



30 Dor

LMC

What can we learn from Star Clusters?

- There are two point of views which perfectly supplement each other
 1. The Star Cluster as global aggregate
 2. Each member as single stellar object
- We are able to study local and global characteristics simultaneously

- The Star Cluster as global aggregate
 1. Distance, age, reddening and metallicity
 2. Kinematics und dynamics
 3. Initial Mass Function (IMF)
 4. Star formation and evolution
 5. Global characteristics of a Galaxy
- Members as single stars
 1. Special star groups: CP, Blue Stragglers, (Super)giants, Binaries, Wolf-Rayet Stars, Variable stars, post-AGB, HB stars, ...
 2. Test of most astrophysical models and theories

Definition of Star Clusters

Star clusters are physically related groups of stars held together by mutual gravitational attraction.

The number of all star clusters in the Milky Way is about 10 000 but only 3000 in catalogues. From these, about 170 Globular Clusters (“old”, Population II).

Working Hypothesis

All members of an individual Star Cluster are born within one Giant Molecular Cloud (GMC) over a time scale of some few Myrs.

What are the immediate conclusions?

All members of an individual star cluster have:

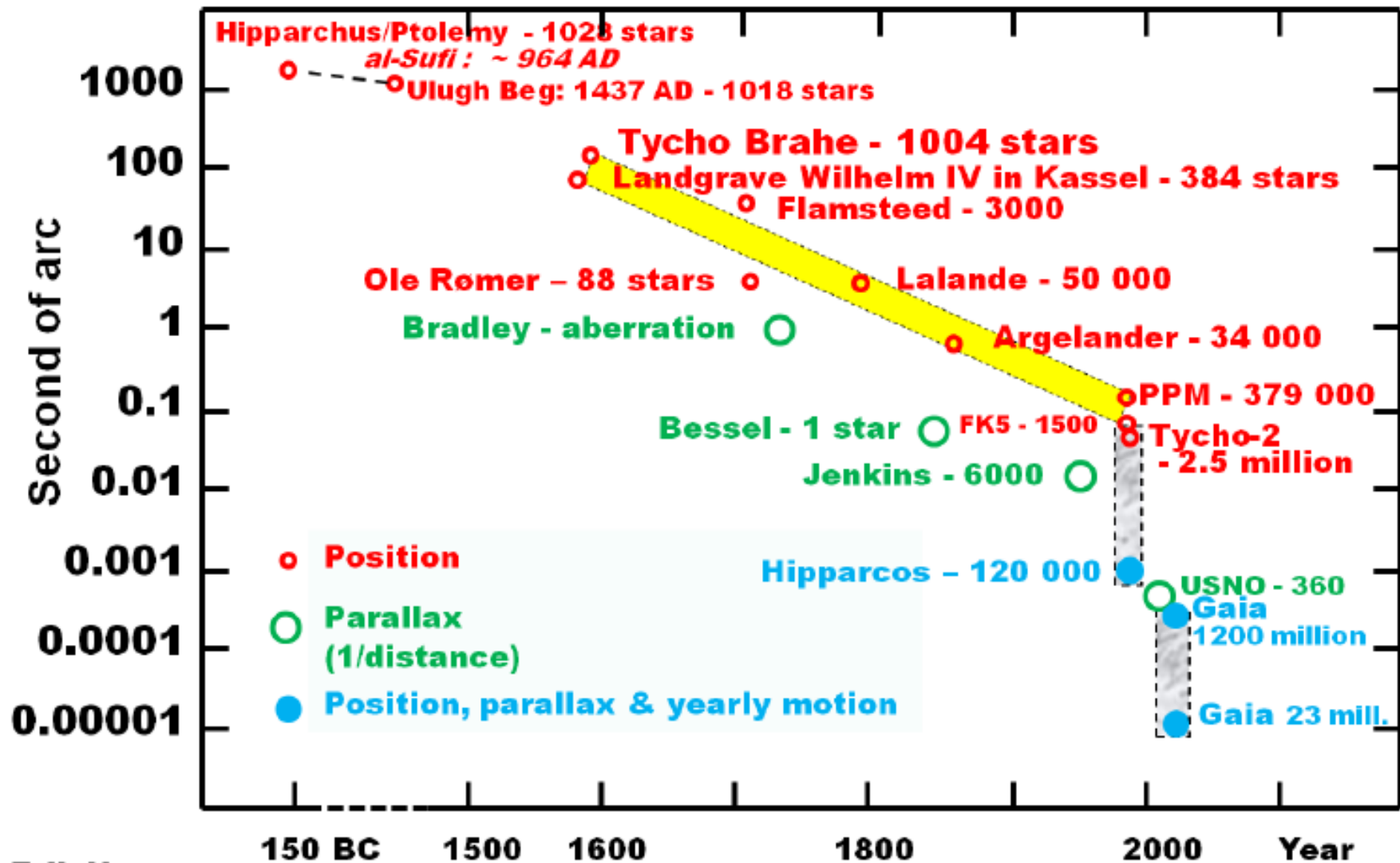
- ***Identical distance from the Sun:*** +- The volume expansion of the cluster (diameters < 25 pc)
- ***Identical age:*** +- Time scale of star formation (a few Myrs)
- ***Identical metallicity:*** +- Inhomogeneities of the initial GMC and the chemical evolution of the giant branch
- ***Identical kinematical characteristics:***
 - + - Intrinsic spread
 - Radial velocity
 - Proper motion

