Backward and forward orbital integration of the Milky Way globular cluster system

Chemerynska I.V. , Ishchenko M.V., Berczik P.P.

Taras Shevchenko National university of Kyiv

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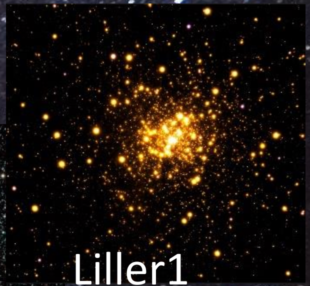
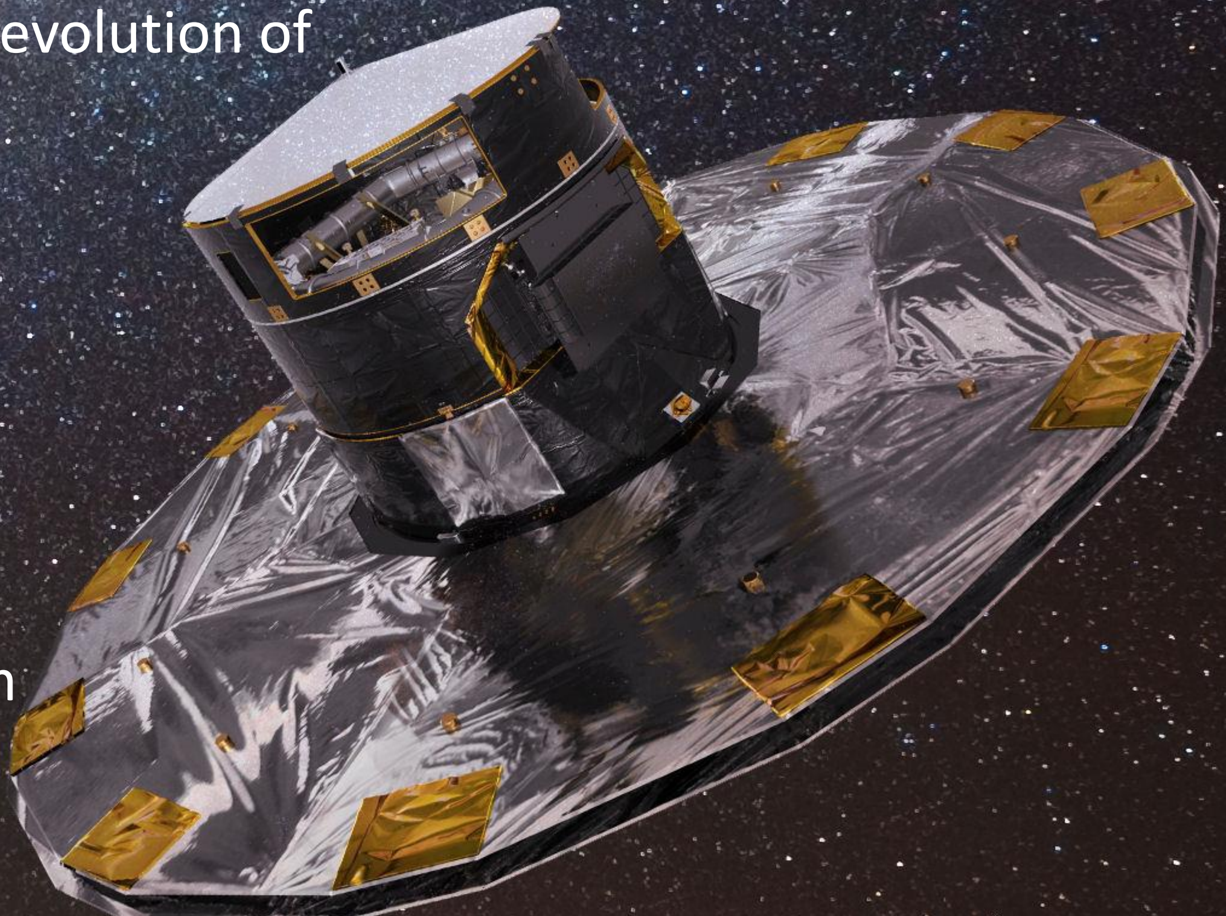
Why are globular clusters so important?



- Play a central role in cosmological studies
- The first stellar systems formed in the early Universe
- Help to understand the formation and evolution of galaxies
- Help in in stellar evolution theory

The source of data on globular clusters are the Vasiliev (2019) and Baumgardt (2019) catalog serves. They contain average proper motions calculated from data of the **Gaia DR2**.



