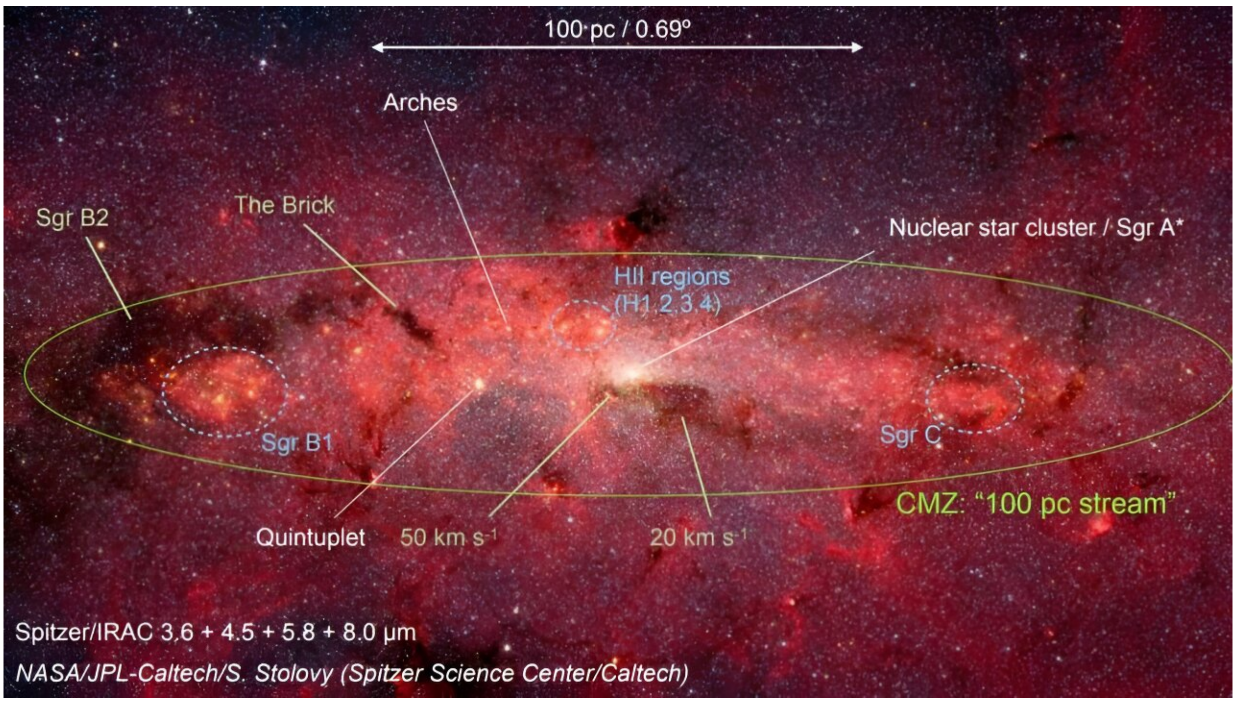
Astronomers want JWST to study the Milky Way core for hundreds of hours

October 26 2023, by Evan Gough



This overview of the Milky Way's galactic center (GC) shows the region of the proposed JWST survey. Credit: NASA/JPL-Caltech/S. Stolovy (Spitzer Science Center/Caltech)

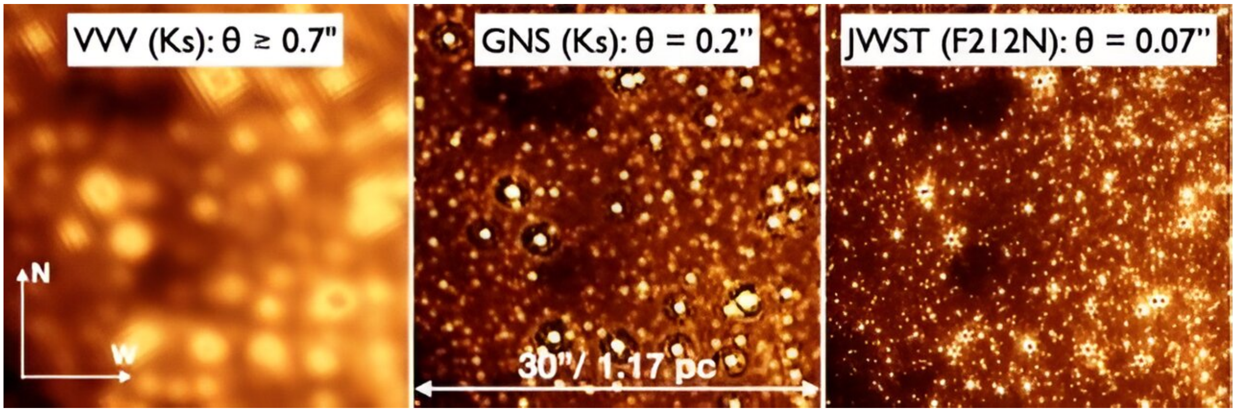
To understand the universe, we need to understand the extreme processes that shape it and drive its evolution. Things like supermassive black holes (SMBHs,) supernovae, massive reservoirs of dense gas, and crowds of stars both on and off the main sequence. Fortunately there's a place where these objects dwell in close proximity to one another: the Milky Way's galactic center (GC.)

