Fourth Midterm - Your Name and ID:

Part Zero: Please write your name and student ID on the top line of this sheet **and** on the front of the Blue Book that you received together with this sheet. Please return both together for grading at the end of the exam. Please use a pen that cannot be erased!

Part One: True or False? Please mark with either T for True or F for False on the line provided in front of each statement. Each correct answer is worth one point:

1. **TRUE** Cepheids were used rather than RR-Lyrae stars in the first measurement of the distance to the Andromeda galaxy.

2. **FALSE** O and B type stars account for most of the stars in the Milky Way's globular clusters.
   K and M stars make up the globular clusters; O and B types have long died in these old clusters.

3. **TRUE** Models of the galaxy and its rotation are needed to extract information on the spiral structure from Hydrogen emission Doppler shifts.
   Without a model the observed redshifts (plural!) as a function of direction cannot be interpreted; if we have a model, we can use it to make predictions about what we should observe in a given direction, and then correct the model if this prediction does not coincide with the observation in that direction.

4. **FALSE** Galaxy rotation curves show that the Dark Matter in a spiral galaxy typically is contained in its halo.
   A galaxy's DM halo extends far beyond the visible confines of the galaxy.

5. **TRUE and FALSE...** A typical jet from an active galactic nucleus extends all the way to the outer reaches of its galaxy's halo.
   A typical jet extends far beyond the outer reaches of the galaxies halo, which is what I wanted you to know. That certainly means that it extends all the way to the outer reaches... Will have to withdraw this question due to ambiguity in my language.

6. **TRUE** On the scale of 1Gpc there is no structure in the Universe.
   The largest structures that we see are of order 200Mpc. Beyond that, the Universe is homogeneous and isotropic.

7. **FALSE** First distance estimates for the largest elliptical galaxies were obtained with the Tully-Fisher relation.
   Tully-Fisher is specific for spiral galaxies; it is not applicable for elliptical galaxies.

8. **FALSE** The ratio of dark to luminous matter is the same on all scales throughout the Universe.
   Within galaxies there typically is 3-10 times as much DM as normal luminous matter, whereas e.g. in galaxy clusters we typically find 10-100 times as much DM as we find luminous matter.

9. **FALSE** Galaxies that have a non-stellar spectrum are called irregular galaxies.
   Irregular galaxies do not normally have a non-stellar spectrum.

10. **TRUE** The Sun will very likely survive and outlive the impending collision between the Milky Way and Andromeda galaxies.

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Part Two: Essay questions. Please explain your answer in a short (few sentences) essay that you enter into the Blue Book. Each correct and complete answer is worth three points:

1. Explain why there are no rotation curves for elliptical galaxies.
   Answer: Unlike in disk galaxies there is no ordered orbital motion in elliptical galaxies. Like the globular clusters and halo stars in our own Milky Way galaxy the stars in an elliptical galaxy move on arbitrary orbits, i.e. in an unordered way. There is very little overall rotation observed in elliptical galaxies.

2. In the distance ladder: Which is the rung between parallax and variable stars? Which diagram do we consult to estimate the luminosity of stars when we apply that rung's method?
   Answer: The rung in between parallax and variable stars is the spectroscopic parallax: estimating a star's distance by extracting its luminosity from the Hertzsprung-Russell diagram.

3. Where does an active galactic nucleus get its energy from? Explain how that relates to the "blobs" of radiation we often see along a jet.
   Answer: Energy in an AGN is taken out of the gravitational energy released by matter falling into the central Black Hole. The "blobs" come from variations in how much matter falls into the Black Hole: if matter stops falling in, the jets will stop; if new matter starts falling in again, the jets get restarted. A new "blob" of radiation comes out along the jet axis.

4. Explain why Hubble's Law does not tell us something about recession velocities of distant galaxies but about the nature of space itself.
   Answer: Recession velocities mean that galaxies are moving through space just as Andromeda (one of the very few blue-shifted galaxies) races towards the Milky Way and the Milky Way races towards Andromeda. The redshift implied by Hubble's Law is observed even if both galaxies sit perfectly still in their local environment: it comes from the expansion of space between the galaxies, not from a motion of the galaxies at their respective places in the universe.

5. How do we think the largest elliptical galaxies were made? Are they very old objects in the universe?
   Answer: Unlike the smallest elliptical galaxies the largest elliptical galaxies are not very old. They are the results of mergers of typical disk galaxies in which the gravitational forces of the merging disk galaxies randomize the motion of the stars in the resulting elliptical galaxy.

Grand total: 25 points. All the best!