The NFW Milky Way potential

Where:

- $r^2 = X^2 + Y^2 + Z^2 = R^2 + Z^2$
- where $M_b,\ M_d,\ M_h$ are the masses of these components
- $b_b,\ a_d,\ b_d,\ a_h$ are the scale parameters of the components

- $\Phi_{bulge}(r) = -\dfrac{M_b}{\left[r^2+b_b^2\right]^{1/2}}$
- $\Phi_{disk}(R,Z) = -\dfrac{M_d}{\left[R^2+\left(a_d+\sqrt{Z^2+b_d^2}\right)^2\right]^{1/2}}$
- $\Phi_{halo}(r) = -\dfrac{M_h}{r}\ln\left(1+\dfrac{r}{a_h}\right)$

Bajkova, Bobylev (2020)

Miyamoto, Nagai (1975)

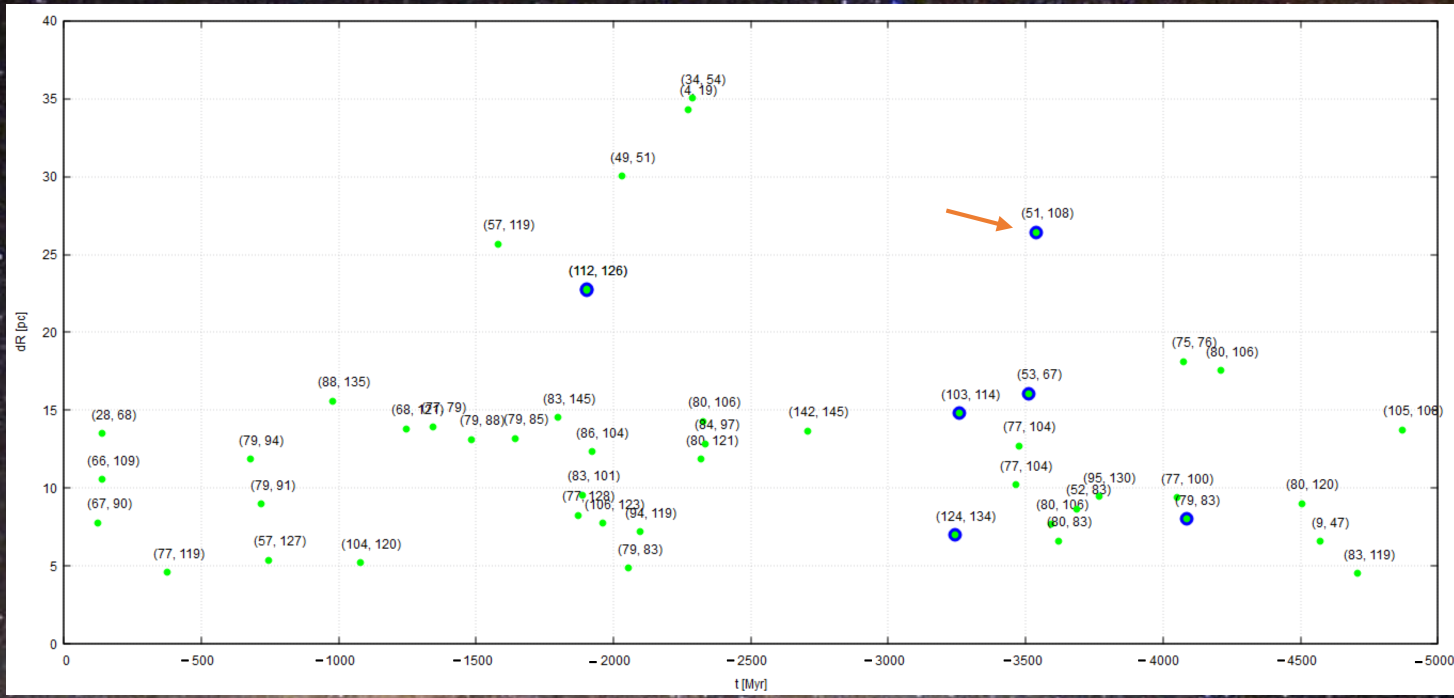
Navarro et al. (1997)

