Neeraj Kulkarni

RESEARCH PROPOSAL

WORSTER SCHOLARSHIP

Neeraj Kulkarni & Suoqing Ji

Modern theories of galaxy formation unequivocally predict that galaxies form when regions of the universe collapse gravitationally to form giant balls (or 'halos') of dark matter which are initially filled with hot (10^6K) gas. Stars, planets, dust, and nebulae etc. form the disk of the galaxy, but remain embedded in this much larger halo of dark matter and million-degree gas.

While the existence of a hot halo surrounding every galaxy is a very clear prediction of current theories, recent groundbreaking telescope observations have discovered large amounts of *cold* (10^4K) gas, precisely where it is expected to be hot! This unexpected but near-ubiquitous discovery of cold gas in the outskirts of galaxies remains entirely unexplained. This cold gas raises at least three important questions, which may point to important gaps in our understanding of galaxies:

1. Since cold gas does not have enough pressure to hold itself up against the gravity in a galaxy halo, how does this cold gas persist in the outskirts of the halo?... it should "fall" in toward the center of the galaxy,

2. Since gas shrinks as it cools, cold gas should occupy a tiny fraction of the volume of the halo ... yet we find it in every sightline through the galaxy,

3. Telescope observations indicate that this cold gas takes the form of small clouds, which are likely billions of years old. Yet, known fluid-dynamics instabilities should very efficiently destroy such small clouds, perhaps in a time as little as a million years (i. e., in a thousandth of their observed age).

These apparent inconsistencies can all be understood if the cold gas isn't contiguous, but is instead made of much smaller fragments scattered throughout space like the water droplets in a fog. Thinking of this cold gas as a collection of tiny fragments suspended in an ambient hot medium would explain both how it is able to stay suspended despite gravity, and also how such a small quantity of gas is able to fill the entire volume of the galaxy halo. Our research group has recently identified the existence of a a new hydrodynamical instability which fragments cold gas into tiny pieces, precisely as required by the observations; we refer to this fragmentation as "*shattering*."

We have already demonstrated the existence of the shattering instability, and we have shown that it may be the key to understanding these new observations of galaxies. But we do not yet understand how the instability fundamentally works. This summer, Neeraj will investigate the detailed physics behind shattering using a combination of hydrodynamical simulations and analytic theory.

Neeraj will run a suite of hydrodynamical simulations to investigate how cooling and gas dynamics drive the shattering instability causing gas to fragment into small clouds. Neeraj will identify the range of parameters over which shattering is effective, and will determine what sets the size-scale for the fragments. His results will be immediately applicable to hitherto-unexplained observations of galaxies. Neeraj began work on this project last summer, and is familiar with the process of running and analyzing simulations as well as the variety of the fluid processes involved.

During this project, Neeraj will be exposed to the methods used by working theorists in astronomy. These include:

1. reading and interpreting observational data as published in astronomy journals,
2. using simulations and analytic methods to develop theories to explain the data,
3. and ultimately using the theory to make predictions that can be observationally verified (or refuted!)

We expect the results of this project will be submitted for publication by the end of the summer. This comprehensive project entails reading and interpreting observational papers, formulating analytic theories, running hydrodynamical simulations on super-computers to test them, and ultimately writing and publishing a scientific paper. This project will train Neeraj in essentially all of the skills required for independent research in theoretical astrophysics.