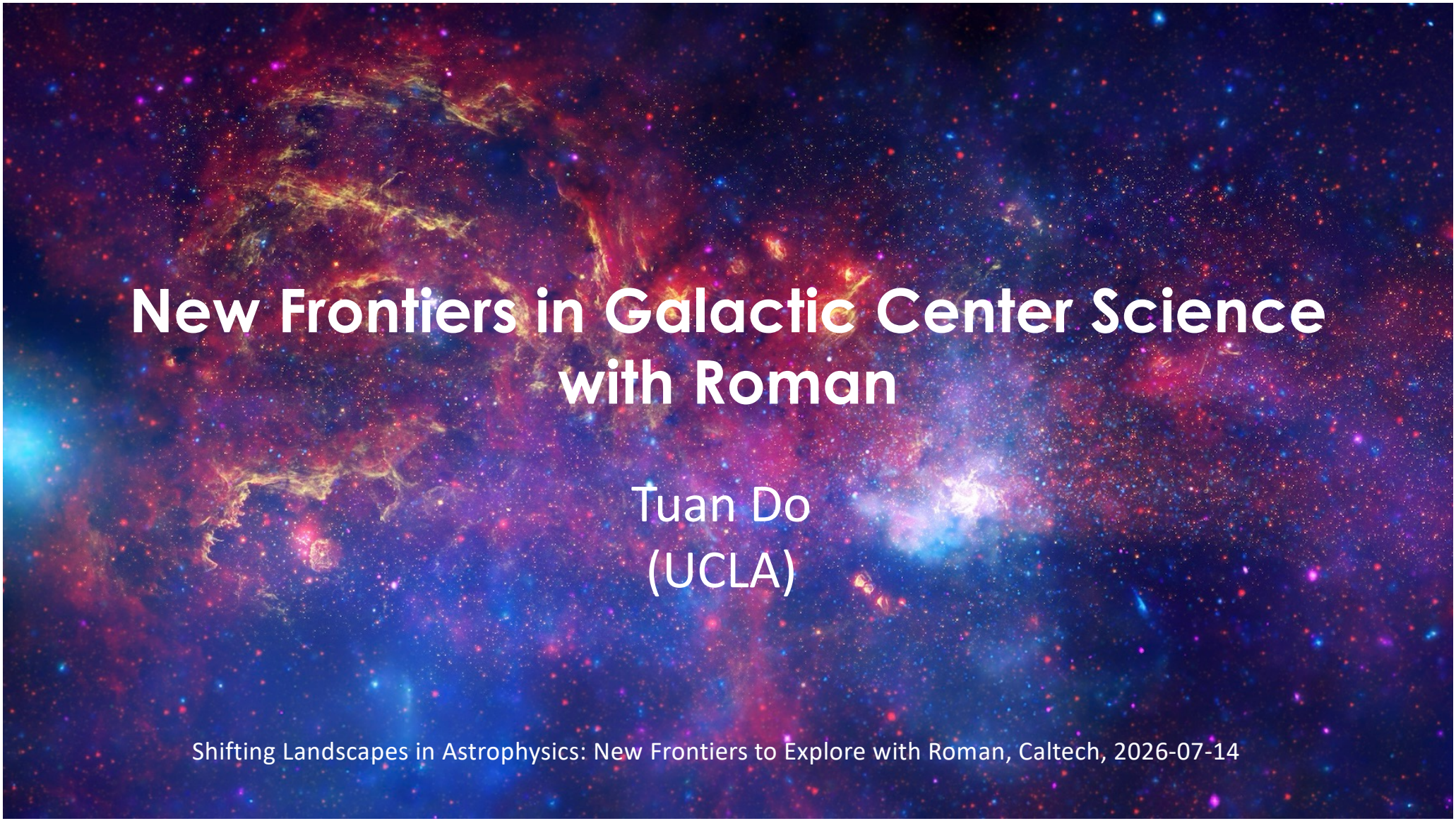
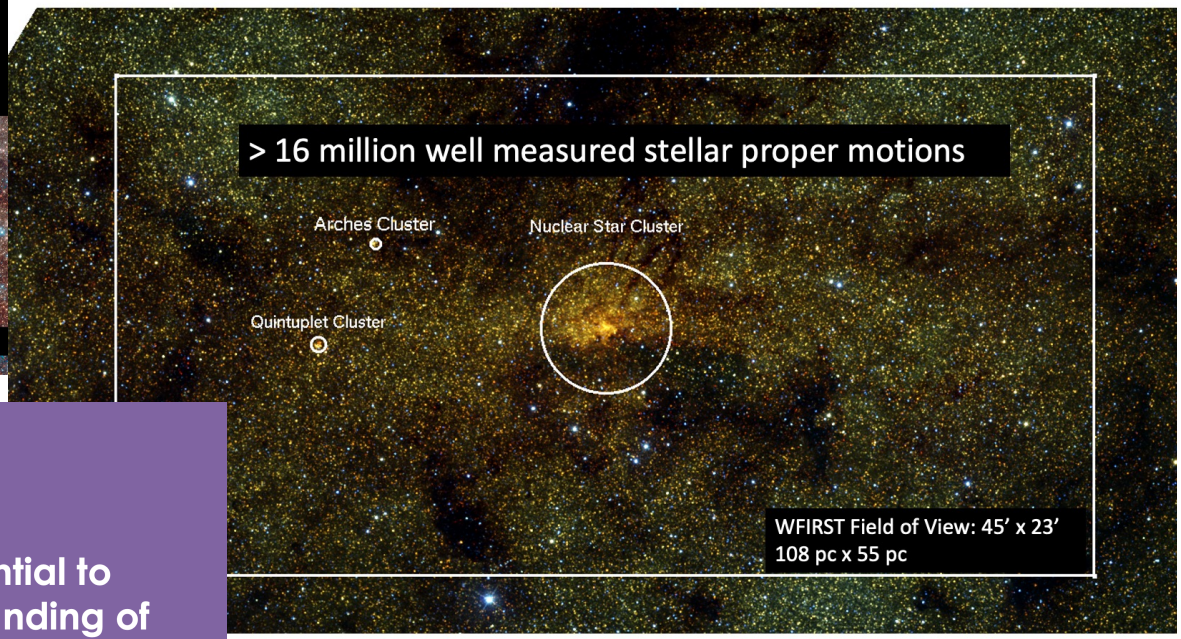


New Frontiers in Galactic Center Science with Roman

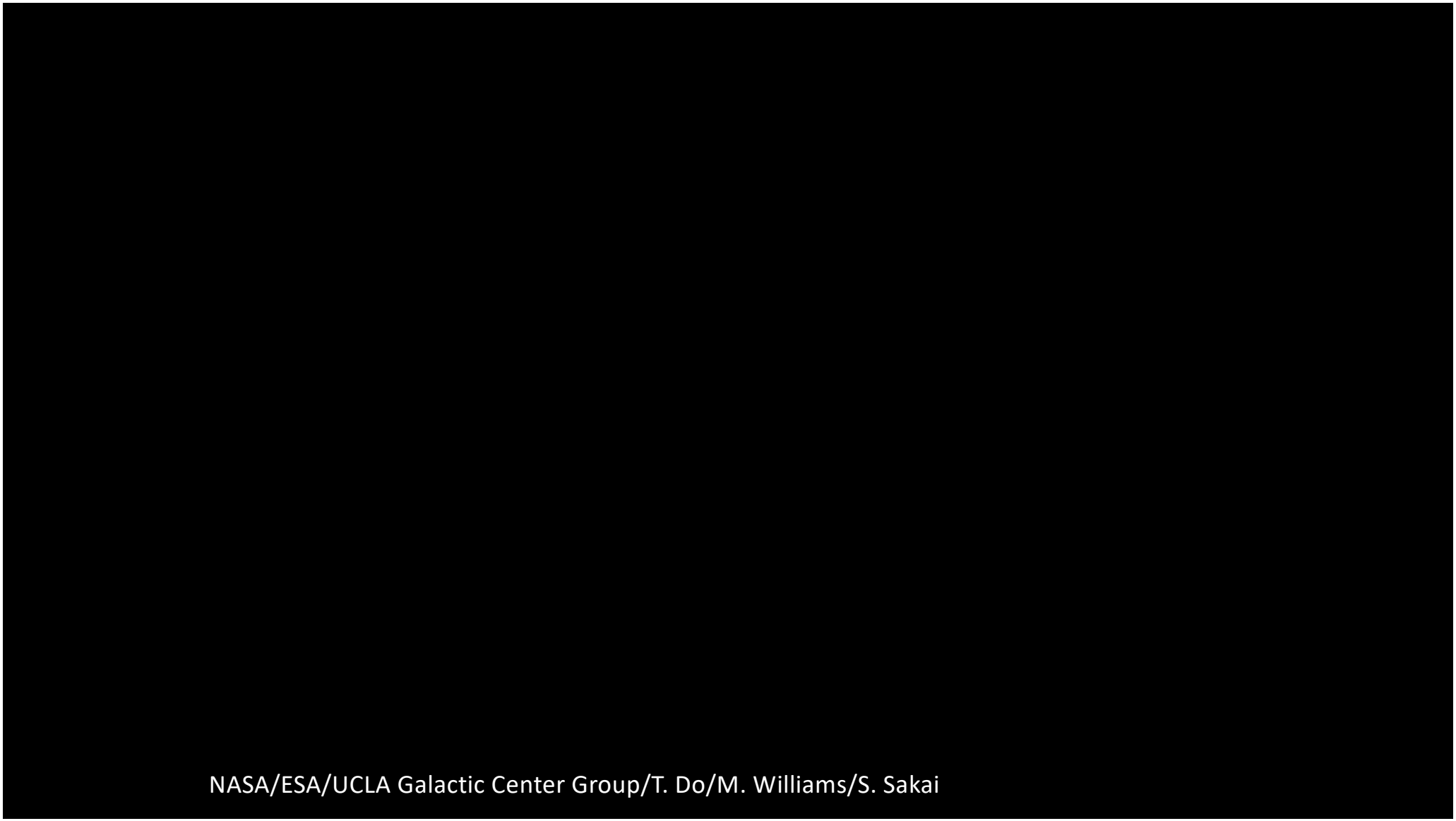
Tuan Do
(UCLA)