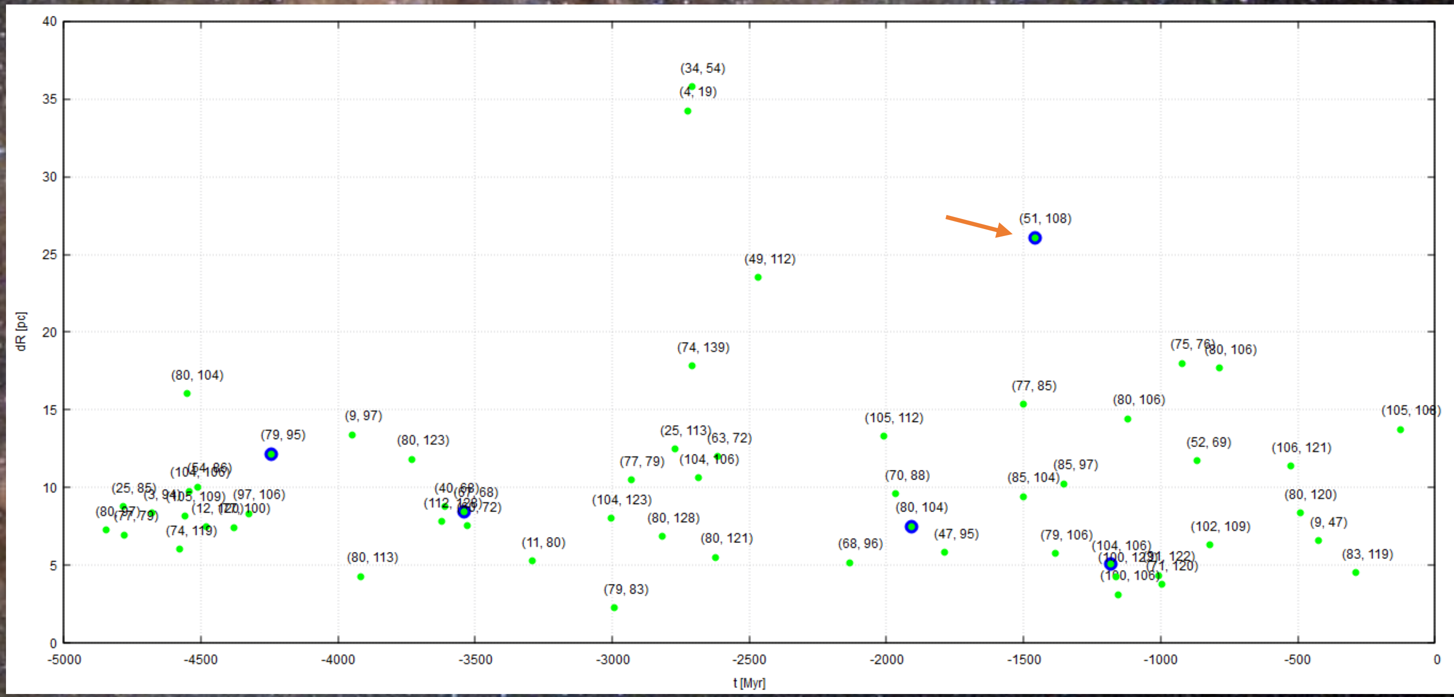
Parameter	Value
M_b [M_0]	443±27
M_d [M_0]	2798±84
M_h [M_0]	12474±3289
b_b [kpc]	0.2672±0.0090
a_d [kpc]	4.40±0.73
b_d [kpc]	0.3084±0.0050
a_h [kpc]	7.7±2.1
$R_\odot$ [kpc]	8.30
$V_\odot$ [km s^{-1}]	243.9
$M_{G(R\leq 200kpc)}$ [$10^{12} M_\odot$]	0.75±0.19

