ARC 2021 Poster Competition

April 6, 2021

Peeping Into The Past of Galaxies in 6 Billion Years old Universe

APRIL 6, 2021

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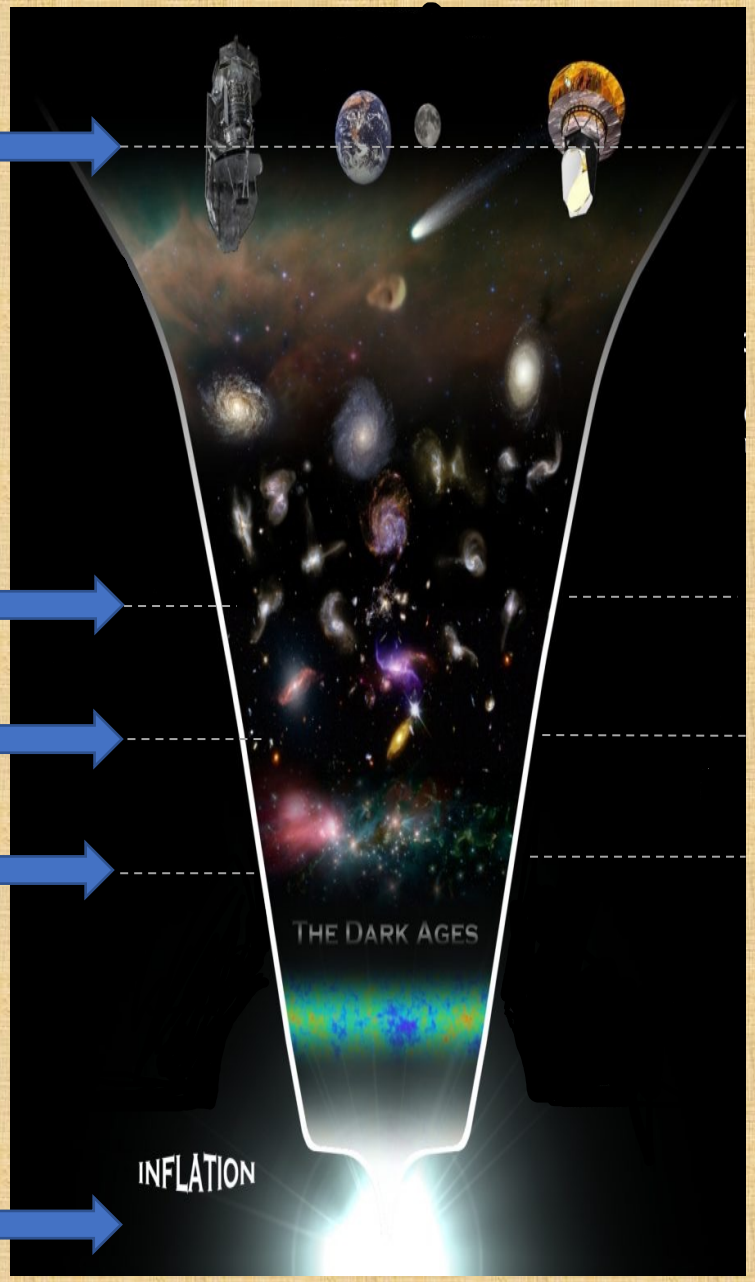
Timeline of our Universe



TODAY (DEAD GALAXIES)

13.8 Billion Years

(ALIVE GALAXIES)

