

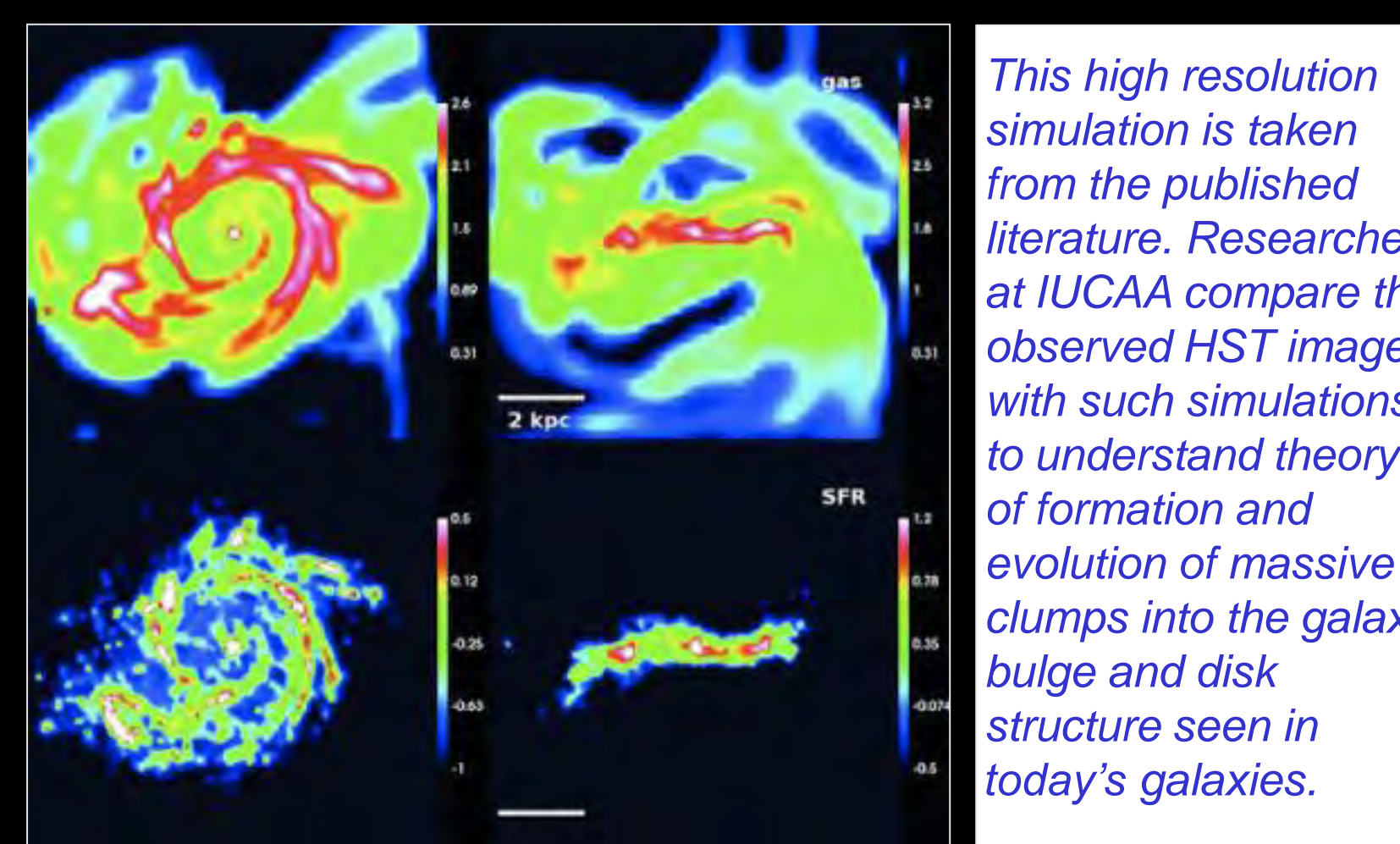
Most of the luminous galaxies in the present-day universe have regular Hubble-type morphologies. However, as one steps out in redshift, towards earlier epochs of cosmic time, irregular morphologies become more common. The observed structural changes may be attributed to (a) increased merger activity in the past, (b) dominant star formation which overwhelms light from older stars, (c) effect of only observing morphology in rest frame. Also, there is significant size evolution with redshift. Current research in this area focuses on quantifying the evolution of galaxy sizes and structure as a function of cosmic time & to see how this compares with the prediction from theories of galaxy formation and evolution.

