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Seeking the earliest galaxies with cosmic telescopes

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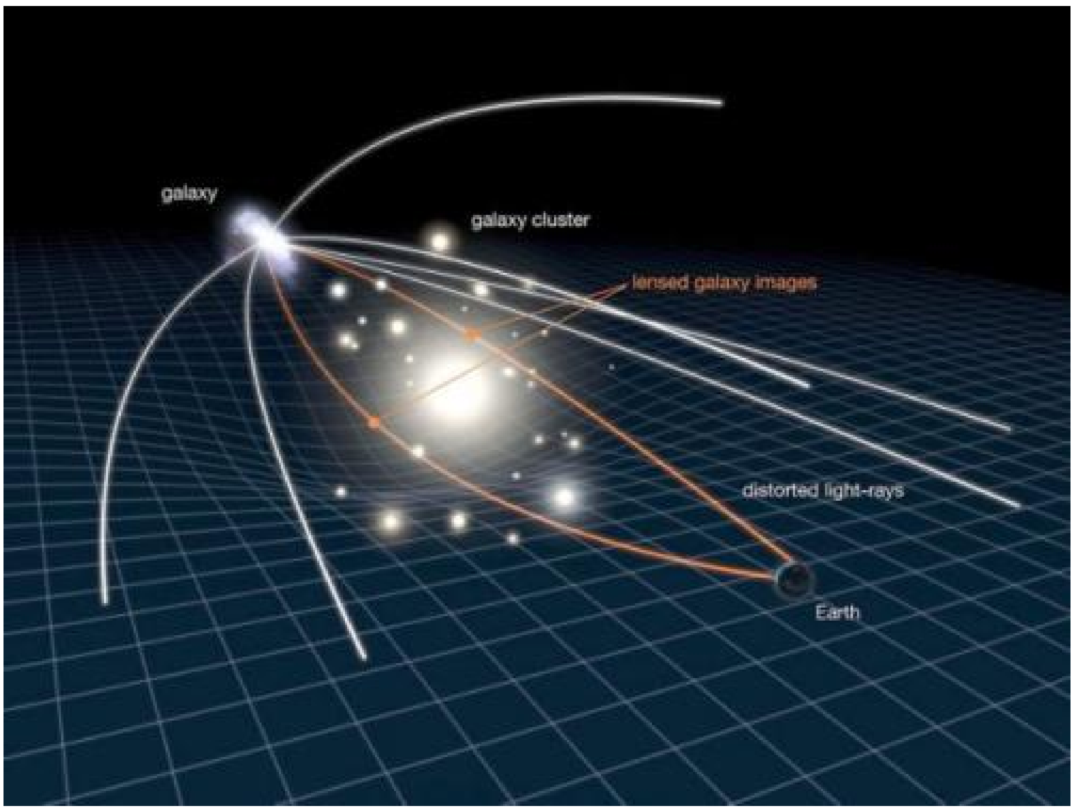


Massive objects in space cause space and light to bend around them, effectively magnifying light from background objects and enabling astronomers to view objects farther away in space and time than with any manmade telescope. Credit: NASA

(Phys.org)—With a recent NSF award, UA scientists will use galaxy clusters as astronomical lenses to peer farther into the depths of space than any manmade telescope is capable of viewing - to the time when the universe's earliest stars and galaxies still were forming from the gravitational collapse of gas and dark matter.

The University of Arizona is renowned for making some of the world's largest and most precise optics for some of the world's greatest telescopes. Now, UA scientists are making use of lenses that defy human ability to build: They are made up of clusters of galaxies and dark matter.

With a $600,000 grant from the National Science Foundation, UA professor of astronomy Ann Zabludoff and her team at Steward Observatory, including graduate students Ken Wong and Decker French, along with Mark Ammons at Lawrence Livermore National Laboratory and co-principal investigator Charles Keeton at Rutgers University, are working to find and analyze these cosmic lenses.

By magnifying objects even farther way in space, these natural cosmic lenses may enable astronomers to see farther back in time than possible with any manmade telescope, to the time of the formation of the universe's very first stars and galaxies.

"We're talking about stuff back to literally the dawn of time," Zabludoff said. "Twelve billion years ago closing in on 13 billion years ago."