Shifting Landscapes in Astrophysics: New Frontiers to Explore with Roman, Caltech, 2026-07-14

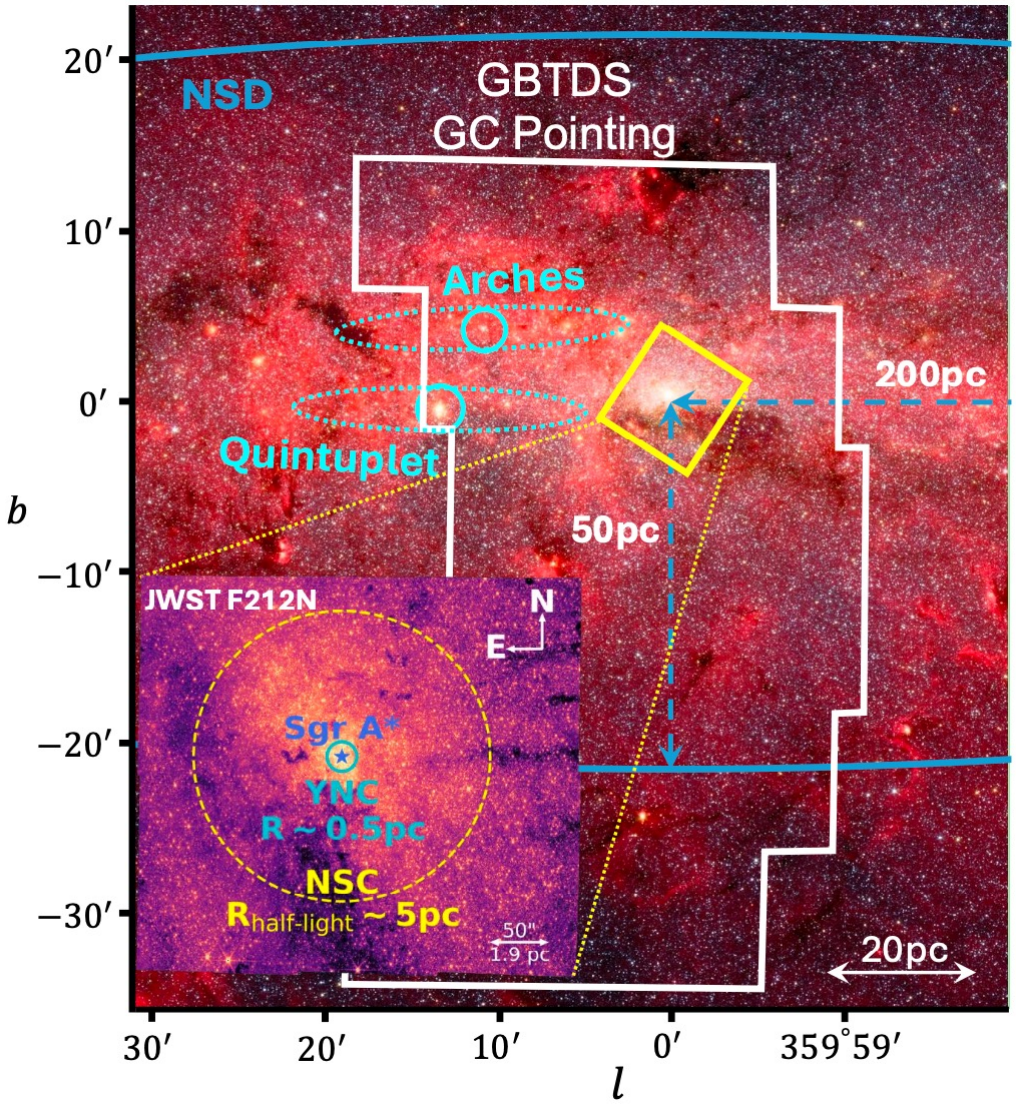
From 2019:



WFIRST has the potential to transform our understanding of the Galactic center.



NASA/ESA/UCLA Galactic Center Group/T. Do/M. Williams/S. Sakai



Science Areas from the Galactic Center GBDTS Pointing

(1) what is the nature accretion onto of our supermassive black hole?

(2) What are the physical properties, origin, and evolution of our Galactic nucleus?

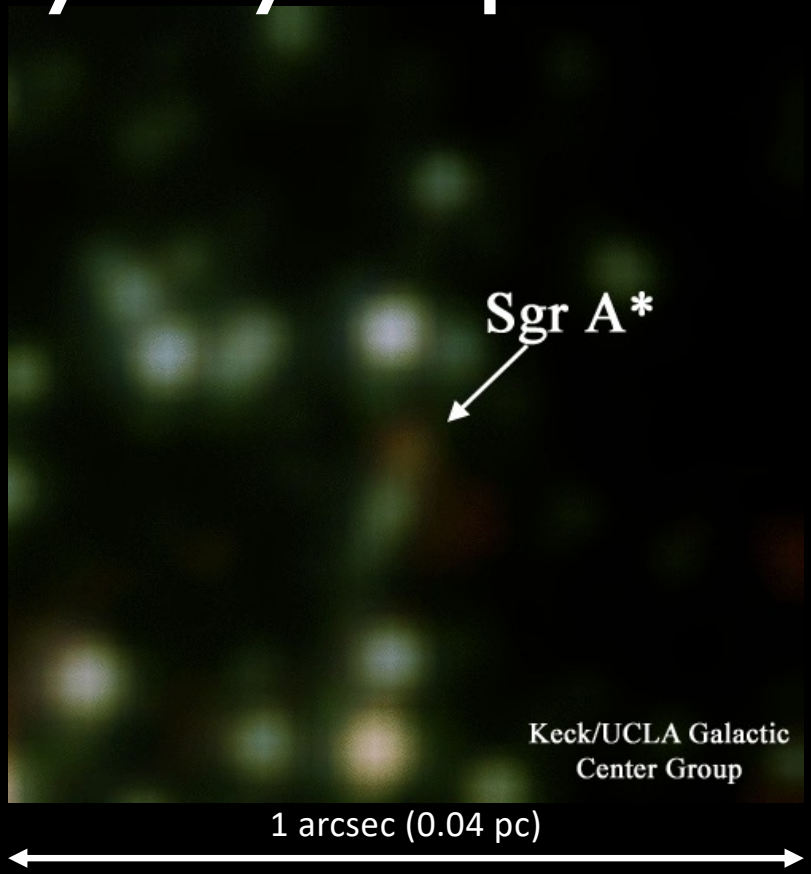
(3) How do stars form in extreme environments?

(4) How do star clusters dynamically evolve in galactic nuclei?

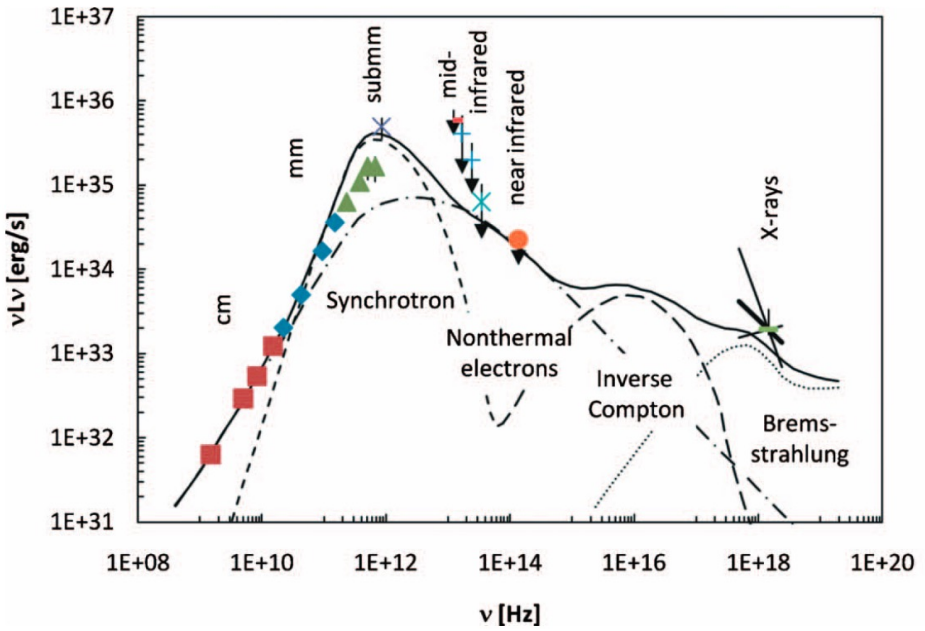
What is the nature accretion onto of our supermassive black hole?

Sgr A* is the emissive counterpart to the Milky Way's Supermassive Black Hole

Keck Adaptive Optics Observations

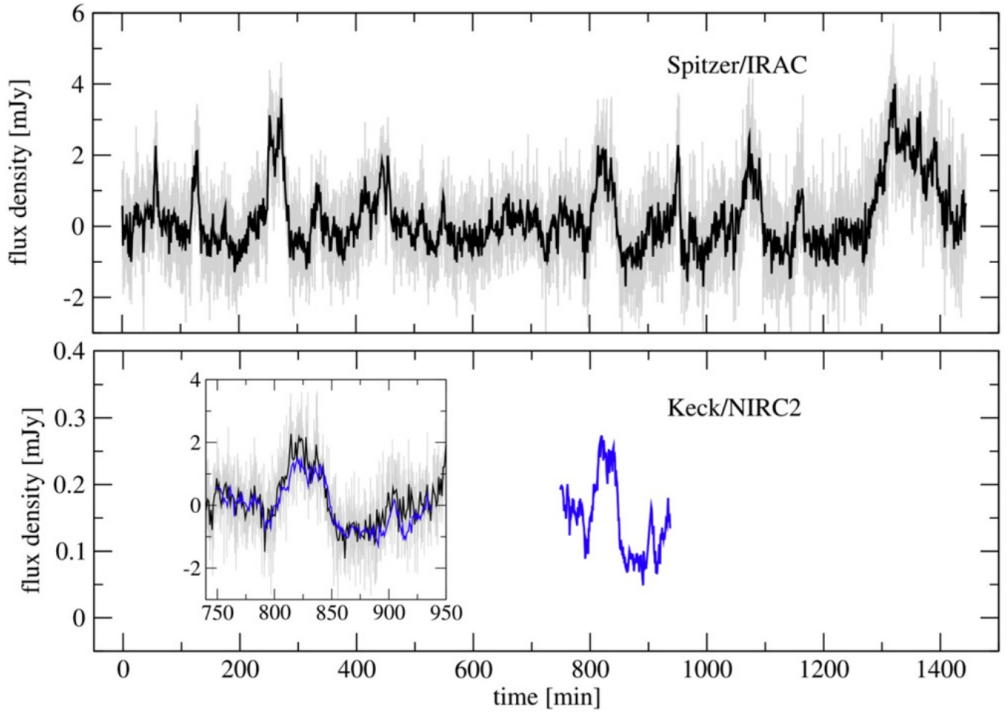


Sgr A* gives us a chance to study supermassive black hole accretion at all time scales



