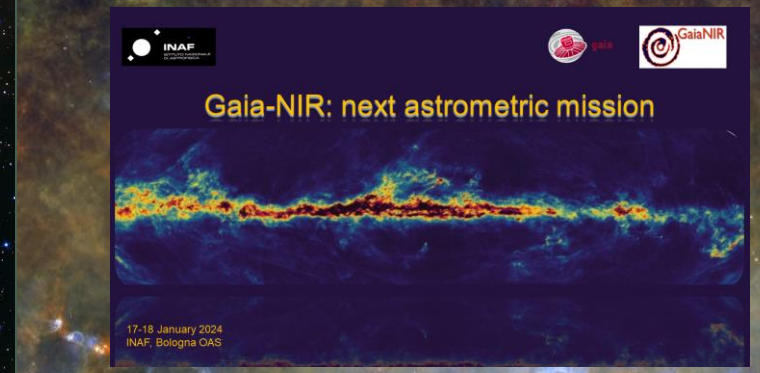


# The young supermassive star clusters: an opportunity to study stars and planets formation in starbursts

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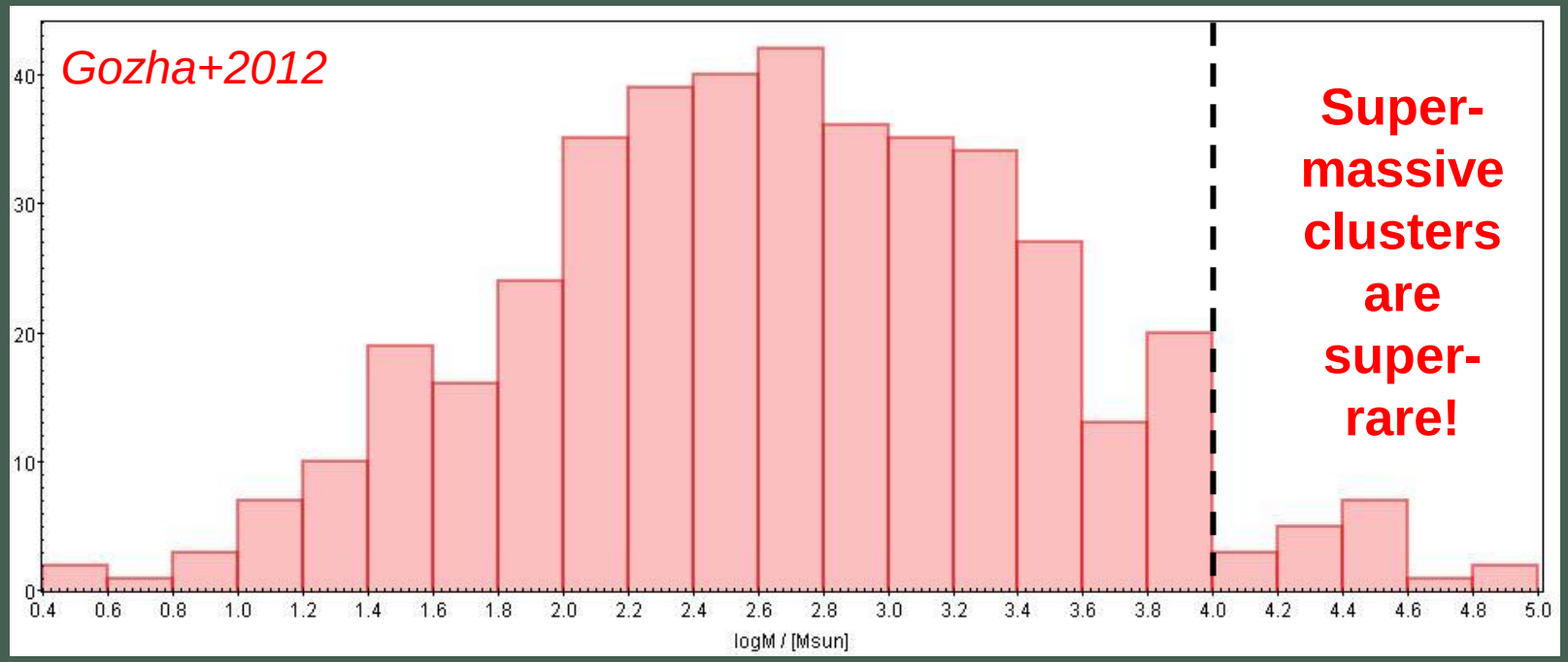
# Young Supermassive Star Clusters (SSCs)

Clusters with M > $10^4$ $M_\odot$, but definition can depend on the context *(Focus Meeting at Beijing IAU GA, 2013)*

Mass distribution of star clusters in the Milky Way.

**Clusters with mass >$10^4$ $M_\odot$ are very rare**.




$10^4$ $M_\odot$ is an arbitrary limits, which corresponds to massive clusters with thousands of members, and more than several hundreds of massive stars.

# Massive stars in SSCs

A random sampling of the IMF results in a **relation between the mass of clusters and that of their most massive star**

Very massive clusters host hundreds massive stars, among which the most massive known stars. This is important since:

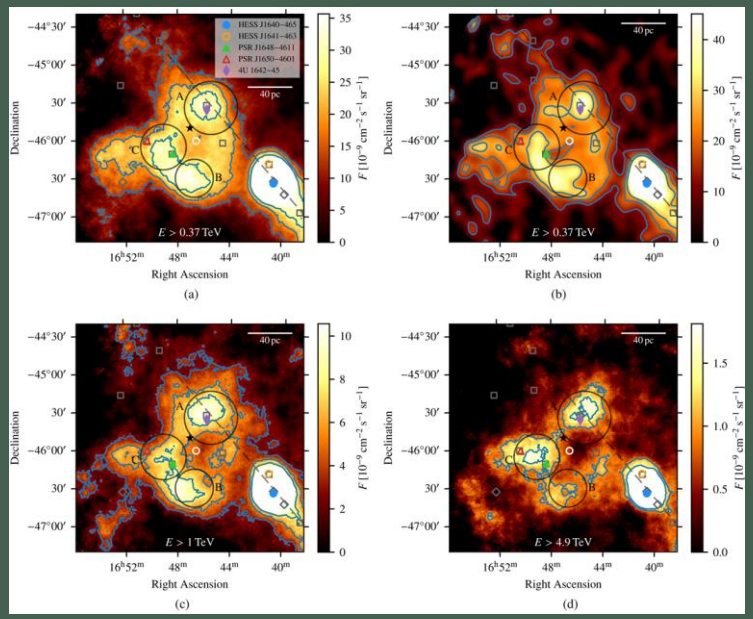
- Massive stars are rare!

- Massive stars are intense sources of UV radiation, X-rays and energetic particles (mostly in close binary systems with colliding winds), which impact:

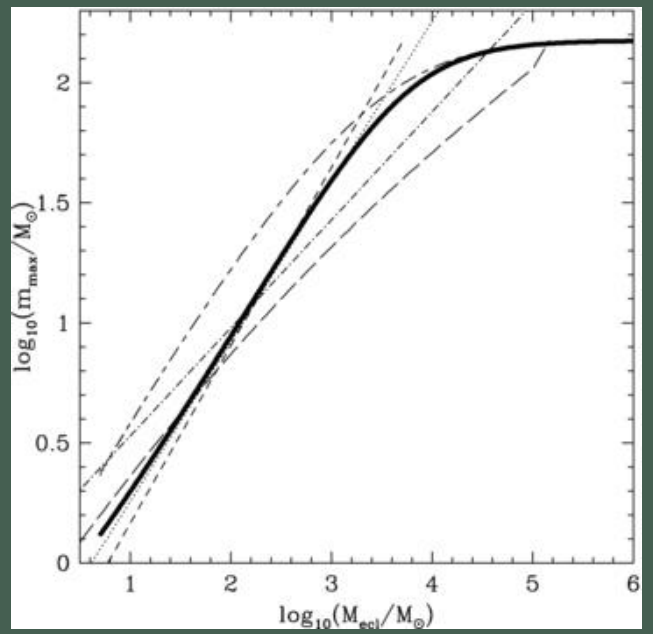
➢ The star formation process in the parental cloud