For years, astronomers have been trying to detect the very first stars and galaxies that formed after the Big Bang, Zabludoff said, to see how the stars and galaxies built up a mass of subatomic particles called baryons over time.

"Baryons are the stuff of which we and the things in our experience are made," said Zabludoff. Protons and neutrons, which make up the nuclei of atoms, are baryons. Effectively, all visible matter is made up of baryons and electrons.

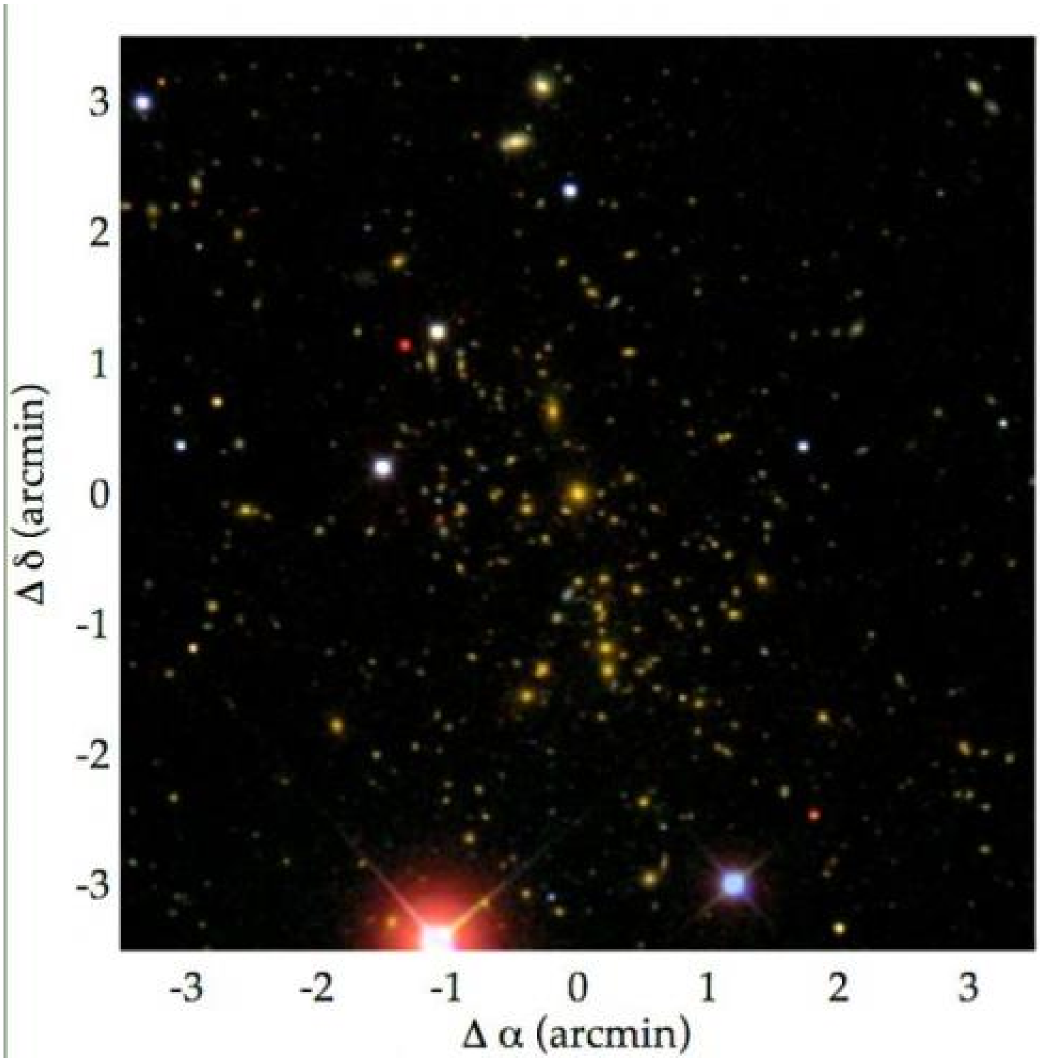
"What we do know about the gas distribution in the early universe is that it looks like this wonderful web, almost a spider web of gas," Zabludoff said. "It's natural to imagine that the galaxies form in the interstitial regions of these filaments and the baryons, including the gas, that we see fall into the galaxy."

"The big sticking point is that these galaxies are very faint because they're so distant," she said: The most powerful, cutting-edge telescopes on the planet may never be able to detect them.