Astronomers know this, and they've studied the GC intensely. There are many unanswered questions in astronomy and astrophysics, and some of the answers are hidden in the densely-packed GC. But while its densely-packed nature make it an area practically begging to be studied, it also makes it difficult to study. Only the most powerful telescopes have the angular resolution to make sense of the Milky Way's central region and its crowded constituents.

Fortunately, the James Webb Space Telescope has the angular resolution to make sense of the region. A new white paper lays out the case for a multi-epoch, large-area, multi-wavelength survey of the Milky Way's inner 100 parsecs.

The paper, published on the *arXiv* preprint server, is titled "The JWST Galactic Center Survey: A White Paper." More than a hundred participants from more than 80 institutions around the world are listed authors, with Rainer Schodel from the Instituto de Astrofisica de Andalucia (CSIC), Granada, Spain listed as first author.

"JWST has the unique capability to provide us with the necessary, game-changing data," the authors write. "As a community, we have identified the key unknowns that are limiting the potential of the galactic center as a laboratory for extreme astrophysics and understanding how galactic nuclei shape the galaxy population."



These images from the white paper show how the JWST's high angular resolution can help scientists figure out what's going on in the GC. The left image was captured with the the ESO's Vista Telescope in 2010. The middle image was captured in 2019 with the ESO's VLT, and the image on the right is from the JWST. Credit: L: Minniti et al. 2010; M: Nogueras-Lara et al. 2019; R: JWS Proposal 1939, PI J. Lu.

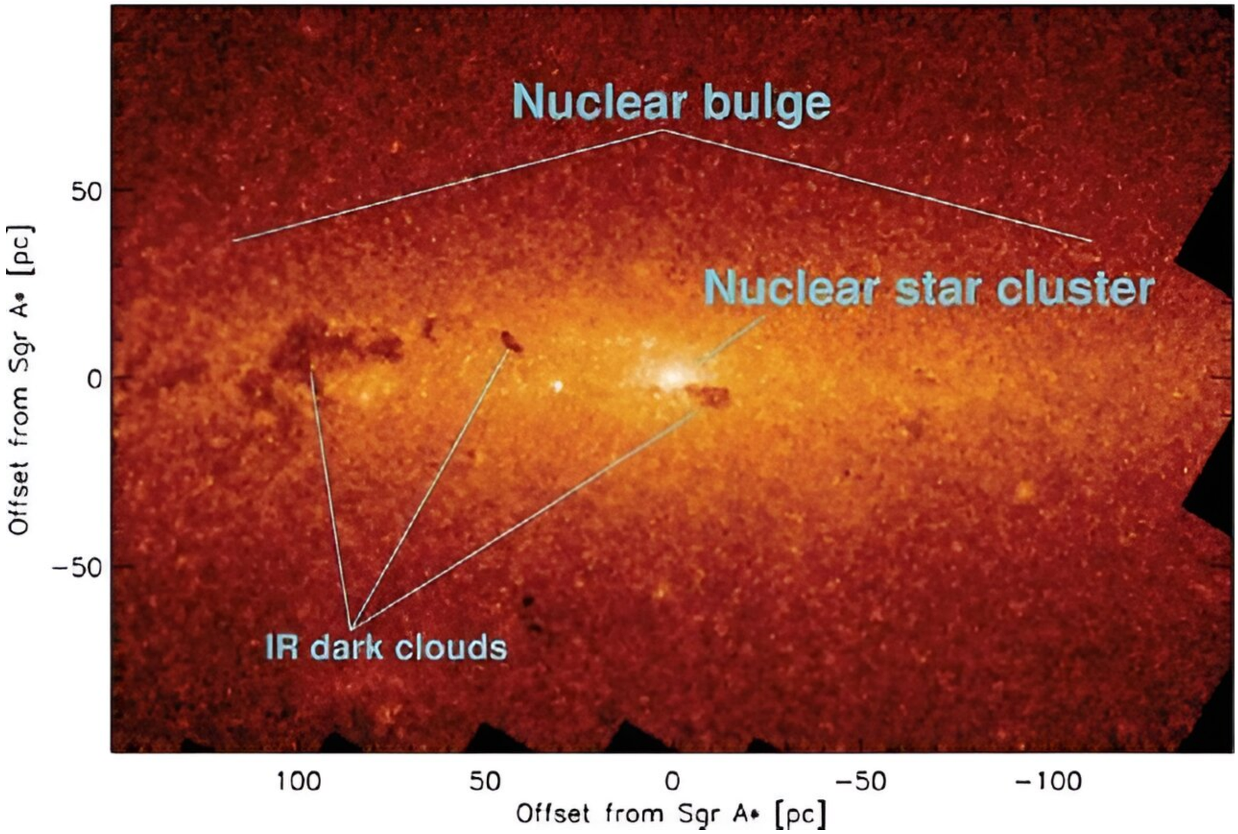
What are the unknowns in this turbulent region? Sgr. A*, the SMBH at the heart of it all, draws matter inexorably towards itself, shredding stars that get too close and creating an enormous swirling mass of gas and dust. Vast gas clouds are caught up in it all, and out of these clouds, stars in their multitudes are born and then extinguished, many as ultra-powerful supernovae. The Milky Way's nuclear star cluster is there, too, and is many times more massive than Sgr. A*, an anomaly in galaxies. And then there's the nuclear bulge, where old, comparatively metal-rich stars congregate.