From Genzel et al. (2010)

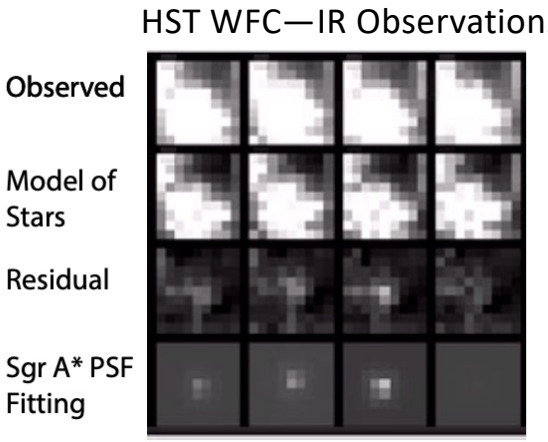
Sgr A* is variable at all time scales probed

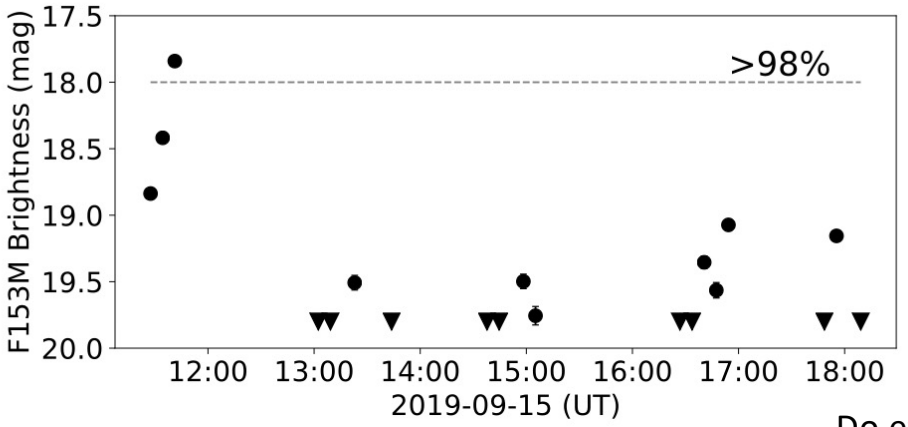


Longest time continuous observations: 24 hrs w/ Spitzer

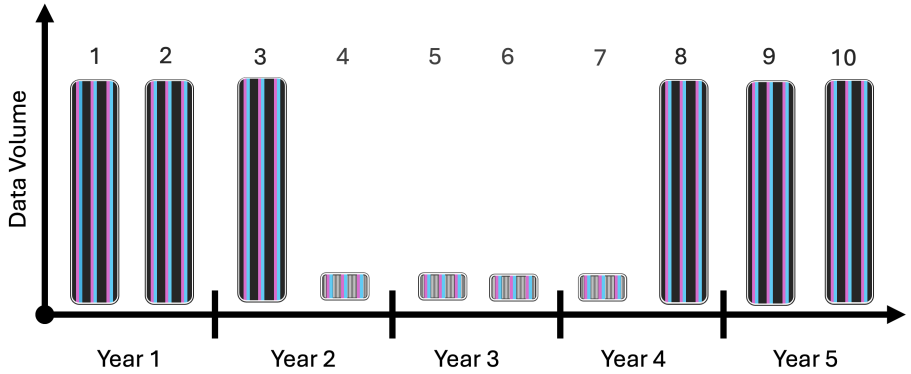
From Witzel et al. (2018)

Roman will offer unprecedented continuous observations (~70 days)



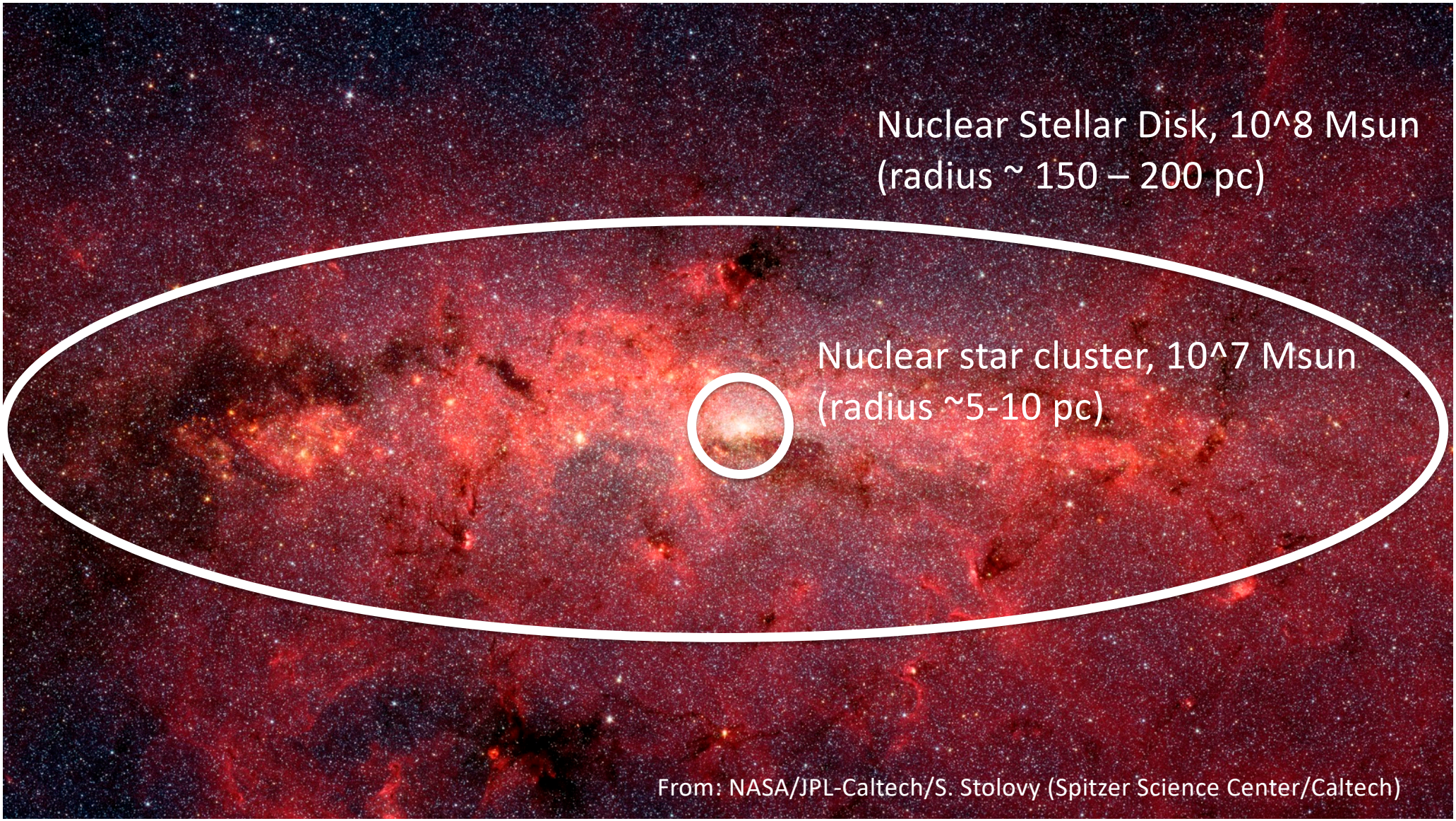


Do et al. (in prep.)

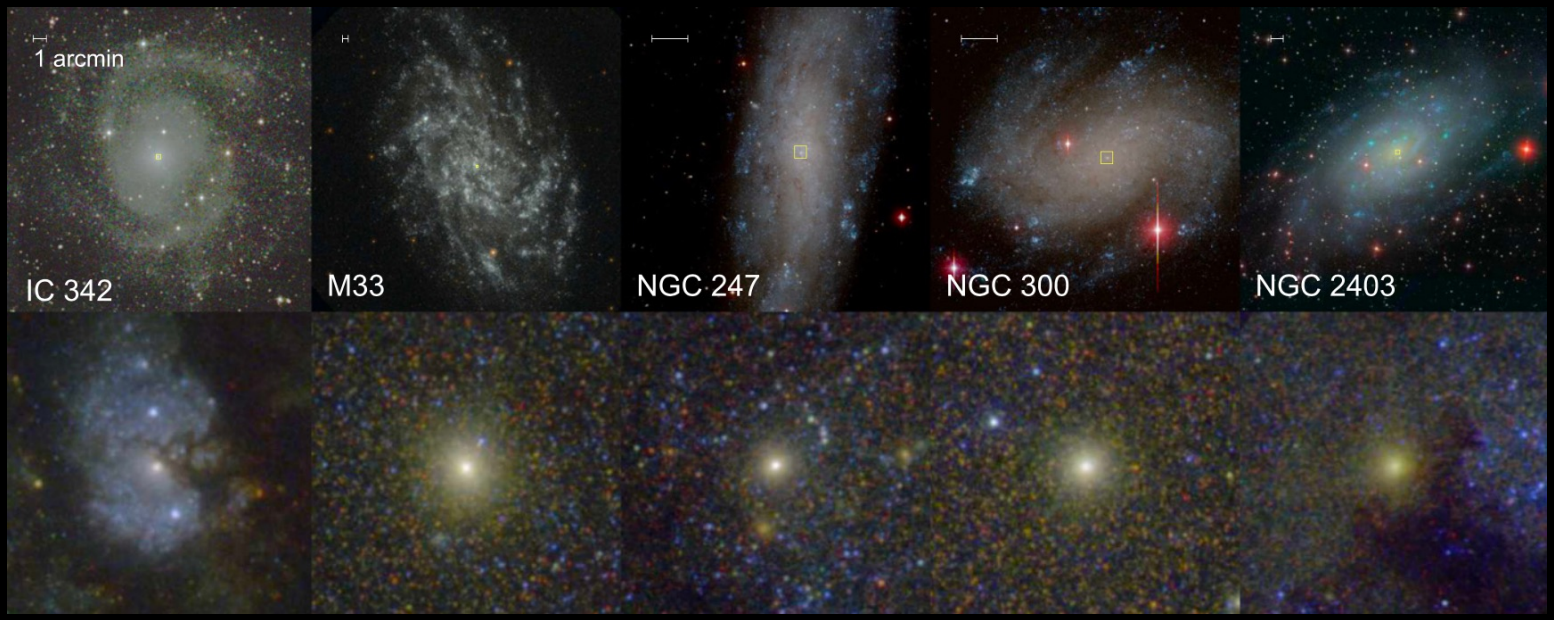


GBTDS schedule (Roman Docs)

What are the physical properties, origin, and evolution of our Galactic nucleus?