OUR SAMPLE

6 BYr

FIRST GALAXIES

1 BYr

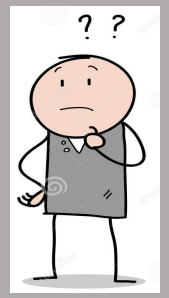
FIRST STARS

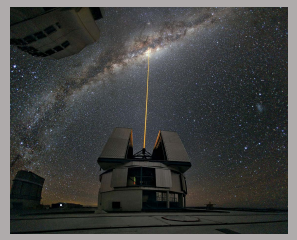
400 MYr

BIG BANG

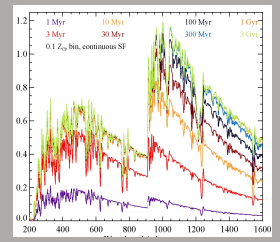
Time = 0

Curious Human + Telescope + Supercomputer + Models

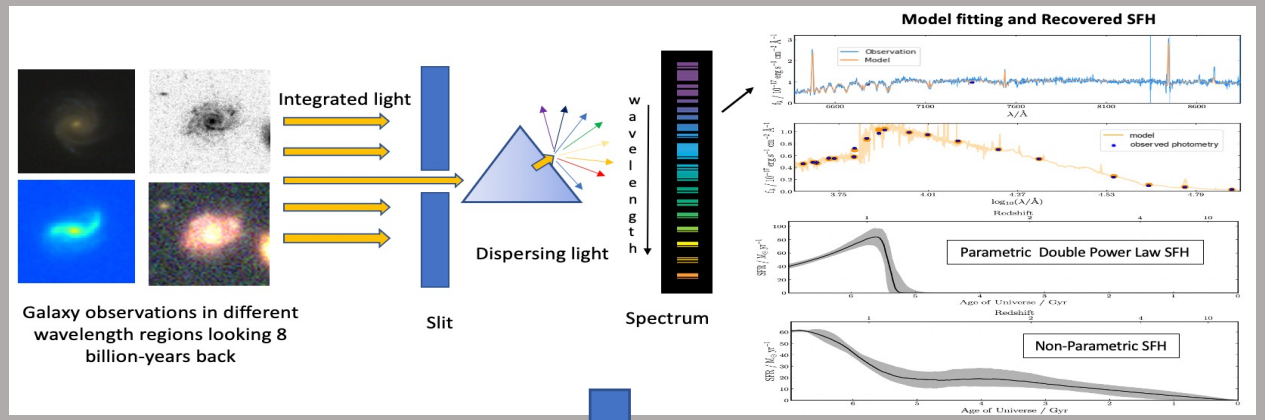




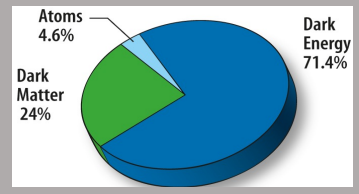
Pitt CRC



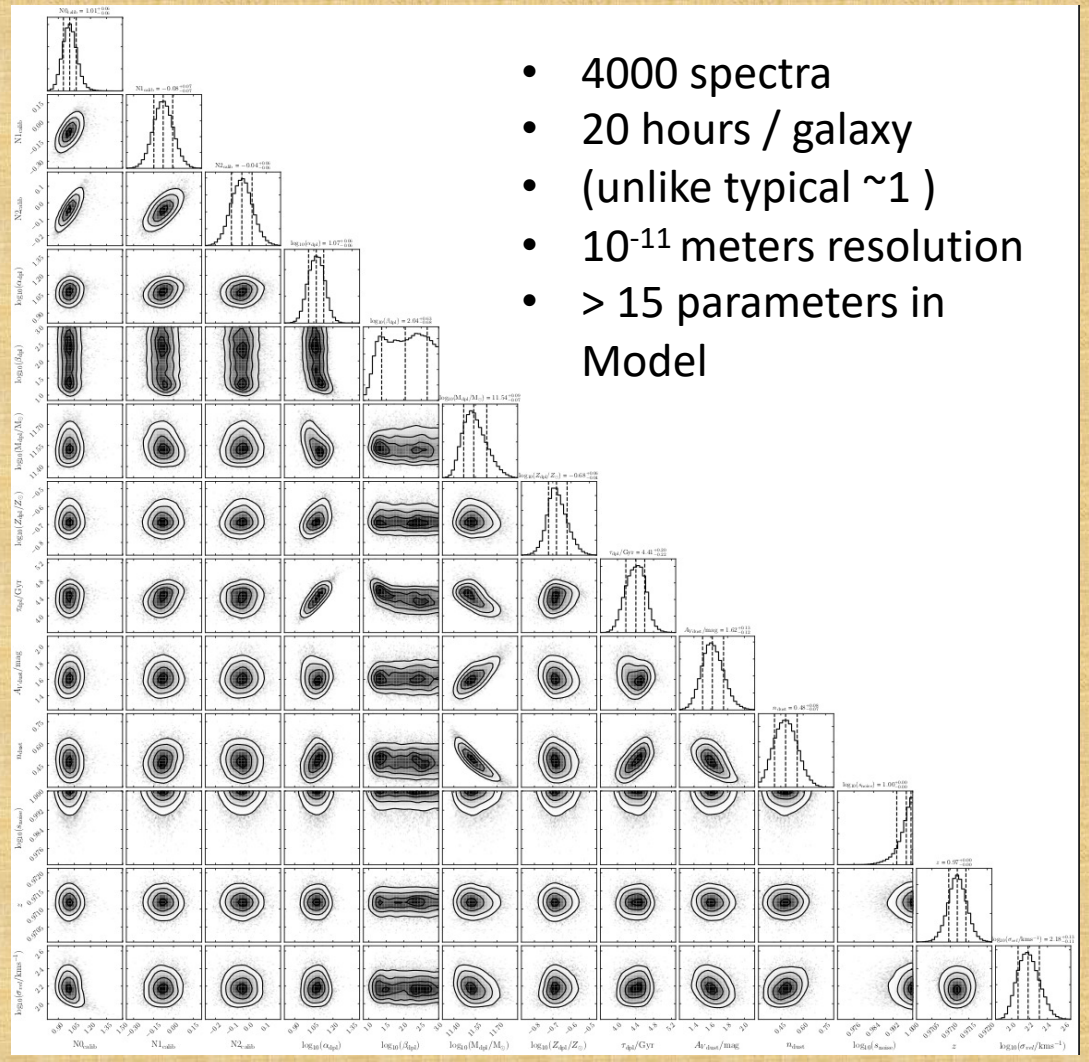
Recovering PAST (t=0 to t=6 BYr) activities from the spectrum



