The Multi Age Stellar Populations of Terzan 5 as revealed by JWST

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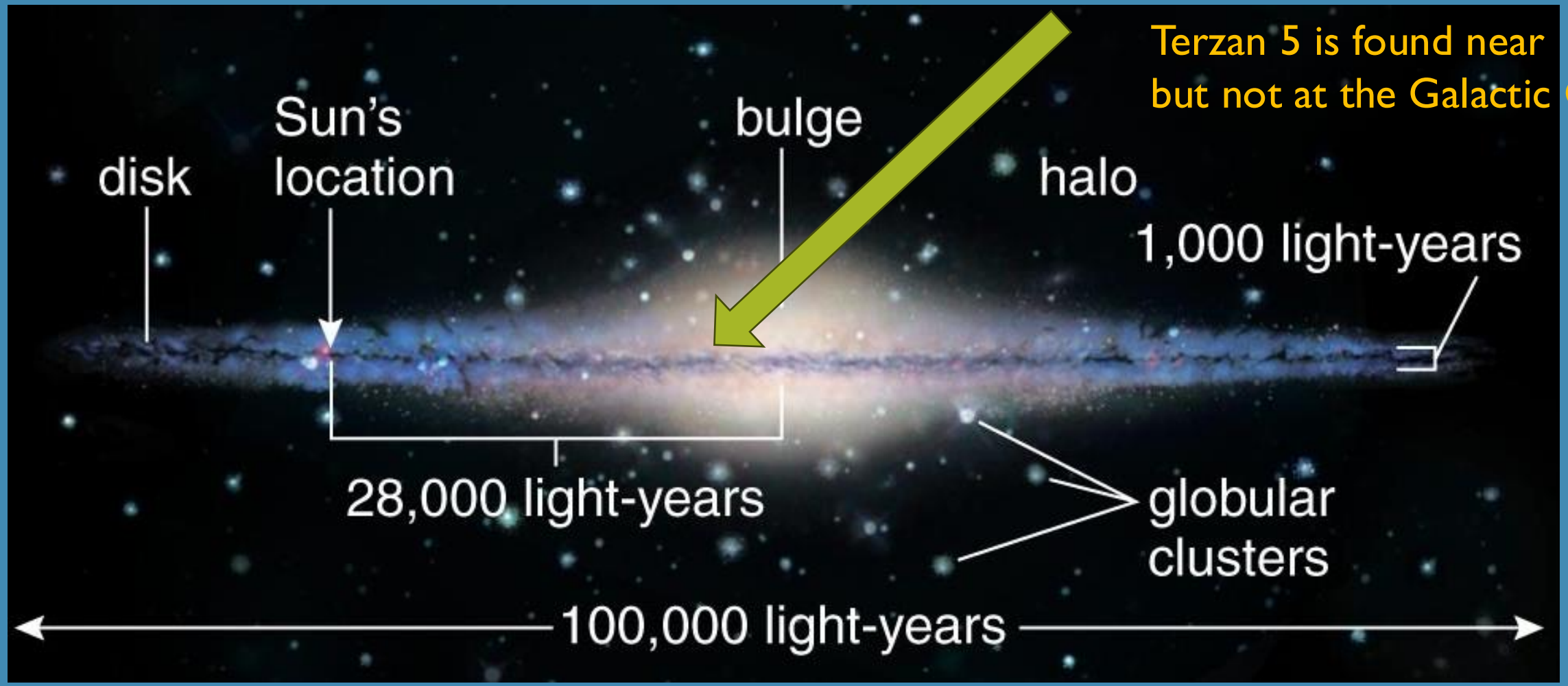
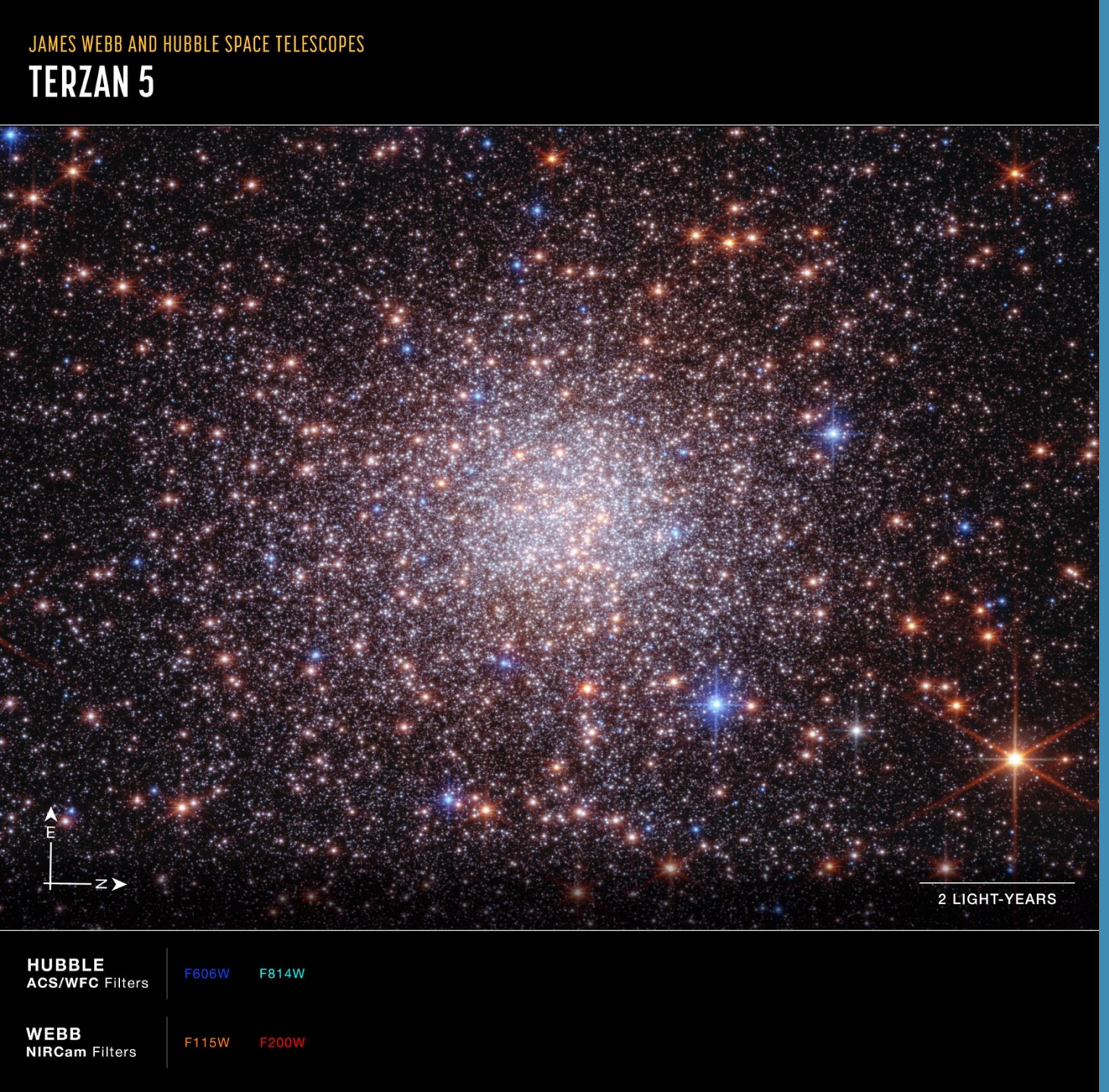
"Globular" clusters have 1 million stars and are 12 Billion years (Gyr) old. Most are found in the halo and bulge of the Milky Way, 1000s of light-years from the Sun



