

CIELO: LCO IN SPACE

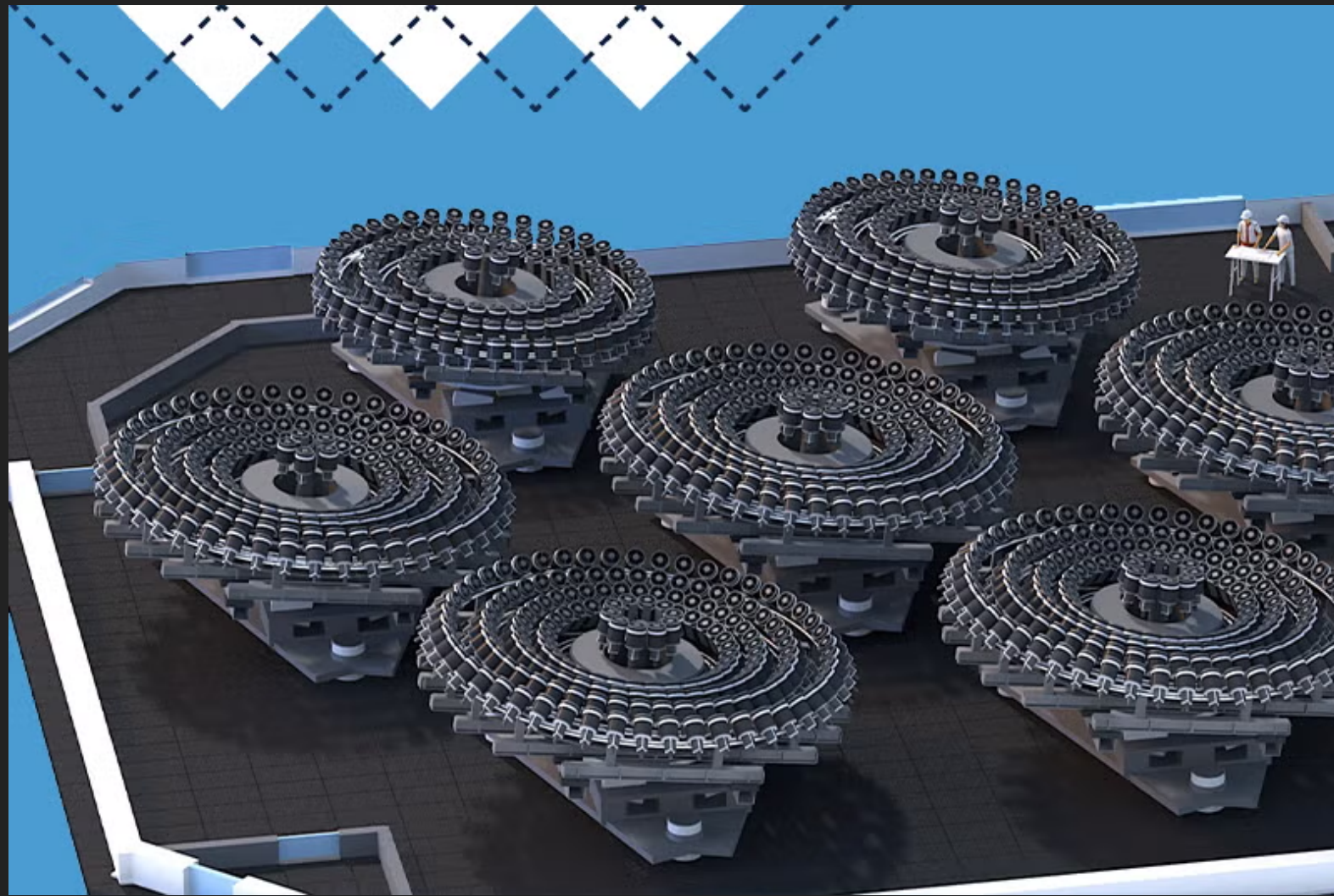
THE CONSTELLATION OF INTER-WAVELENGTH
EXPLORERS IN LOW-EARTH ORBIT

CURTIS MCCULLY



Las Cumbres Observatory

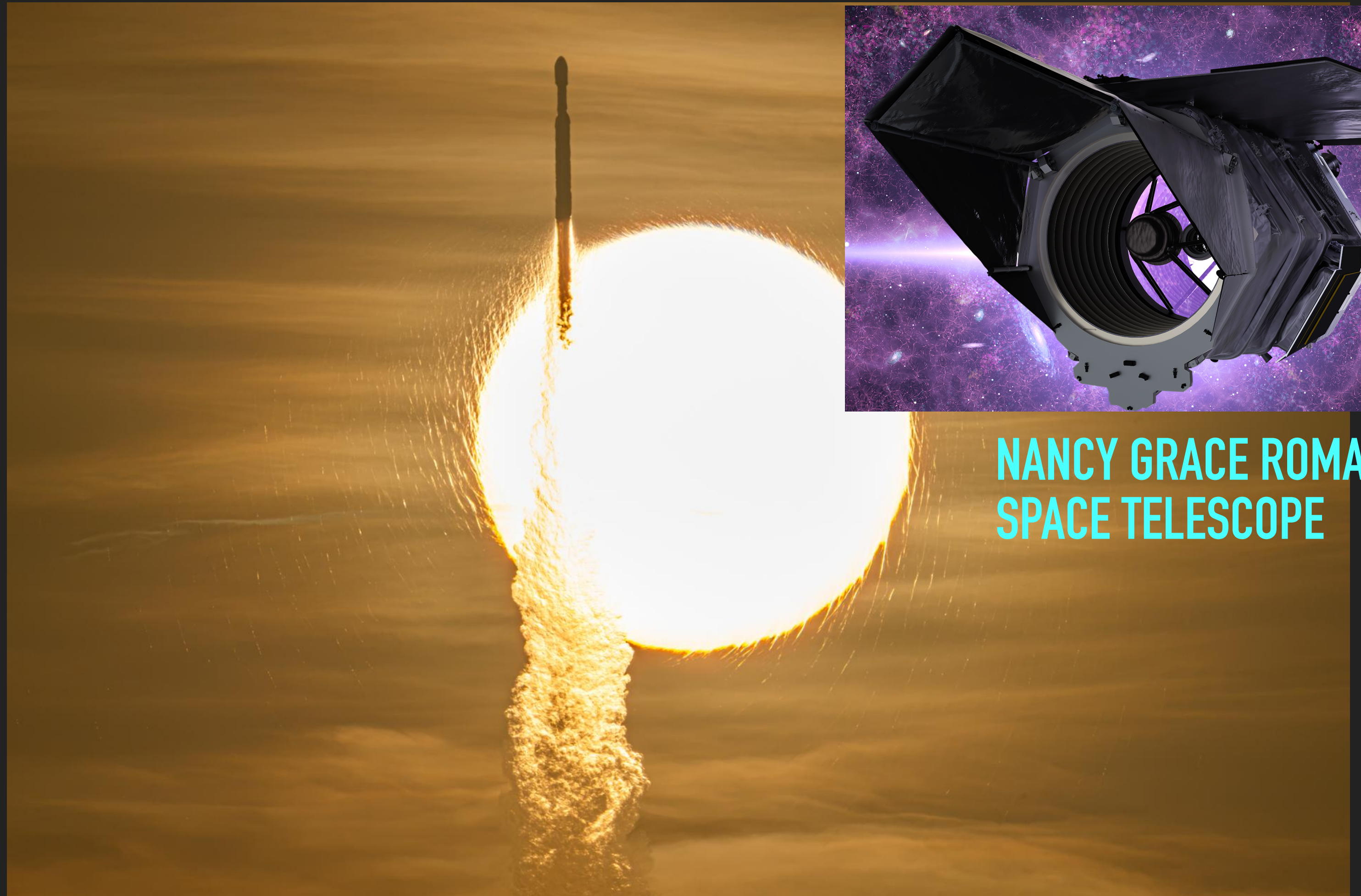
THE GOLDEN AGE OF TIME DOMAIN AND MULTI-MESSENGER ASTRONOMY (TDAMM)