Even after efforts to use Hubble Space Telescope to detect the earliest galaxies, "there has been one possibly correct detection," Zabludoff said. "It was a heroic effort, but you don't learn a whole lot from just one object."

To view the earliest stars and galaxies, astronomers use a method pioneered by Swiss astronomer Fritz Zwicky, based on Einstein's theory of general relativity and the fact that mass in space bends space around itself, therefore also bending light.

"If you imagine a background source emitting light in all directions, and if there were nothing that was bending space, then some very small fraction of its light rays would align with our position and we wouldn't detect much of its overall emitted light. Therefore it would appear very faint to us," Zabludoff said.



UA scientists use galaxies (fuzzy orange sources in this image) to identify regions in space where mass is clustered. Massive objects in space can be used as gravitational lenses to magnify light from objects in the background, even farther in deep space. Credit: Sloan Digital Sky Survey

However, she added, "if there is some massive object in the foreground, bending space and therefore light around it, some of the light rays from the background object still come through, and, in addition, some of the light rays that would normally have shot out in other directions are now bent around toward us and we get more light. You have effectively a magnification of the background object."

This is what astronomers call a gravitational lens: A lensing effect produced as light is bent by the gravity of a massive object in space.

"People have been seeing evidence of these gravitational lensing effects for years now," said Zabludoff. "There are beautiful images where it's very clear that light from galaxies in the background to some big cluster of galaxies in the foreground is being stretched and magnified."

Astronomers have explored this method to detect previously inaccessible distant galaxies, Zabludoff said, because by magnifying the light of distant galaxies there is a better chance of detecting more than one.

"But you don't get this for free," she added. "And the tradeoff is the following: You can magnify the light of the background galaxy and make it more detectable, but when you magnify the distant universe, you end up seeing a much smaller piece of it. By magnifying you're zooming in, and as a consequence your chances of having a galaxy in that precise location go down."

Yet there may still be a chance to use gravitational lenses to magnify a region of space and at the same time magnify a large area, Zabludoff said.

"There could be directions in the sky where a gravitational lens or multiple lenses line up in such a way that you get the benefits of the magnification, but you also get a much larger area surveyed of the distant universe," she said.

"Galaxies cluster gravitationally, and there are directions in the sky where you can find the mass is stacked up along the line of sight, so not just one big cluster of galaxies, but possibly two or three or four."

Just as with optical lenses, two or more gravitational lenses along a line of sight could interact in such a way that the size of the magnified region is larger than it would be with just one lens, said Zabludoff.

"There may be some sweet spots,'" she said.

But if so, they are probably rare. "In general, massive systems are very rare, and the chances of having them lined up is rarer still."

"But it's a big sky," Zabludoff said. Undaunted, the team looked through archival data from past sky surveys to find locations where massive galaxy clusters lined up in such a way as to create the ideal gravitational lensing effects.

"We put together a theoretical program to ask: If I have a bunch of mass in a particular direction, how do I need to distribute that mass along the line of sight to get the maximum benefit? We calculated what those ideal gravitational lens telescopes would look like, and we used that information as a filter," Zabludoff said.

The team matched real data from past sky surveys with their modeled scenarios and selected 200 spots to search in the sky. Zabludoff's team has begun surveying 10 of its selected 'sweet spots' using the Giant Magellan Telescope in Chile and the Multiple Mirror Telescope in Arizona.

"We've started looking at a few already, and they've turned out to be pretty spectacular," said Zabludoff. "The magnified area is turning out to be a lot bigger than what scientists see using traditional single-cluster lensing studies."

"This allocation of NSF resources was given to us to both further develop the theory of how these beams work, and also to survey them so that we can characterize how the mass is distributed and make very specific predictions about how the magnification will vary over the sky in that direction," Zabludoff said.

"We need to know the magnification over the sky in each selected region very well because if we do detect something in the background, we need to know how much it's been magnified to know anything about its intrinsic properties."

"And then comes the payoff," she said. "We go out and try to find magnified distant galaxies in these fields."

It may be a few years before astronomers reach the point of being able to view gas and stars enter an early galaxy for the first time, but with the aid of gravitational lenses, it is most likely possible eventually to observe the formation of the universe's first stars and galaxies out of the blackness of distant space.

Provided by University of Arizona