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THE BOUNTY OF "EMPTY" SPACE

Deep-field images uncover more of the universe than we ever thought possible

By Fabio Pacucci

THIS PAST JULY ASTRONOMERS WORKING WITH THE JAMES WEBB SPACE TELESCOPE (JWST) released the deepest astronomical image ever obtained, leaving the world in awe. Against the background of a galaxy cluster named SMACS 0723, seen as it appeared 4.6 billion years ago, myriad galaxies of different shapes and sizes appear like bright gems in the darkness of the cosmos. Some of these lighthouses were already shining when the universe was just a few hundred million years old. To understand how we reached this remarkable achievement—how astronomers have sailed to galactic islands so remote from us in space and time, collecting photons whose journey started breathtakingly close to the big bang—it helps to know how deep-field observations came to be.

The origin of Webb's first deep field is best traced to the early 1990s, with the launch of JWST's predecessor, the Hubble Space Telescope. The concept of deep-field observations was still in its infancy back then. Hubble was primarily designed for targeted observations. Astronomers would point the telescope to a source at a specific spot in the sky and expose (or "integrate") as needed, depending on the source's brightness. But Hubble could also be used for deep-field imaging, which is the opposite: astronomers would point the telescope to a sky region devoid of any visible source and use a very long exposure time to observe as many faint sources of light as possible, thereby reaching "deep" into the cosmos. From its perch in low-Earth orbit, above our planet's starlight-scattering atmosphere, Hubble was the best platform for deep-field imaging astronomers had ever known.

Not everyone thought the approach would prove revolutionary. In a famous article published in *Science* in 1990, John Bahcall of the Institute for Advanced Study in Princeton, N.J., and his colleagues argued that a deep-field image from Hubble would not reveal significantly more galaxies than ground telescopes. Bahcall, a giant in astrophysics, was widely known for his work on the problem of solar neutrinos and his calculations of the distribution of stars around a massive black hole. He contributed fundamentally to the development of the Hubble Space Telescope from its original concept in the 1970s to its launch. Bahcall thought Hubble deep-field images could be used to study the sizes and shapes of faint galaxies and to take a census of quasars (a rather old-fashioned word for accreting supermassive black holes), but he didn't believe they would reveal new populations