Terzan 5 lies behind clouds of dust and is best studied in the infrared



Terzan 5 looks like a globular star cluster and is 10^6 Msun, but it is not like globular clusters.

Nearly all globular clusters have stars that have the same age – around 12 billion years, the age of the Milky Way

Using Webb + Hubble, we find 4 groups of stars in Terzan 5 with ages from 12 to 2.5 billion years (Gyr).

We infer that Terzan 5 may once have weighed 1 billion Suns.

This discovery was made by isolating the member stars of Terzan 5 against the complex background of the Galactic bulge using images taken over 20 years with Hubble and Webb

Table 1: Summary of the JWST/NIRCam and HST/ACS datasets used in this work, including observational epochs, filters, number of exposures and readout modes (if appropriate), and exposure times.

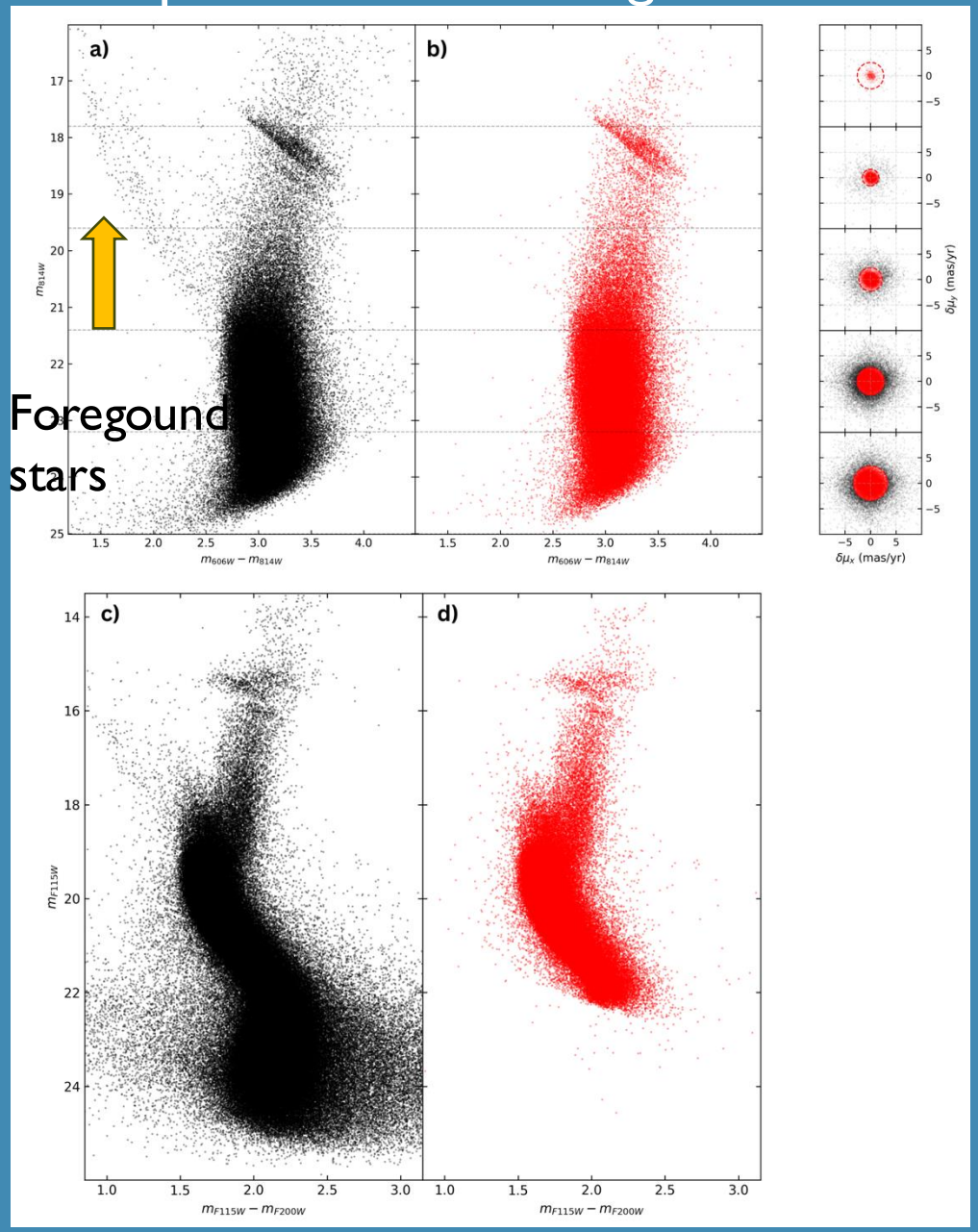
Instrument	Proposal ID	PI	Date	Filter	Exposures	Exposure Time (s)
JWST/NIRCam	GO 5502	Ferraro	2024 September 19-20	F115W	8 BRIGHT2	966.4
				F115W	8 RAPID	21.47
				F200W	8 BRIGHT2	751.6
				F200W	8 RAPID	21.47
	GO 5502	Ferraro	2025 April 4	F115W	8 BRIGHT2	966.4
HST/ACS	SNAP 9799	Rich	2003 September 17	F606W	1	340
				F814W	1	340
				F814W	2	10
	GO 12933	Ferraro	2013 August 18-19	F606W	5	365
				F606W	1	50
				F814W	5	365
				F814W	1	10
	GO/DD 14061	Ferraro	2015 April 20-21	F606W	3	397
				F606W	2	398
				F606W	1	50
				F814W	3	371
				F814W	2	372
				F814W	1	10