ARGUS ARRAY



VERA C. RUBIN OBSERVATORY

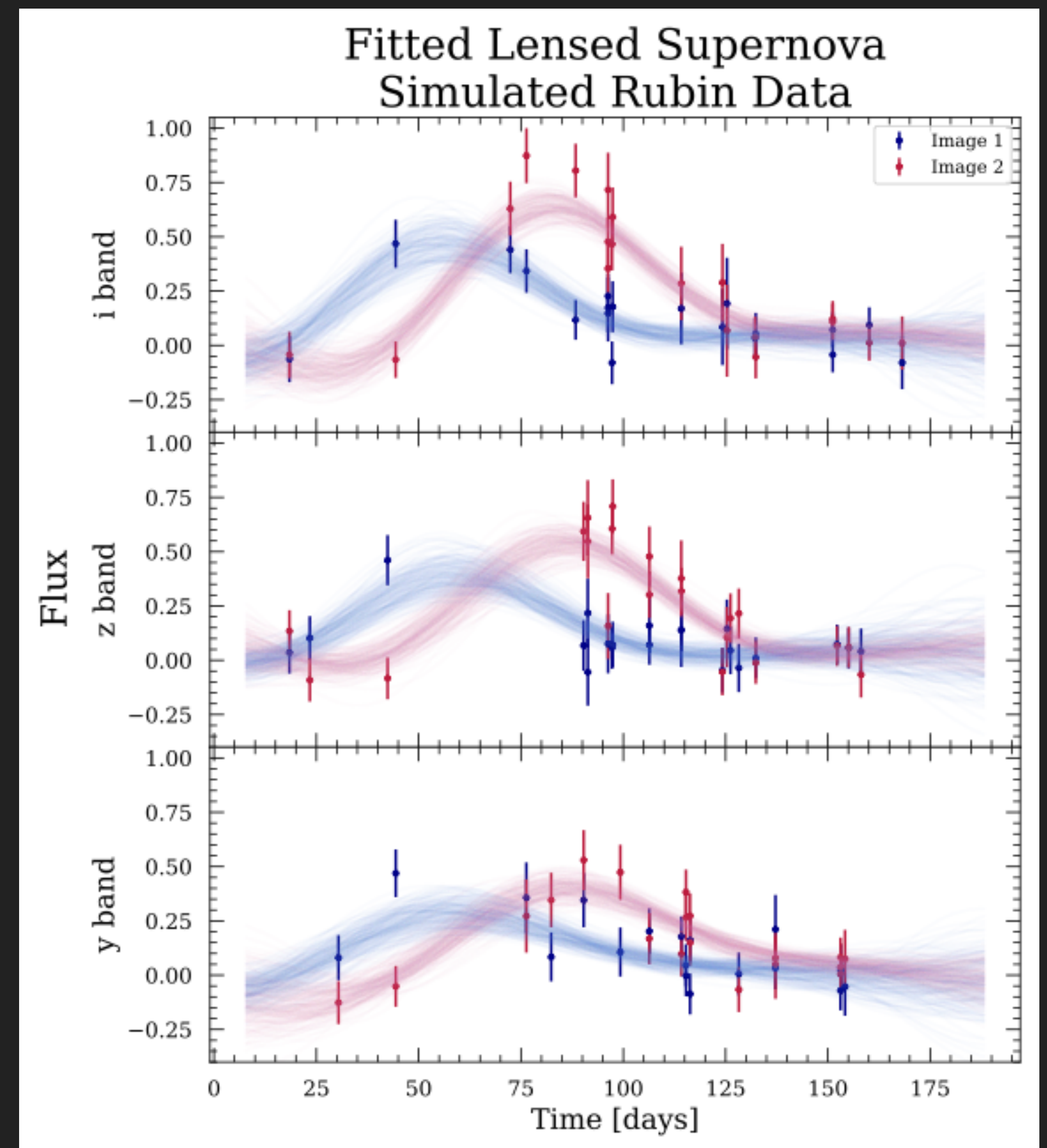


NANCY GRACE ROMAN
SPACE TELESCOPE

WE ARE ENTERING THE LARGEST SURVEY ERA IN HISTORY. THE NUMBER OF TIME-VARIABLE SOURCES IS GOING TO BE ASTRONOMICAL.

BUT SURVEYS CAN'T DO EVERYTHING

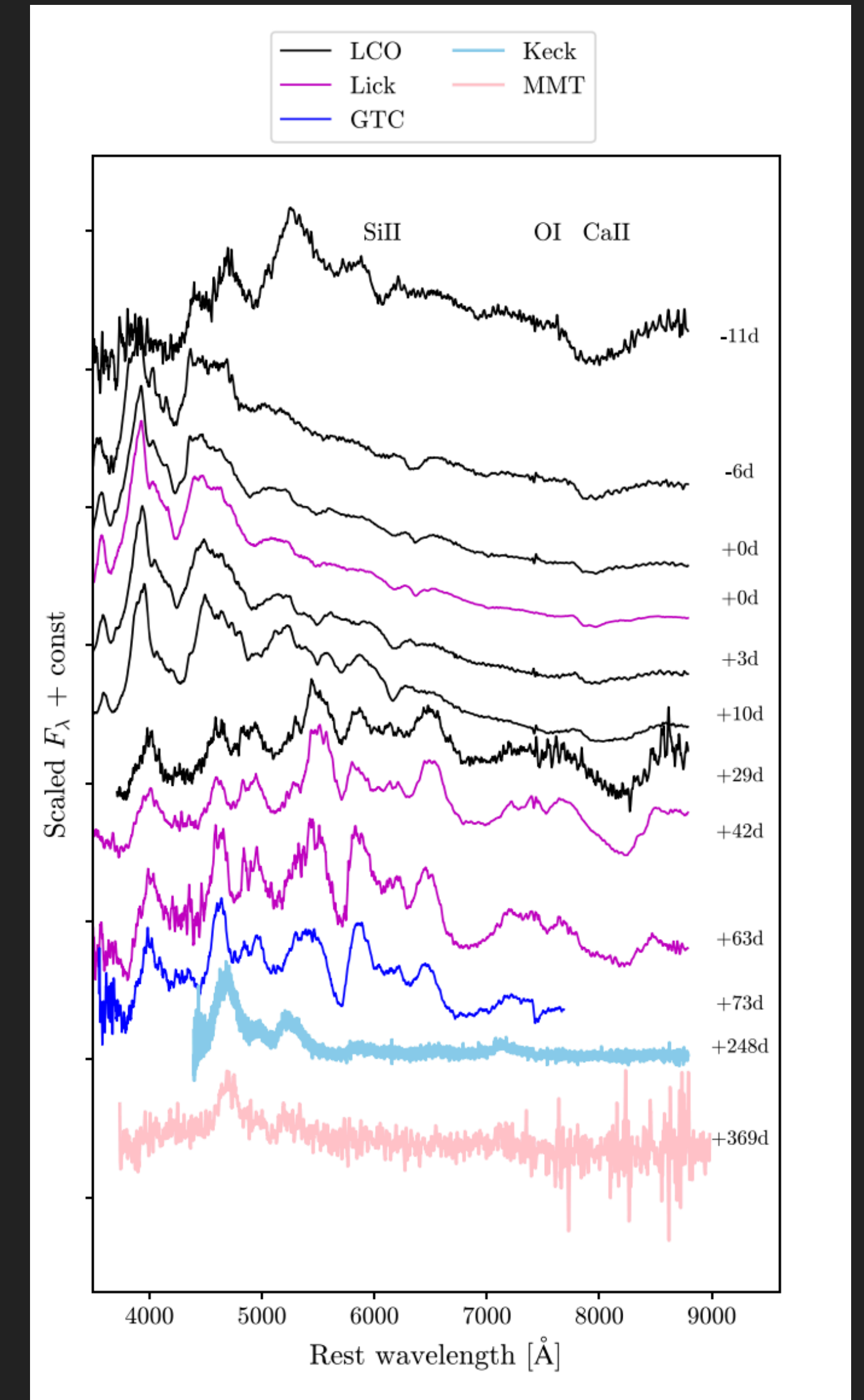
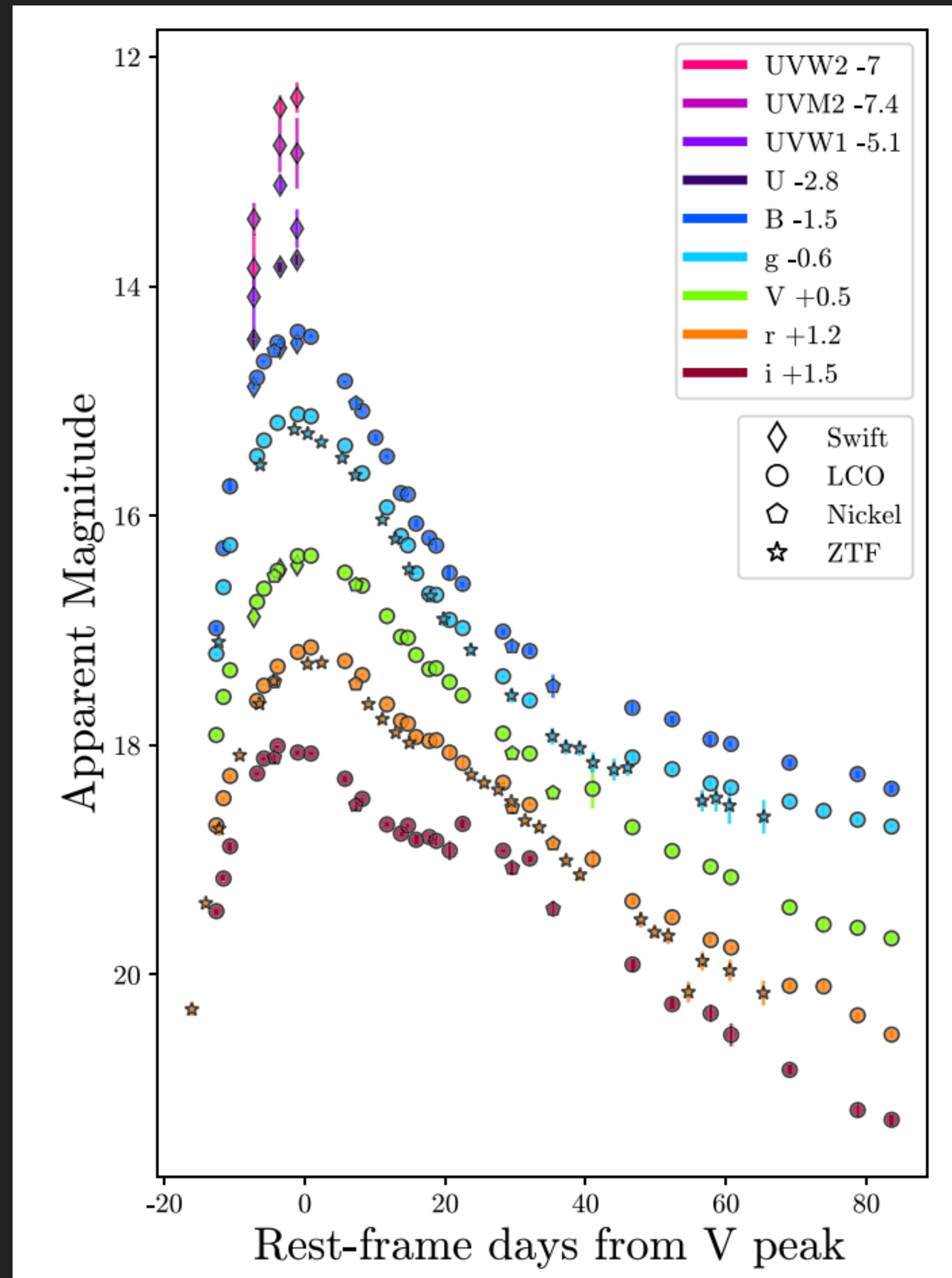
Discovery is only the first step. Survey light-curves alone can only produce so much science. We need follow-up observations to fill in the light curves, increase wavelength coverage, and for spectroscopy. We need to be able to react to new discoveries from these surveys as they happen so we catch them before they fade.