- How galaxies form and evolve?
- What is their chemical composition? (Carbon, Oxygen required for life!)
- Why and how they *suddenly* stop forming stars?
- How their age, mass, star-formation rate, gas + dust content relate to their environment and nuclear activity?
- Connecting the known to the UNKNOWN !!



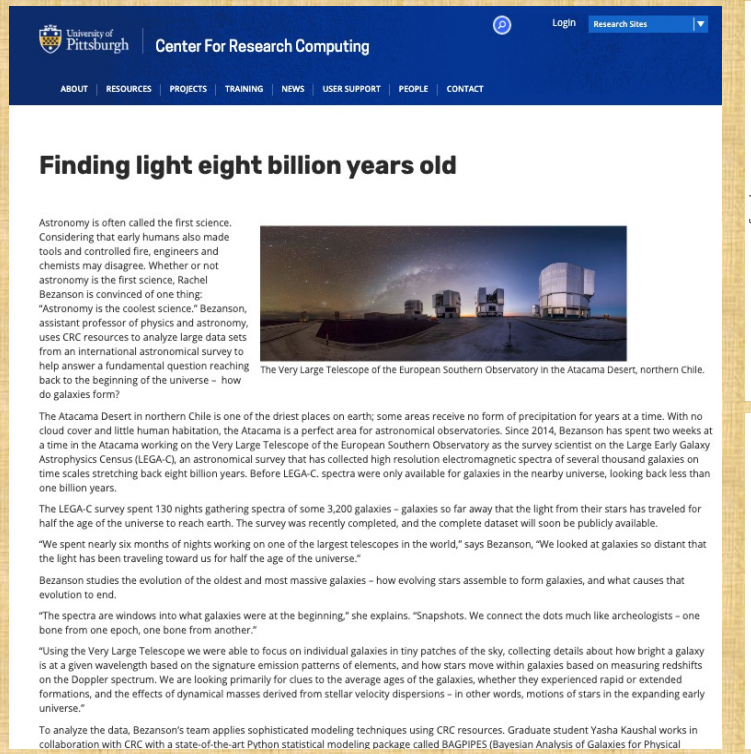
Challenges: Rich Data and Computational Resources