## Studying The Phases of Galaxy Evolution & Formation

### Hubble Space Telescope (HST) Images of High Redshift Actively Star Forming Galaxies

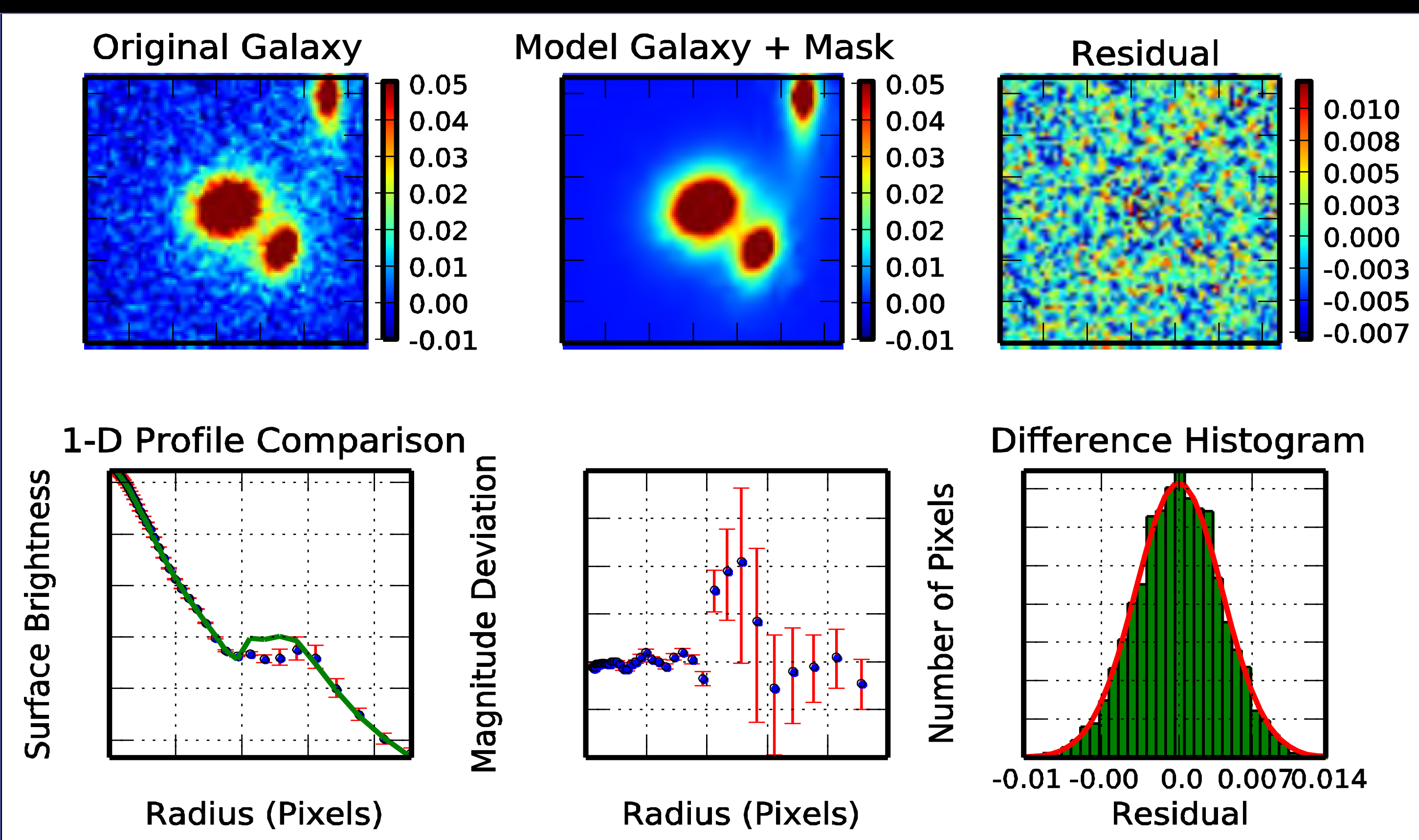


### Hydrodynamical Simulations of Star Forming Galaxies at High Redshifts



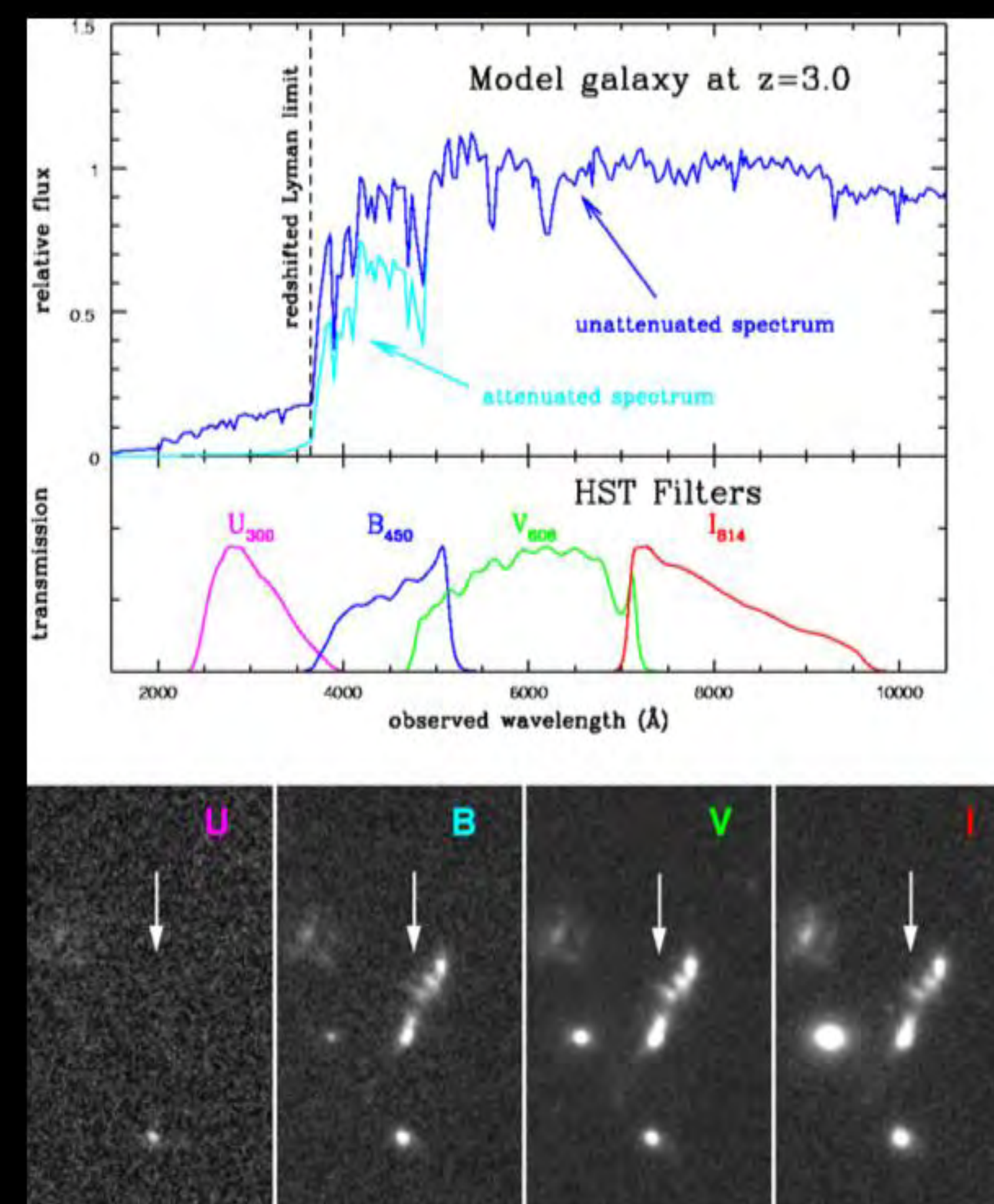
Galaxies at high redshifts seen at  $z > 2$ , correspond to a time when the Universe was less than 3 billion years old. Many of these galaxies have clumpy or chain-like structure and are a unique population of galaxies unlike that seen in the present-day Universe. Their star-forming clumps are massive, containing about 10-100 million stars comparable to dwarf galaxies seen today. In contrast, the most intense star-forming regions seen in our own Milky Way galaxy are forming less than 100,000 times the number of stars that are forming in the high-redshift clumps. **How do these massive clumps evolve? What would they finally become? Is the physics of star formation different at early cosmic times? What factors contribute to the observed differences among the galaxies of the past and present? These are some of the questions that researchers at IUCAA are trying to address.**

