Example of a specific research question, related to one of our "big questions" – demonstrating also how specific skills and techniques are used in tackling an actual research questions, and also emphasizing the interplay between theory and observation/experiment.

Let's take one of these big questions as a case study in how an individual researcher (you!) might engage in the research enterprise:

Big question: How common are planets around other stars and what are they like? Can/do they harbor life?

Any individual researcher (and indeed any research group) can only tackle one small part of any of these (or smaller) questions. For example, in order to understand how the planet formation process works, someone might study the *timescale* over which dusty, gaseous circumstellar disks dissipate, presumably converting some of their material into planets.

How are researchers trying to answer these questions?

Observationally:

- Identify disks and characterize their strengths (excess IR emission – note: stars and their disks are too small in angle to take a picture of them, even with the biggest telescopes, so we often look at *spectra* in order to get clues about the physical characteristic of the objects; interferometric 'imaging' – using the phase information in (long-wavelength) EM radiation to reconstruct an image from an array of telescopes).
- Survey stars of different ages.

  Note: issue of our basic understanding of stellar structure and evolution is involved here, if we need to figure out the ages of stars; this is stuff in textbooks, but is continually being refined: Kuhn's "normal science"; scientists studying one problem or field use the results from another field as their starting point.

Techniques:

spectroscopy, radiative processes, image synthesis and analysis

Theoretically:

Orbital dynamics; accretion models -- Make a model of a young star with a disk, constrain the trajectories of the disk particles and the properties of the star with known physics. Step the evolution of the system forward in time (by numerically solving differential equations).

Techniques:

plasma physics, fluid dynamics…some analytic modeling, but *numerical modeling,* as in so many subfields, is an increasingly important part of theory.

How is progress made?

Ideally: **Theorists** and **Observers** get together at a meeting and the theorists say, “we put in thus and such *physical effect*, and the time for a disk to form planets went from 50 million years to 10 million years (in our numerical simulations).” Physical effects might include (in addition to gravity), viscosity, magnetohydrodynamical instabilities, radiation pressure…

And the observers say, “interesting; we found lots of disks around 5 million year old stars, but none around 25 million year old stars.” (Thus in the real world, circumstellar disks form planets somewhere between 5 and 25 million years into their existence.)

Then another theorist comes along and says, “when I put in yet *another physical effect* in addition, I get formation times a bit longer; 20 million years.” The theorists turn to the observers and suggest, “Go out and find stars that are *between* 5 and 25 million years old and figure out if they have disks or not. The result will tell us how important this additional physical effect is.”

Lesson: theory guides observations, then new observations suggests refinements to theories, and ultimately, the right observations can discriminate among theories, telling us which ones are right.