DISSECTING VIRGO SCRIPT

When we look out into the Universe we see that gravity clumps things together. Stars are clumped together into groups of hundreds and thousands **[Pleiades]**, and into large clusters containing of hundreds of thousands [**M9 globular].** Galaxies are collections of hundreds of billions of stars [**M51],** galaxies themselves are grouped together [**Stephan's Quintet**], sometimes into large clusters containing thousands of galaxies [**Virgo Cluster**]. Galaxy clusters are the most massive gravitationally bound structures in the Universe.
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The Virgo cluster is our nearest galaxy cluster which makes it a great place to study the growth and evolution of galaxies.

The Virgo cluster is so named because of the constellation it lies in. Virgo is easy to locate on the sky – look overhead to the big dipper and follow the arc of the handle stars to the bright red star Arcturus, then speed along to the blue star Spica – Spica is the brightest star in the constellation Virgo**. [Constellation sequence]**

The Virgo cluster is located 50 million light years away and contains over a thousand galaxies. At the core we see giant elliptical galaxies such as M87. This galaxy has a prominent jet at the center, the result of matter falling into the supermassive at the core. As we move out from the center of the cluster, the types of galaxies change, we see more giant spiral galaxies, such as this one M90 a galaxy similar in structure to our own Milky Way. Moving even further out to the outskirts to the cluster we find more of these small irregularly shaped galaxies. **[Optical Virgo Cluster Tour]**

This image can be a bit misleading; here we are only seeing the bright cores of the galaxies. If we expose the camera for a very long time as we have done in this region of the cluster we can begin to make out faint structures between the galaxies**.[Deep Exposure Sequence]** We see that the galaxies have large extended halos of stars **[1st Overlay],** we can also find evidence of the tidal interactions between the galaxies **[2nd overlay]** including these thin streams of stars, the result of a small galaxy being ripped apart. **[3rd overlay]**. The images tell us that the cluster is dynamic, constantly changing over time.

So far we've been looking at stars, but there is far more stuff in the gas between the stars. Most of that gas is extremely hot, roughly 10 Million degrees! Because it is so hot it doesn't glow in visible light, it glows in X-rays. Using orbiting X-ray telescopes we are able to map out the location of this hot gas. **[X-ray sequence]**.

A small fraction of the gas is cold, this gas is very important because it is cold was that is able to form stars. To find this gas astronomers use radio telescopes, and the largest in the world is the Arecibo telescope on the island of Puerto Rico. Built in to the surrounding landscape the collecting dish stretches 1,000 feet across. Here we're actually beneath the dish, while we can see through it, radio waves bounce off. **[Arecibo sequence]**

This telescope has discovered hundreds of sources of cold gas inside the Virgo Cluster. As we would expect, most (the blue ones) are located inside galaxies, however there are a few (shown

in magenta) isolated pockets of cold gas. We suspect that these gas clouds were stripped from their galaxies during gravitational interactions. **[ALFALFA sequence]**

So we've seen the hot has and the cold gas, but what about the warm gas. To find that astronomer Hsiao-Wen Chen is using the Hubble Space Telescope to analyze the light from distant quasars behind the Virgo cluster. When the light passes through a cloud of warm gas some of it will be absorbed, allowing us to find any clumps that lie along the line of sight. **[Hsiao-Wen images]**

The red circles show the locations of the distant quasars being studied. The yellow bulls-eyes show how many clusters were detected along that line of sight, some have several some none.**[absorption line overlays]**

The space between galaxies is filed with gas, some hot some warm some cold. Studying the interactions between these different phases of gas as well as the interactions between the gas and stars allows us to play astronomical weatherperson forecasting how the cluster will grow and evolve in the future. **[full overlay sequence]**