Nuclear Stellar Disk, 10^8 Msun
(radius ~ 150 – 200 pc)
Nuclear star cluster, 10^7 Msun
(radius ~5-10 pc)
From: NASA/JPL-Caltech/S. Stolovy (Spitzer Science Center/Caltech)

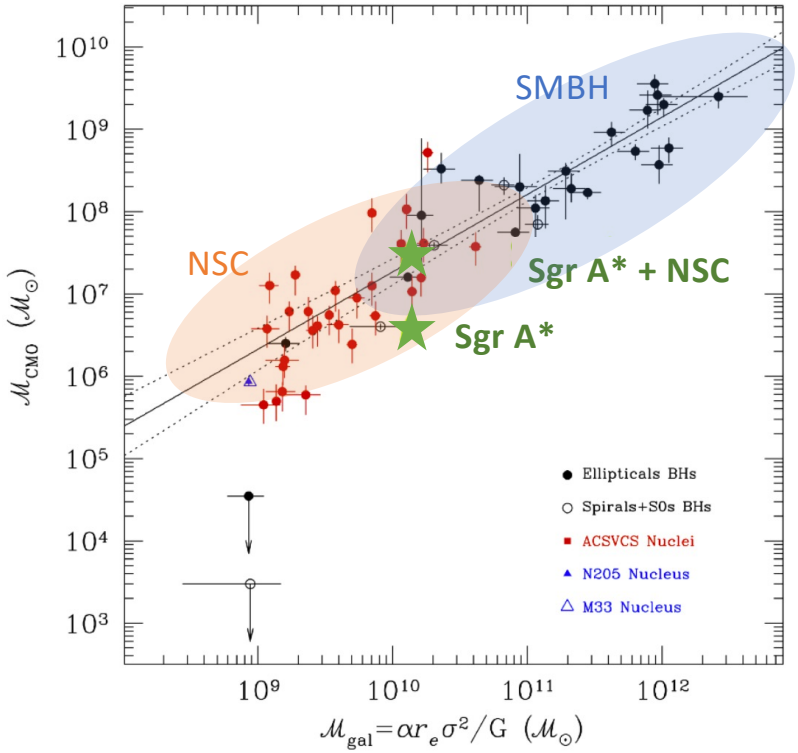
Nuclear star clusters are massive, & dense star clusters at the centers of many galaxies



HST images of NSCs from Carson et al. (2015)

See also: Böker et al. 1999, 2002, Walcher et al. 2005, Georgiev et al. 2014, Neumayer et al. (2020)

The formation and evolution of nuclear star clusters, massive black holes, and galaxies are likely related



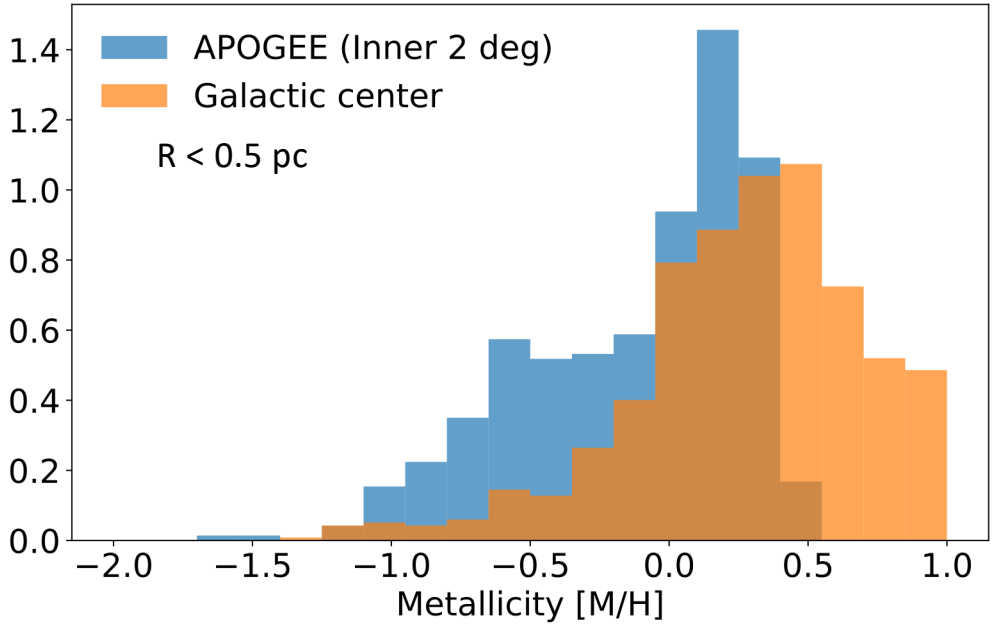
How do supermassive black holes and the formation of galactic nuclei relate to galaxy evolution?

From Ferrasese et al. 2006, Schoedel 2011

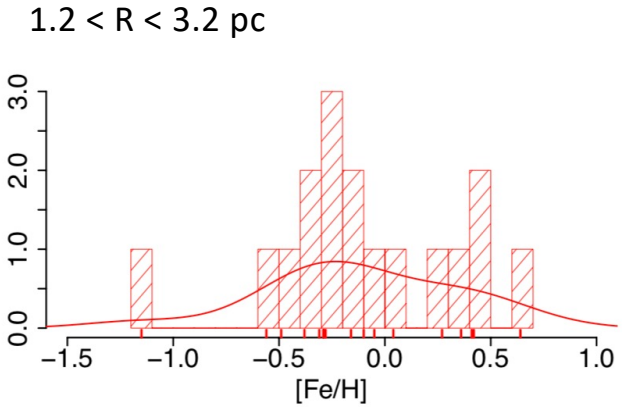
See also: Wehner & Harris 2006 , Graham 2012, McConnell & Ma 2013, Capuzzo-Dolcetta et al. 2017


Half-light radius: 4.2 pc (~2’) (Schoedel et al. 2014)
Total Mass: ~10^7 Msun, 5-10 Gyr old
(Chatzopoulos et al. 2014, Schoedel et al. 2009, Pfuhl, et al. 2011)
HST WFC3-IR, F127M, F139M, F153M (Hosek, T. Do et al. in prep)

The NSC is likely very, metal-rich even compared to the inner bulge



Do et al. (2015, 2018)

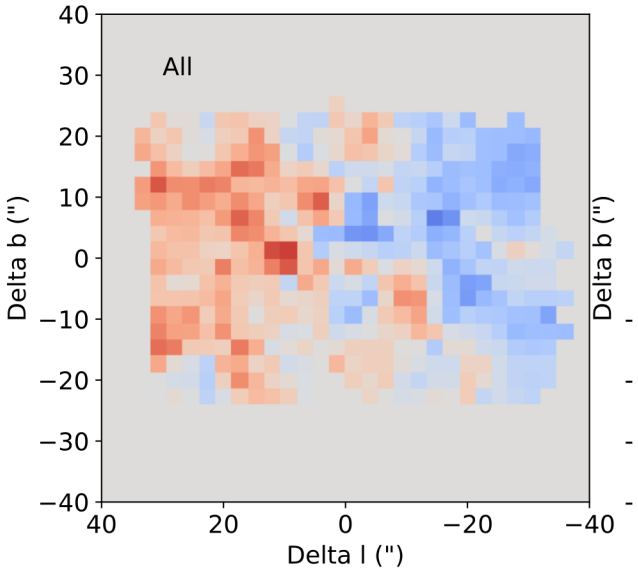


From high-resolution observations (Rich et al. 2017)

Also: Ryde et al. (2015, 2016), Do et al. (2015), Feldmeier-Krause et al. (2017), Rich et al. (2017), Garcia Perez et al. (2018), Thorsbro et al. (2020), Schultheis et al. (2025)

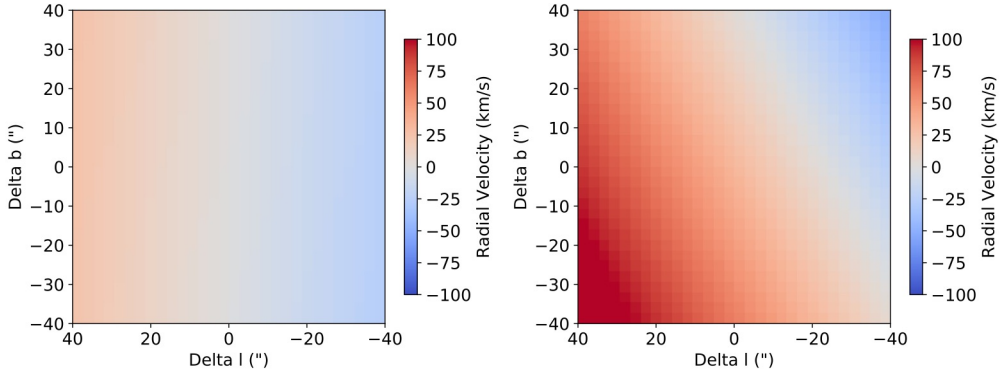
Different kinematic signatures for different metallicity populations?

