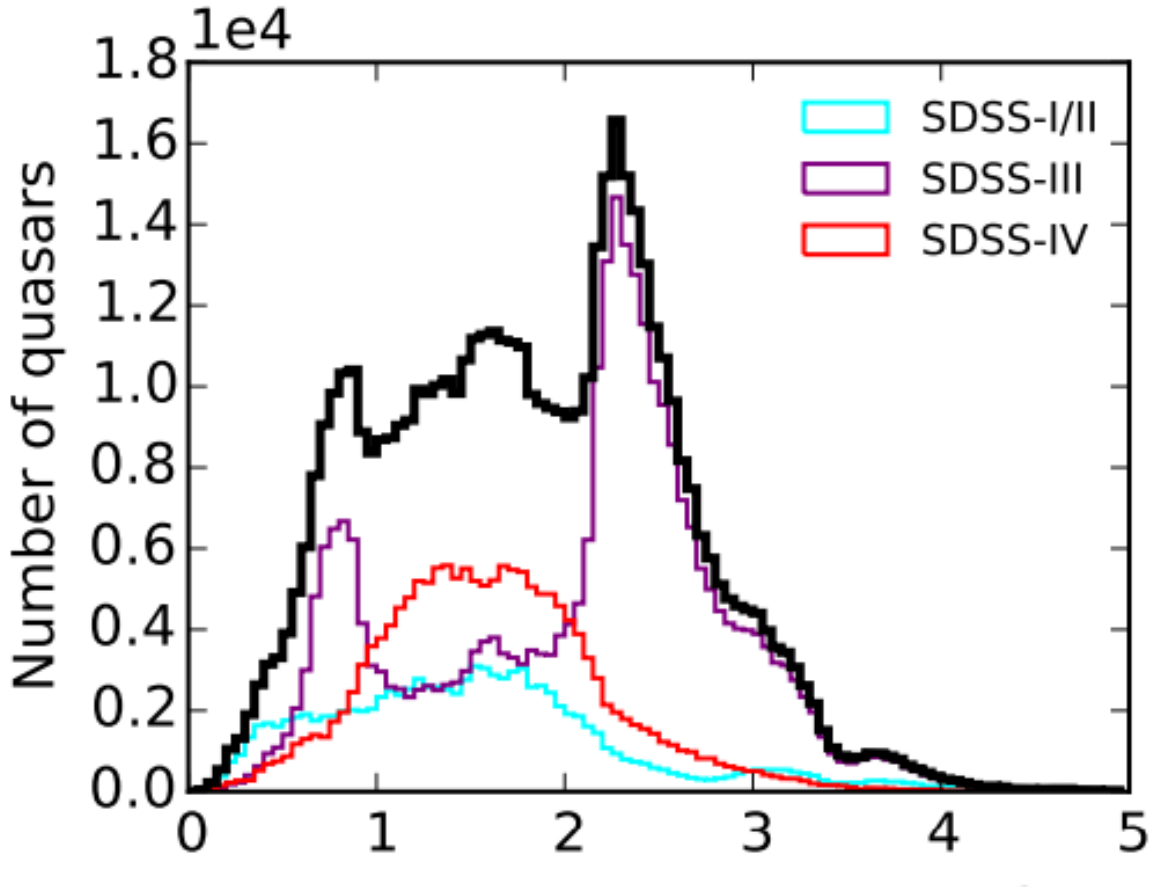

Figure 2: Histogram of redshift of quasars discovered in various incarnations of the SDSS, shown in colour. The black histogram is the sum of the 3 coloured histograms.