JWST's Canadian instrument delivers, says CANUCS Team!

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Halifax, NS — On July 11, 2022, the entire world got to see the very first image taken by the James Webb Space Telescope (JWST). It was an image now called Webb's Deep Field of Galaxies, centred on a cluster of galaxies named SMACS 0723 and containing no less than 7000 galaxies! This image has proven to be an important target for the study of galaxy evolution as it contains a large number of very distant galaxies which shed light on how galaxies formed and evolved in the early Universe. However, until now, there has been a lack of accurate and comprehensive distance measurements to galaxies in this field.

Thanks to Canada's contribution to the Webb mission, this has now changed! A team of Canadian and international astronomers, led by Dr. Gaël Noirot, a postdoctoral researcher at Saint Mary's University in Halifax, has now carefully inspected and analyzed the large Webb Deep Field of Galaxies. More specifically, the astronomers, who are all members of the aptly named CANUCS program (for Canadian NIRISS Unbiased Cluster Survey), used the Canadian NIRISS (for Near Infra-Red Imager and Slitless Spectrograph) instrument on board the JWST to collect spectra from galaxy targets in the image. These spectra are a type of scientific data created by breaking down the light of an object to reveal additional information such as the object's age or distance.

Using JWST's made-in-Canada NIRISS instrument, the team has now measured the *redshifts* of nearly 200 galaxies whose distances from Earth were previously unknown. "NIRISS is perfect for doing this because it can measure the redshifts of hundreds of galaxies at once," said Dr. Noirot who is lead author of the study published this month in the *Monthly Notices of the Royal Astronomical Society*.

'Redshift' is a precise measurement of a galaxy's distance based on the unique chemical signatures seen in its spectra. Because the Universe is expanding, the light emitted from distant objects such as galaxies is being stretched, and their spectral features are seen at longer (i.e., redder) wavelengths than originally emitted (Figure 1). This redshift, which is the difference between an object's observed and emitted colour, tells us about its distance from us. "Our work on SMACS 0723, Webb's First Deep Field of Galaxies and first science image ever released by JWST, has produced the largest JWST spectroscopic catalogue of its kind with reliable redshift measurements" explains Dr. Marcin Sawicki, who is Professor and Canada Research Chair at Saint Mary's University and co-author of the study. "Our recently-published study will be a valuable resource for the astronomical community and open up new avenues of research in JWST's first Deep Field of Galaxies" adds Dr. Noirot.

From this redshift catalogue, the researchers have uncovered many new galaxies which are members of the SMACS 0723 cluster whose light has taken more than 4 billion years to reach us. Clusters, which are huge groups of galaxies held together by the force of gravity, can contain up to thousands of galaxies. Their study helps us understand galaxy evolution in some of the most extreme environments in the Universe, and allows us to peer into the distribution of dark matter and the evolution of structures.

"As a Canadian-led project, we are even more excited that this significant improvement, compared to previous studies of SMACS 0723, was enabled by the spectroscopic capabilities of the Canadian-made instrument NIRISS on board JWST," says Dr. Chris Willott of the National Research Council of Canada (NRC) and lead of the Canadian Space Agency-funded CANUCS team. "This Canada-made technology is letting us use JWST to its fullest potential" elaborates

Dr. René Doyon, Director of the Trottier Institute for Research on Exoplanets and Professor at the Université de Montréal as well as the Principal Investigator behind the NIRISS instrument. NIRISS was funded by the Canadian Space Agency and designed, built and tested by Honeywell Aerospace in Cambridge and Ottawa, with contributions of key optical components from the Université de Montréal.

Within their huge collection of galaxy redshifts, the researchers identified three other galaxy overdensities at much greater distances than SMACS 0723 and which had not been seen previously in this field (Figure 2). These galaxy overdensities are potentially newly discovered galaxy clusters located 8 to 10 billion light years away. Capturing these galaxy overdensities at different cosmic times is like watching a time-lapse movie of these clusters' growth, from their infancy in a young Universe to the present day. These clusters represent ideal targets for future studies to better understand how galaxies and the clusters they inhabit have evolved from their state in the very early Universe into what they look like today, including our own galaxy the Milky Way.

While astronomers wait for these future studies, one thing the CANUCS team has already discovered is the magnificent "Sparkler" galaxy within one of these galaxy clusters. The Sparkler is a highly magnified galaxy, some 9 billion light years away, that is bursting with what appears to be the oldest star clusters to have formed after the Big Bang. The Sparkler galaxy captured the public's imagination around the globe when it was first discovered by the CANUCS team in September 2022. What the team's new NIRISS redshift catalogue has now revealed is that The Sparkler is not an isolated galaxy, but that it resides in one of the newly-discovered galaxy overdensities. "The fact that The Sparkler does not live alone but is a member of a family of galaxies has important implications for how first star clusters formed after the Big Bang" explains Dr. Sawicki, who was also a co-author of that earlier study.