Average radial velocity maps



Do et al. (2020)

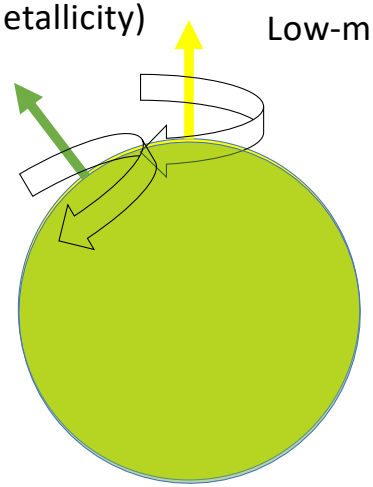
Metallicity and velocity data are consistent with having two distinct chemical-dynamical populations



Main population (high-metallicity)

Low-metallicity population

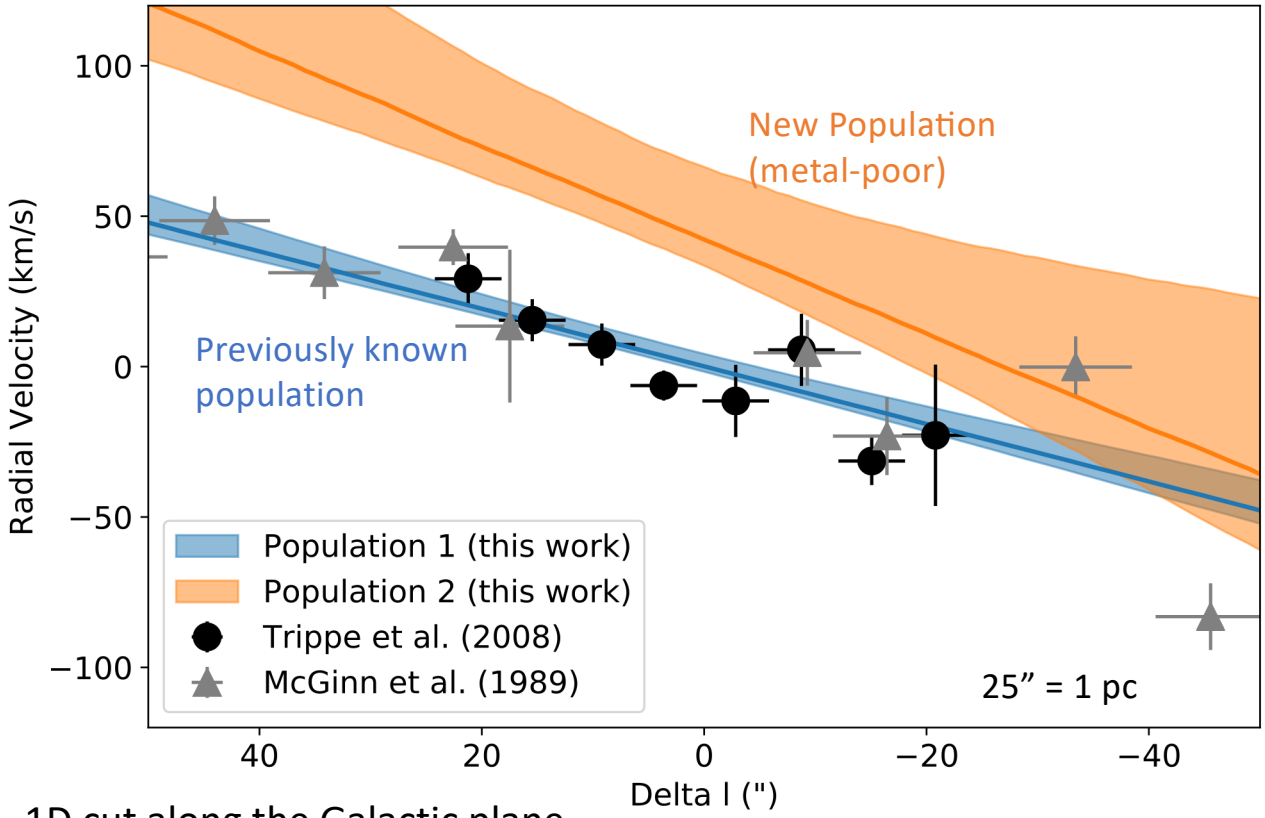
Do et al. in prep



Is this an infalling cluster?

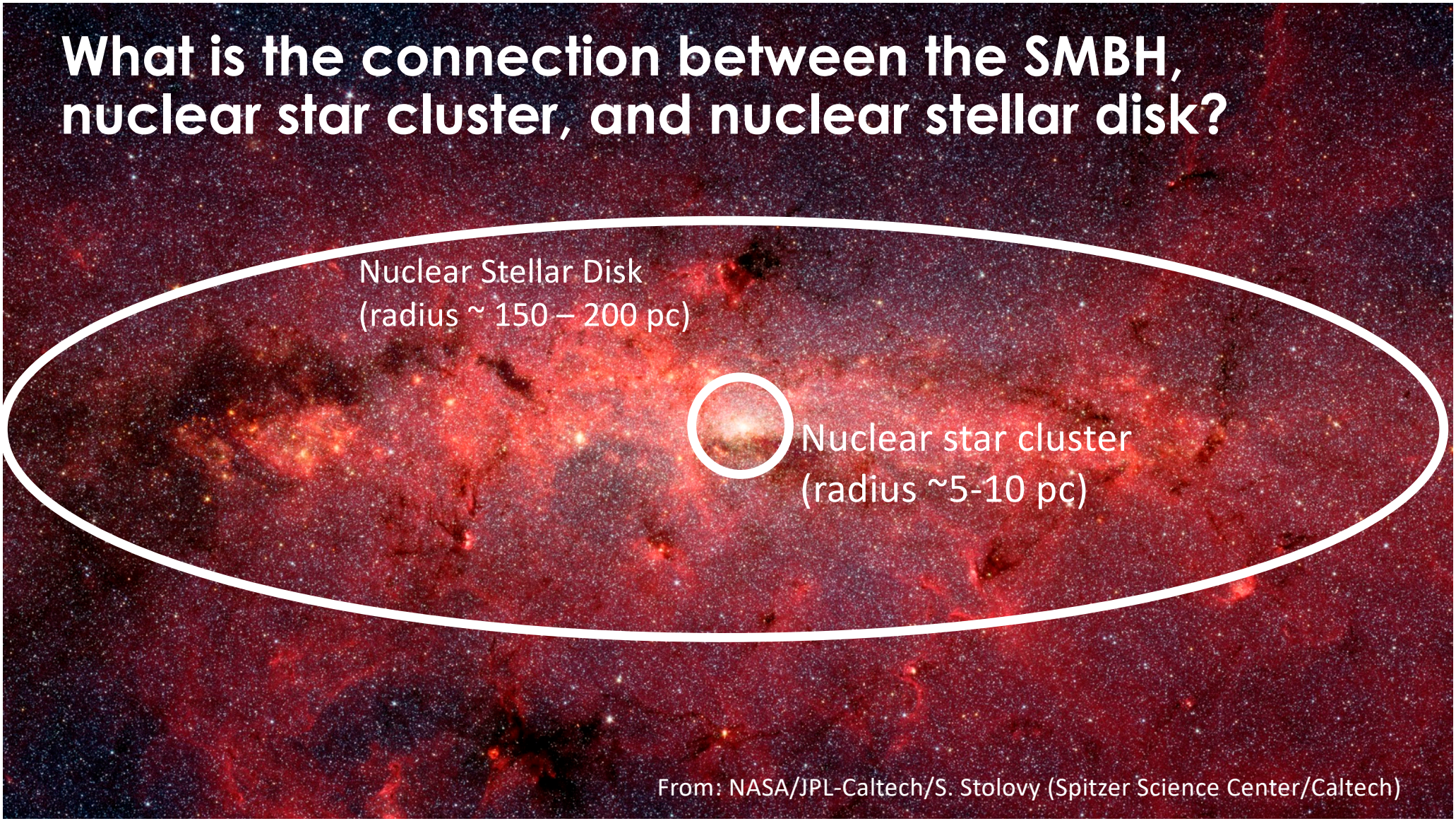
Additional measurements helpful to confirm differences in rotation direction and extent of sub-components

Can we constrain the presence of a stellar stream or infalling cluster?

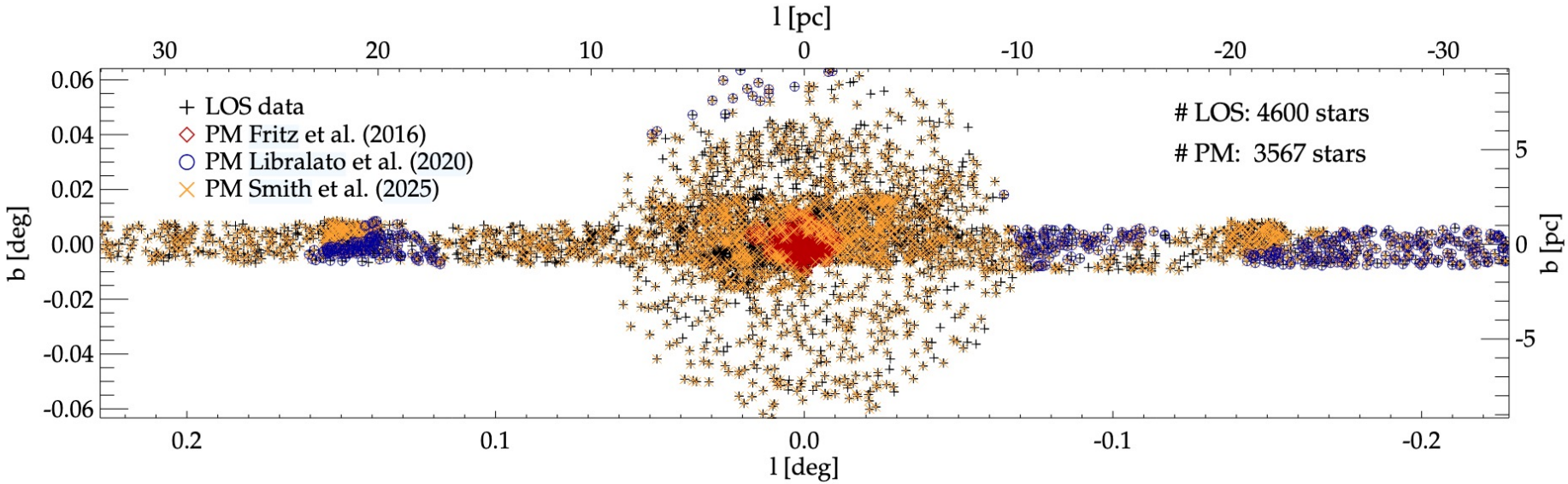


1D cut along the Galactic plane

Do et al. 2020.