Backward and forward integration

- For green objects:
  $$dR = 2(R_{hm1} + R_{hm2})$$

- For blue objects:
  $$dR = 2(R_{hm1} + R_{hm2})$$
  $$+$$
  $$dV < 250\ km/s$$





$* R_{hm}$ *–half mass radius*

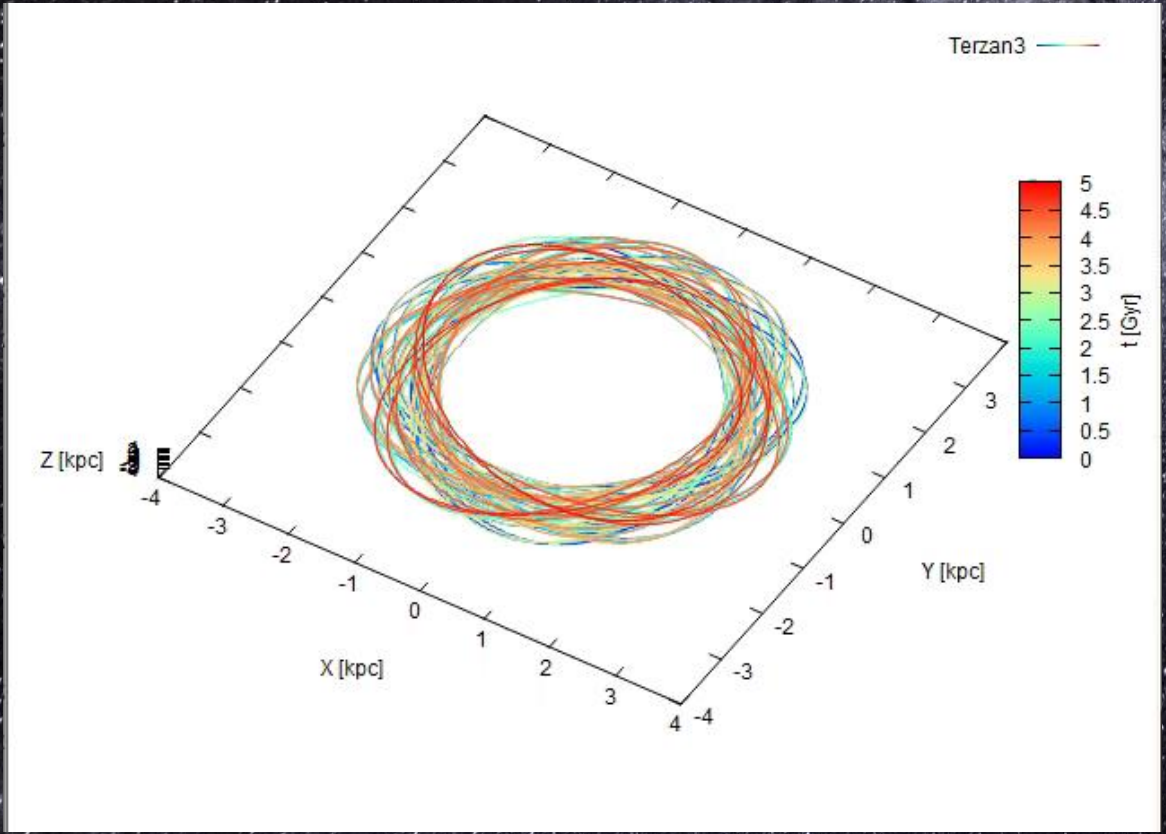
https://people.smp.uq.edu.au/HolgerBaumgardt/globular/

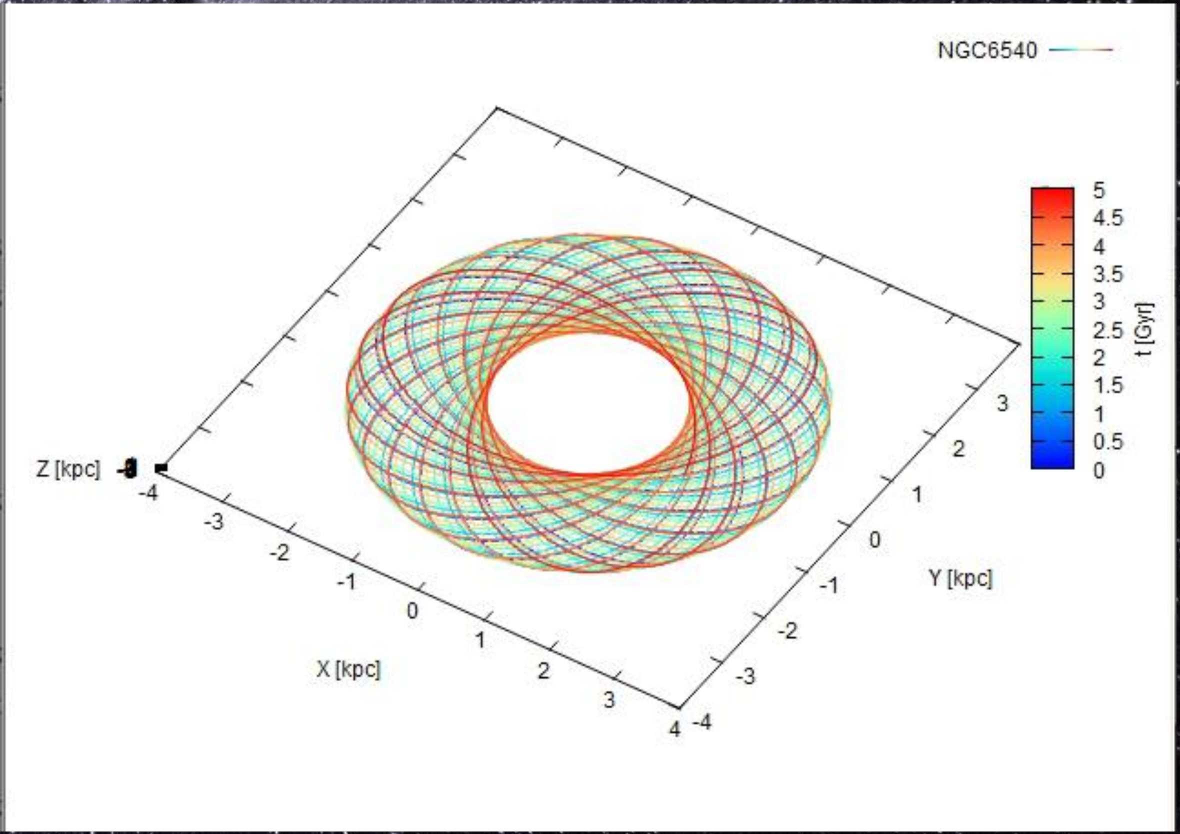
Distance from Sun:	8100 pc
V-band magnitude:	12.00
Mass:	$8 \cdot 10^4\ M_\odot$
Half-mass radius:	9.97 pc
Power-law MF slope:	α = -0.80
Galactocentric distance:	2500 pc