## Pipeline Software To Automate the Galaxy Parameter Estimation



The output from PyMorph. The top left panel shows the image of the galaxy, top middle shows the model image and the top right shows the residual (difference between galaxy and model) image after the fit. Lower left panel shows the one dimensional profile comparison of original (as data points) and model (as a solid line) for the galaxy. The lower middle image is the difference of the 1-D profiles of input and model galaxy. The lower right image is the histogram of the residual image, with the best fit Gaussian shown in red.

## Technique for Identifying High Redshift Galaxies



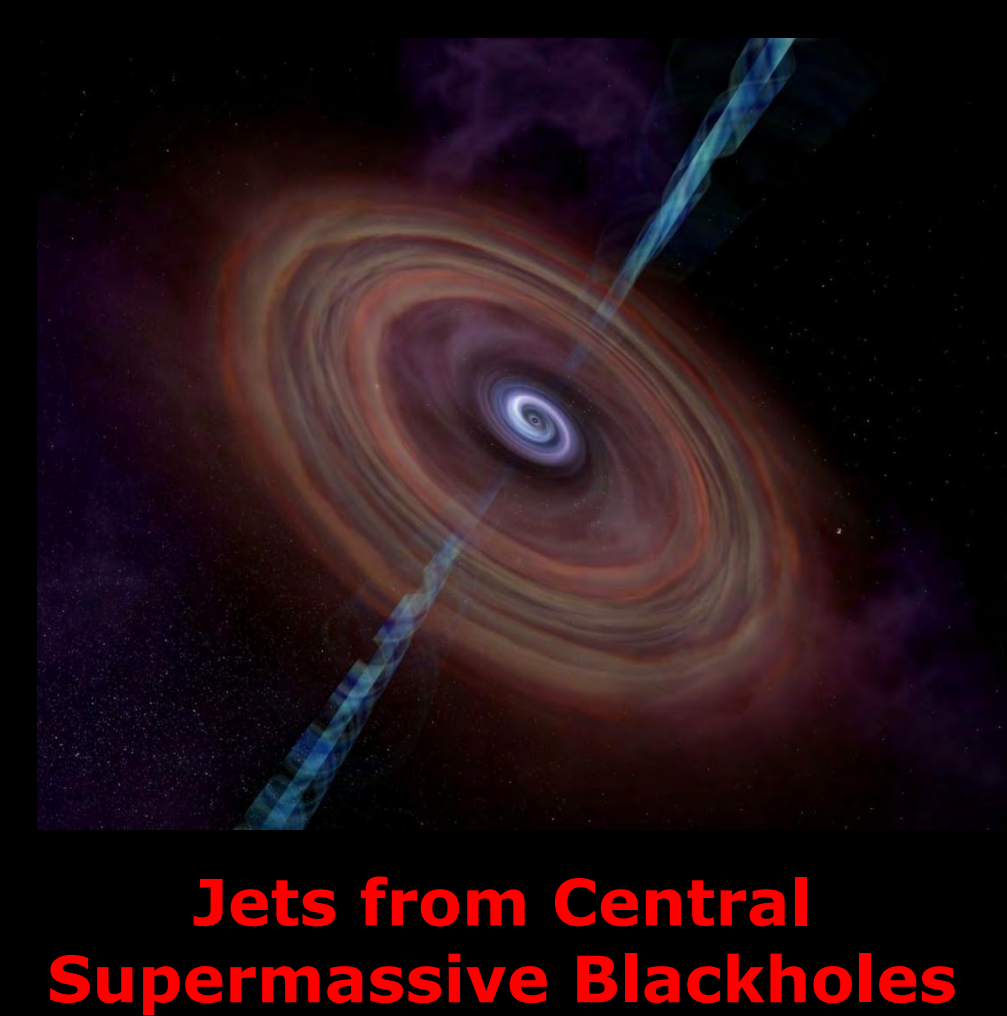
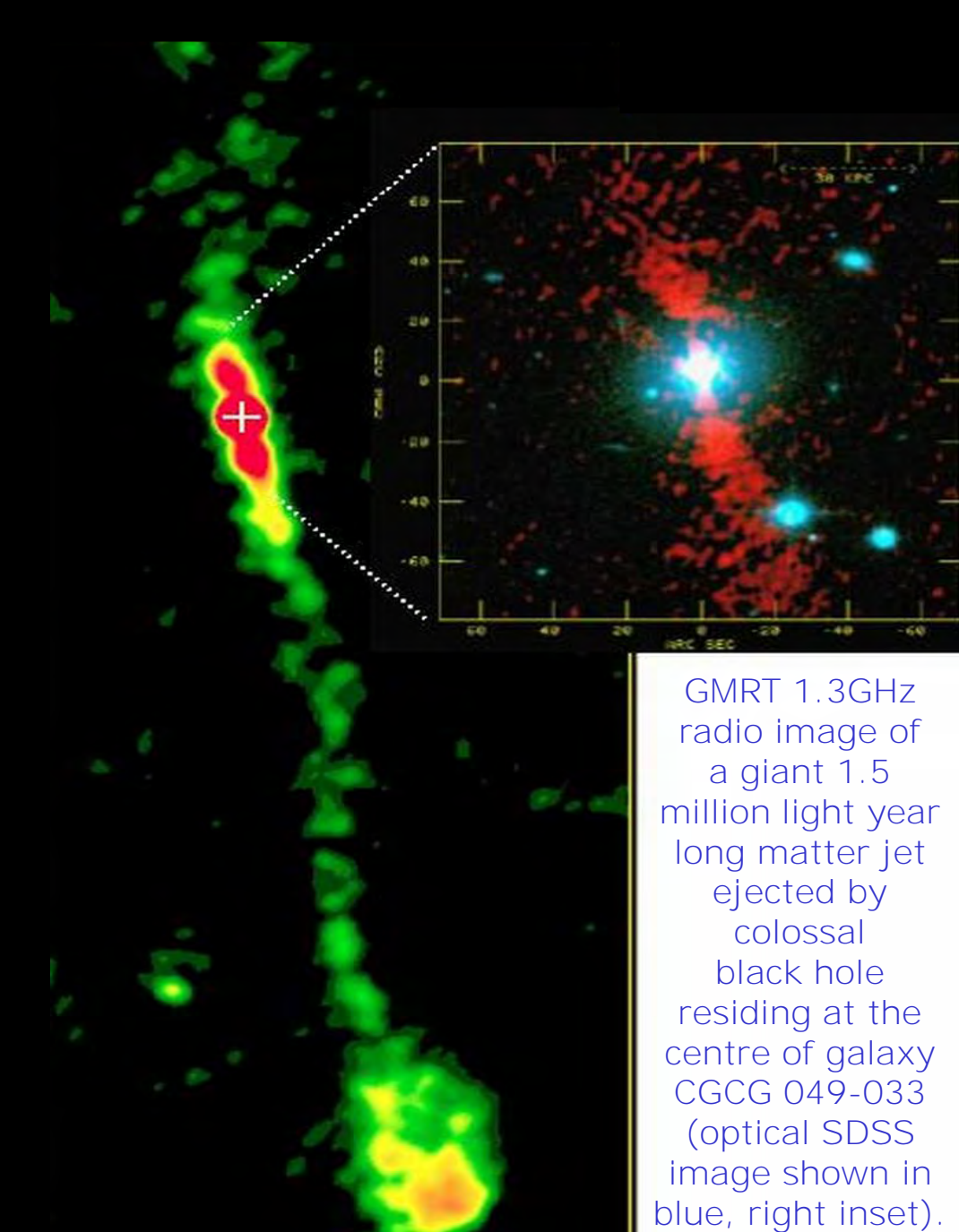
### Lyman-break Galaxies:

