Introduction Astronomy 2024 / 2025

Mock Exam

January 12 2025

Please note

This exam has 30 points in total. There are different types of (sub-)quesitons: multiple-choice questions, essay questions, and questions where you need to perform calculations. For the essay questions, a few lines suffice. Please answer all questions (including the multiple choice questions) on your separate paper, *not* on the question sheet.

Please note that there is a list of constants and conversion factors that might be helpful at the end of this exam. Additionally, you should have received a formula sheet. You can use a simple electronic pocket calculator to solve questions. You are not allowed to use any other material.

1 Not A, but B

a. (3 pt) The binary system Sirius A and B is located relatively close to us at a distance of 2.6 parsec. Sirius A is well-known (also beyond Groningen) as it is so bright on the sky, the star has an absolute magnitude in the V-band of 1.4. White dwarf companion Sirius B is about 10 000 times fainter in the V-band compared to Sirius A. What would be the apparent magnitude for Sirius B in the V-band?

See written out sheet.

b. (1 pt) As companions, Sirius A is completely outshining Sirius B, but if Sirius B would be alone on the sky at the same position would it be visible to the naked eye? Please take into account that your naked eye can see stars as faint as $m_V = 6$ in excellent conditions.

No. (Apparent magnitude larger than 6). Note that if the answer given is "yes", but the answer to a. is wrong and smaller than 6, then the point is still given.

c. (1 pt) What would be the parallax angle in degrees of Sirius B?
See written out sheet.

2 Looking at the hydrogen gas

As you know, we can learn a lot about a galaxy by studying its gas in different states. In this question you see below different statements about the observations of hydrogen gas. For each statement, indicate which state of hydrogen it is most applicable to. No further explanation is needed.

- HI - neutral atomic hydrogen
- HII - ionised atomic hydrogen
- H_2 - molecular hydrogen

a. (1 pt) Can be traced very far out for external disk galaxies, great tracer to measure rotation curves.

HI

b. (1 pt) Difficult to observe. Is often traced by CO instead.

H_2

c. (1 pt) In the Milky Way the distribution of this gas has a bit a donut-like shape. It peaks around 4 kpc from the center of the Galaxy.

H_2

d. (1 pt) Can be found around young stars.

HII

e. (1 pt) Emits at 21 cm.

HI

3 AGN

When quasars were discovered, researchers first thought they were looking at a star. However, there were broad emission lines in strange places, and they turned out to be looking at a very distant and bright object, many times brighter than the Milky Way itself. Fig. 1 shows an example of a quasar spectrum.

a. (2 pt) Using this spectrum, derive the redshift of the quasar. Your answer should be a number.

Points breakdown: Use Equation 30 (0.5 pt). Read off number correctly (0.5 pt). Fill in formula correctly (0.5 pt). Correct answer (0.5 pt).
You should have used:

$$z = \frac{\lambda_{obs}}{\lambda 0} - 1 = 4.787 - 1 = 3.787 \tag{1}$$

Read-off margin for the lines:

- **Ly** β: 4800 - 4950 $\AA$, gives z = 3.68 - 3.82
- **Ly** α: 5700 - 5900 $\AA$, gives z = 3.68 - 3.85
- **OI**: 6150 - 6400 $\AA$, gives z = 3.71 - 3.90
- **CIV**: 7300 - 7490 $\AA$, gives z = 3,71 - 3.83

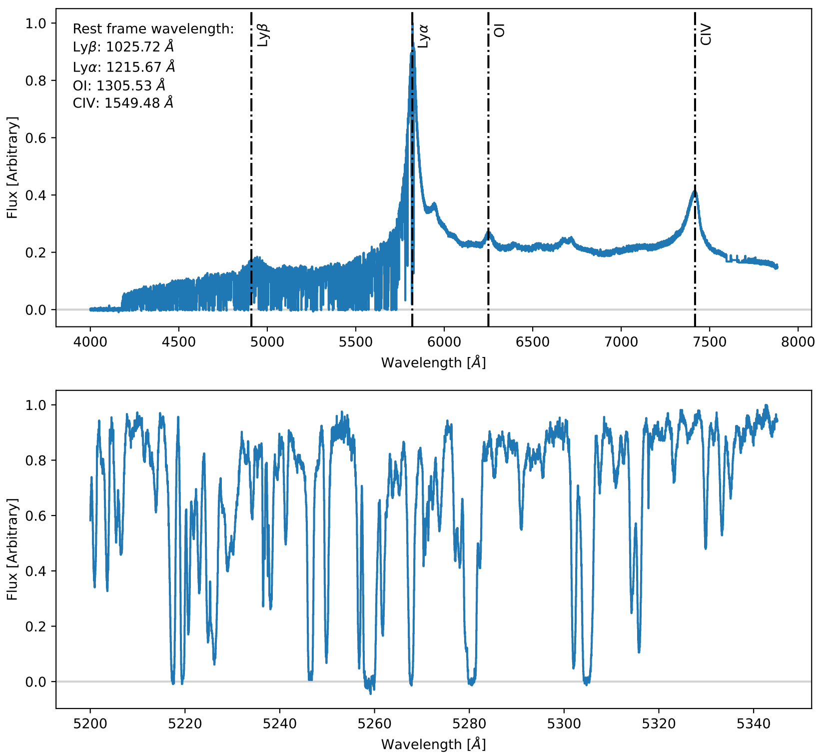

Figure 1: **Top panel**: Spectrum of the quasar PKS 1937-101 as observed by the ESPRESSO spectrograph. The dashed-dotted lines indicate the wavelength of a number of emission lines. Their restframe wavelength is indicated in the top left. **Bottom panel**: Zoom-in of the region between 5200 - 5350 Å showing the Lyman alpha forest.