➢ The dispersal of disks in nearby low-mass stars

➢ The planets formation and evolution in nearby disks




*γ-ray images of the area around Westerlund1 from HESS (Aharonian+2022)*




*Elmegreen 1983 [long dashed line], Elmegreen 2000 [short-dashed line], Bonnel+2003 [dotted line], Larson+2003 [dash-dotted line], Weidner & Kroupa 2004 [thick-solid line], Oey & Clarke 2005 [short-dashed–long-dashed line]*

# Feedback from SSCs environment

The energetic environment of SSCs can affect:

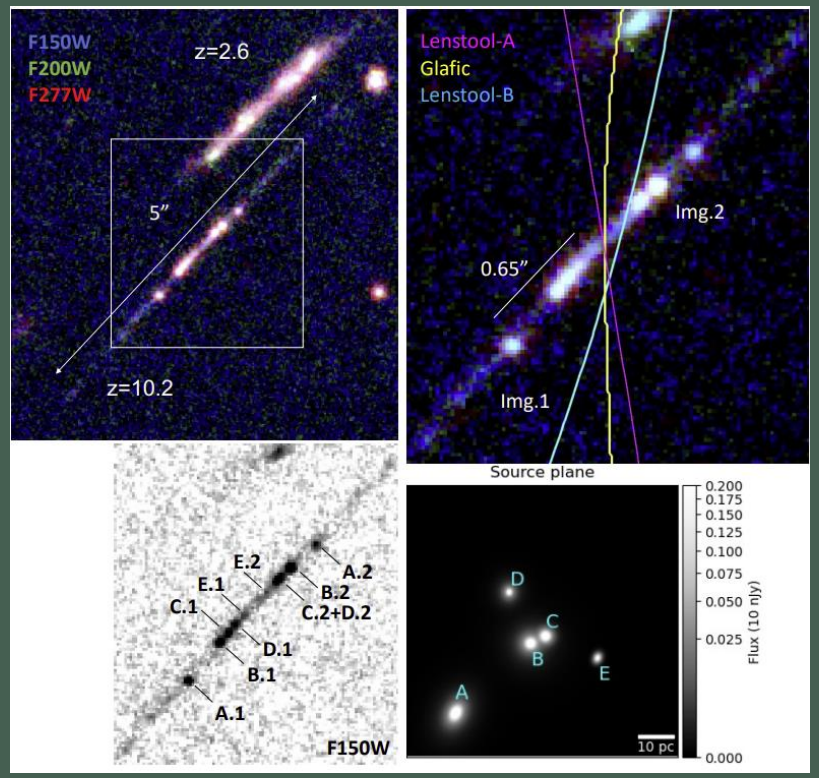
- Binarity (especially in the high-mass regime)
- Evolution of massive stars (effects of binarity) and production of compact objects
- Timescales for disks dispersal (through photoevaporation and close encounters)
- Planets formation and early evolution (chemical evolution of disks, formation of solids, effects on atmospheres)
- IMF and formation of brown dwarfs (physical properties of the parental cloud)

It is also important to understand how these clusters form, and how (and if) they disperse.

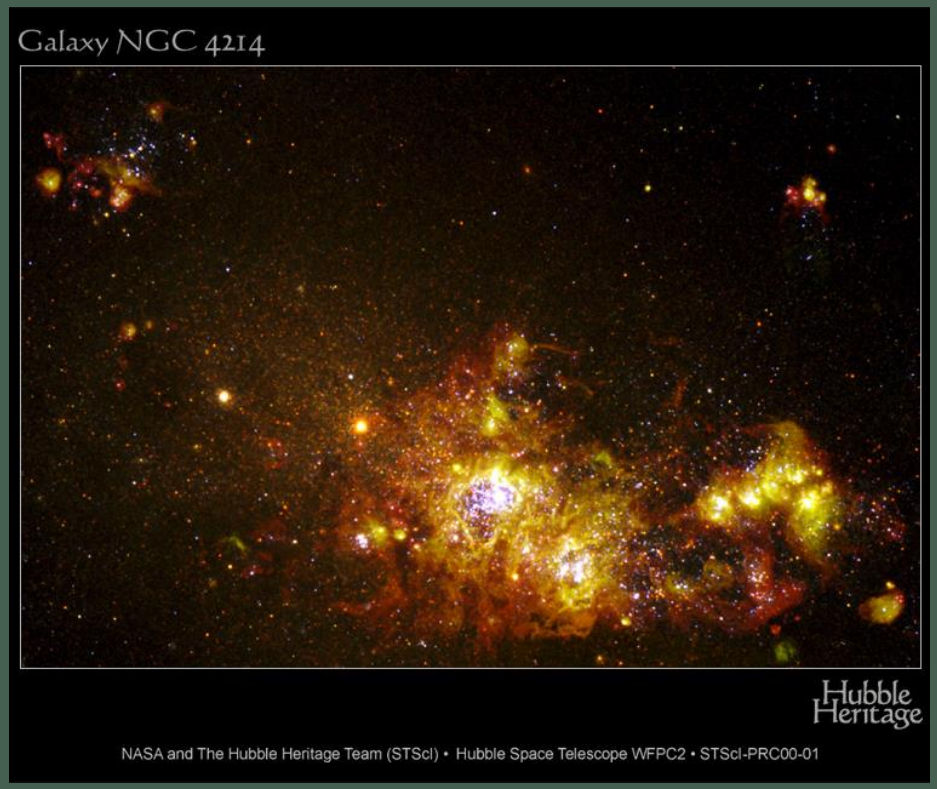
# SSCs products of starburst episodes

In galaxies experiencing starbursts, star formation mainly takes place in concentrated and very massive clusters *(e.g. de Grijs+2001, 2003)*