Global Astrometric Interferometer for Astrophysics (Gaia)

- Radial Velocity Spectrometer (RVS)
- Resolution ($\lambda/\Delta\lambda$) about 11 500
- Spectral range: 845 – 872 nm
- All objects brighter than 17th magnitude
- 150 million objects
- Accuracy between 1 km/s and 15 km/s depending on spectral type and magnitude

- Parallaxes and proper motions

Astrometric Accuracy during 2000 Years



Global Astrometric Interferometer for Astrophysics (Gaia)

GAIA'S REACH

The Gaia spacecraft will use parallax and ultra-precise position measurements to obtain the distances and 'proper' (sideways) motions of stars throughout much of the Milky Way, seen here edge-on. Data from Gaia will shed light on the Galaxy's history, structure and dynamics.

Previous missions could measure stellar distances with an accuracy of 10% only up to 100 parsecs*



Sun

Galactic Centre

Gaia's limit for measuring distances with an accuracy of 10% will be 10,000 parsecs

Gaia will measure proper motions accurate to 1 kilometre per second for stars up to 20,000 parsecs away

*1 parsec = 3.26 light years

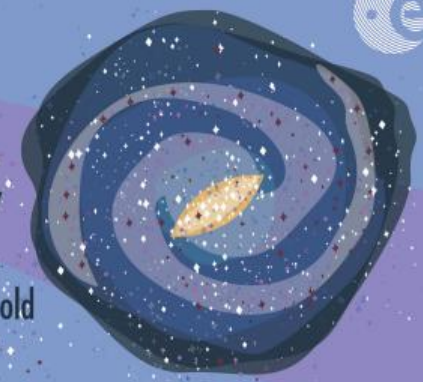
→ GAIA DATA RELEASE 1



14
September 2016
1000 days
since launch

- 1 spacecraft
- 2 telescopes
- 10 mirrors
- 1 camera
- 106 CCDs
- 937,782,000 pixels

1 Milky Way
>100,000,000,000 stars
~13,000,000,000 years old



~1,500,000 km from Earth

Content of the release

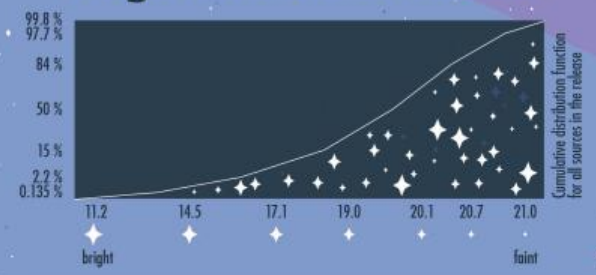
Total number of sources in primary astrometric data set:
2,057,050
with position, magnitude, parallax & proper motion

Total number of sources in secondary astrometric data set:
1,140,622,719
with position & magnitude