Image Credit: Hubble Legacy Archive

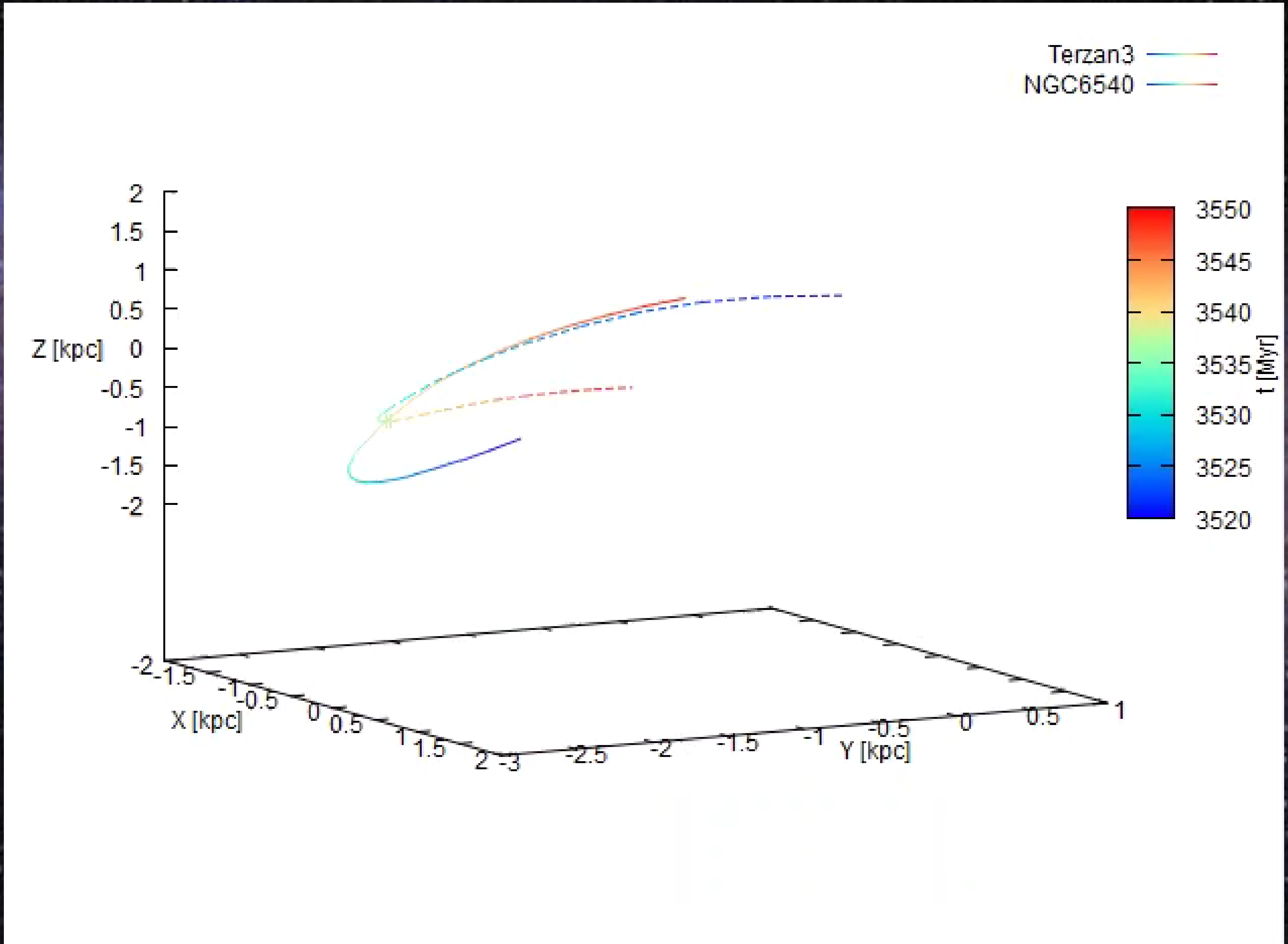
Distance from Sun:	5200 pc
V-band magnitude:	9.30
Mass:	$4.1 \cdot 10^4\ M_\odot$
Half-mass radius:	3.41 pc
Power-law MF slope:	α = -0.14
Galactocentric distance:	3300 pc