Hayes et al. 2024

COMPARED TO NEARBY OBJECTS THAT HAVE FOLLOW-UP OBSERVATIONS

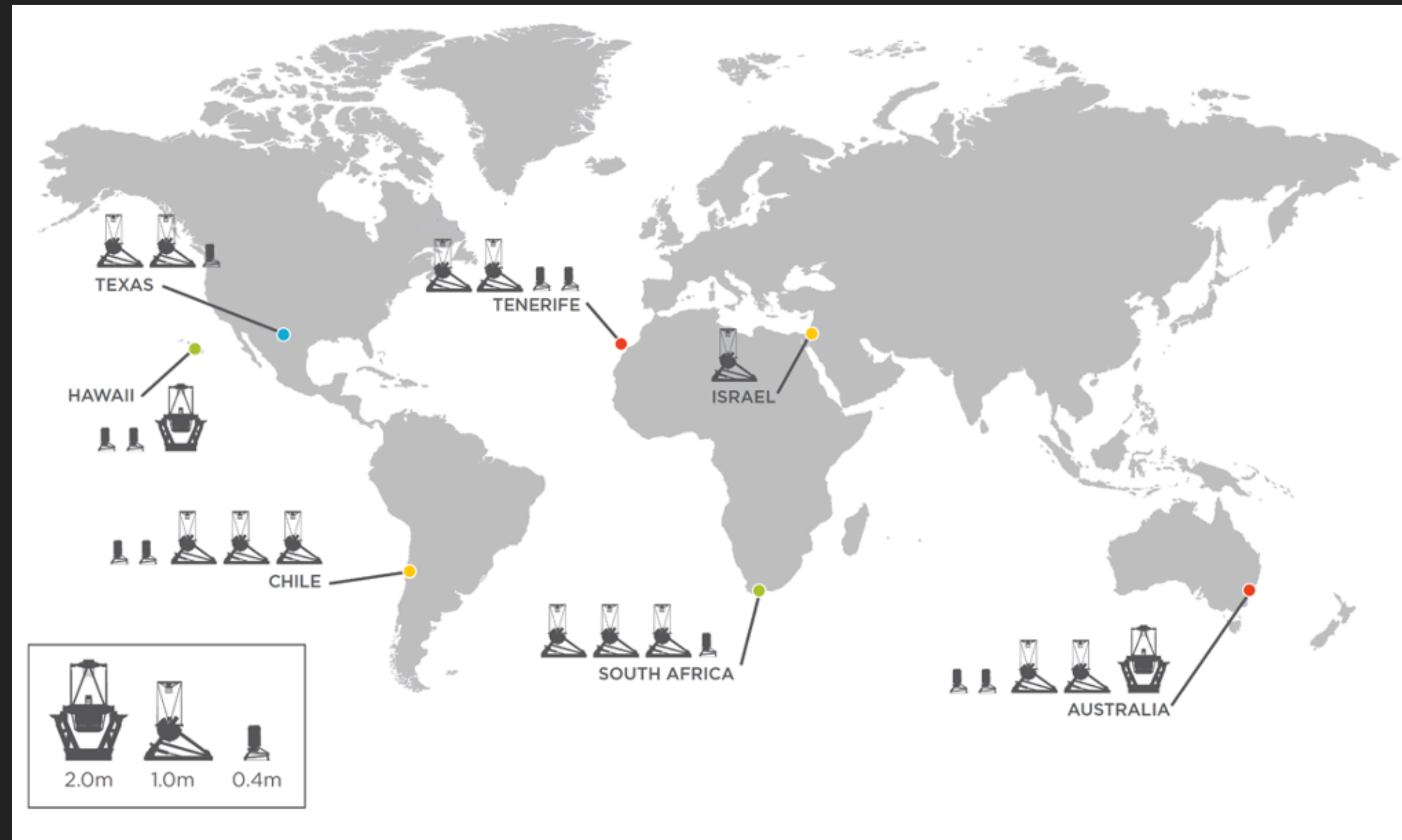
The science we can do with survey **and** follow-up **combined** is at an entirely different level. The surveys are still essential to discover objects young, but don't negate the need for other facilities.



Padilla-Gonzalez et al. 2024

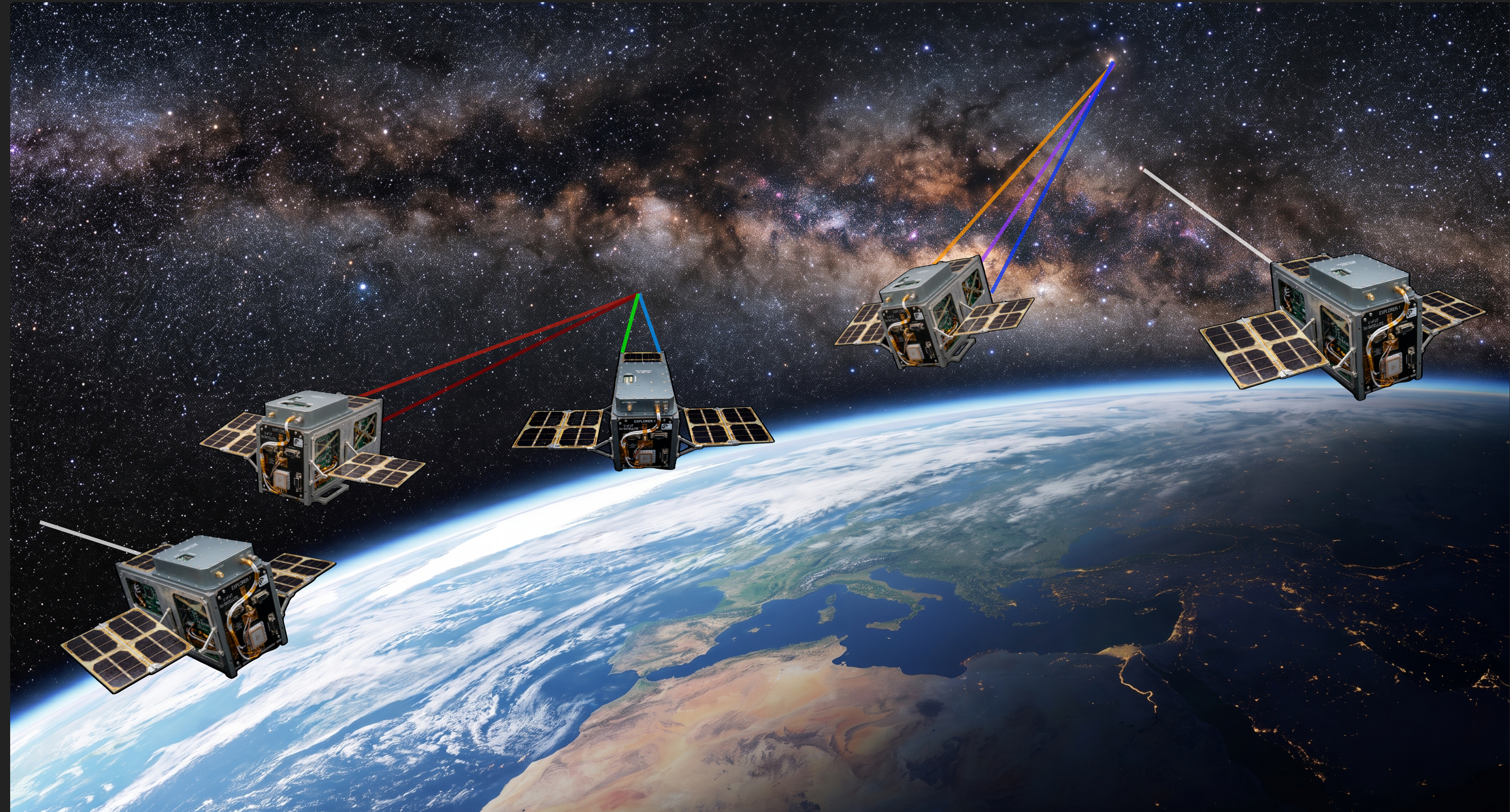
SO HOW DID WE COLLECT SO MUCH DATA?