3194 Variable stars
• 599 Cepheids (43 new discoveries)
• 2595 RR Lyrae (343 new discoveries)

2152 Quasars
with position & magnitude
Data collected over 14 months

Magnitude distribution



Data challenge so far
>50 billion focal plane transits
>110 billion photometric observations
>9.4 billion spectroscopic observations
~120,000 hours of computing time to identify stars
6 data processing centres

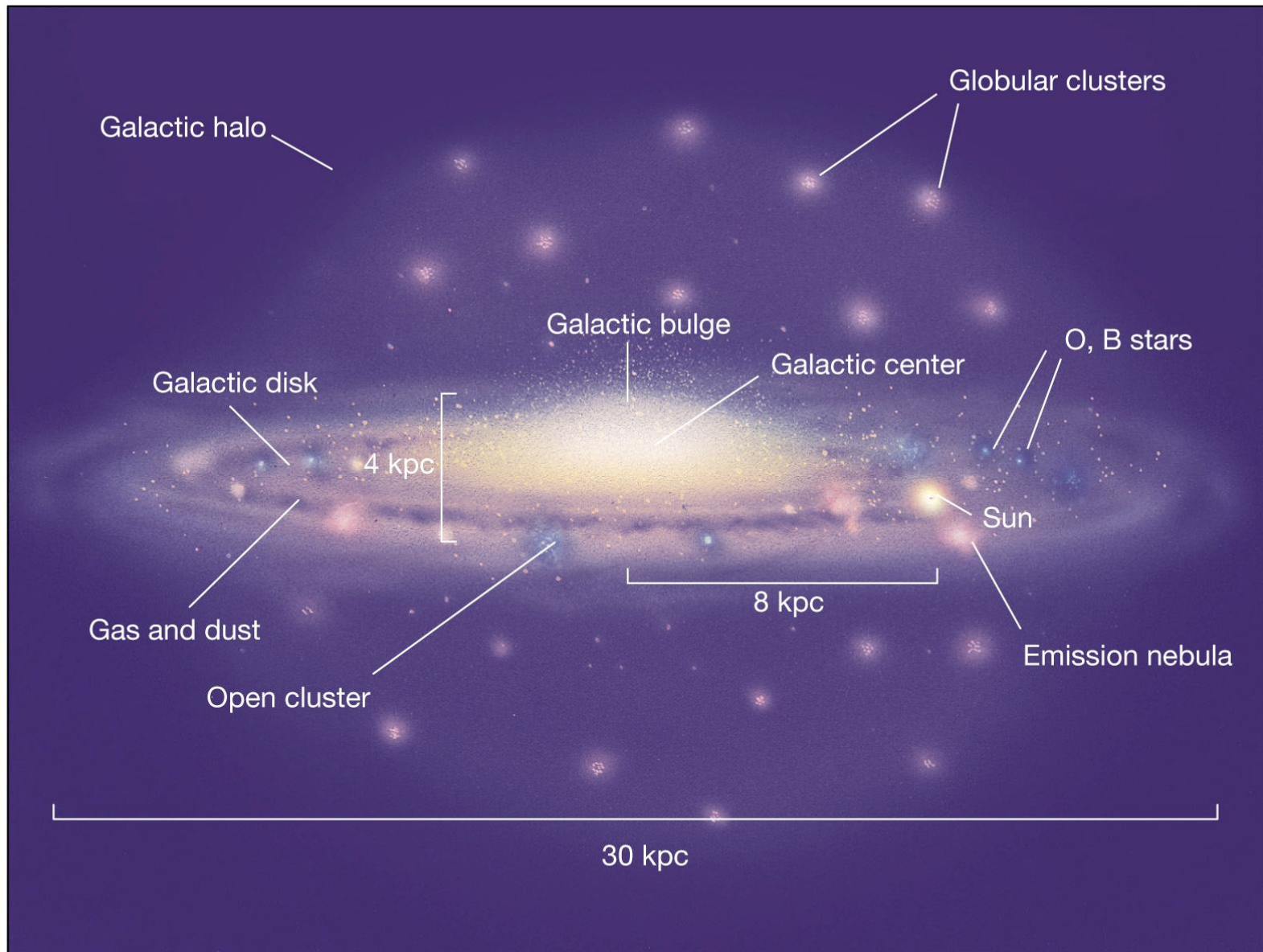
1 day on Gaia
637,000,000 astrometric measurements
155,000,000 photometric measurements
13,000,000 spectrometric measurements
70,000,000 celestial objects
40 GB of data downlinked to Earth