*HST image of M51*

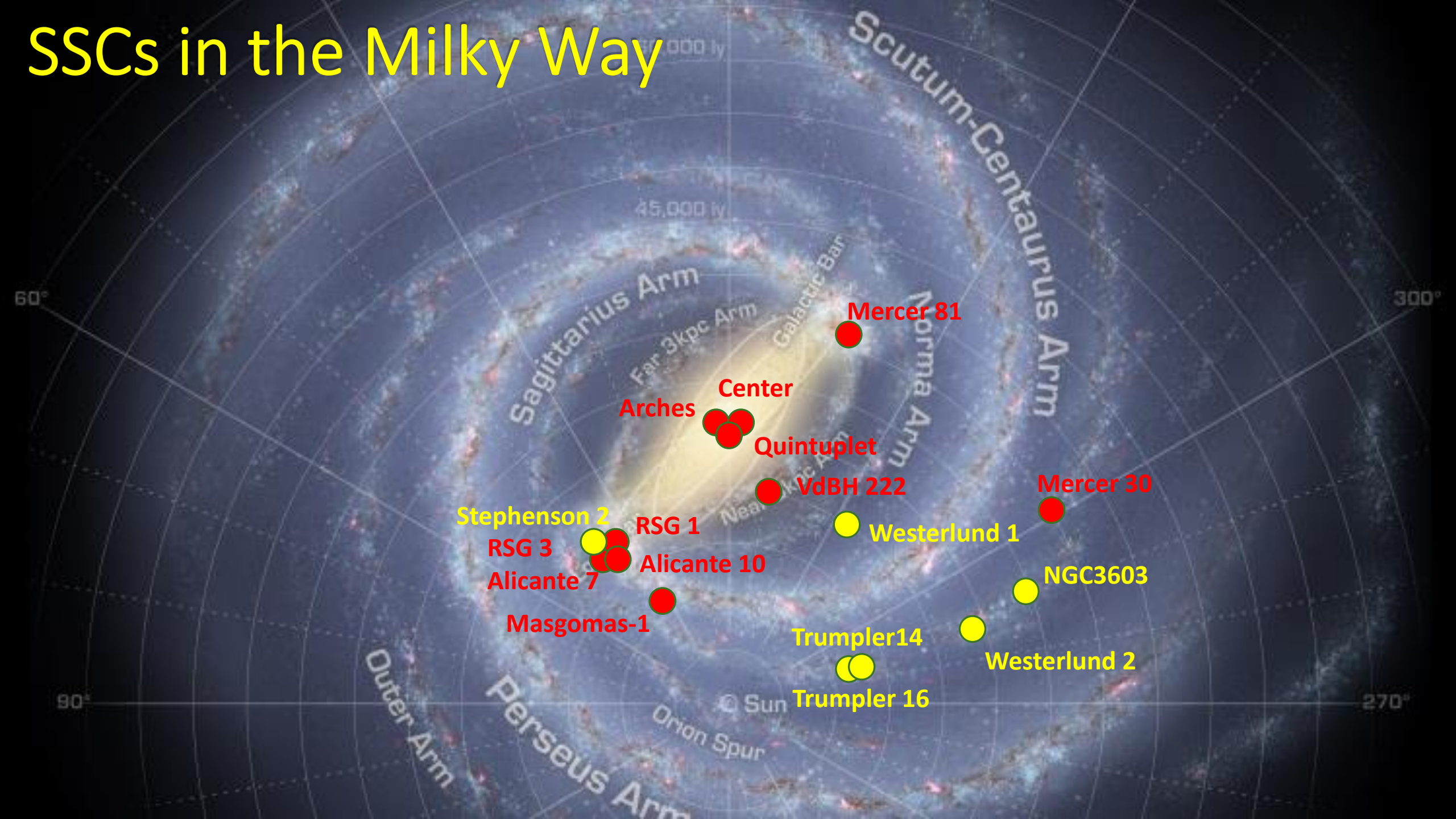



*Proto-super massive clusters in the Cosmic Gems galaxy (z~10.2), Adamo+2024*




*NGC4214 (HST)*

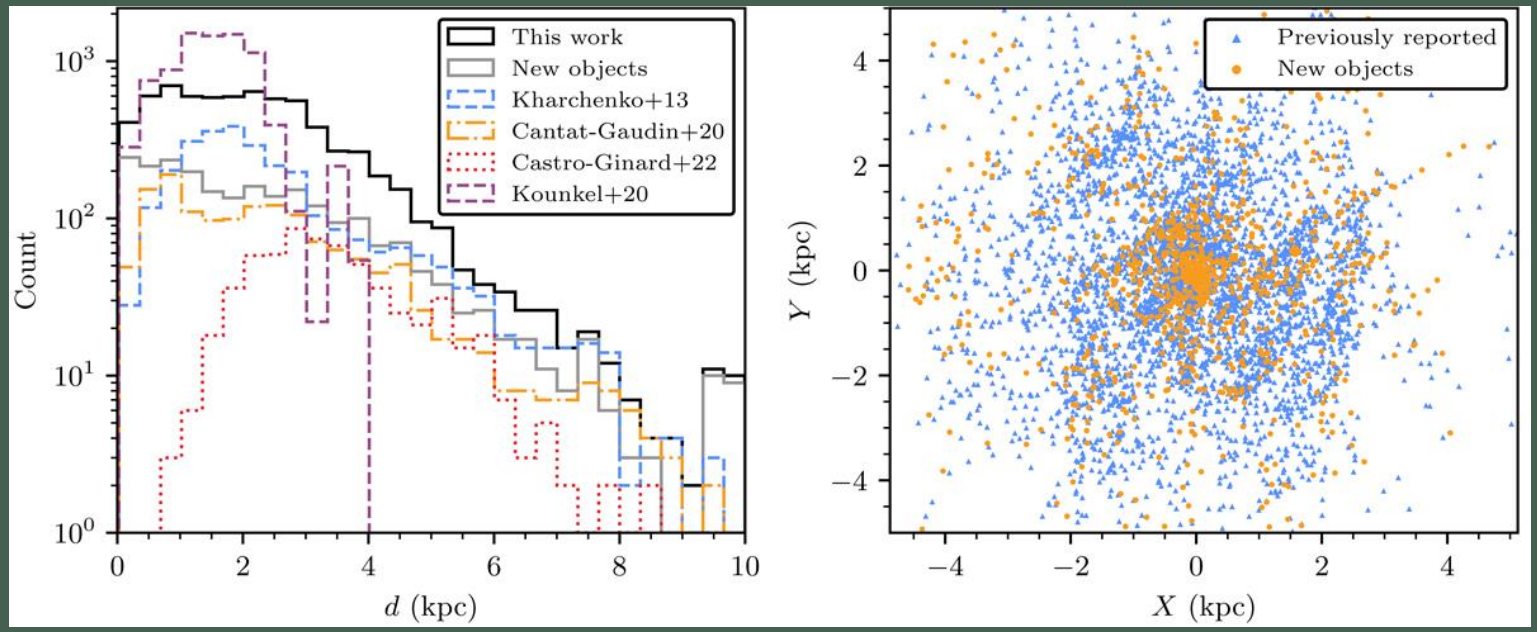
# SSCs in the Milky Way

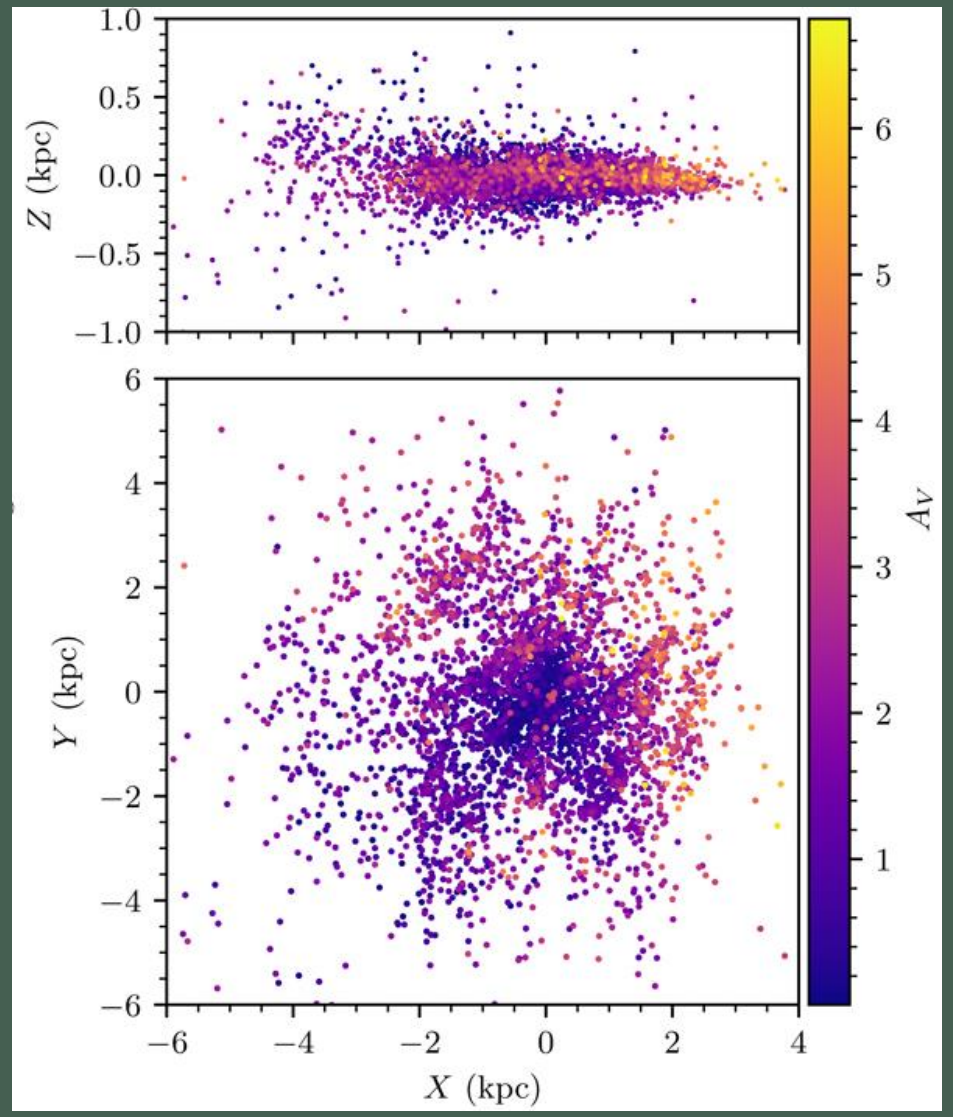


# Star clusters: The Gaia Revolution

Gaia has brought a revolution in the star clusters science.

