FINAL EXAM: ASTR 698

This is an open book take home exam. You are allowed three hours. It is due in my mail box or office Wednesday December 8, 2004 by Noon.

1. You need to design a spectrograph with the following constraints. The whole instrument needs to fit in a room that is 6 meters square. The grating available to you is ruled at 400 lines mm^{-1}. You desire the sky projection of the slit to be $d\alpha = 1''$ for a $w = 0.02$ mm slit width. You want a spectral purity of $\Delta\lambda = 0.1$ Å for first order, $n = 1$. You have in hand a detector with 30 μm pixels.

   (a) First you need a collimator. What is the focal length of the collimator, f_{coll}, for the desired slit projection? Can this fit in your spectrograph room?

   (b) Now you need to determine the tilt of the grating, i.e., the angle between the grating normal and the collimated incident light beam). For the desired spectral purity for first order, what is the angle of incidence, α?

   (c) Given the detector you inherited, what must be the camera focal length, f_{cam}, if you are to sample the spectral purity (resolution element) with three pixels at a wavelength of 5000 Å? HINT: you will first need to compute β for $\lambda = 5000$ Å. Would you say that you might need to add a "correcting" lens to shorten this to a smaller effective focal length (commonly done)?

   (d) At $\lambda = 5000$ Å and spectral purity $\Delta\lambda = 0.1$Å, what is your resolution for a $1''$ slit? For a $1.5''$ slit?

   (e) For your resolution, calculate the approximate facet angle, ϕ, of your grating.

   (f) Apart from the constraints place upon you for the size of your spectrograph room, does it otherwise impact your design as to how far away the grating is from the collimator? Does it matter how far the camera is from the grating? Explain why for both questions.

2. Explore the statistical dependence of absorbers sizes (in kpc) on the three parameters: (i) α, the faint–end slope of the luminosity function, (ii) β, the luminosity dependent gas cross–section, (iii) L_{min}, the minimum galaxy luminosity contributing to the absorbing gas cross–section. Where

$$R_* = \mathcal{N}(z)^{1/2} \left[\frac{\pi c f_c \Phi^*}{H_o} \frac{dX}{dz} \Gamma(2\beta - \alpha + 1, t_{min}) \right]^{-1/2},$$

   where $t_{min} = L_{min}/L^*$. Note that this equation corrects an error in the "book"– be careful. Assume $f_c = 1$, $z = 1$, a flat concordance cosmology,

$(\Omega_m, \Omega_\Lambda) = (0.3, 0.7)$, and luminosity function normalization of $\Phi^* = 3\times10^{-2}$ Mpc^{-3}. You will require the *Numerical Recipe* routines *gammln.f*, *gammp.f*, *gcf.f*, and *gser.f* to compute the Γ function and the Incomplete Γ function. They can be obtained on the web site under the Exam 2 link (double precision).

(a) For $L_{min} = 0$, on a single graph, plot R_* as a function of $\mathcal{N}(z)$ over the range $0.5 \leq \mathcal{N}(z) \leq 5$ for (i) $\alpha = 1$ and $\beta = 0.2$, (ii) $\alpha = 1$ and $\beta = 0.4$, (iii) $\alpha = 1.2$ and $\beta = 0.2$, (iv) $\alpha = 1.5$ and $\beta = 0.4$. Clearly label your curves.

(b) For $L_{min} = 0.05L^*$, on a single graph, plot R_* as a function of $\mathcal{N}(z)$ over the range $0.5 \leq \mathcal{N}(z) \leq 5$ for (i) $\alpha = 1$ and $\beta = 0.2$, (ii) $\alpha = 1$ and $\beta = 0.4$, (iii) $\alpha = 1.2$ and $\beta = 0.2$, (iv) $\alpha = 1.5$ and $\beta = 0.4$. Clearly label your curves.

(c) If you were writing a journal paper and showing your plot, you would need to describe the physical reasons for the behavior of R_*. In terms of the physical meaning of α, β, and L_{min}, breifly discuss the behavior of R_* as it depends upon these parameters. To which is R_* most sensitive? What physically is the interplay between α and L_{min}?

3. In our discussion of the paper "QSO Absorption Line Systems and Early Chemical Evolution"' (Lauroesch et al., 1996, PASP, 108, 64), we examined abundance variations as a function of metallicity, [Fe/H]. For the following, concentrate on § 2 of the Lauroesch paper.

   (a) What is the quantitative general trend for *each* of the intermediate mass even–Z elements as a function of [Fe/H]? For which elements are there data?

   (b) What is the quantitative general trend for *each* of the iron–peak even–Z elements as a function of [Fe/H]? For which elements are there data?

   (c) What is the quantitative general trend for odd–Z elements? For which elements are there data? Be specific how each of the elements behaves (they are not all identical).

   (d) What "simple picture" has been inferred from these trends? Where is the bulk of carbon and nitrogen thought to arise in this picture?

   (e) For the above measurements, why were photospheric abundance patterns measured instead of gas phase abundance patterns? How large can the effect be for iron in "warm" gas? In absorbing clouds, which element is used as a proxy for metallicity (iron abundance), i.e. tracer of Type Ia products? Why? Which element is a good tracer for Type II products? Why? (HINT: see § 5.1).