Las Cumbres Observatory built and operates 26 robot telescopes with apertures ranging from 40cm to 2m around the world. The multiplexing throughput lets us collect statistical samples of extremely dense data, including both light curves and spectra. The observatory acts as a single network opening up capabilities for rapid response and continuous monitoring not afforded by single instruments.



CIELO: THE CONSTELLATION OF INTER-WAVELENGTH EXPLORERS IN LOW-EARTH ORBIT

CIELO is a mission concept to build a constellation of UVOIR instruments. The spacecraft bus and optical design would be modular. CIELO would have varying instrumentation across individual nodes that would include multi-channel imaging and low-to-medium-resolution spectroscopy.

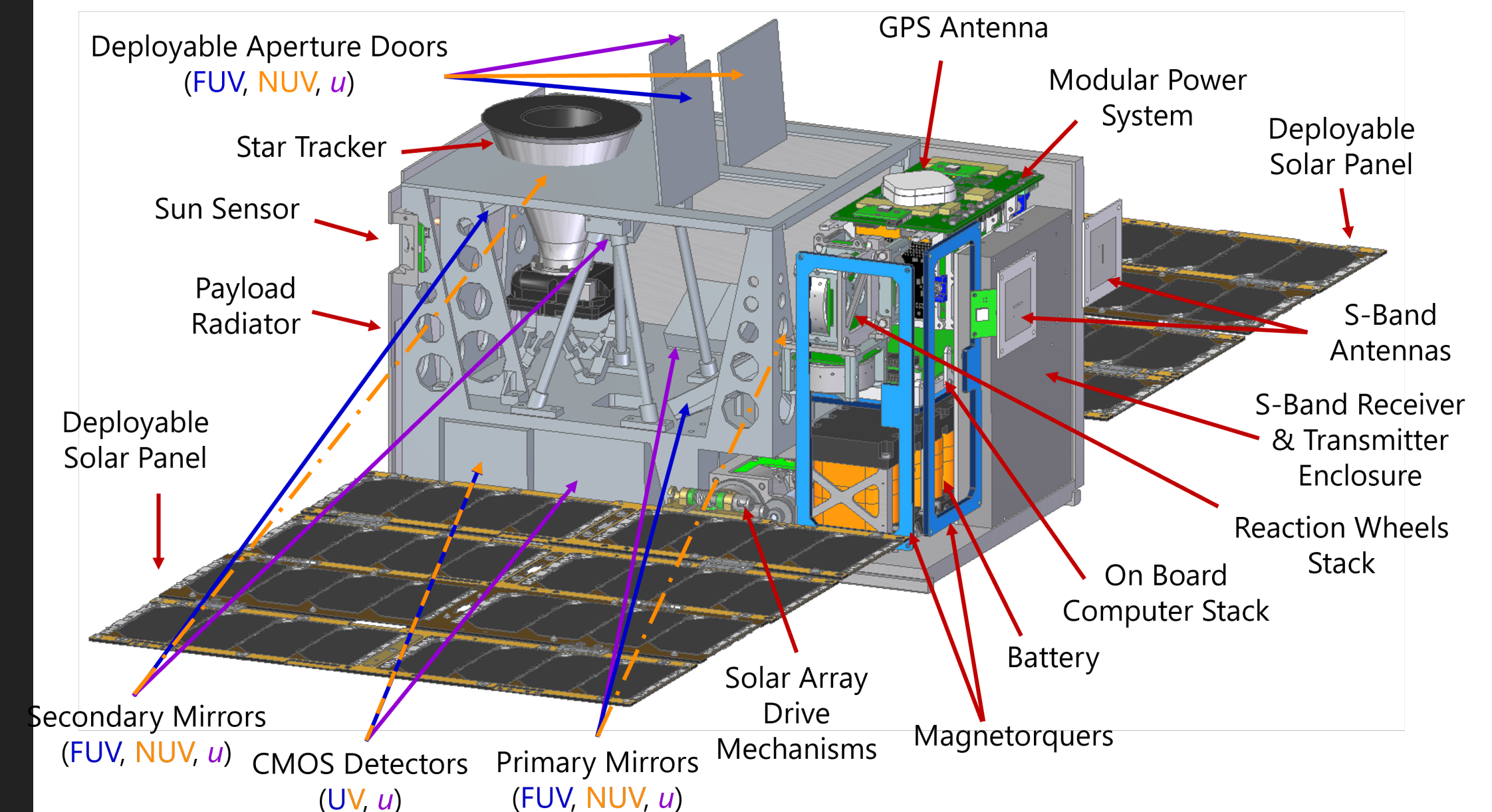
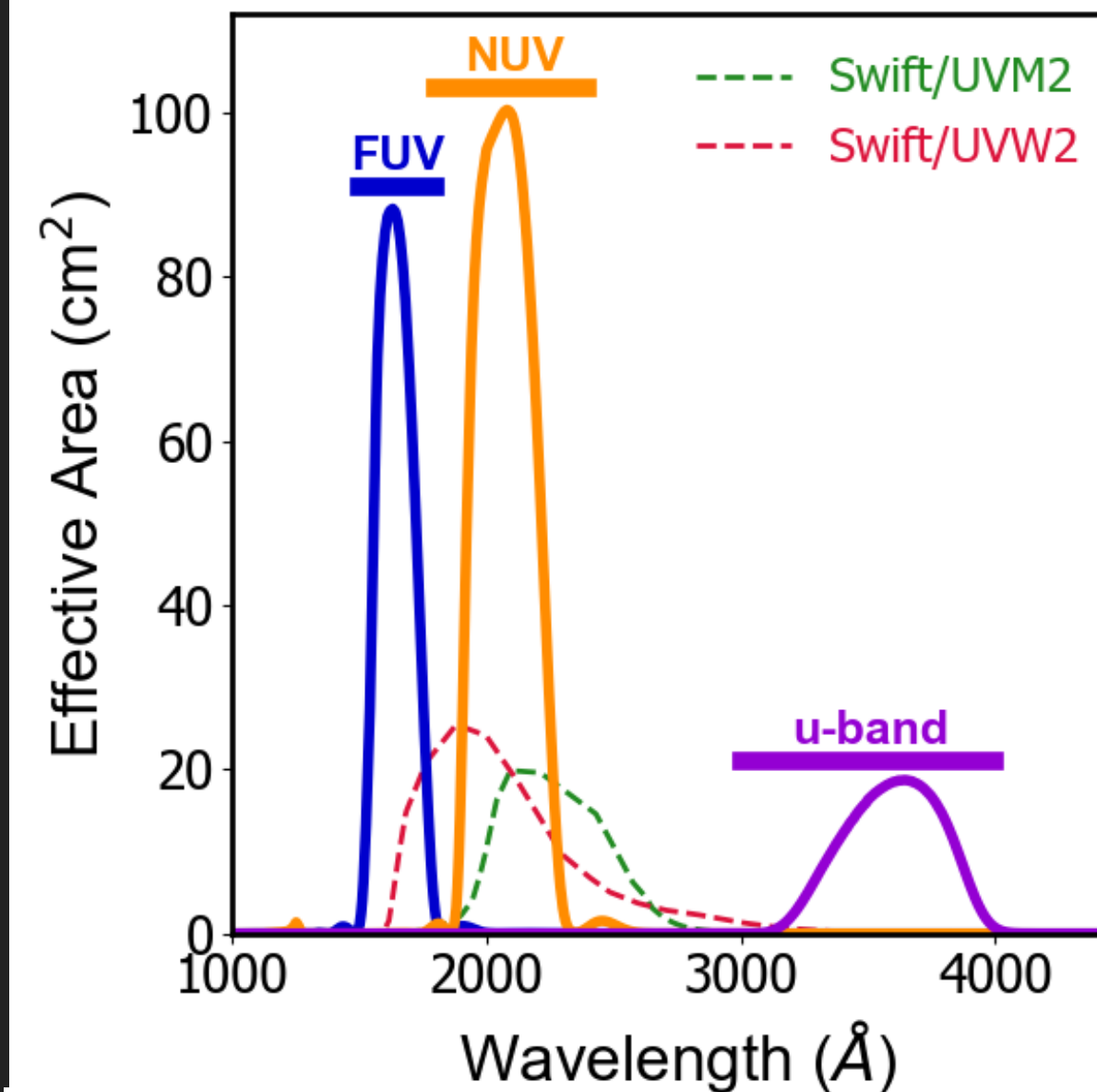


LCO in Space!