2003!

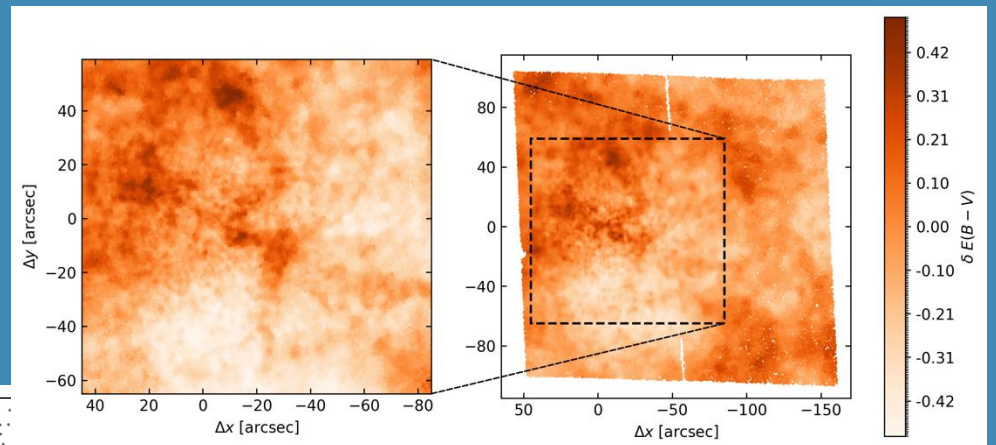
A 26 year collaboration with Keck Telescopes, Hubble and JWST