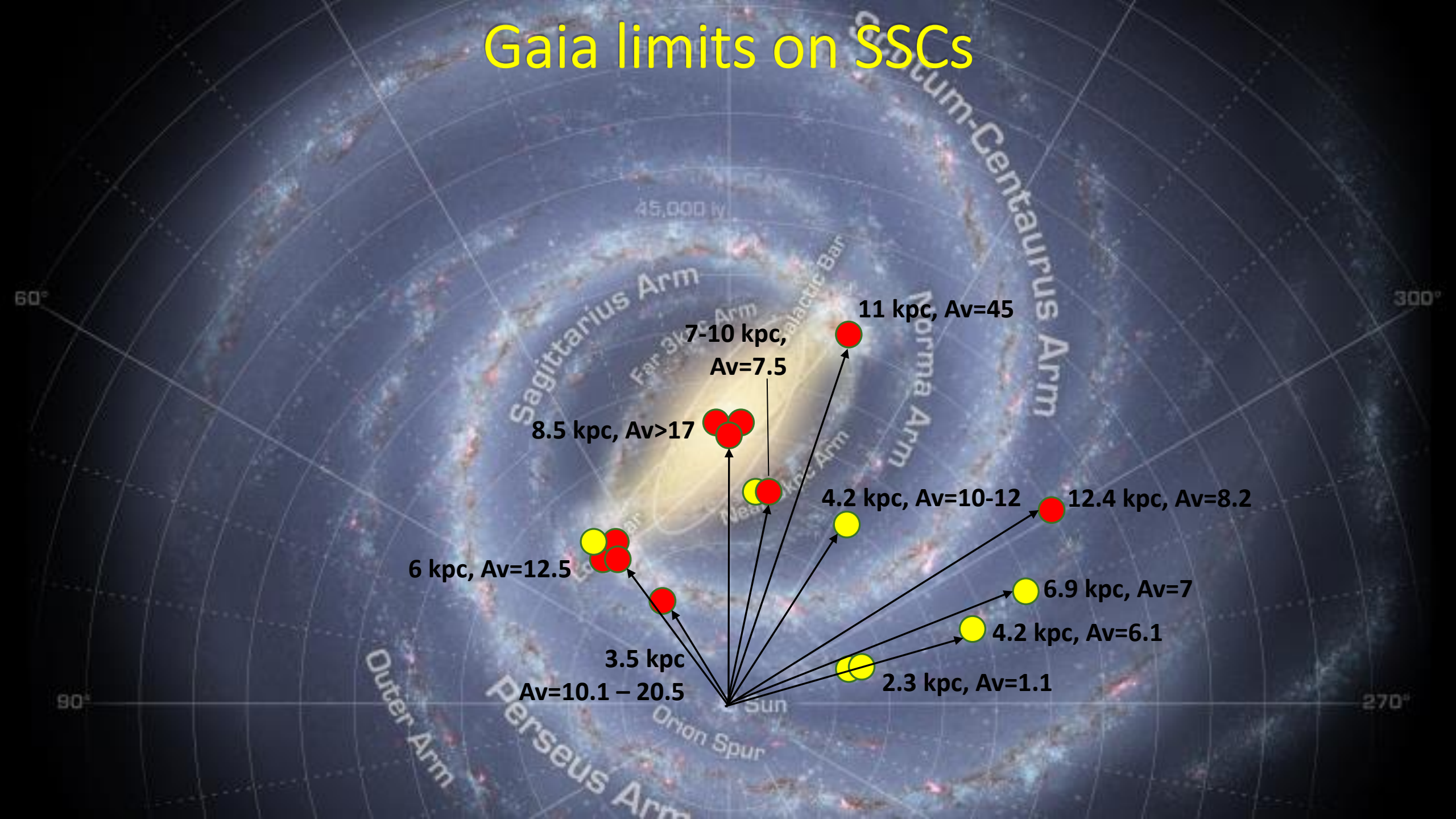
In DR3, parallaxes are good out to 3 kpc and systematics are well understood *(Lindegren+2021, Maiz-Apellaniz+2021, Eyer+2023)*



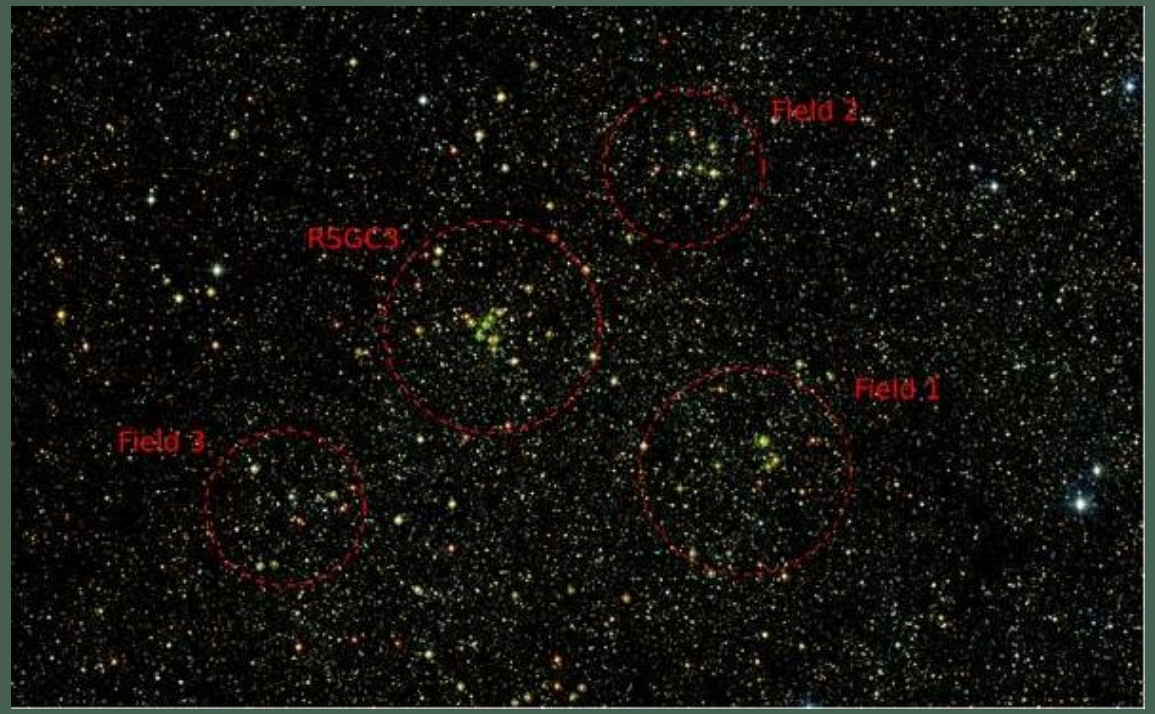

*Distance, positions and extinction of star clusters in Hunt&Reffert 2023*

# Gaia limits on SSCs



# Gaia limits on the most distant SSCs

High interstellar extinction and extreme crowding, typical of SSCs, mess up the clustering algorithms and the astrometric capabilities of Gaia