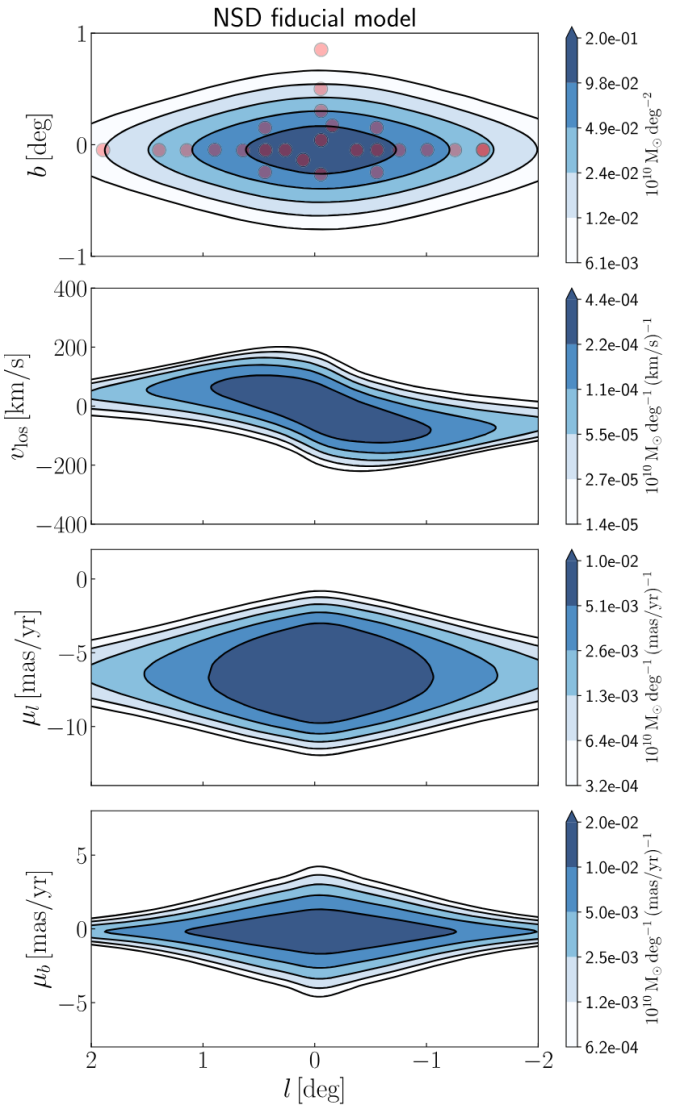

What is the connection between the SMBH, nuclear star cluster, and nuclear stellar disk?
Nuclear Stellar Disk
(radius ~ 150 – 200 pc)
Nuclear star cluster
(radius ~5-10 pc)
From: NASA/JPL-Caltech/S. Stolovy (Spitzer Science Center/Caltech)

It is challenging to observe at high angular resolution across the entire NSC+NSD



Kinematic data from the inner 30 pc with proper motion and line of sight radial velocities

From Feldmeier-Kraus et al. (2025)

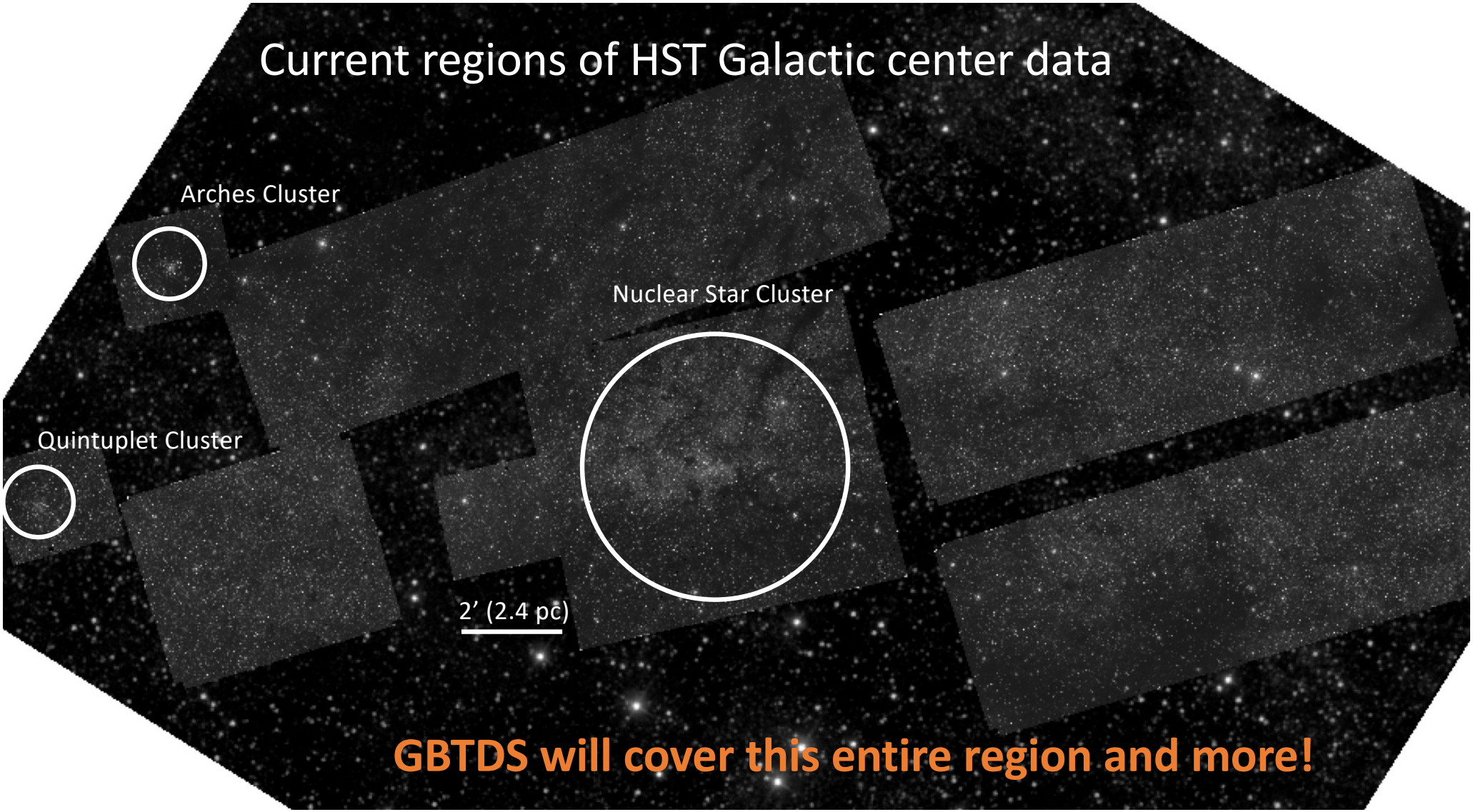


Dynamical models currently rely on incomplete and poorly sampled data

Model of the nuclear stellar disk from self-consistent distribution function models of proper motion and radial velocities (central 2 deg, ~280 pc).

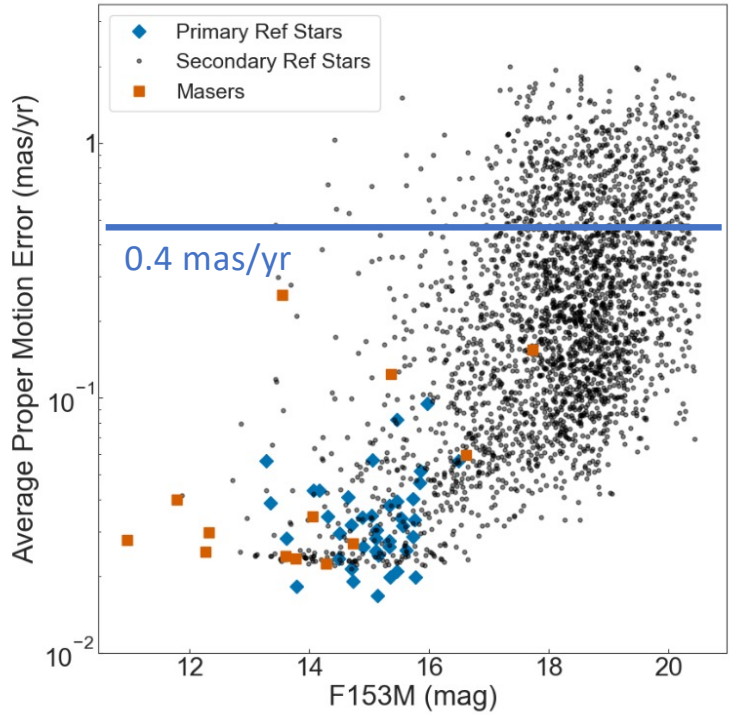
Best fit: R_{disk} ~ 89 pc, 11x10^8 Msun

From Sormani et al. (2024)


Current regions of HST Galactic center data
Arches Cluster
Nuclear Star Cluster
Quintuplet Cluster
2’ (2.4 pc)
GBTDS will cover this entire region and more!