UVIA: STARTING THE JOURNEY

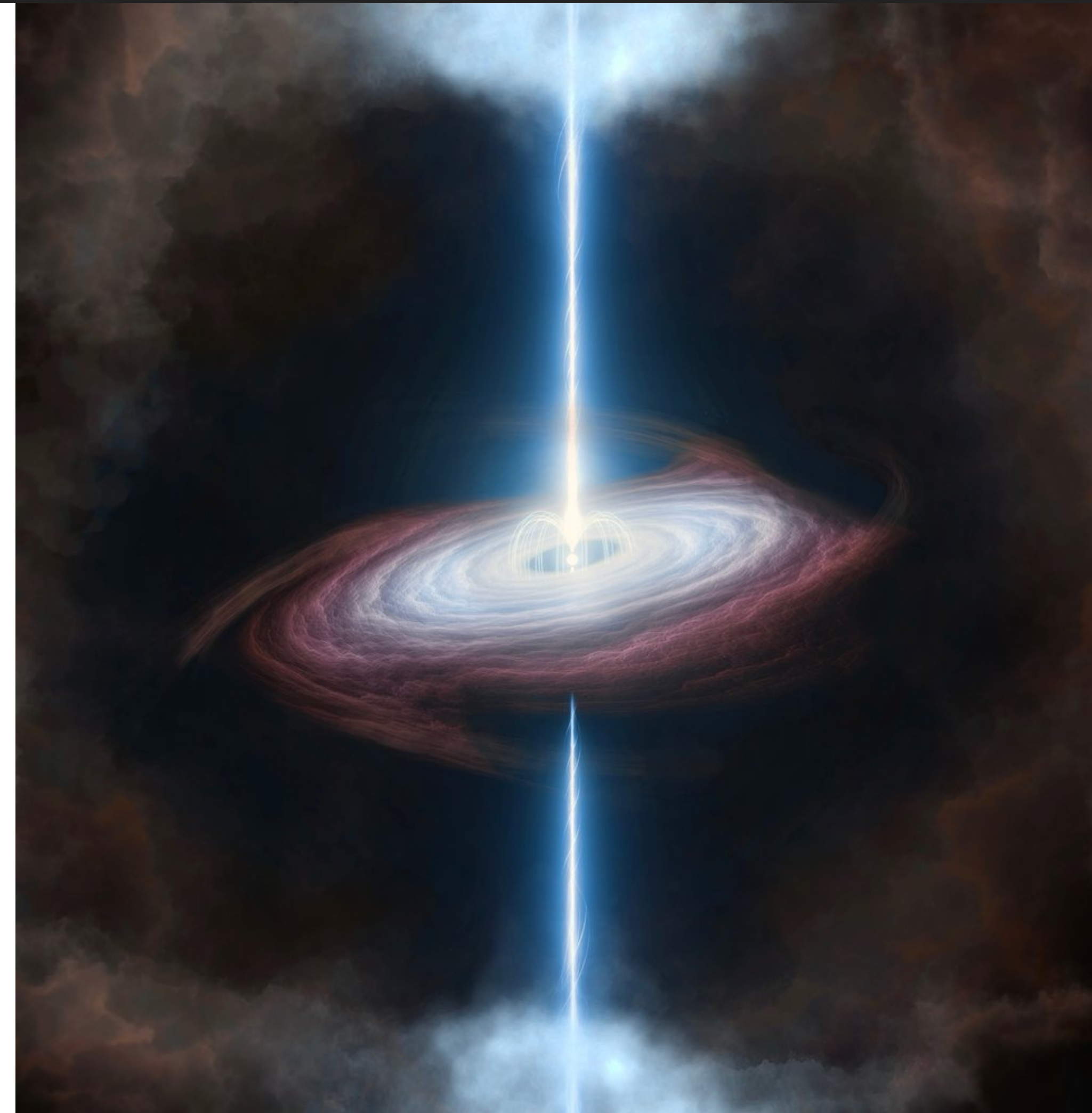
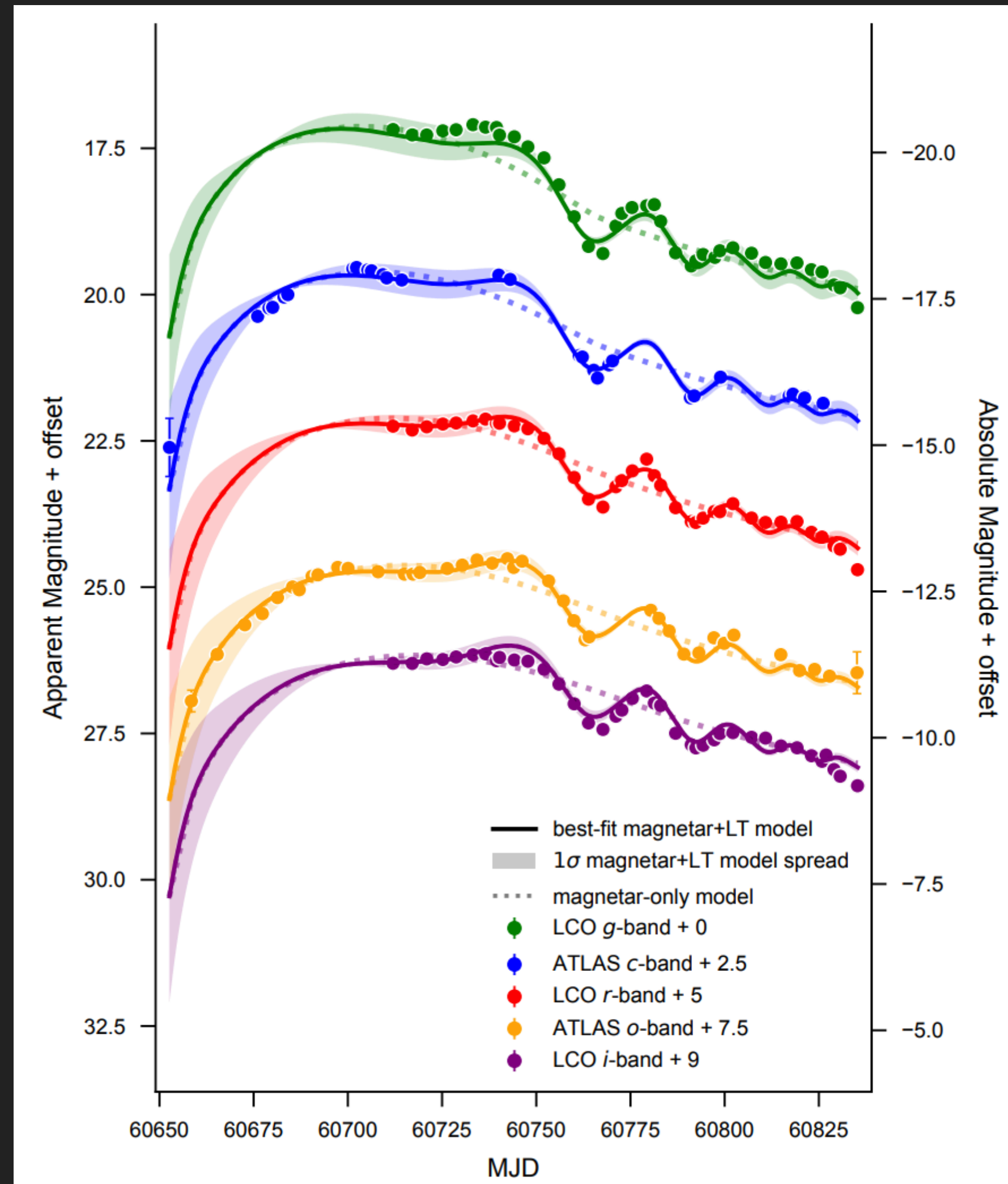
UVIa is a small-sat project proposed to observe local Type Ia supernovae to produce cosmology templates, search for companion shock signatures, and probe explosion models. Due to improvements in technology, UVIa has more effective area than Swift without the red leak. UVIa will act as a pathfinder to build a modular small-sat design to use for a larger constellation like CIELO.