- 4000 spectra
- 20 hours / galaxy
- (unlike typical ~1)
- 10^{-11} meters resolution
- > 15 parameters in Model

Corner Plot Analysis for 1 Object using *BAGPIPES* tool

https://crc.pitt.edu/Finding-Light-Eight-Billion-Years-Old/



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Finding light eight billion years old

Astronomy is often called the first science. Considering that early humans also made tools and controlled fire, engineers and chemists may disagree. Whether or not astronomy is the first science, Rachel Bezanson is convinced of one thing: "Astronomy is the coolest science." Bezanson, assistant professor of physics and astronomy, uses CRC resources to analyze large data sets from an international astronomical survey to help answer a fundamental question reaching back to the beginning of the universe – how do galaxies form?

The Very Large Telescope of the European Southern Observatory in the Atacama Desert, northern Chile.

The Atacama Desert in northern Chile is one of the driest places on earth; some areas receive no form of precipitation for years at a time. With no cloud cover and little human habitation, the Atacama is a perfect area for astronomical observatories. Since 2014, Bezanson has spent two weeks at a time in the Atacama working on the Very Large Telescope of the European Southern Observatory as the survey scientist on the Large Early Galaxy Astrophysics Census (LEGA-C), an astronomical survey that has collected high resolution electromagnetic spectra of several thousand galaxies on time scales stretching back eight billion years. Before LEGA-C, spectra were only available for galaxies in the nearby universe, looking back less than one billion years.

The LEGA-C survey spent 130 nights gathering spectra of some 3,200 galaxies – galaxies so far away that the light from their stars has traveled for half the age of the universe to reach earth. The survey was recently completed, and the complete dataset will soon be publicly available.

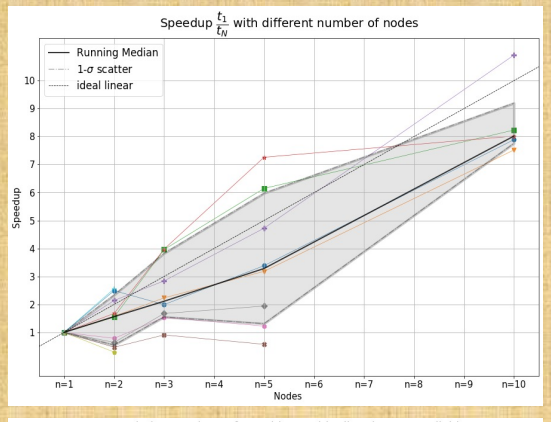
"We spent nearly six months of nights working on one of the largest telescopes in the world," says Bezanson, "We looked at galaxies so distant that the light has been traveling toward us for half the age of the universe."

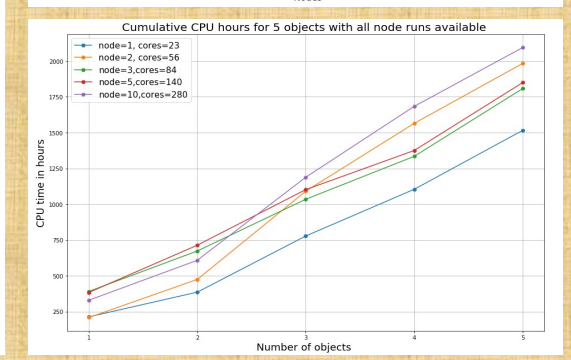
Bezanson studies the evolution of the oldest and most massive galaxies – how evolving stars assemble to form galaxies, and what causes that evolution to end.

"The spectra are windows into what galaxies were at the beginning," she explains. "Snapshots. We connect the dots much like archeologists – one bone from one epoch, one bone from another."

"Using the Very Large Telescope we were able to focus on individual galaxies in tiny patches of the sky, collecting details about how bright a galaxy is at a given wavelength based on the signature emission patterns of elements, and how stars move within galaxies based on measuring redshifts on the Doppler spectrum. We are looking primarily for clues to the average ages of the galaxies, whether they experienced rapid or extended formations, and the effects of dynamical masses derived from stellar velocity dispersions – in other words, motions of stars in the expanding early universe."