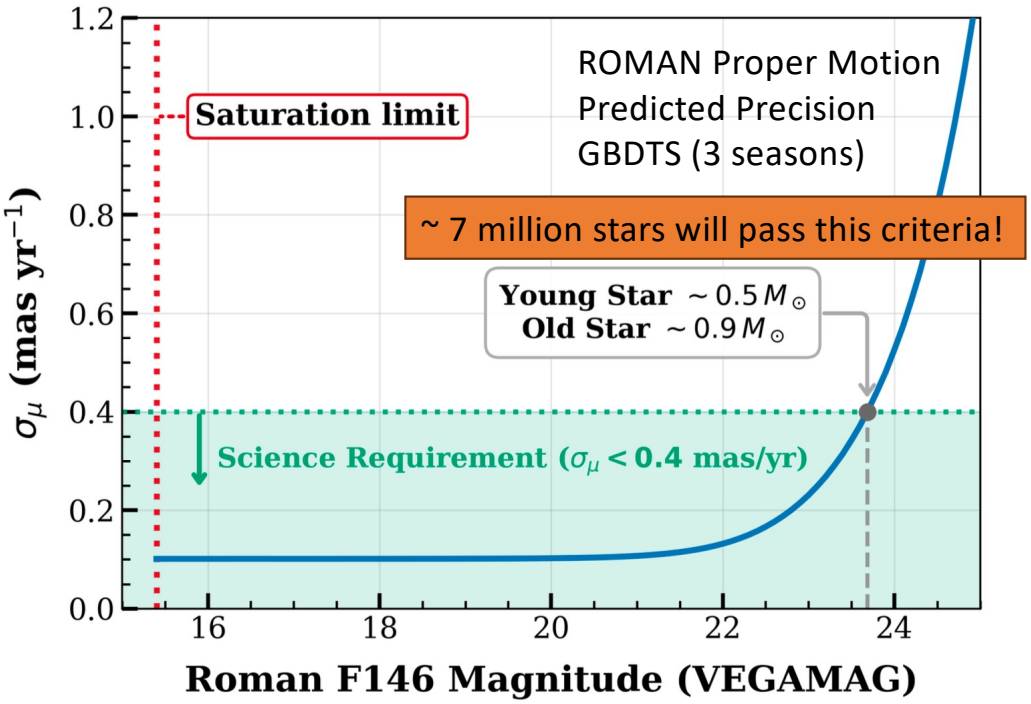
Roman GBTDS will quickly achieve the similar astrometric precision as HST given the large number of measurements

From 13 years (14 epochs) of HST observations of the Galactic center



From Hosek et al. (2025)

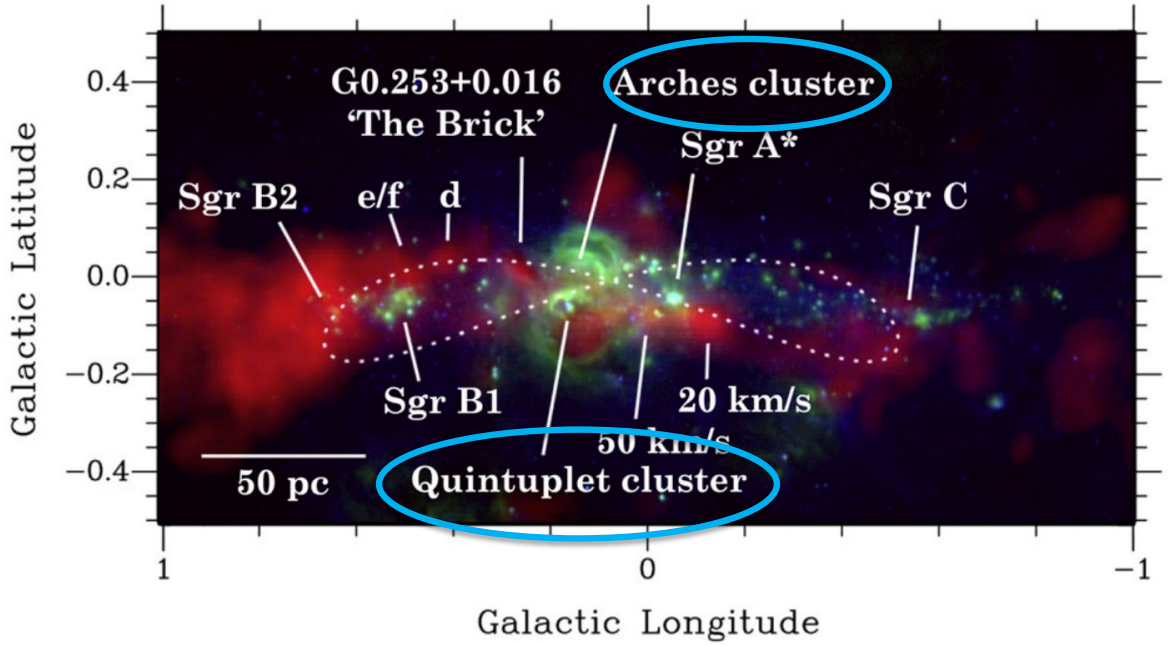
The expected proper motion error as a function of F146 mag for the GC field after the first three seasons (9 months) of the GBTDS.



How do stars form in extreme environments?

How do star clusters dynamically evolve in galactic nuclei?

Star formation in the Galactic center is challenging due to its extreme environment



What triggers star formation? Do stars form in the molecular ring?
Why is star formation so **inefficient** at the Galactic center?

From: Kruijssen et al. (2015)

Compared to solar neighborhood:

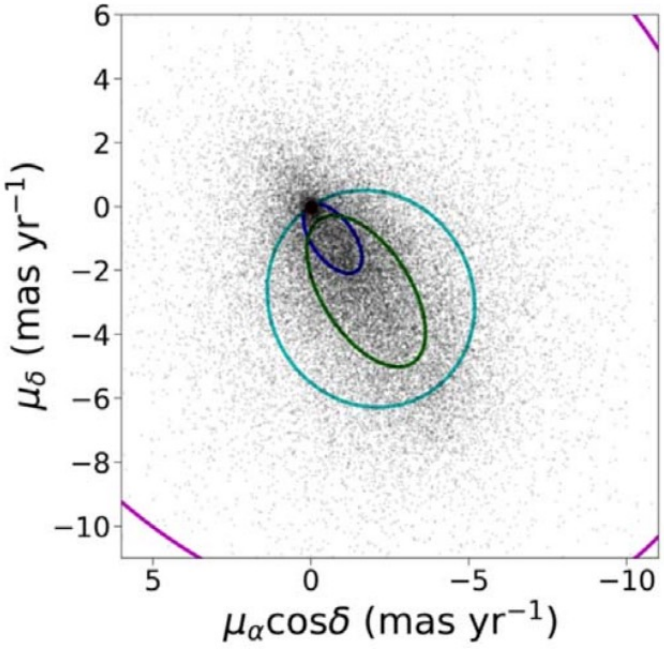
100 x Surface stellar density: $10^{3.9}$ $M_\odot$ pc^{-2}
20 x Surface gas density: $10^{2.8}$-$10^{3.2}$ $M_\odot$ pc^{-2}
2-5 x Gas temp.: 50 - 100 K
10 – 100 x Magnetic fields: 10-1000 µG
1000 x Turbulent gas pressure: P/k ~ 10^9 K cm^{-3}

(Henshaw et al. 2023, Rathrone et al. 2014)

Conditions are closer to galaxies @ z ~ 2

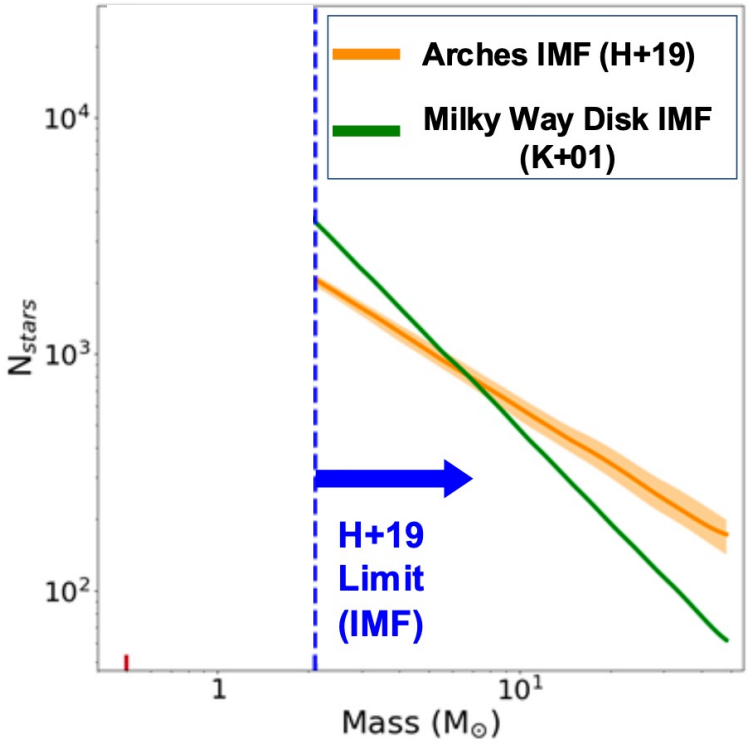
Red: Molecular Gas
Green: MSX 21.3 micron
Blue: MSX 8.28 micron

Massive star clusters at the Galactic center gives us a probe star formation and the dynamical evolution of star clusters



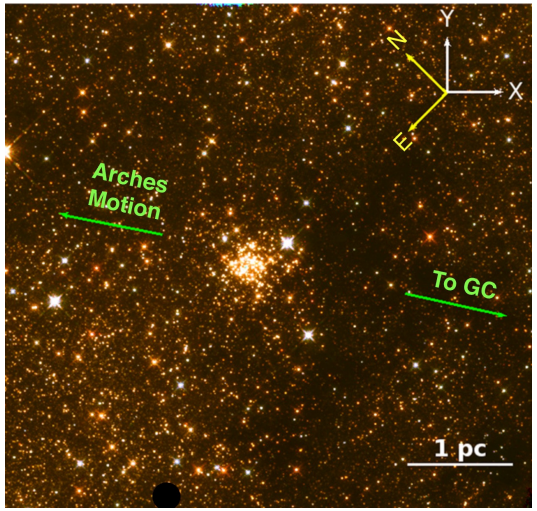
Proper motions allow for more accurate selection of cluster members

From Hosek et al. (2019)