Hoadley et al. 2025



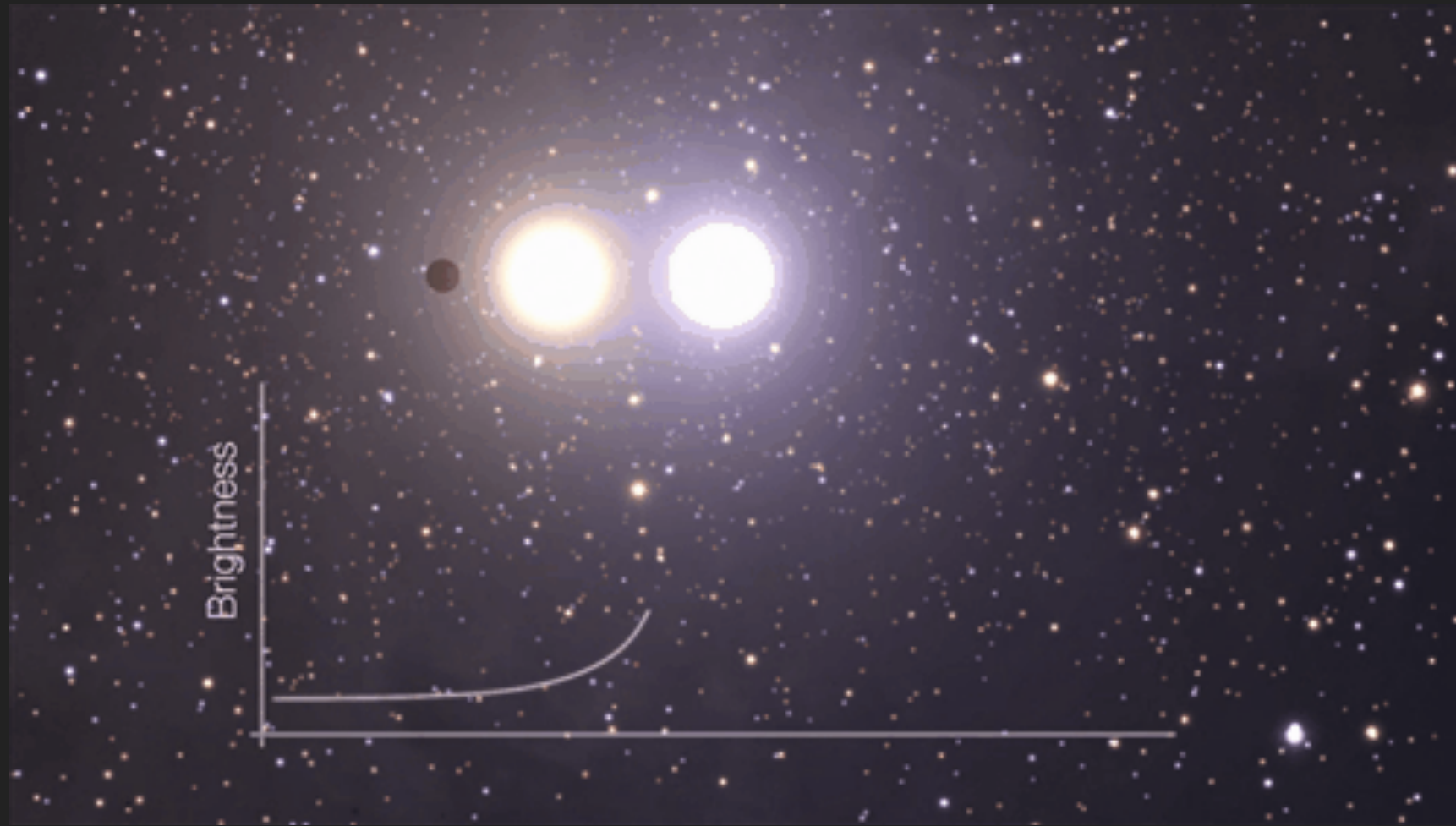
SOME SCIENCE CASES: SUPERNOVAE

Superluminous Supernovae are powered by a central engine, likely a magnetar. This magnetar can have an accretion disk that spins down due to General Relativistic effects.

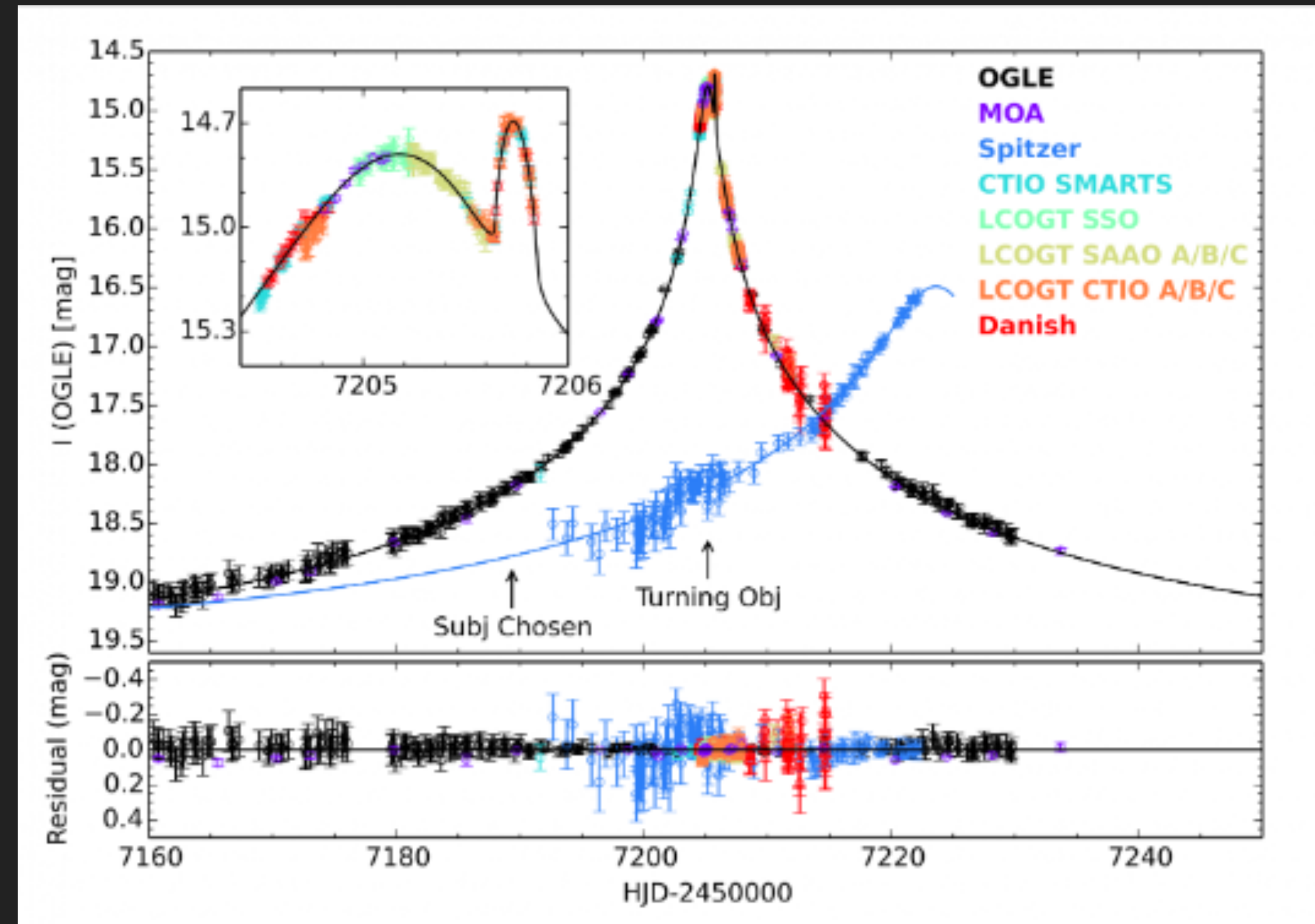


Farah et al. 2026

SOME SCIENCE CASES: MICROLENSING



When light passes near a background star, most excitingly when there is a large planet in the system, the star will appear brighter for a short time due to microlensing. Without follow-up most surveys will not get the planetary blip in the light curve.