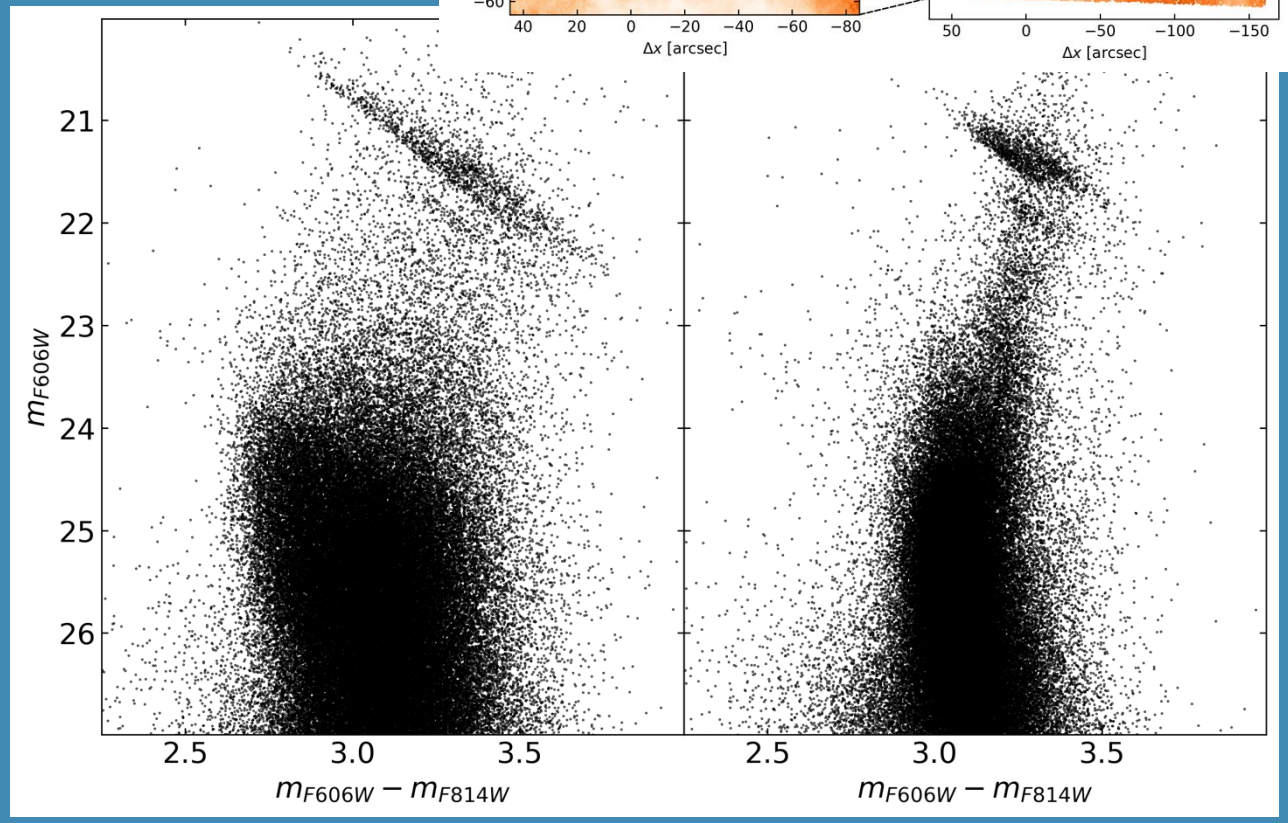
Two Special Techniques are critical to the analysis