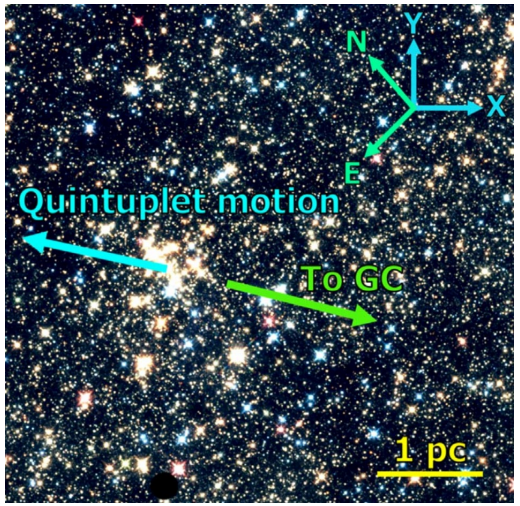
The Arches cluster has a top-heavy IMF (more massive star fraction than locally)

Roman will enable measurements of the orbits and tidal tails of Arches and Quintuplet clusters



HST WFC3-IR

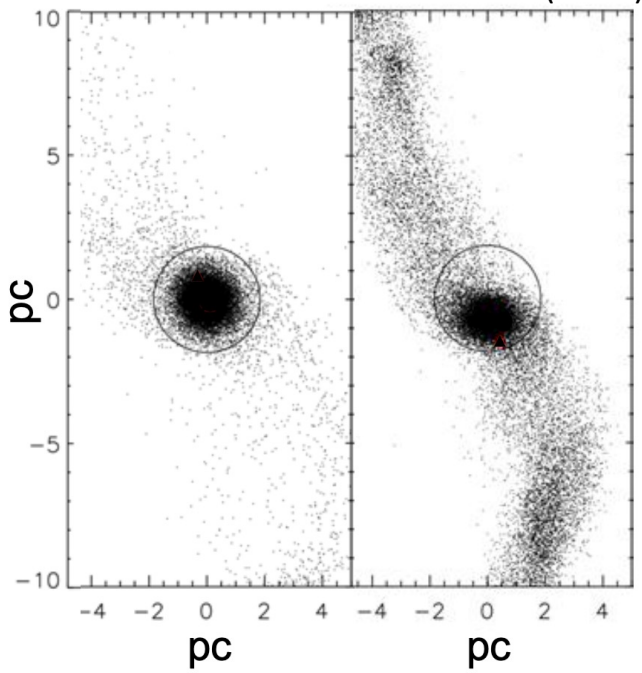
Hosek et al. (2015)



HST WFC3-IR

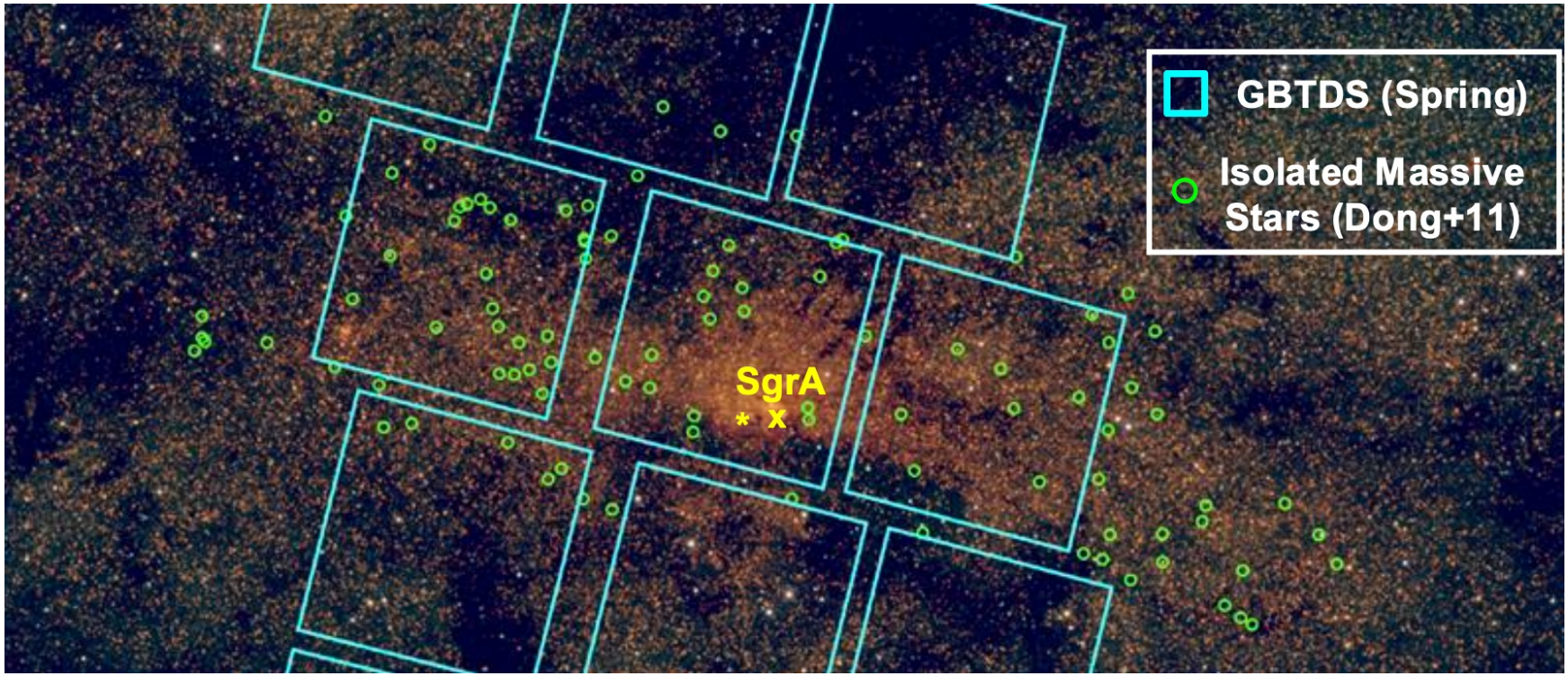
Rui et al. (2019)

Kim et al. (2018)

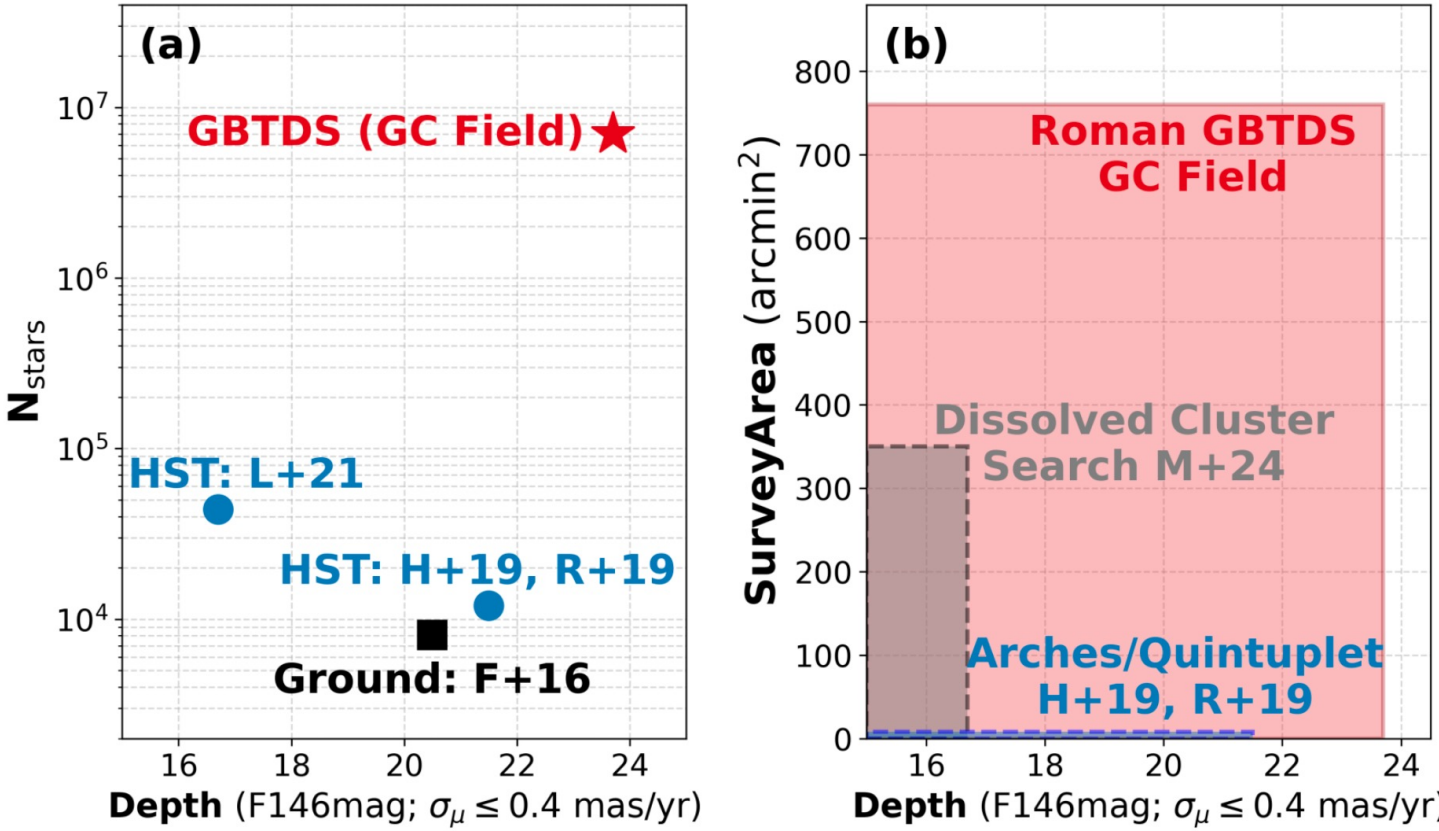


Tidal tails can extend >10 pc from the cluster

What is the origin of isolated massive stars at the Galactic center?



Roman will provide high HST-level proper motion precision over very large areas for the first time



Do et al. (in prep)

Conclusions

- Roman will provide unprecedented combination of high-resolution, large field of view, and high precision proper motion of millions of stars in the Galactic center GBDTS. **Thanks to everyone who made it possible to add this field to GBDTS!**
- It will enable studies of all scales from Sgr A* to the nuclear star cluster and nuclear stellar disk. This will also enable study of massive star clusters in the region.
- Additional science areas not mentioned: compact objects and black holes, binary stars, Miras, Cepheids, RR Lyrae stars, hyper velocity stars, etc.