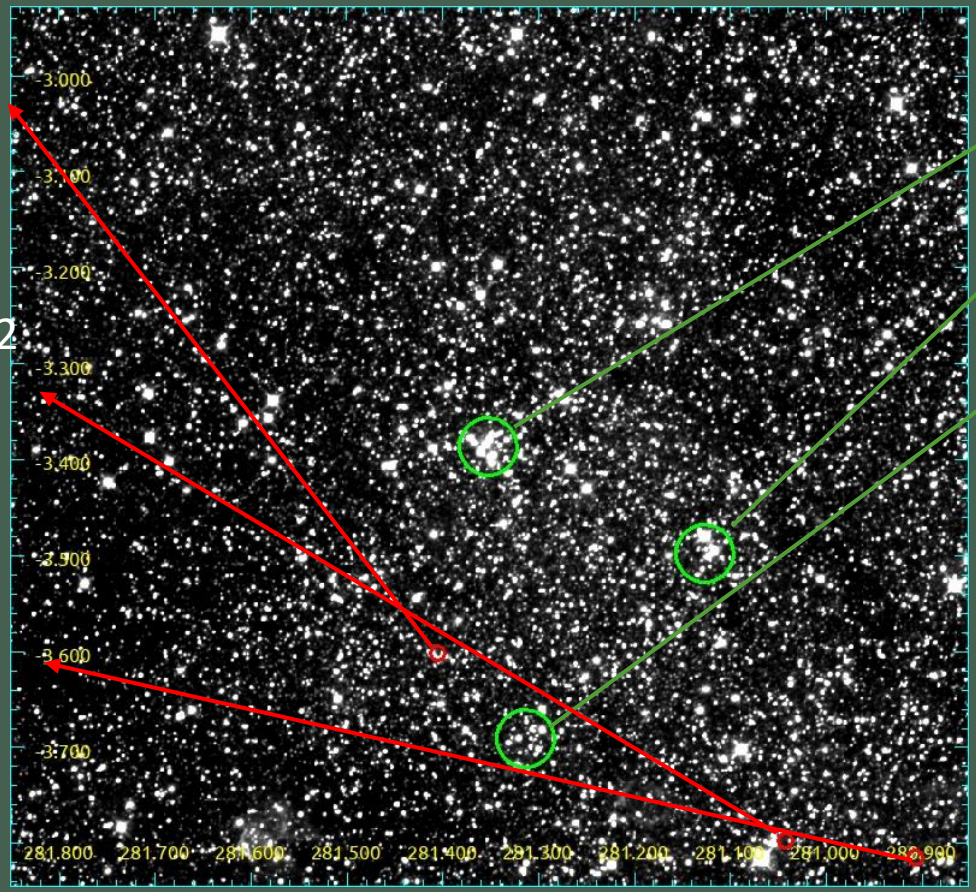



González-Fernández & Negueruela 2012

FSR87
2320 pc
74 Myrs

CWNU1292
2800 pc
5.5 Myrs

HSC285
2870 pc
50 Myrs




RSG3

Alicante 7

Alicante 10

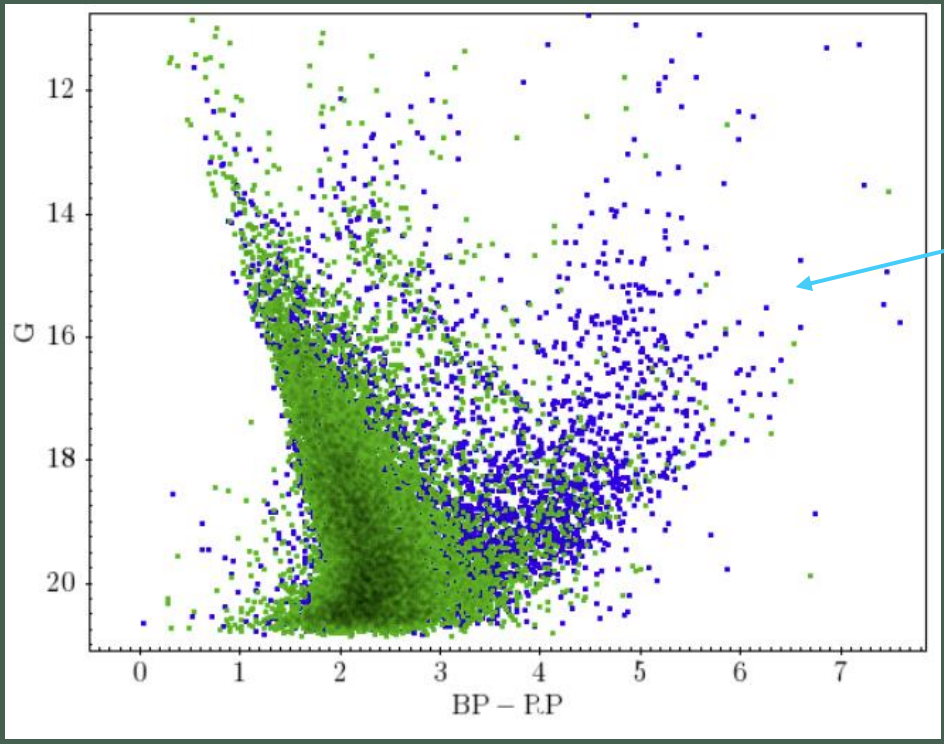
About 6 kc

In the direction of the Scutum-Crux complex, cluster search with Gaia (*Hunt&Reffert 2023*) can reach up to about 2.3 kpc

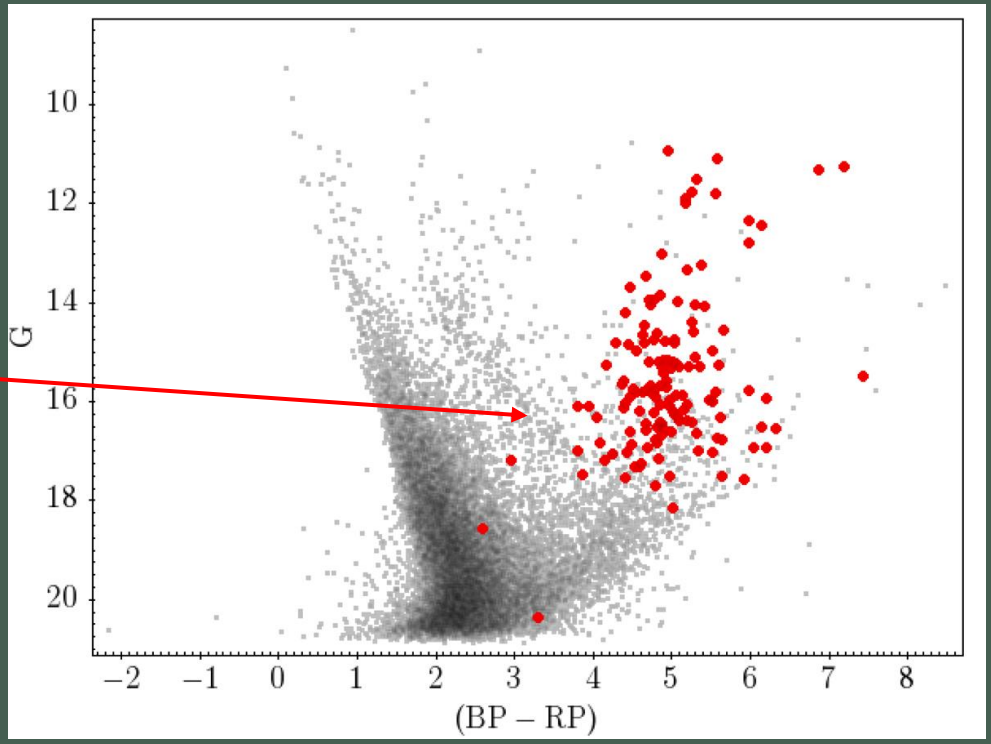
# Gaia limits on nearby SSCs

Extinction and crowding can mess up the determination of the parameters also of nearby SSCs.