The team of astronomers will have the chance to improve upon their galaxy redshift catalogue during Webb's second year of scientific operations which is currently underway, as they have received time to re-observe the Webb Deep Field of Galaxies in even greater detail with the NIRISS instrument. "The astronomy community clearly recognised the value of our first NIRISS redshift catalogue and wants us to do another, even better version in JWST's first deep field," says Dr. Noirot, who is also the Principal Investigator of this observing program.

The team reports that their catalogue and the results of their study has already enabled further work in JWST's first deep field by several independent teams, and will support additional research into the formation of galaxies, the distribution of dark matter, and the evolution of the Universe.

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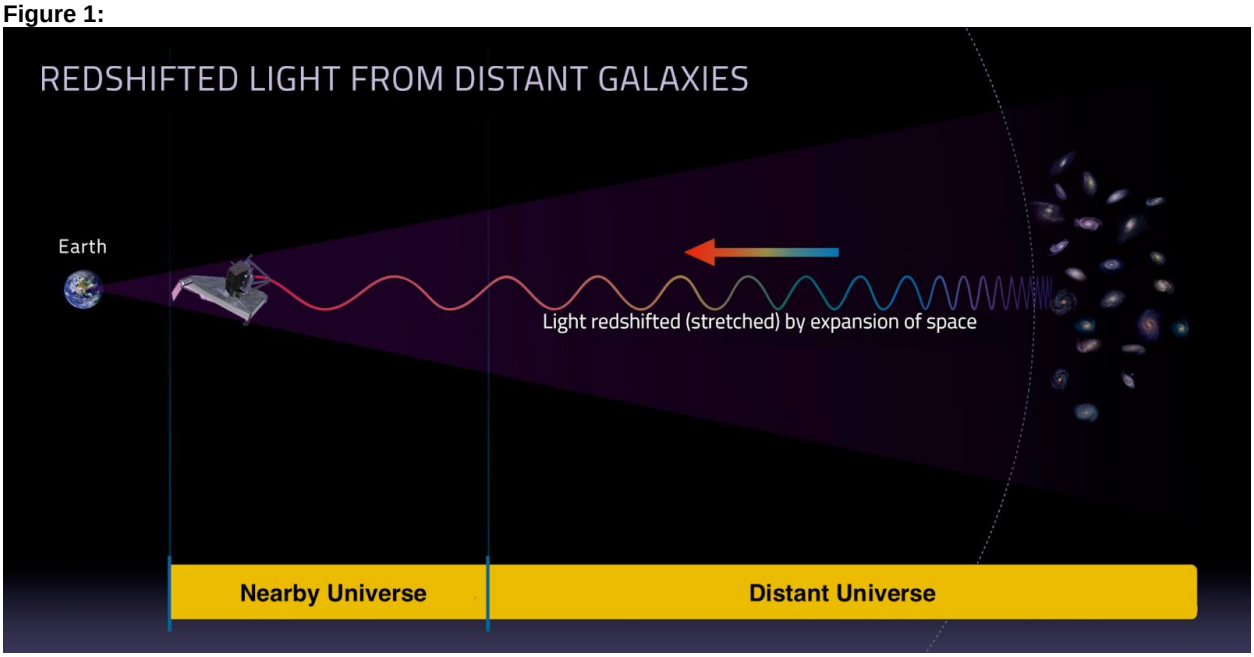
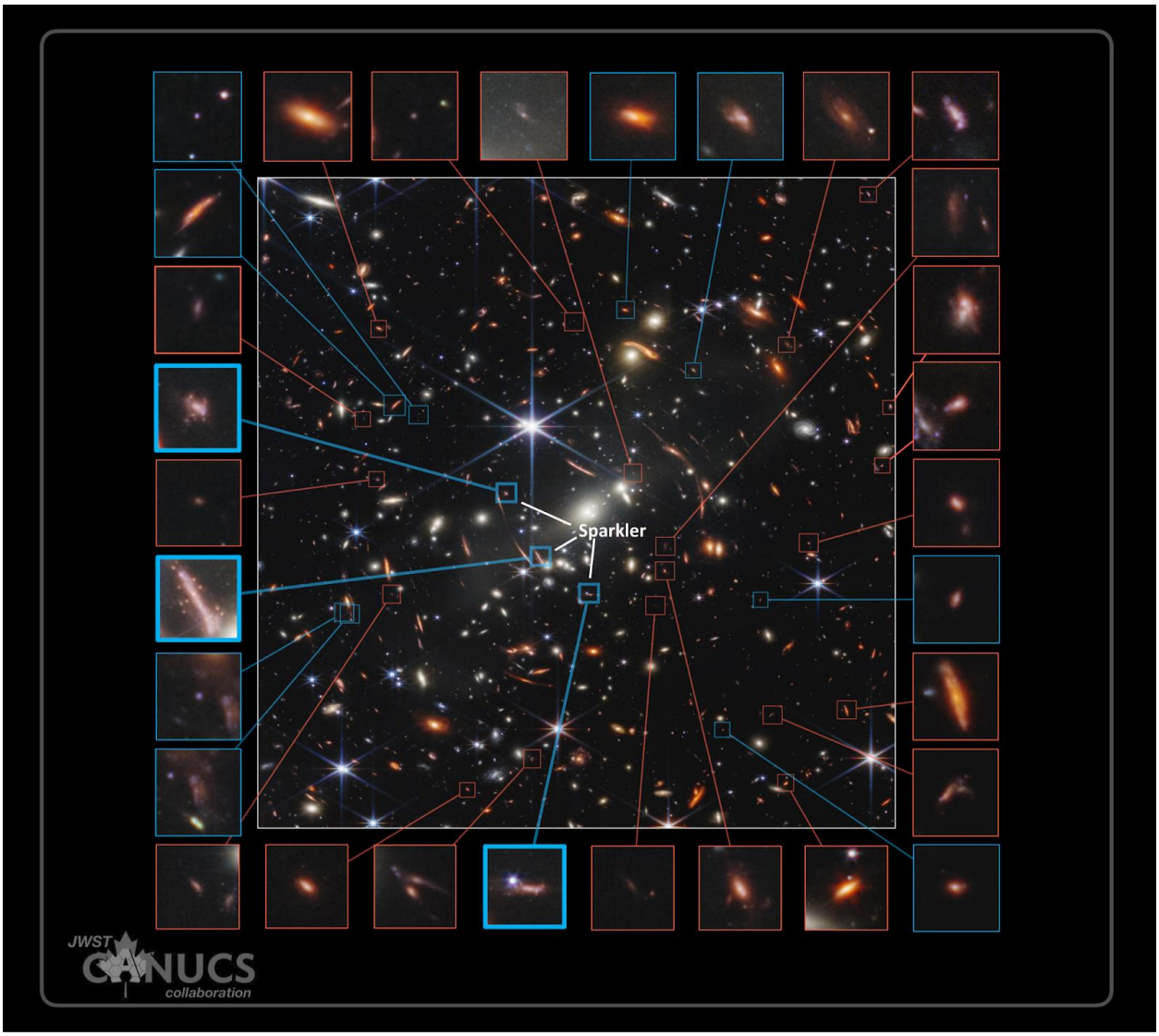
Images:

Figure 1:



Caption: This image shows the principle of cosmological *redshift*. As shown, the light from distant galaxies is being stretched into longer wavelengths as it travels through our expanding Universe. When observed with a telescope like JWST, this makes the light of those galaxies appear redder than originally emitted, as longer wavelengths correspond to redder colours.
Original, non-edited image (CSA/STScI): https://www.asc-csa.gc.ca/eng/multimedia/search/image/15614

Figure 2: Caption: This image shows the Webb Deep Field of Galaxies, the very first unveiled science image by JWST. Galaxies that are part of the cluster of galaxies SMACS 0723 appear predominantly white in this image. Galaxies appearing redder and/or elongated are distant galaxies located behind SMACS 0723. Among those, the ones highlighted in blue are part of one of the newly discovered galaxy overdensities published in the new redshift catalogue. “The Sparkler” is a galaxy imaged three times due to an effect called gravitational lensing and whose light has been magnified and distorted. Thanks to this effect, the CANUCS researchers had discovered last year that this galaxy hosts numerous bright “sparkles” which are potentially some of the oldest star clusters ever observed (see more info at https://www.utoronto.ca/news/researchers-reveal-galaxy-sparkling-universe-s-oldest-star-clusters). Galaxies highlighted in red are potential members of the same newly-discovered cluster of galaxies that contains The Sparkler. The researchers will follow-up on The Sparkler and its family of galaxies with new JWST observations they will obtain in this field.
Credits: NASA, ESA, CSA, STScI. Post-stamps: Shannon MacFarland (SMU).



Link to published paper: https://academic.oup.com/mnras/article-abstract/525/2/1867/7115326
Link to preprint version of the paper: https://arxiv.org/abs/2212.07366
Link to The Sparkler press release: https://www.utoronto.ca/news/researchers-reveal-galaxy-sparkling-universe-s-oldest-star-clusters