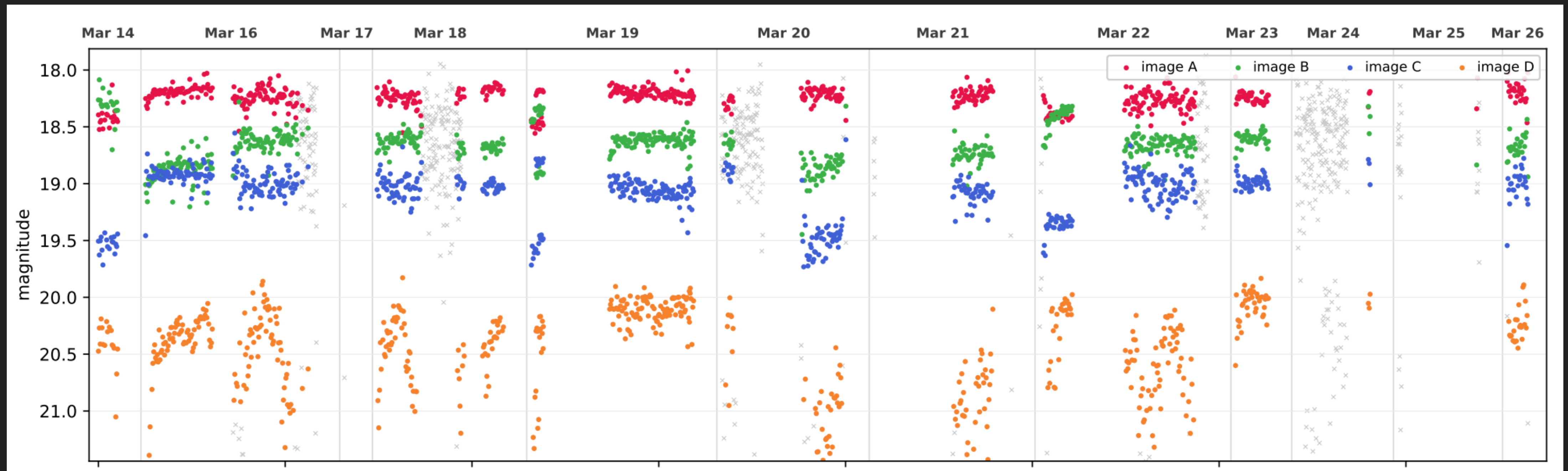
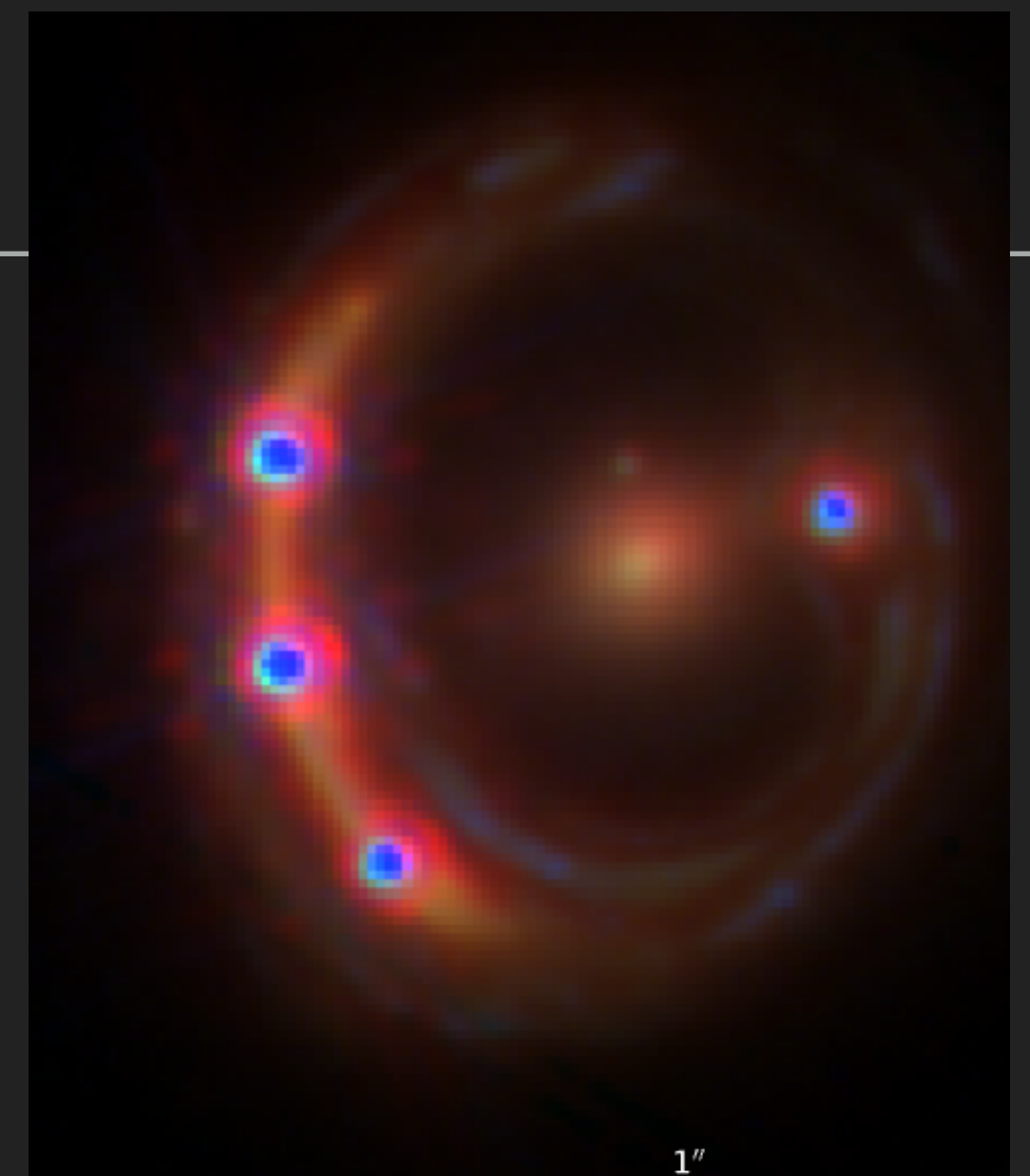


Street et al. 2016

We would have missed this planet without the densely sampled light curve. Different lines of sight will see the brightening at a different time, further constraining the physical system.

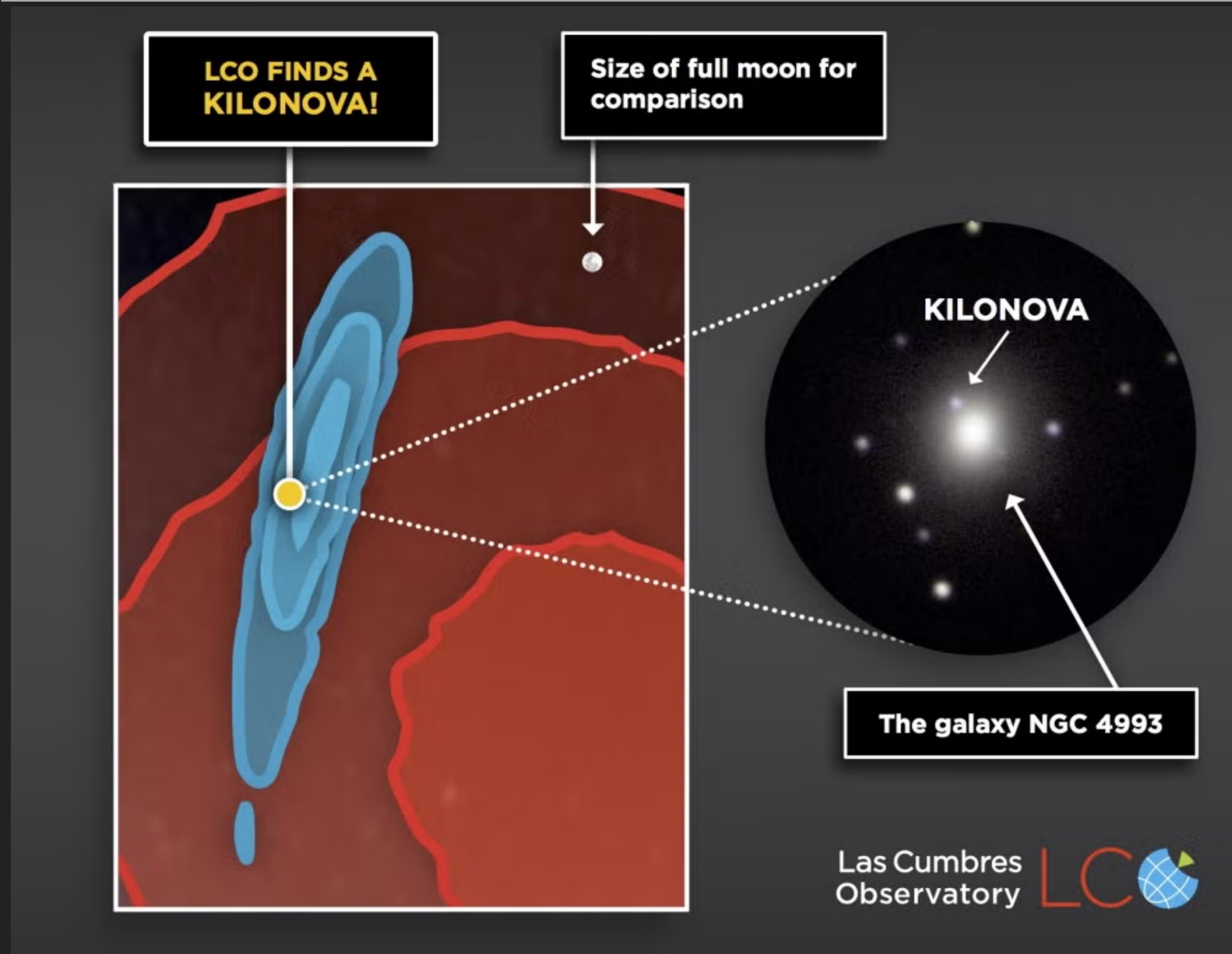
SOME SCIENCE CASES: AGN (LENS RECONSTRUCTION)

Measuring the lag times between each image pair provides independent measurements of the Hubble Constant and provides novel constraints on dark matter substructure. For the short-delay (<1 d) image pairs, continuous monitoring is essential.

