Problem Set 7

Due in class, Friday 25 May 2012

Reading: See the on-line syllabus for lecture-by-lecture readings.

Collaboration policy: See the on-line collaboration policy.

Homework Problems:

1. Galaxy Spin Parameter
   By conserving angular momentum for the gas in a halo with dimensionless spin parameter $\lambda = 0.05$, derive the characteristic disk scale length as a function of formation redshift,
   \[ r_D \simeq 3h^{-1}\text{kpc}(v_c/100\text{km s}^{-1})H_0/H(z_f) \]

2. Quasar Lifetimes and Demographics
   By measuring the autocorrelation function of quasars and/or the cross-correlation of QSOs and galaxies, one learns that quasars inhabit dark matter halos of mass $M_{\text{halo}} \simeq 10^{12.5} M_\odot$. The surprising part of the result is that the characteristic halo mass shows little or no variation with either redshift or QSO luminosity.
   a) Comment on what this implies about the quasar phenomenon and its connection to dark matter halos.
   b) Using the Press-Schechter formalism, estimate the co-moving abundance of halos of mass $\log M_{\text{halo}} = 12.5$ at redshift $z = 2.5$, and at $z = 0$. The observed co-moving space density of quasars at $z \sim 2.5$ is $\Phi_{\text{QSO}} \simeq 3 \times 10^{-6} \text{ Mpc}^{-3}$. By comparing the space densities of the host halos with that of the observed QSOs, estimate the fraction of time supermassive blackholes are radiating as QSOs, and thus the “lifetime” of the quasar phase.
   c) The space density of bright quasars plummets rapidly at $z < 2$ – by $z = 0$ it is less than 1% of its peak at $z \sim 2.5$. How might you account for the rapid decline in the context of hierarchical structure formation? Use some rough calculations to support your answer.

3. The Quasar Proximity Effect
   Some combination of young galaxies and QSOs was responsible for re-ionizing most of the hydrogen atoms in the universe at $z \sim 10$, and the descendants of these sources maintained the high ionization of the IGM subsequently. The net effect of the sources of H-ionizing photons is to produce a relatively uniform ionizing background with intensity $J_\nu \simeq 3 \times 10^{-22} \text{ ergs s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1} \text{ steradian}^{-1}$. One method used to measure $J_\nu$ involves searching for an enhancement in the ionization level of the IGM near powerful sources of UV photons of known ionizing luminosity (such as QSOs), commonly known as the “quasar proximity effect”. If one observes a quasar at $z = 3$ to have an apparent (AB) magnitude of $m = 18$ at its rest-frame Lyman limit, calculate the extent (in physical Mpc) of the “proximity zone” – the region within which the QSO’s influence on the ionization level of the IGM could be
measured (e.g., by observing a decrease in the overall level of Lyα absorption). What is the corresponding redshift range \( \Delta z \) for the “proximity zone” around the quasar at \( z = 3 \)? If the QSO is radiating isotropically, what would be the angular size on the sky of the proximity zone? What is the light travel time to the edge of the proximity zone transverse to the line of sight, and how does it compare with your estimate of QSO lifetimes in the previous problem?