Test case: Westerlund 1. Not accurate members selection led to not realistic distance and age estimate (about 2.8 kpc, *Aghakhanloo+2020, 2021*), corrected by more accurate members selection *(Negueruela+2022)*

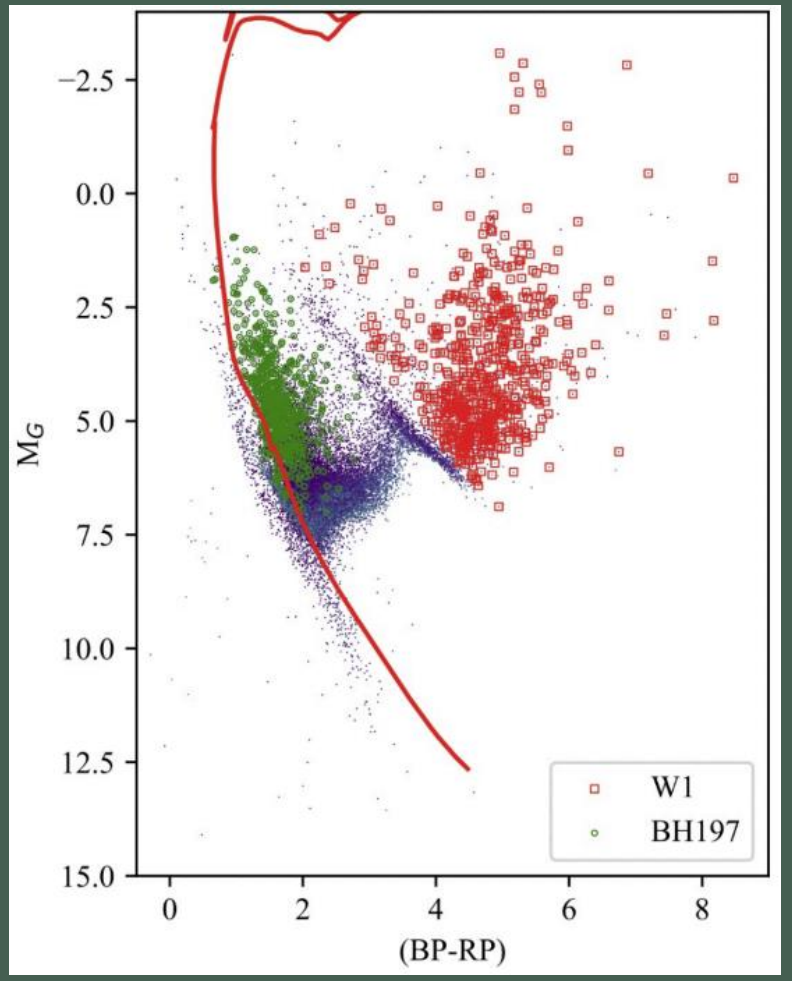



Stars extracted with the algortihm used by Aghakhanloo+ (blue) and used by Negueruela+ (red) to measure the properties of Westerlund 1