This survey, if it takes place, will help astrophysicists untangle some of nature's most perplexing, stubborn questions. In their white paper, the multi-national team of astronomers lays out five key questions that the JWST can help address in an observing campaign focused on the GC:

1. What is the formation history of the galactic center and its relation to the overall formation history of the Milky Way?
2. How much stellar mass formed in the past ~30 Myr and what does this imply for the overall energetics of the GC?
3. What is the origin of, and environmental variation in, the stellar initial mass function?
4. Why is the star formation rate one to two orders of magnitude lower than predicted by standard star-formation-dense-gas relations?
5. What is the 3D structure of the interstellar medium (ISM) orbiting and fueling accretion and star formation at the galactic center?

This is an ambitious list of questions that helps define the current state of astronomy and astrophysics. Perhaps the only things not mentioned are dark matter and dark energy, and those two phenomena are outside of the JWST's primary focus.

Success depends on being able to resolve more detail than previous studies of the region. "By being able to resolve physical processes down to size scales separating individual stars, the survey will provide a foundation for addressing key open questions in other fields," the authors write. The GC is an extreme environment, and is often the case in science, understanding the extremes helps us understand nature's boundaries.



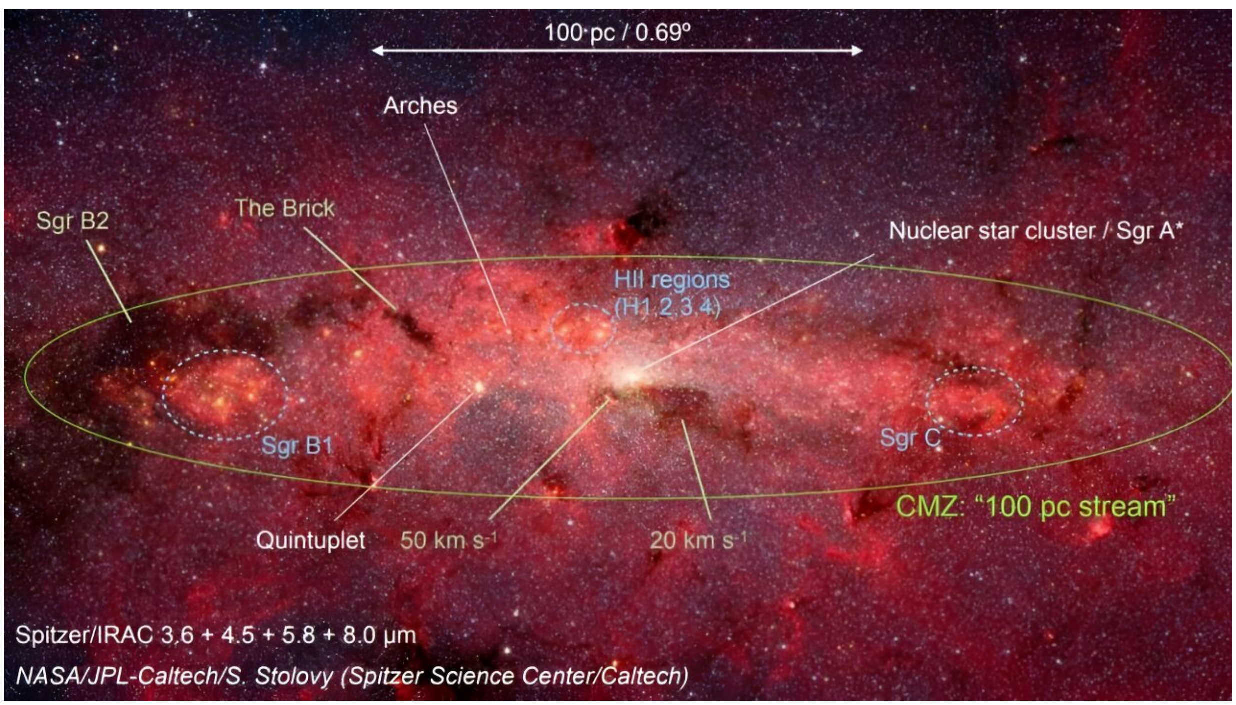
This image shows the Milky Way's nuclear bulge and its nuclear star cluster (NSC.) The Milky Way is one of the few instances where evidence shows an NSC in a galaxy that also has an SMBH. Credit: Schoedel et al. 2008

"What drives the mass flows and energy cycles in extragalactic nuclei and high-z environments?" the authors ask. "What shapes star formation and the evolution of nuclear star clusters, nuclear stellar discs and their interaction with central black holes?" These are all compelling questions.

The proposed survey is designed to address them. As a multi-epoch survey, it would examine the GC in three separate epochs separated by 1, 5, and 10 years. It would observe the nuclear stellar disk and associated [giant molecular clouds](#) (GMCs) in the central molecular zone (CMZ,) a region containing about 60 million solar masses of star-forming gas. To see inside the region accurately, the survey would utilize the JWST's NIRCam and its system of filters.

