For the 2021 Qualifying Exam, the first question that you will be asked following your research presentation and discussion, will be drawn from the list below. You may be asked more than one question from this list.

RADIATIVE PROCESSES

- A. Briefly explain Bremsstrahlung radiation. Draw a diagram including an acceleration vector attached to the electron. Describe the small angle scattering approximation. How does thermal free-free opacity scale with plasma electron density and temperature as well as frequency?
- B. Explain the connection between detailed balance, the Einstein A and B relations, Kirchoff's law and the Milne relations, and give an example of their use to connect the bremsstrahlung emission spectrum and the free-free absorption coefficient.
- C. Derive an expression for the electron cyclotron frequency of a non-relativistic electron of charge e and mass m, spiraling in an external magnetic field of strength B.

INSTRUMENTATION (note that you are responsible only for the course you took, i.e. not optical if you participated only in the radio class, and not either if you are a declared theorist taking six electives instead of four)

- D. Describe quantitatively the point spread function of a diffraction-limited optical telescope. Explain how diffraction spikes arise, and what determines their positions and intensities. Under what circumstances will the PSF be broadened by atmospheric turbulence?
- E. Derive a general expression for the signal-to-noise ratio of a point source seen by an optical / near-infrared telescope as a function of seeing, telescope diameter, sky brightness (expressed in mag/arcsec^2), detector noise and dynamic range, and total integration time.
- F. Derive an expression for the point source sensitivity of a radio interferometer as a function of the frequency, bandwidth, system temperature, diameter of each dish, and number of dishes.

STARS

- G. Using the Virial theorem and assuming the star is made out of an ideal gas throughout, derive an expression for the central temperature and pressure. Using these expressions, calculate approximate Pcore and Tcore values for a Sun-like star. What does it tell about the physical process occurring at the core of main sequence stars? Why would this derivation not work for post-main sequence stars?
- H. Draw a rudimentary spectrum of a. an M-dwarf, b. the Sun, c. an A-type star, d. an O-type star. Explain how the spectrum can be used to estimate the temperature of the star, and which absorption lines (e.g., H, He, metals) you would expect to see.

  Now describe the four main sources of opacities in stars. Where in stars and for which type of stars is each source of opacity important? What is the Rosseland opacity and in what context is it relevant?

- I. Describe the main stages of pre-main sequence stellar evolution and their corresponding timescales. In particular develop the condition for cloud collapse and fragmentation. Discuss any hypothesis you are making and their consequences.

GALAXIES

- J. Draw a typical galaxy rotation curve (for a Milky Way-like galaxy). Explain how rotation velocity relates to enclosed mass. Draw the curve we would typically get if we predicted this from just the observable baryonic matter, and discuss the difference and what it means physically.

- K. Draw a typical galaxy SED from FUV through FIR. Label broad portions of the spectrum in wavelength, and explain what they are coming from. What sources dominate the UV? What dominate the optical/NIR? What dominates the M/FIR?

- L. A satellite galaxy falls onto the Milky Way. Assume the galaxy is small compared to the Milky Way, what will happen to its orbit? Name some processes that will act to modify the secondary galaxy? What, approximately, is the "tidal radius" and what happens there? How is this different (qualitatively) if that galaxy has equal mass to the Milky Way?

HIGH ENERGY

- M. What condition triggers explosion of a white dwarf into a Type Ia supernova? Could this happen before the white dwarf reaches the Chandrashekhar mass limit? Sketch condition on a density temperature diagram.

- N. Explain the compactness problem for Gamma Ray Bursts. What are typical Lorentz factors for jets?

- O. Derive the Eddington luminosity. Explain its relevance to the peak frequency of the emitted radiation. Explain its consequences for accretion onto neutron stars and black holes.

INTERSTELLAR MEDIUM

- P. What are the various phases or constituents of the ISM? Describe typical densities, temperature and global mass of each component.

- Q. Derive and compute the wavelength of the Lyman alpha line of Fe XXVI in the context of the Bohr model. If you want a higher precision what corrections would you be making? Please comment on the expected splitting of the n = 2 state.

- R. Explain Figure 24.7 from Draine's book

EXTRAGALACTIC/COSMOLOGY

- S. What is the difference between the growth of density perturbations in the matter-dominated era versus the radiation-dominated era? Write down or explain how you would estimate expressions for both.

- T. Write down the Friedmann equation, including matter, dark energy, radiation, and curvature terms. How does each of these scale with redshift? What does that mean for the relative times when each term would dominate?

- U. Draw a cartoon of the size of the co-moving region containing some mass that will collapse into a dark matter halo. Label the maximum/turnaround size. Label the time of virialization. What is meant by the critical (linear) density at which a structure will collapse? What is meant by virialization? How does the virial radius relate to the turnaround radius?

SURPRISE TOPIC

- What is the most interesting colloquium or tea talk that you attended (in person or virtually) over the past year? Summarize the results.