Gaia DR2: 25. April 2018

Clusters in Spiral Galaxies

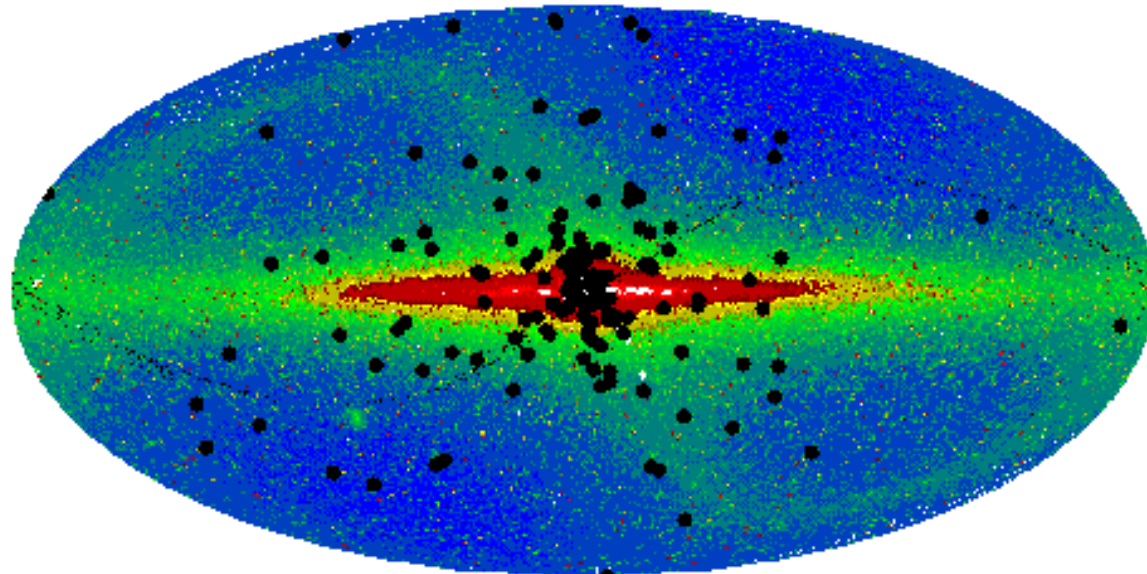
- In Spiral Galaxies as in our Milky Way, we can clearly distinct between
 1. Young clusters in the disk (Open Clusters)
 2. Old clusters in the halo (Globular Clusters)
- For other types of Galaxies, for example the LMC and SMC, this simple classification is **not valid** any more.

Location of Star Clusters



Location of Globular Clusters

- Globular Clusters are also found in
 1. **Galactic Bulge** – formed there
 2. **Galactic Disc** – path



Characteristics – Open Clusters

- **Age:** 1 Myr – 5 Gyr (Population I)
- **Metallicity:** -1.0 to +0.6 dex (factor 10 to 4) compared to the Sun
- **Distance from the Sun:** > 45 pc
- **Mass range of the members:** 0.08 to 100 $M(\text{sun})$
- **Total masses:** up to 40000 $M(\text{sun})$
- **Absolute linear diameter:** 2 to 25 pc

Characteristics – Globular Clusters

- **Age:** up to the age of the host galaxy
- **Metallicity:** -0.5 to -2.5 dex (factor 3 to 300) compared to the Sun
- **Distance from the Sun:** > 2000 pc
- **Mass range of the members:** 0.08 to 20 $M(\text{sun})$
- **Total masses:** up to $10^6 M(\text{sun})$
- **Absolute linear diameter:** up to 100 pc

Star Associations and Moving Groups

Besides classical star clusters according to our definition there are also

- Moving Groups
- Stellar Associations
- Open Cluster remnants
- (Star Forming regions)

There is a **continuous transition** between star clusters and these four types of stellar aggregates

