

Answer all questions. Some questions may require you to consult other sources: if so, remember to reference the sources used in standard style (see the Department's web page on "Plagiarism and Collusion" for instructions on referencing). Always use your own words, unless there is justification for a brief direct quote—if there is, use quotation marks. This exercise counts 5% towards your total module mark.

1. Explain, *in your own words*, the problems associated with attempting to observe the spectra of spiral galaxies (or "spiral nebulae" as Slipher calls them in the nomenclature of the time), and why Slipher's solution of replacing the 18½ inch camera of his spectrograph by a 3¼ inch instrument improved the situation. [4]
2. Slipher says that the spectrum of M31 in Andromeda "shows a pure stellar type of spectrum, with none of the composite features to be expected in the spectrum of the integrated light of stars of various types". (The spectral type he quotes is G–K.) With hindsight, this is very surprising, as a spiral galaxy like Andromeda certainly *does* contain "stars of various types". Suggest possible reasons why Slipher might not have observed this. [2]
3. Slipher comments on the implications of the nebular velocities in the context of "the Campbell-Kapteyn discovery of the increase in stellar velocity with "advance" in stellar spectral type." Irritatingly, he does not reference the papers in question (there are two, one by Campbell, one by Kapteyn). *Find* the papers (this exercise should convince you of the importance of properly referencing your sources!), read what they say, and discuss the implications for spiral nebulae. [3]
4. In hindsight, the most important feature of Slipher's results is that of the 15 nebulae observed, 11 are definitely redshifted, one is uncertain, and only three are definitely blueshifted (I assume that the "[blank]" entry for NGC 598 is supposed to indicate that it is definitely negative but that the value is hard to determine accurately). However, although Slipher notes this, he does not emphasise it—he is rather more interested in the indications that nebulae to the south of the Milky Way have a smaller average velocity than those on the north, and that edge-on spirals have higher velocities than face-on. Why do you think this is? Comment on the reality, or otherwise, of the effects that he *does* talk about. [3]
5. How accurate are Slipher's results, compared to modern measurements? Discuss possible reasons for any large discrepancies. [3]