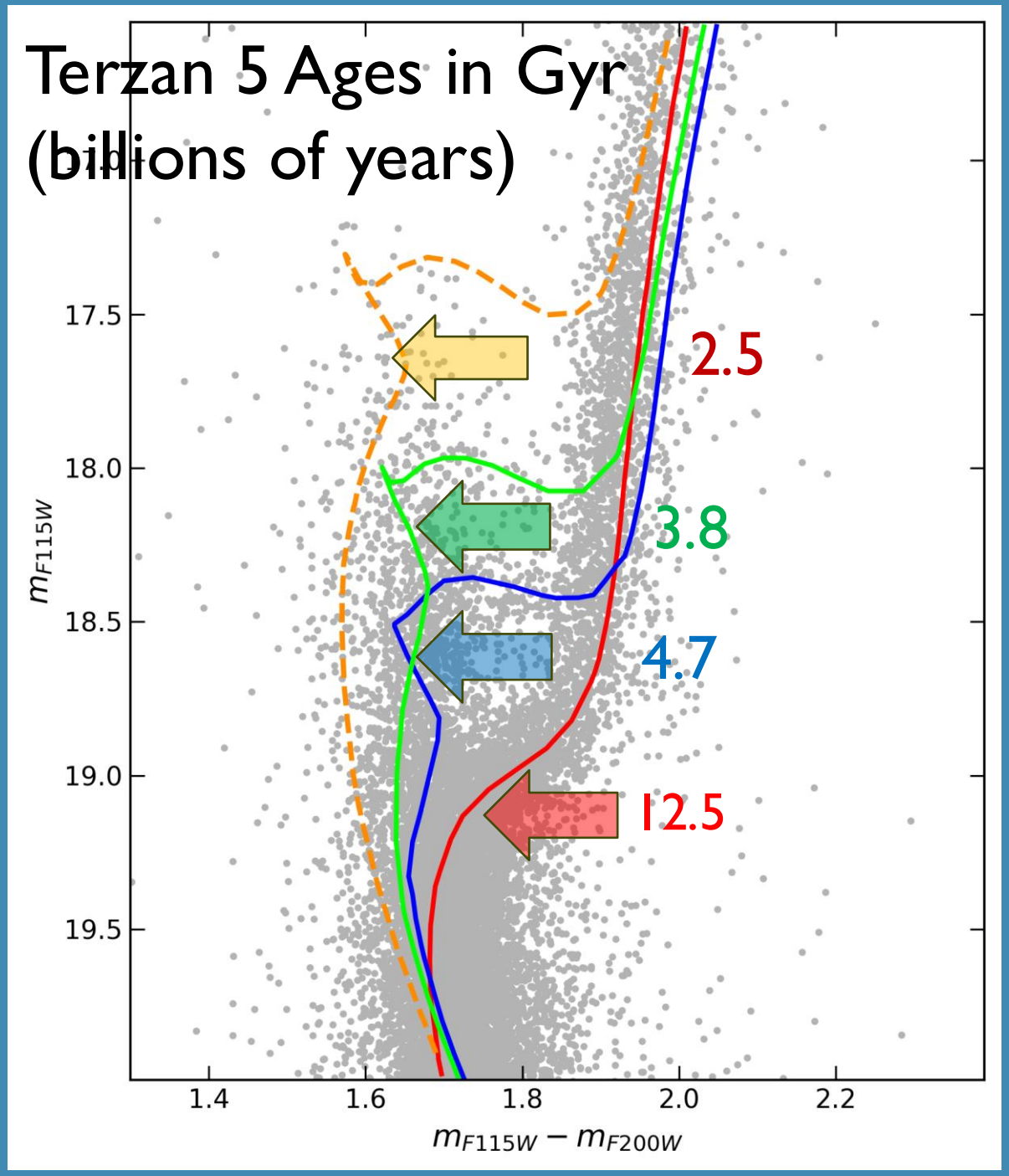
Proper motion cleaning



Correction for foreground dust







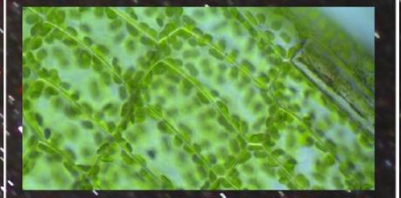
Two "bursts" of stars had been known in Terzan 5. Our new data refined their ages to 12.5 Gyr and 4.7 Gyr

We discovered two additional bursts with age 3.8 and 2.5 Gyr

For roughly 12 billion years, Terzan 5 held onto gas and formed new generations of stars Implies that Terzan 5 must have been more massive than today

The "Cosmic Calendar" Universe begins on January 1 and present day is 31 December Most Globular Clusters formed as Milky Way began to form - end of February

January	February	March	April	May	June
New Year's Day: The Big Bang  13.8 billion years ago	12.5 Gyr	Milky Way Galaxy forms  11 billion years ago			

July	August	September	October	November
	The Sun and planets form 4.7 Gyr  4.5 billion years ago	First known life appears 3.8Gyr 3.5 billion years ago	Oxygenation of the atmosphere 2.2 Gyr 2.3 billion years ago	First complex cell life evolves  2 billion years ago

THE SCALE:

1 month = 1.1 billion years

1 day = 37.8 million years

1 minute = 26,238 years

Concept Credit: Carl Sagan

At present we know of only one other cluster like Terzan 5 that has had multiple bursts billions of years apart.

To have more than two bursts, Terzan 5 must once have been more massive, in order to hold on to the gas as it formed stars and explosive supernovae, and continued to form stars. Next: Search for dark matter that explains missing mass- low mass stars or ???

Today, Terzan 5 is 10^6 Solar masses. Once, it may have been 100-1000 times more massive- it might even have dark matter today.