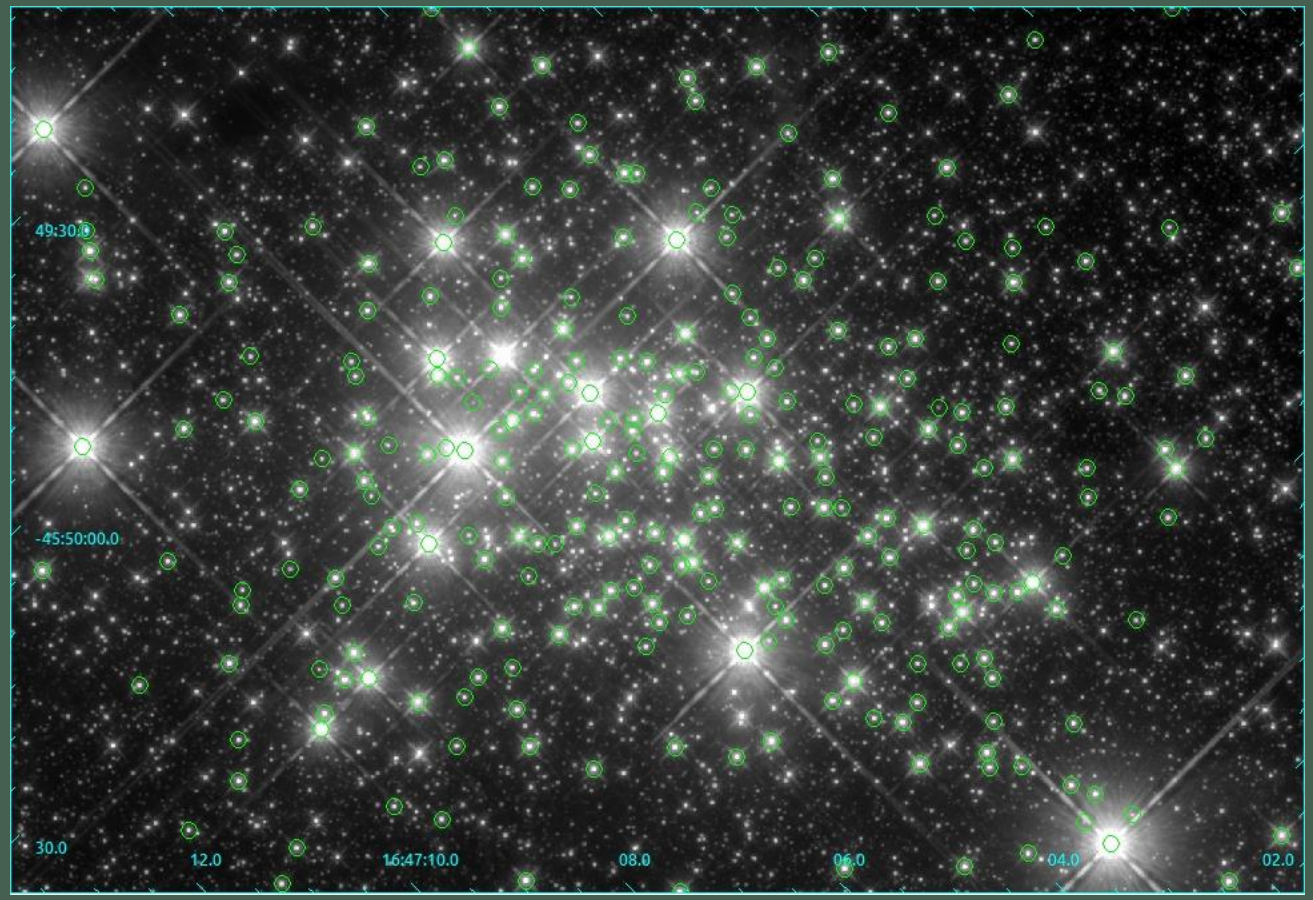


# Gaia limits on the nearby SSCs

High extinction and crowding strongly limit Gaia/DR3 completeness in SSCs

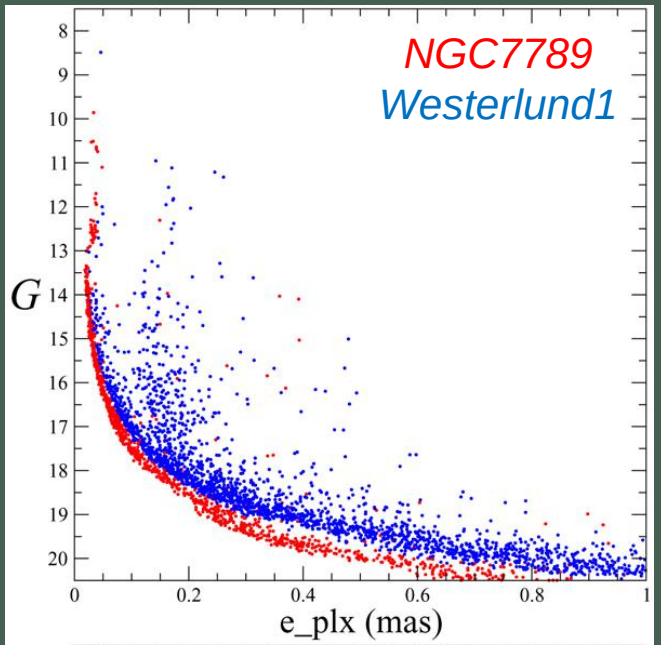


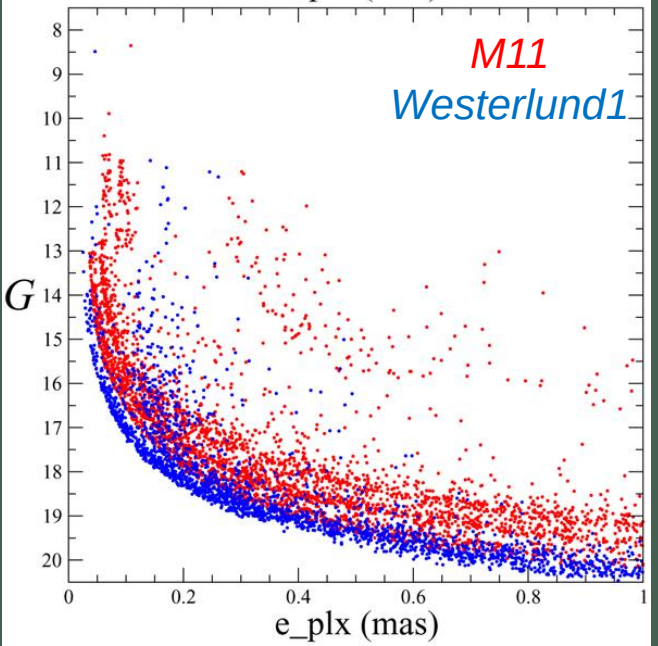

*CMD and HST H band image of Westerlund 1 with candidate members (Prisinzano L., priv. com.)*



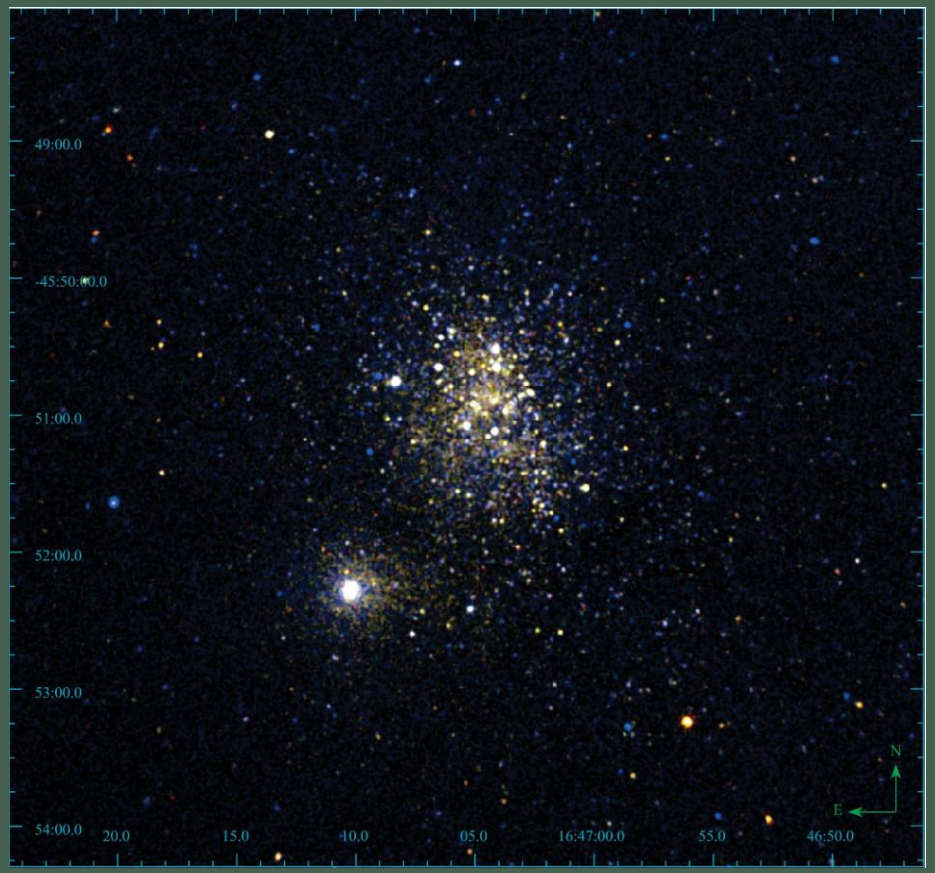
# Gaia limits on the nearby SSCs

*How crowding affects the errors on parallax for stars in Westerlund 1, compared with NGC7789 (older, less dense) and M11 (more crowded).*
*Clark+2019*

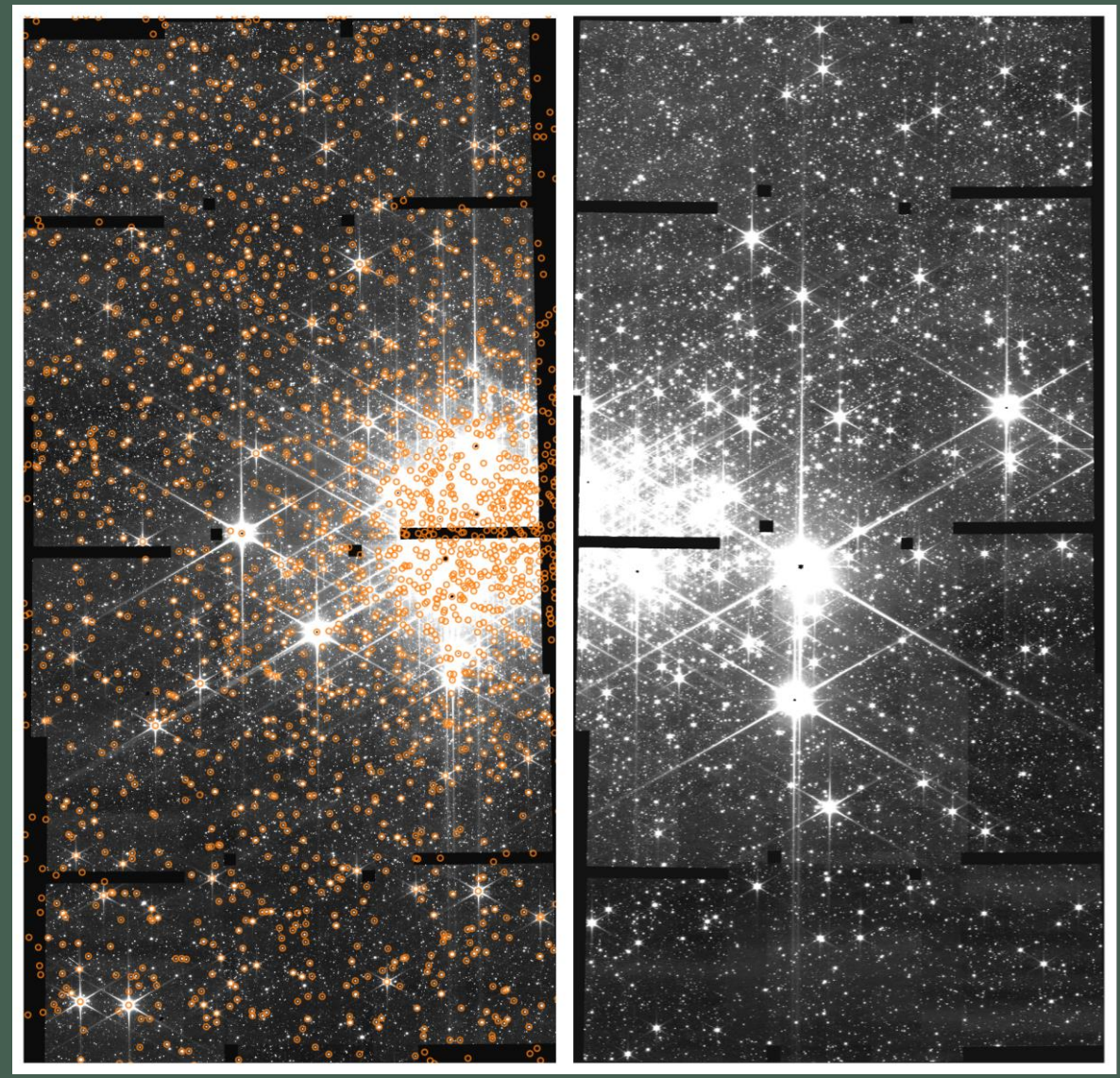


# The multiwavelength approach: EWOCS




*Chandra/ACIS-I (Guarcello+2024) and JWST/NIRCam (Muzic and Almendros-Abad in prep.) images of Westerlund 1*



Despite its capabilities, Gaia is thus not efficient to unveil the low-mass populations of nearby SSCs. A multiwavelength approach is still needed.

