Exam: Active Galactic Nuclei

Date: Nov 5 2008
Time: 9:00–12:00
Location: Kapteyn Room

Please write your name and student number on all exam sheets and hand all material in after the exam. Write clearly and structured.

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1. Describe in short [15][1]:

   - Big Blue Bump
   - Ly-α forest
   - The Gunn-Peterson effect
   - Reverberation mapping
   - Baldwin-Phillips-Terlevich diagram

2. **(a)** Give the defining characteristics, including differences, for Seyferts and quasars (QSOs) of types 1 and 2. [10]

   (b) Describe possible unification schemes between these Seyfert galaxy types 1 & 2, also and between them and QSOs. In this context, mention three possible important causes for the differences that we see between AGN types. [10]

3. **(a)** Draw and describe the general structure of a giant radio galaxy, indicating each of the components by name. [5]

   (b) What is the physical cause of radiation loss by electrons and what is synchrotron self-absorption? What is the effect of these processes on the shape of the radio spectrum? [5]

   (c) What causes Polarisation of synchrotron emission in a radio galaxy. [5]

   (d) How does the effect of Faraday rotation depend on frequency? [5]

4. Black holes in AGN grow through accretion of gaseous material. In the following question you will examine whether $10^9\,M_\odot$ BHs can exist at a redshifts of $z > 6$, as found in the SDSS.

[1] Points for each question.

(a) Describe what is meant by the Eddington luminosity. The equation for the Eddington luminosity is given by $L_{\rm edd} = 4\pi G M m_{\rm p} c/\sigma_{\rm e}$. [5]

(b) Assume now that the Thomson cross-section is $\sigma_e = 6.65 \times 10^{-29}\,{\rm m}^2$, the proton mass is $m_p = 1.67 \times 10^{-27}\,{\rm kg}$, $G = 6.67 \times 10^{-11}\ {\rm m}^3{\rm kg}^{-1}{\rm s}^{-2}$, the speed of light is $c = 3 \times 10^8\,{\rm m/s}$ and $M_\odot = 2 \times 10^{30}\,{\rm kg}$.

Given an efficiency η for turning accreted mass into radiation, write the Eddington luminosity as an accretion rate dM/dt and as function of the mass M of the black hole. Express the equation in units of solar mass (per year). [10]

(c) Note that the solution of (b) is a simple linear differential equation. Solve the equation with the boundary condition that the initial mass of the black hole is $100\,{\rm M}_\odot$ at $t = 0$. [10]

(d) How long does it take for the BH to grow from $100\,{\rm M}_\odot$ to $10^9\,{\rm M}_\odot$? Assuming that the BH has 1 Gyr to grow before $z = 6$, is likely that these BHs exist at all at these redshifts under the assumption they grow through standard gas accretion limited by the Eddington luminosity? If so, what efficiency η is needed and what could this say about the spin of the BH? [10]

(e) If AGNs accrete over the entire age of the Universe (13.6 Gyr) at the Eddington limit, what mass would the BH have at present if it started of at $100\,{\rm M}_\odot$? If SMBH are limited to $< 10^{10}\,{\rm M}_\odot$ what is the maximum amount of time the AGN can radiate at the Eddington luminosity? [10]