Image Credit: PanSTARRS DR1, PS1 Science Consortium

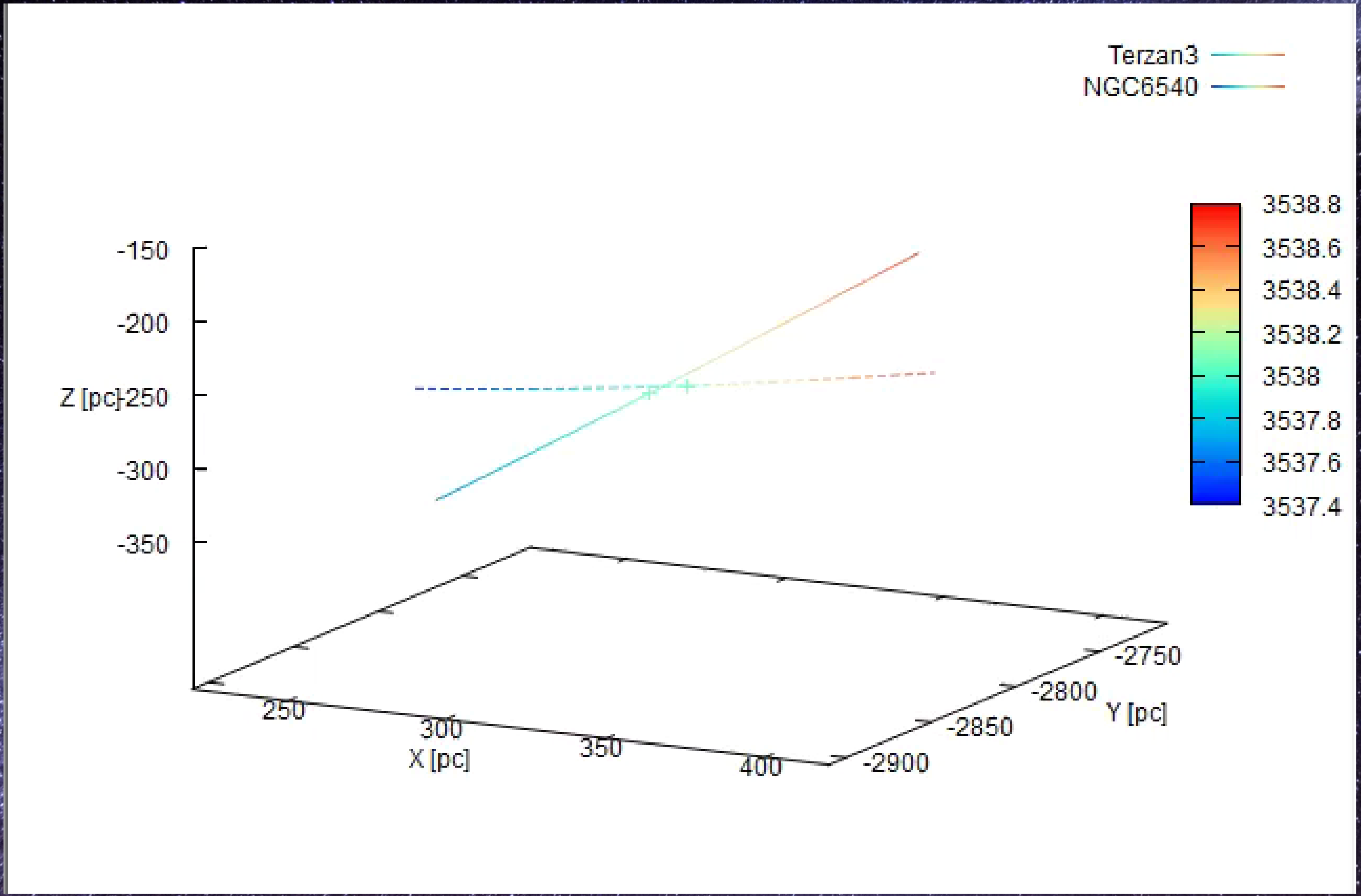


