ASTRONOMY 8400 – SPRING 2024
Midterm Answers

1. Some techniques for detecting AGN:
   a) Point-like sources in radio surveys – miss radio-quiet AGN
   b) Objective prism surveys – miss AGN with weak or no emission, red AGN
   c) Variability surveys – not all AGN are highly variable
   d) Color imaging – miss red AGN in blue-selected samples
   e) X-ray point sources – miss obscured AGN in soft X-ray surveys

2. Masses of SMBHs in AGN:

a) - H2O masers – resolved spectra;
advantage: highly accurate; disadvantage: only edge-on systems
- Extended disks of ionized gas – resolved spectra
advantage: easily detectable; disadvant: non-gravitational forces affect the gas
- Reverberation mapping of BLR – unresolved
advantage: accurate; disadvantage: can only use for Seyfert 1s

b) - empirical relation between BLR size and AGN luminosity,
$R_{BLR} \propto L_{\lambda}(5100Å)$, plus FWHM of emission line
- stated uncertainty in fit is 0.43 in log, or close to a factor or 3
- causes are likely due to uncertainiies in distances and measured parameters (distances, fluxes, widths of lines) plus inherent uncertainties in geometry, etc.

3. Seyfert 1 vs. Seyfert 2 spectra
   a) Optical: both show strong narrow emission lines, Sey 2s lack broad emission lines and strong nonstellar continuua
   b) UV: same as for optical, plus Sey 2s lack the little blue bump due to hydrogen recombination and Fe lines
   c) Infrared: both show strong IR emission due to hot dust from torus, Sey 1s tend to show stronger emission in near-IR as you look into the throat of the torus. Sey 1s tend to show Silicate emission, Sey 2s show Silicate absorption.
   d) X-ray: both tend to show strong emission in hard X-rays (except highly Compton-thick Seyfert 2s), Seyfert 1s show strong soft X-rays, which are absorbed by the torus in Seyfert 2s
   e) Radio: both types are radio weak, no real differences

4. a) Isothermal accretion disk:

Virial theorem says that 1/2 of gravitational potential goes into heating the gas; the other 1/2 is radiated away:

$$L = \frac{GM\dot{M}}{2r}$$

$$L = 2\pi r^2 \sigma T^4$$

$$T = \left(\frac{GM\dot{M}}{4\pi\sigma r^3}\right)^{1/4}$$

b) If the radiation is dominated by a disk with radius $r = (\text{const.})\, R_s$:

$$T \propto \left(\frac{M\dot{M}}{R_s^3}\right)^{1/4} \propto \left(\frac{M\dot{M}}{M^3}\right)^{1/4} \propto \left(\frac{\dot{M}}{M^2}\right)^{1/4} \propto \left(\frac{\frac{L}{L_E} M}{M^2}\right)^{1/4}$$

$$T \propto \left(\frac{L}{L_E}\right)^{1/4} M^{-1/4}$$

$\rightarrow$ temperature decreases with increasing mass: radiation peaks in the X-rays for stellar mass black holes, EUV for SMBHs

5. a)

$M(r) = M_{BH}$

$$a(r) = a_r(r) + a_g(r) = \frac{1}{r^2}\left[\frac{L\sigma_T \mathcal{M}}{4\pi c\mu m_p} - GM_{BH}\right]$$

For accretion: $\frac{L\sigma_T \mathcal{M}}{4\pi c\mu m_p} < GM_{BH}$

For $\mu = 1, \mathcal{M} = 1$: $L < \frac{4\pi G c m_p}{\sigma_T} M_{BH} \equiv L_E$ (Eddington Luminosity)

For radiative driving: $\frac{L\sigma_T \mathcal{M}}{4\pi c\mu m_p} > GM_{BH}$ (independent of r)

$\mathcal{M} > \frac{4\pi G c\mu m_p}{\sigma_T} \frac{M_{BH}}{L}$

$\mathcal{M} > \mu \frac{L_E}{L}$

→ cannot accelerate NLR knots unless $\frac{L}{L_E} > \mu \mathcal{M}^{-1}$

b) Need $L/L_E < 1/1000\ (10^{-3})$ → LINERS

6. Brief description of the following:

a. SDSS: all sky imaging survey in visible light with 6 filters followed by multi-object spectroscopy to detect galaxies and quasars for mapping the structure of the Universe

b. Type 1 and 2 AGN are the same, just viewed at different angles with respect to a dusty torus

c. 10^6 to 10^9 solar masses in large galaxies, down to 10^{4-5} solar masses in small galaxies

d. 5 – 10% of AGN are RL

e. FR I vs. FR II galaxy – both radio galaxies, FR Is have lower luminosity and are bright in their centers, FR IIs are brighter at their edges (lobes)

f. Blazar properties – synchrotron emission, relativistically beamed, polarized, highly variable

g. Bolometric luminosities of Seyfert galaxies and those of quasars: $10^{43} – 10^{45}$ and $10^{45} – 10^{47}$ ergs s^{-1}, respectively

h. Blazar continua: synchrotron emission at low energies, inverse Compton at higher energies

i. LINER – low-ionization nuclear emitting line region

j. All-sky optical survey repeated every few weeks

k. Transfer function – convolution with continuum light curve gives emission-line light curve, depends on geometry and size of BLR (for 1-d case)

l. Fe Kα emission – resonance fluorescence due to ejection of inner shell electron, likely arises in the accretion disk close to the SMBH

m. ADAF – advection dominated accretion flow (low Eddington limit case)

n. Compton hump – hump of emission in hard X-rays due to “reflection” (including Compton down-scattering) of hard X-rays by colder disk

o. Swift/BAT

p. Faint Images of the Radio Sky at Twenty Centimeters

q. Highly ionized gas outflowing from AGN seen in absorption

r. Winds or jets from AGN activity providing kinetic energy to the surroundings

s. Broad absorption-line quasars, velocities up to ~0.2c

t. Ionization changes, transverse motion (total column or covering factor in line of sight changes)

u. Extremely variable, strong soft X-ray excess

v. Equivalent width of C IV decreases with luminosity

w. Integral Field Unit, spectra and images at the same time

x. Baldwin Phillips Terlevich diagram – a plot to distinguish ionization source(s) in photoionized gas in a galaxy (stellar, LINER, or Seyfert-like) using line ratios

y. Increase in effectiveness of radiative driving over pure Thomson scatteringw