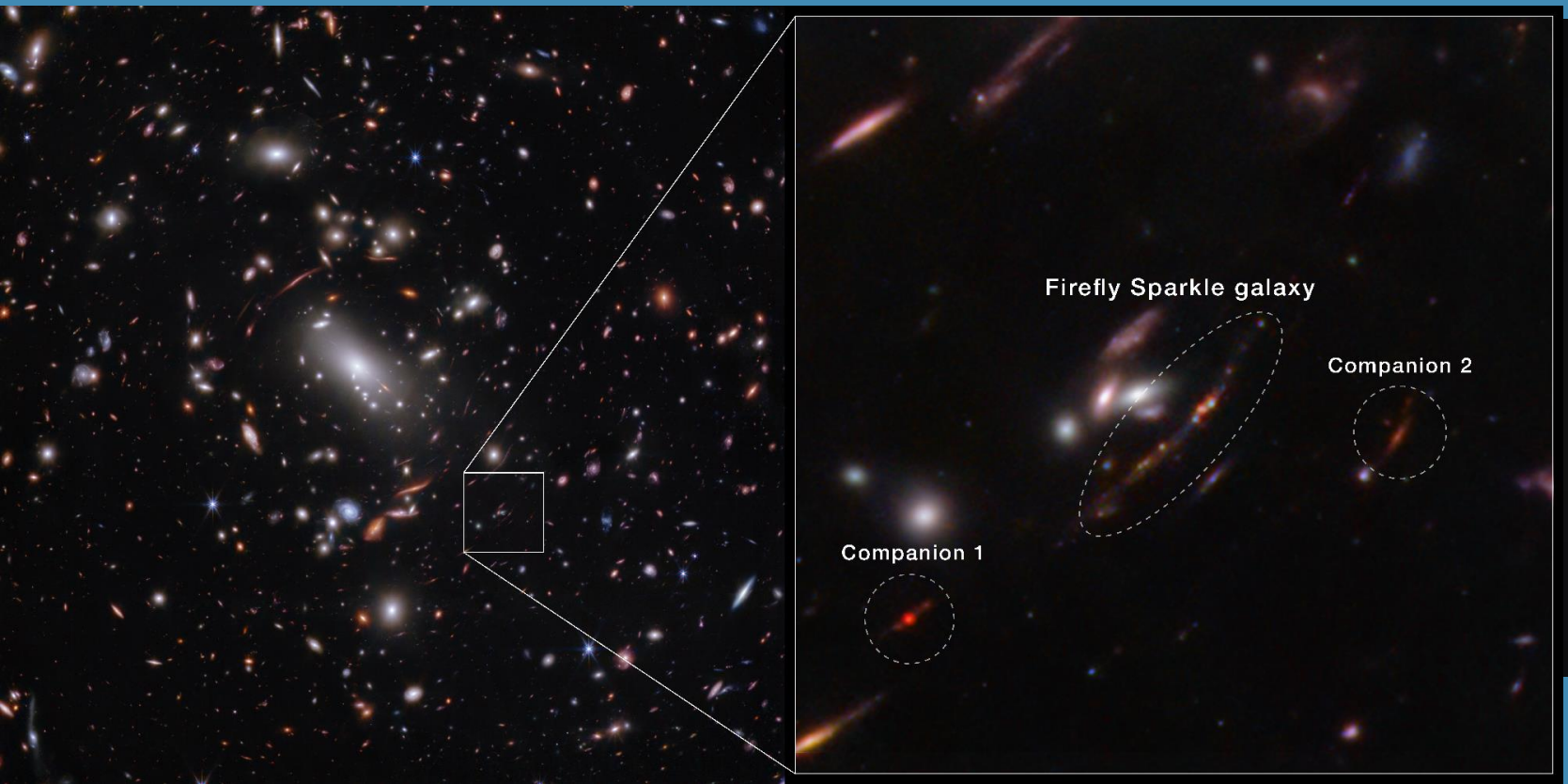
We propose that Terzan 5 is a "Bulge Fossil Fragment" other similar clusters might have built part of the Galactic bulge.

The Nuclear Star Cluster in the center of our Milky Way has a range of age and metal content, is 10^7 Msun and might be a bulge fossil Fragment.

The firefly sparkle galaxy below has a redshift of 8.3, corresponding to an age of 13.1Gyr. The galaxy has multiple clumps; the image below is distorted by "gravitational lensing"

The Milky Way may have looked like this 1 Gyr after the Big bang

Bulge fossil fragments might be the remnants of the clumps below



Artist's concept of Firefly Sparkle

Thankyou

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