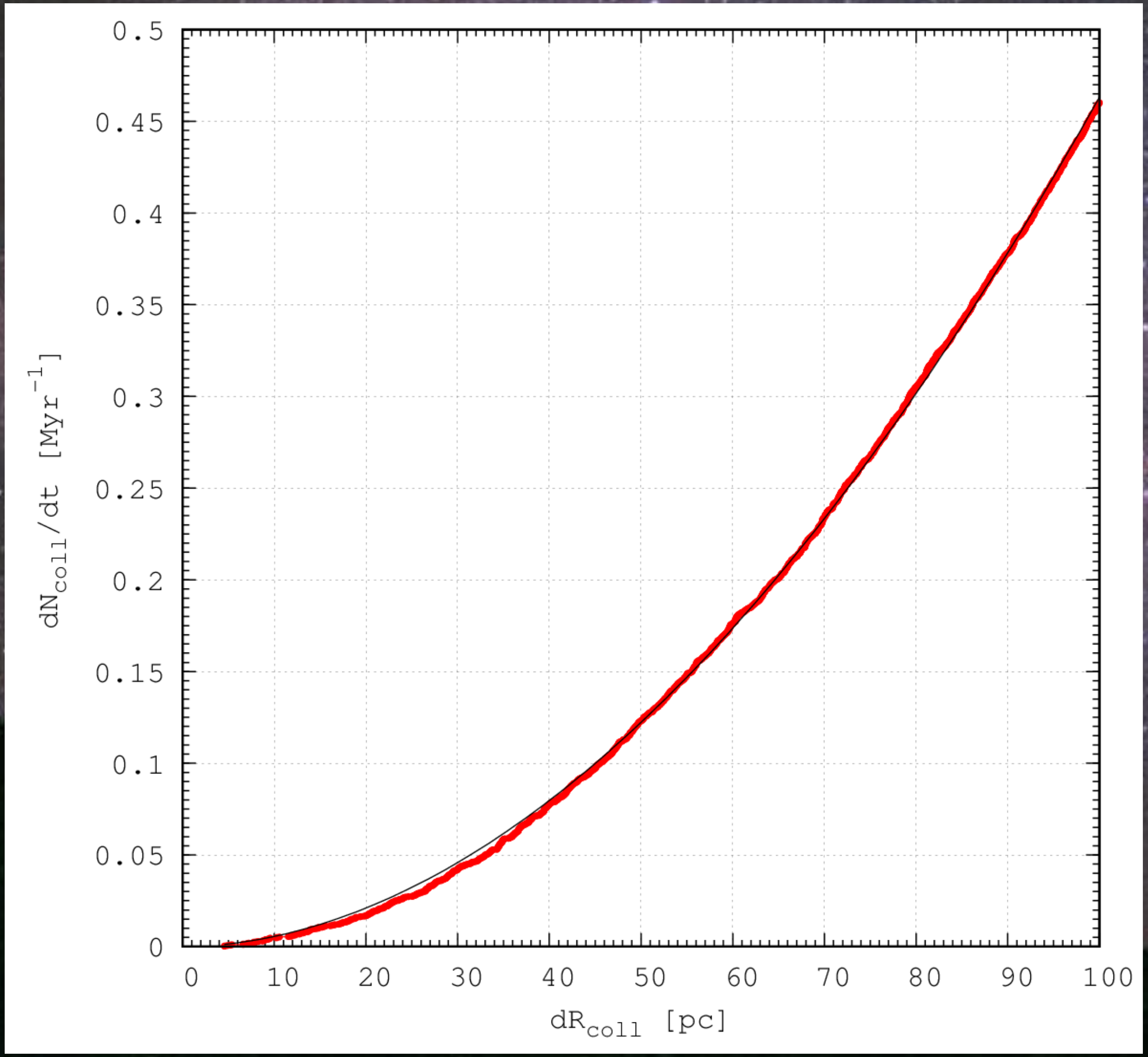


Visualization of orbit



Visualization of orbit (collision)