Example: The Westerlund 1 and 2 Open Clusters Survey (EWOCS)

# The need for GaiaNIR

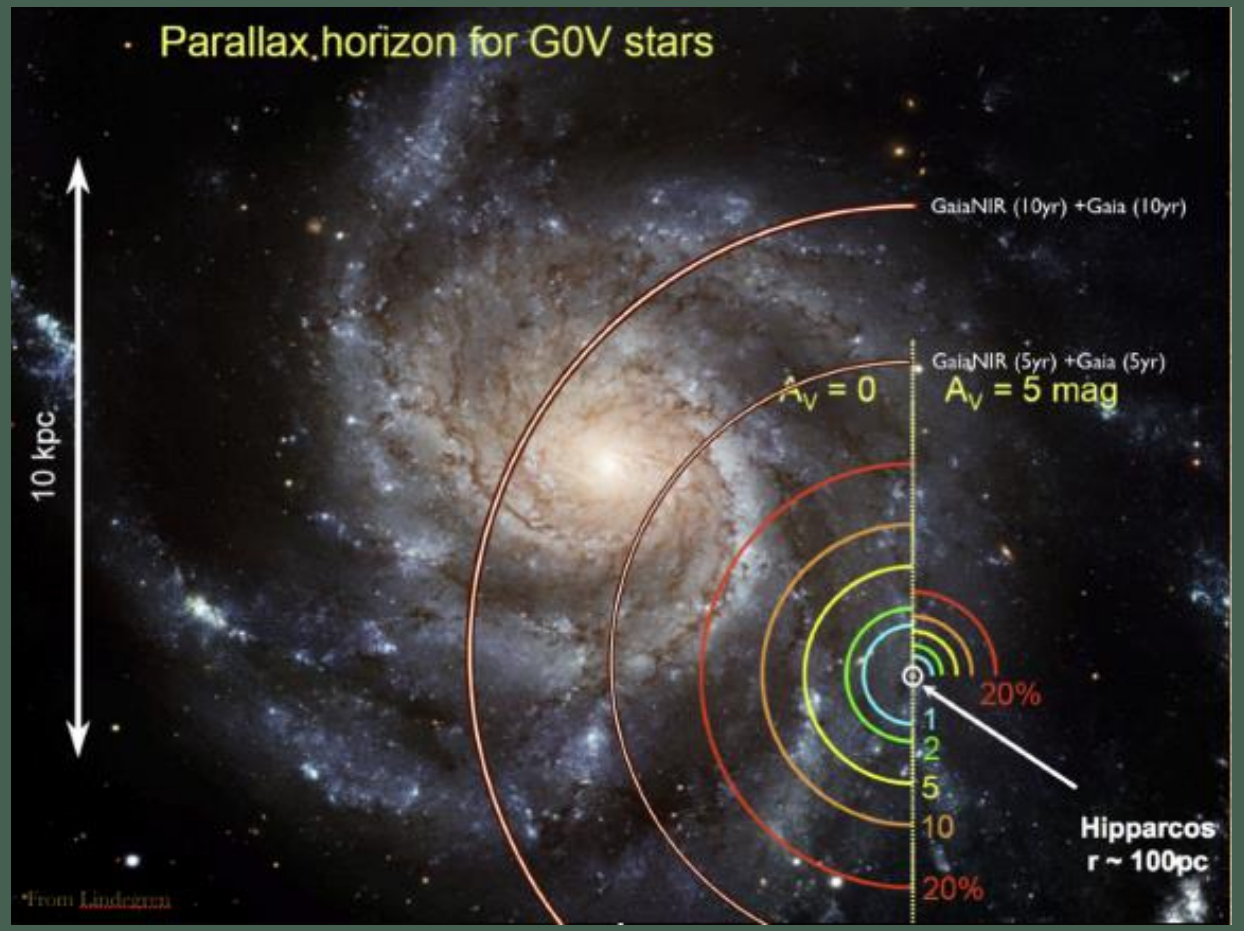
We all know how to pierce dense clouds and highly extinguished regions: GOING TO NIR!

GaiaNIR will allow us to:

- Probe the highly extinguished and distant SSCs such as in the Galactic centre;
- Improve the cluster census up to several kpc.

Attending to the current design, a Gaia-like photo-astrometric precision for a G0V star at Av=10 will be obtained for stars 3-4 magnitude fainter.

GaiaNIR will unveil the low mass population of SSCs, whose emission peaks in the red/NIR part of the spectrum




*Expected volume increase for the Gaia astrometric precision (from D. Hobbs)*

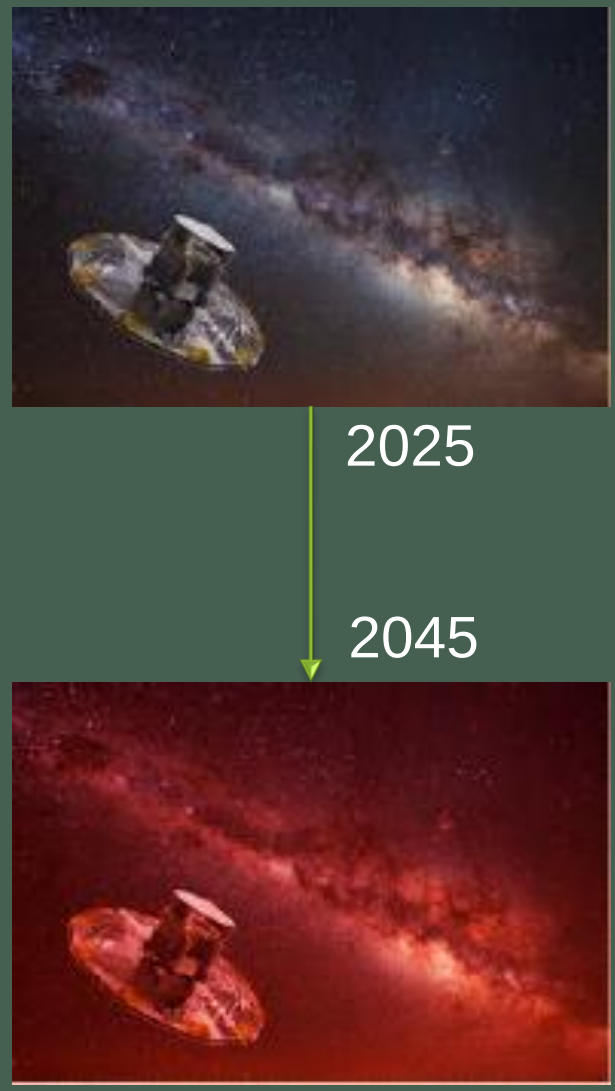
# The need for combined Gaia+GaiaNIR

The new mission, combined with Gaia DRs, will provide a >20 years baseline, improving PMs by a factor 14 or better and parallaxes.

The combined mission will reach the nano-arcsec regime for stars in common. This will have huge impacts for studies of star clusters and SSCs.

The combined mission will have great capabilities in detecting binaries and exoplanetary systems in clusters and star forming regions.

This will allow us to probe binarity and planets in various star forming environments.



# Conclusions

Despite their low number in the Milky Way, supermassive star clusters are very important targets.

Crowding and extinction limit the effectiveness of Gaia for the study of supermassive stars clusters.

We need the photometric and astrometric precision in the NIR bands, we need Gaia NIR.