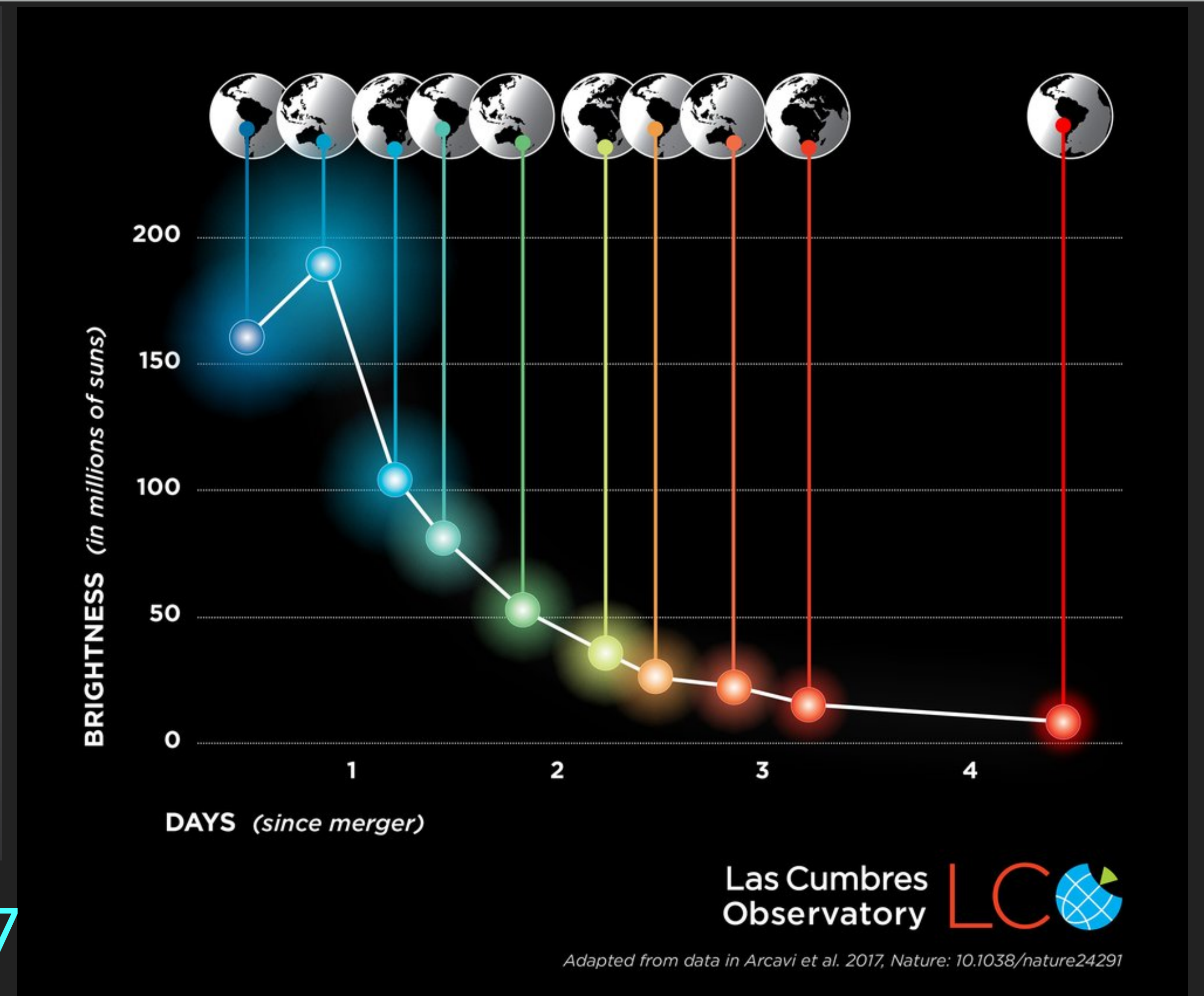


Moustakas et al. in prep

SOME SCIENCE CASES: GW FOLLOWUP



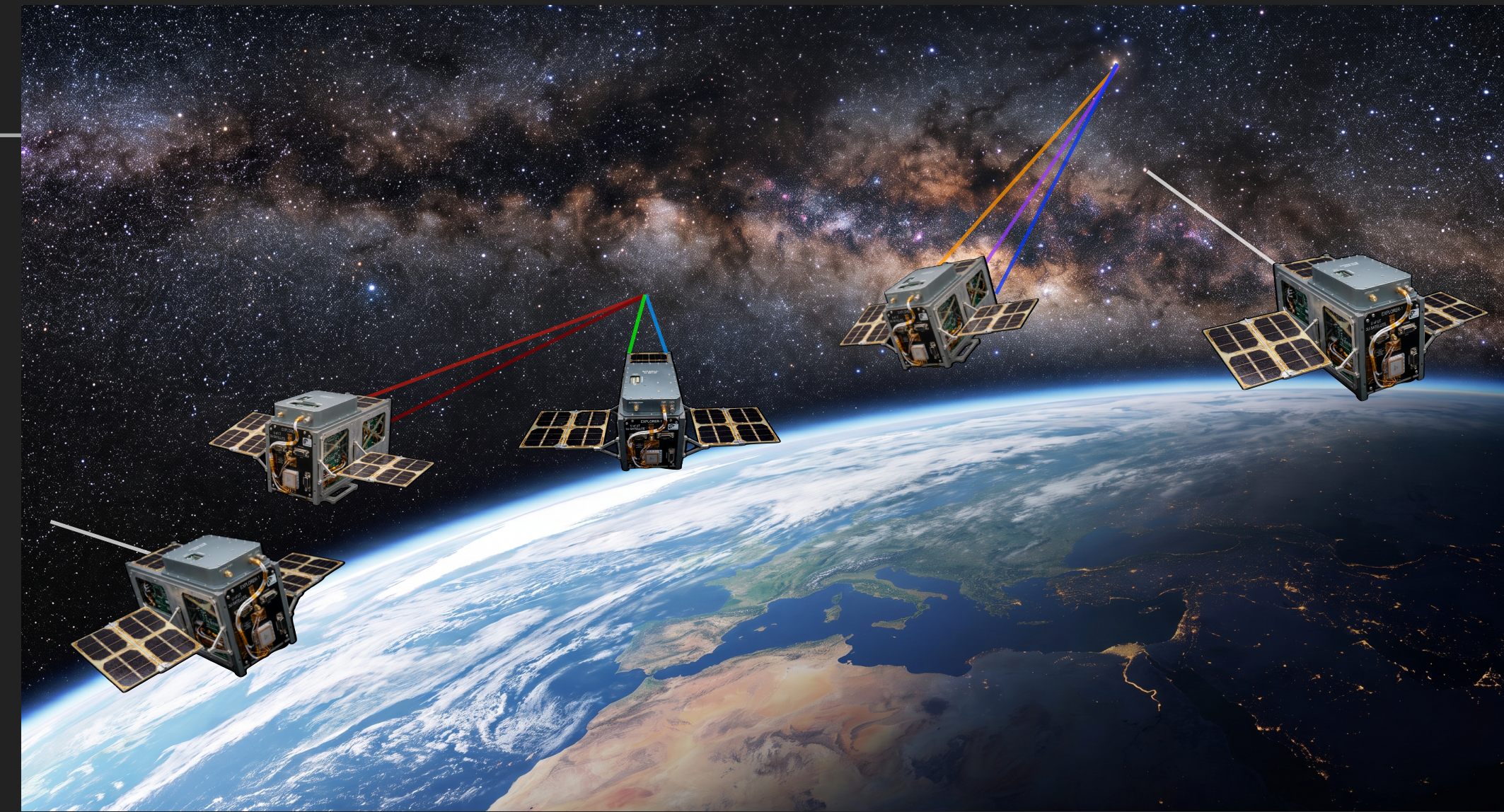
Arcavi et al. 2017



Gravitational wave follow-up requires rapid response to search for the electromagnetic counterpart. Once identified, the kilonova needs constant monitoring because it evolves so quickly.

CONCLUSIONS

CIELO is a concept for a constellation of UVOIR small-sat telescopes that operate as a single network, similarly to Las Cumbres Observatory. These telescopes will focus on rapid-response follow-up and continuous monitoring of light curves and/or low-to-medium-resolution spectra of bright targets.



Now is the time! New surveys like LSST on Rubin, Roman, and Argus are all coming online.

Many of the components are off-the-shelf, making this a cost-effective concept. The system is modular, highly redundant, and extensible.

Las Cumbres Observatory's small *ground-based optical* telescopes have produced more than a hundred papers per year for more than a decade. There is a plethora of science to be done!