Statistics of GC collision rate in MW galaxy

$$f(dR) = 10^{(a\,\lg(dR)+b)}$$

a = +1.9213 +/- 0.001072 (0.0558%)
b = -4.17689 +/- 0.002082 (0.04985%)

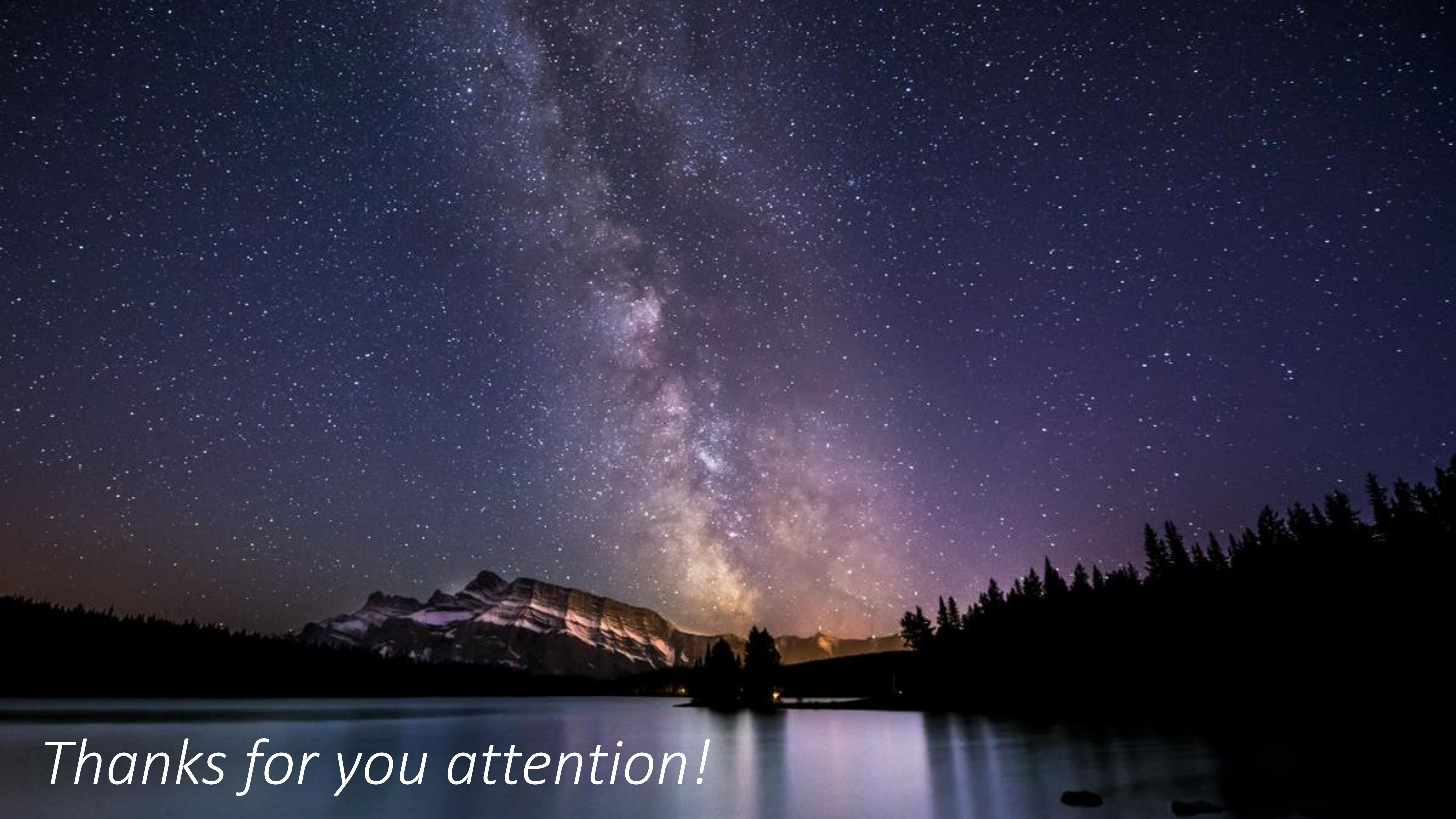
I.e. In each 10 Myr we have at least 1 collision with dR < 45 pc.

Summary

- Backward and forward integrations up to 5 Gyr.
- Check the “collisions” conditions of GC’s.
- Find stable “collisions” pairs.

Our plans:

- determine the mass exchange rate between the individual GC’s…
- examine the possible rotation and angular momentum exchange rate between the individual clusters…
- study of the individual clusters mass function evolution (Initial MF – Present Day MF)…



Thanks for you attention!