Stellar Association

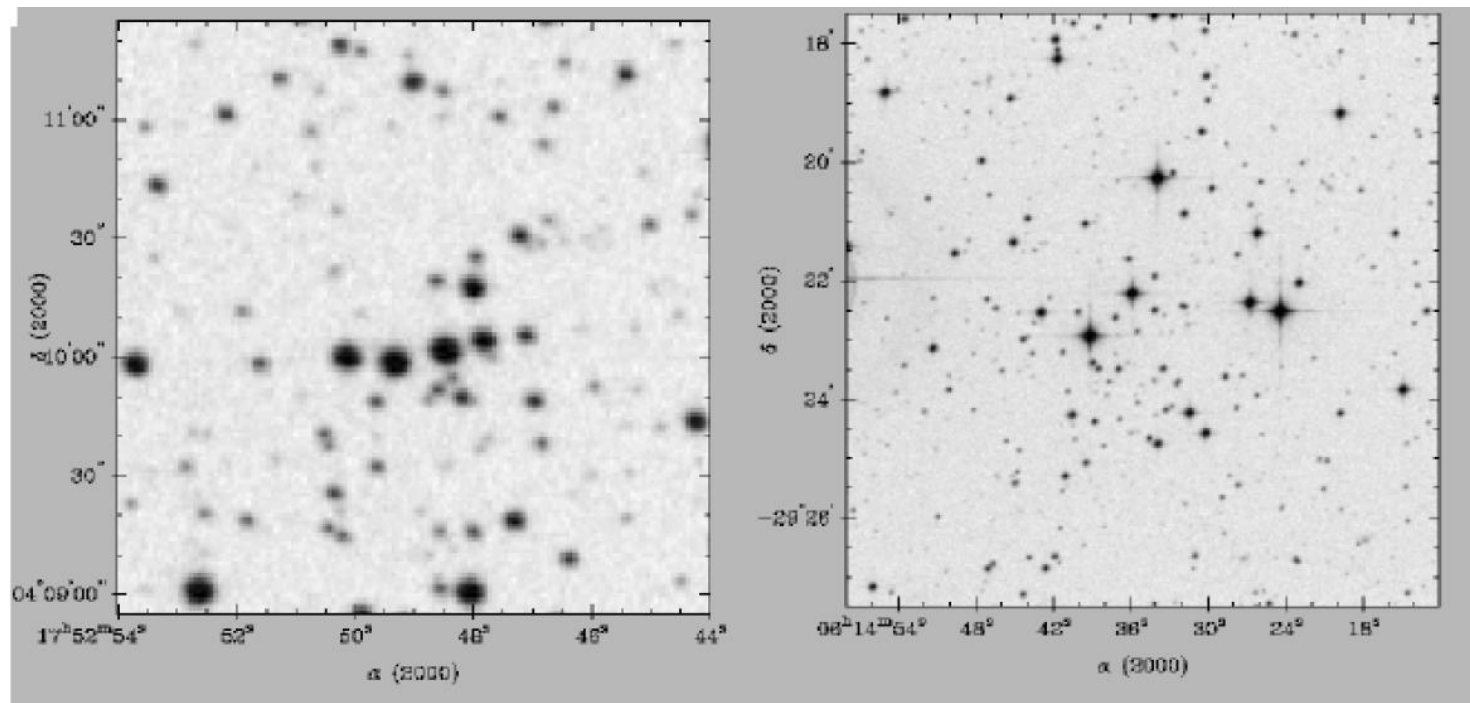
- Concentration of specific star groups, for example O, B or T Tauri Sterne, significant higher than in the galactic vicinity
- Overall density equal to surrounding
- Short life time, only about 10 Myrs because **not gravitationally bound**
- Diameters up to 200 pc
- Example: Orion OB1 association

Moving Group

- Simplified: “dissipating star clusters”
- Density as the surrounding
- Still “same motion”, **weak gravitationally bound**
- Diameters up to 400 pc
- Gaia

Open Cluster Remnants (OCR)

- Pavani & Bica, 2007, A&A, 468, 139
- Simplified: “dissipated star clusters”



Open Cluster Remnants (OCR)

- Very difficult to distinguish from “true Open Clusters”