Hence, a range between $z = 3.7$ and 3.9 is acceptable. If the answer included more than 2 significant digits for the final answer, 0.5 points are subtracted, because that is unrealistic with respect to the read-off error.

b. (1 pt) Would the distance to the quasar using the Hubble law be a good estimation of the true distance? Explain briefly why, or why not.

1+z = 1+v/c (0.5 pt), Hubble's law only valid where $v << c$ (0.5 pt)

c. (1 pt) Can you use standard candles to derive distances to objects at this distance? (If you did not get to an answer for question a., assume a value).

No. (unless answer at a or assumed answer is coherent with yes). Supernovae 1a can reach out to 1 Gpc, Cepheids to tens of Mpc.

d. (2 pt) The lower panel of Fig. 1 shows the same spectrum but over a smaller wavelength range. This part of the spectrum shows a lot of absorption lines. Explain how we can use quasars to study the Intergalactic medium.

As the quasar light travels through the Universe from the distant quasar to us, it travels through the intergalactic medium that will absorb the light at the corresponding wavelengths for the transitions in these atoms (at their redshift). By studying these absorption lines, we can deduce the properties of the gas it traveled through and at what redshift it did so.

4 Two galaxy clusters

The Fornax and Coma Clusters belong to the most nearby clusters of galaxies around us, and therefore serve as important objects to learn about those environments. . The Coma Cluster has a radial velocity dispersion 1.4 times larger than the Virgo cluster, but its radius is the same as the Fornax cluster. The Coma Cluster is 5 times farther away from us.

a. (3 pt) Use the virial theorem (and your equation sheet) to derive and show that the Coma cluster of galaxies has X times more total mass and give a number for X.

See written out sheet.

b. (4 pt) In the galaxy clusters we see more red elliptical galaxies than in the field. Describe two environmental effects that help the transition of blue spiral galaxies into red elliptical galaxies once they enter the galaxy cluster environment. In your description, explain briefly how they work.

Gas stripping, galaxy merging (both 1 point). Also points for additional correct answers (harassment, truncation...). Wrong answers deduct points. Correct explanation for a correct mechanism 1 pt each. Stripping removes the gas and thus the fuel for star formation - galaxy becomes redder. Merging galaxies have more random motions in their stars and less rotation and are more elliptical and/or gas is shocked and starbursts in the interaction making the galaxy more red.

5 Bull's eye

(3 pt) In redshift space, walls and filaments of galaxies at the same redshift look more prominent than they are in "normal" 3D space. This effect is called the "Bull's eye" effect. Explain what causes this effect. You can make a sketch to illustrate your explanation (but you don't have to if you can explain it in words).

Mentioning: Galaxies move towards overdensities, and/or gravitational attraction of real overdense features (1 pt), making them less redshifted behind the wall-feature and more redshifted in front of it (1 pt, can also be in sketch). In a redshift map they would therefore appear as more peaked around the (real but less prominent) wall feature (1 pt).

6 One and one is ...

Two stars are in a close binary and too close together to be resolved by your telescope. One of these stars has a quarter of the luminosity of the other.

a. (2 pt) By how much (in magnitude) is the pair brighter than the brightest star individually?

See written out sheet.

b. (2 pt) If the less luminous star has also a temperature of 0.8 times the temperature of the brighter star, what percentage of the stellar disk (the circle of the stellar surface projected towards us) of the brighter star would be blocked by the fainter star if the fainter star would move in front of it?

See written out sheet.

List of constants and conversion factors that may be useful:

Speed of light: $c \approx 3 \times 10^5$ km s^{-1}

Solar luminosity: $L_\odot = 3.83 \times 10^{33}$ erg s^{-1}

Solar absolute V-magnitude: $M_{V,\odot} = 4.83$

Solar B - V: $(B\text{-}V)_\odot = 0.6$

Solar V - I: $(V\text{-}I)_\odot = 0.72$

Solar mass: $M_\odot = 1.99 \times 10^{30}$ kg

(Current value of) Hubble constant: $H_0 = 70$ km s^{-1} Mpc^{-1}

Gravitational constant: $G = 6.7 \times 10^{-8}$ cm^3 g^{-1} s^{-2}
or $G = 4.3 \times 10^{-3}$ km^2 pc $M_\odot^{-1}$ s^{-2}

1 Mpc = 3.086×10^{24} cm

$k_B = 1.38 \times 10^{-23}$ J/K

mass proton $m_p = 1.67 \times 10^{-27}$ kg

mass electron $m_e = 9.11 \times 10^{-31}$ kg

1 radian = 206265 arcsec