Flat UV continuum of star-forming galaxies show a strong break at 912 Angstrom due to the absorption of ionizing photons by the intervening neutral hydrogen. At redshifts  $z > 3$ , the break feature shifts into the optical and NIR wavelengths. The "Lyman-break technique" which uses a color selection to identify this strong feature as a redshift indicator is the most robust and efficient method used to select star forming galaxies out to  $z > 8$ .

## GMRT 1.3 GHz Radio Image of a Giant 1.5 Million Light Year Long Matter Jet Ejected From a Residing Black Hole

IUCAA and TIFR radio astronomers have discovered an intergalactic particle beam stretching for more than a 1.5 million light years, the longest ever seen. This giant beam (jet) which also emits strong radio waves, emerges from the center of a large elliptical galaxy called CGCG049-033, which is about 600 million light years away. The scientists took a closer look using the Giant Meter wave Radio Telescope (GMRT) and the 100-metre Effelsberg radio dish in Germany. Optical spectrum of the galaxy taken with the IUCAA's 2-meter optical telescope at Girawali revealed a colossal 2 billion solar mass black hole at the center of this giant particle jet.

The new jet's counterpart appears much shorter. That could be because the apparently shorter jet is pointing away from us - so light from its far end might not have had time to reach us yet. The radio waves emitted by the newly discovered jet are strongly polarized, revealing a powerful magnetic field wrapped around the jet and acting as a containing sheath, preventing the high-pressure gas in the jet from dispersing. That could explain why this jet is so long and well collimated.



## Work on Lenticular Galaxies and Bulge Morphology



Lenticular galaxies are like elliptical galaxies with an embedded disk. Until recently, they have been thought of as an intermediate stage of evolution of spiral galaxies into ellipticals via various processes. However, observational evidence indicates that lenticular galaxies themselves come in various forms and the difference in their properties indicates a difference in the process by which they have been formed. Current research involves study of these galaxies using both photometric and spectroscopic techniques. The spectroscopic data is being obtained using the Southern African Large Telescope of which IUCAA is a partner.

The central stellar component of the galaxy is called a bulge. The formation of the bulge was explained using various mechanisms all of which involved violent and rapid processes. However, in the last decade, there have been a lot of studies which have revealed bulges that have formed from slow processes within the disk, termed as secular evolution. The former are called classical bulges and latter are called pseudo-bulges. A detailed photometric study of the two types of bulges has already been performed. Efforts are under way for spectroscopic study of the same.