One telescope can't reveal everything, and the JWST won't be alone in this survey. Success will rely on synergy with other telescopes. ALMA and the Hubble Space Telescope will be part of this observational coalition, as will future telescopes like the Roman Space Telescope, the ESO's Extremely Large Telescope, and Japan's JASMINE infrared astrometry mission.

"Together these surveys herald a revolution in the interpretation of current/future data, bring together research in different sub-fields, and answer key open science questions with enormous legacy potential," Schodel and his colleagues write.



This image shows the Milky Way's GC region and some of the objects of interest, including the nuclear star cluster and associated giant molecular clouds in the central molecular zone. Image Credit: Schodel et al. 2023

One of the questions the survey hopes to address is particularly fundamental in astrophysics: the Initial Mass Function (IMF.) The IMF describes how mass is distributed during star formation in a giant cloud of gas. The IMF is like an agglomeration of smaller sub-functions in star formation, and it also links individual star formation to larger issues of galaxy formation and evolution. "Thus, understanding the properties of the IMF and how it behaves in different environments has far-reaching implications for star formation theory and beyond," the paper states.

The Milky Way's galactic center is the only GC we can observe, and it's been a tricky target. But the JWST has the power to probe this tumultuous astrophysical maelstrom more deeply than ever before. Along with the SMBH, the NSC, and gas clouds, there are other mysteries. The GC contains hundreds of mysterious magnetized radio filaments that are so far unexplained. Then there are the questions around stellar feedback and how it interacts with the Interstellar Medium (ISM) and how black hole feedback plays into it all.

If this survey takes place, it'll provide answers that shift the horizon of our knowledge, and also highlight new questions. This survey will far surpass other GC surveys and observations. The authors claim that they can discern the proper motion for more than 10 million stars in the GC. "Such revolutionary data would enable exploring the GC kinematically down to almost solar mass main sequence stars," the authors write, and that would be an enormous contribution.

As always, there will be surprises, and those surprises will almost certainly spread to scientific topics beyond the study of the GC. "The project proposed in this White Paper has implications for the entire GC community—and beyond," the authors write.

More information: Rainer Schoedel et al, The JWST Galactic Center Survey—A White Paper, *arXiv* (2023). DOI: 10.48550/arxiv.2310.11912

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