To analyze the data, Bezanson's team applies sophisticated modeling techniques using CRC resources. Graduate student Yasha Kaushal works in collaboration with CRC with a state-of-the-art Python statistical modeling package called BAGPIPES (Bayesian Analysis of Galaxies for Physical

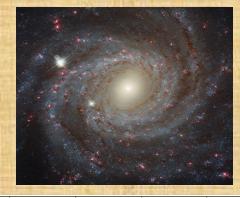


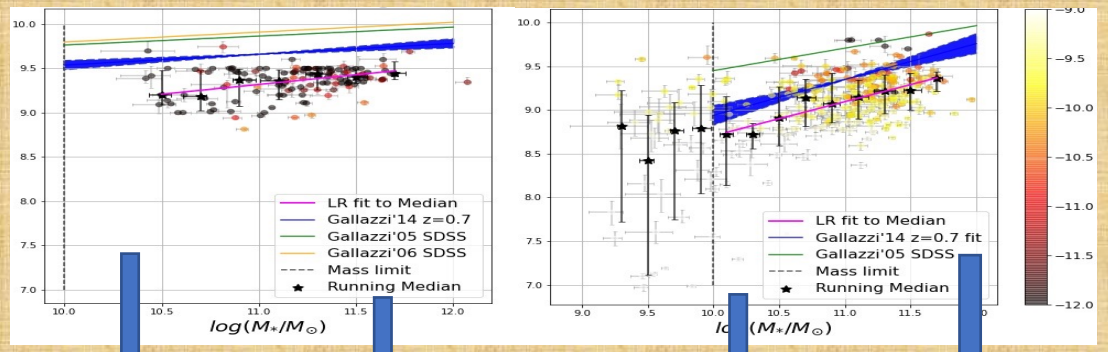


- ~450 CPU hours/galaxy/ SFH required
- Proposal approved for **3.5 million CPU hours**
- Efficient parallelization: 14 nodes (392 cores) can be used simultaneously with close to ideal Speedup.
- ~ **1 month** to fit full data-set

Initial Results and Future Work

- At any epoch of time, less-massive galaxies have younger stellar populations than their massive counterparts.
- More heavy metal enrichment (C, O, N, Fe etc.) for massive galaxies than less massive ones.
- Use more sophisticated tool (*Prospector*) this summer.
- Extend the analysis to 3-5 Billion years old Universe.
- Future surveys like JWST/DESI will give sample of > 10 million galaxies

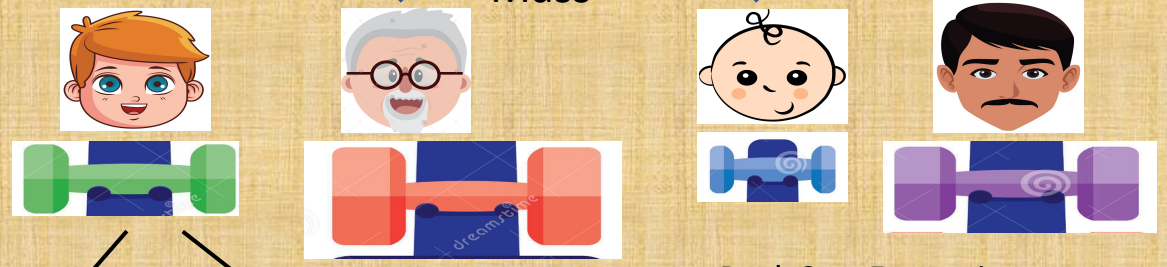




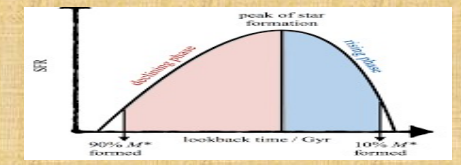
Age

SFR

Mass



Peak Star Formation Of Universe



8 BYr ago

Today

Star formation in rings **??**