For the 2013 Qualifying Exam, the first question that you will be asked following your research presentation, and any questions related to it, will be drawn from the list below. You may be asked more than one question from this list.

RADIATIVE PROCESSES

- A. Derive the total power and characteristic frequency of synchrotron radiation from a relativistic particle of mass m, charge e, and energy E moving in a magnetic field B. Use this to explain why synchrotron radiation is generally negligible for protons.
- 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. Draw the energy levels of the hydrogen atom and identify which transitions are allowed. Which ones are in the visible part of the spectrum? Which level has no allowed decays, and what is its main decay mode?

INSTRUMENTATION

- 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 an expression for the point source sensitivity of a radio interferometer as a function of the frequency, bandwidth, system temperature, diameter of each dish, number of dishes, etc.
- F. Describe some of the common technologies for detecting gamma rays, the approximate energy range over which they are applicable, and some of their main advantages and disadvantages.

STARS

- G. Explain what is the Hayashi track, and describe what types of objects live on it. Qualitatively explain how it arises and what assumptions are required for its derivation.
- H. Estimate the temperature as a function of depth in the Sun's convection zone. What is the temperature at the base of the convection zone?
- I. Describe the major sources of opacity in stars, and how each depends on density, temperature, and metallicity.

GALAXIES

- J. Define two-body relaxation and estimate its time scale in (a) a globular cluster; (b) the Milky Way's disk. In which cases is two-body relaxation important?

- K. Draw qualitatively the spectral energy distribution of the Milky Way, and describe how its morphology might appear to an external observer as a function of wavelength.
- L. Describe at least three methods to probe the gravitational potential of galaxies, their assumptions, and their realm of applicability.

HIGH ENERGY

- M. Describe the mechanisms by which cosmic rays gain and lose energy. Which mechanisms are appropriate to which type of particle? Which ones produce electromagnetic radiation that we can observe, and in what wave bands?
- N. Discuss the equation of state of relativistic/nonrelativistic degenerate gases of electrons and neutrons and derive the Chandrasekhar mass limit for white dwarfs. (A heuristic approach, as in Shapiro and Teukolsky, is sufficient.)
- O. Derive the equation for the effective temperature of an accretion disk around a black hole of mass M with accretion rate Mdot, as a function of radius r. Specify the assumptions required to get an answer, and comment on what could go wrong with them. Define the Eddington luminosity and explain its relevance to the peak frequency of the emitted radiation.

ISM

- P. Draw the cooling function for gas of solar metallicity, and describe the cooling mechanisms in each part of the curve. Explain the relevance of this function to multiphase ISM models.
- Q. Draw a typical spectrum of an HII region, including both lines and continuum, and explain the major processes that give rise to each feature.
- R. Explain quantitatively what determines the temperature of dust grains and their thermal emission spectrum. Give examples of astrophysical environments with different dust temperatures.

EXTRAGALACTIC/COSMOLOGY

- S. Put on a timeline, and describe the principal events in the thermal history of the universe, from kT = 10 TeV to kT = 0.1 eV.
- T. Give a semi-quantitative discussion of the connection between flucuations of the cosmic microwave background on angular scales of arcminutes to degrees, and the baryonic structures (galaxies, clusters, correlations of galaxies) observed in the local universe, redshift $z < 0.5$.
- U. Which elements/isotopes are produced in Big Bang Nucleosynthesis and in what quantities? Explain qualitatively how the yield of each depends on the cosmic baryon density and why.