Main Sequence Runaway Project

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Content

Intro: What are Runa

y: Why are Runaways

Observations: Where are

Where does the word „Runaways“ come from?

- The motions of stars can be characterized with multiple components:
  1. Stars rotate around the center of the Galaxy in a disk. This is where star formation takes place (rotation velocities of order 100-250 km/s)
  2. Stars are born in open clusters. Think Pleiades, Orion.
  3. Stars have a velocity dispersion within their clusters (of order <5 km/s)

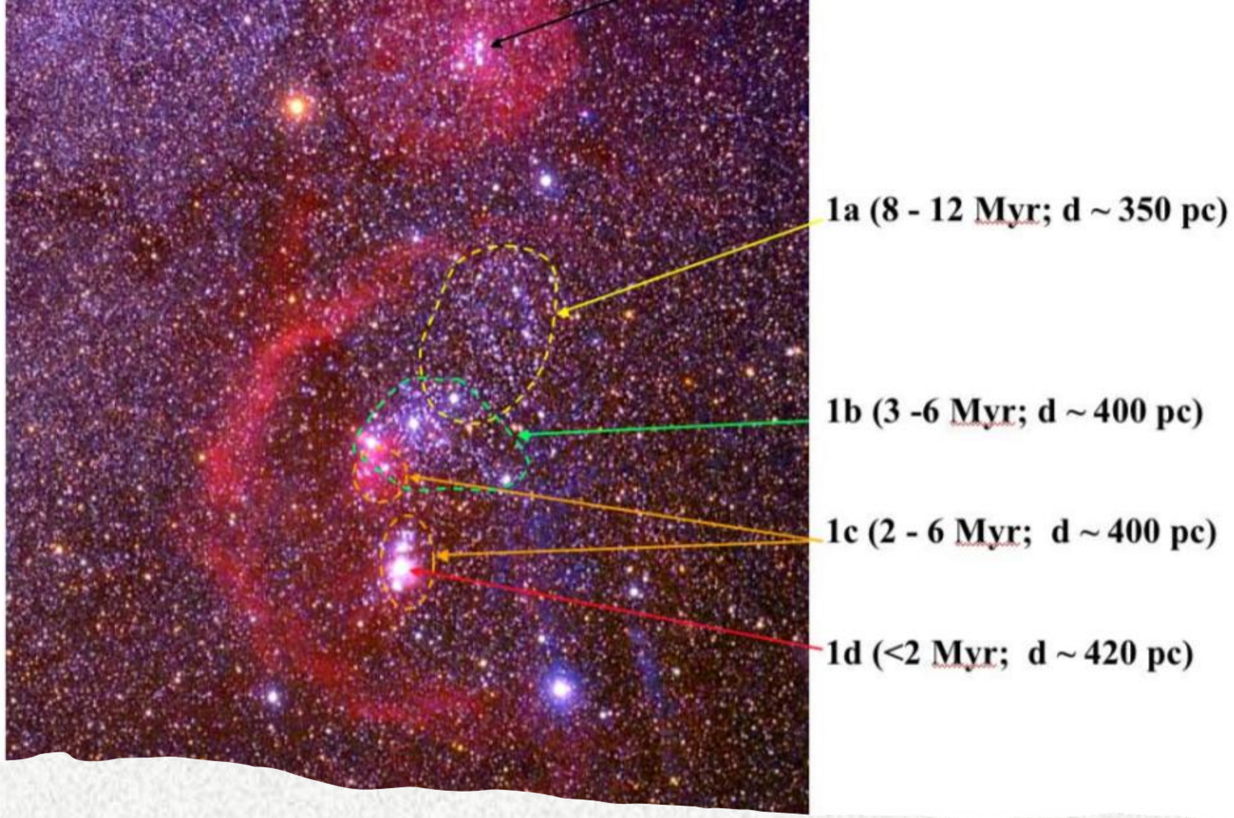
So what happens if you find young stars outside the Milky Way disk going away from it?

↓

Formed in the Disk and kicked out (Remember this for later)

What are Runaways and why are they interesting?

- Runaway stars are stars classified based on their „ejection“ or „space“ velocities
  - Multiple ejection populations
    - $v_s > 30$ km/s (Runaways)
    - $v_{esc} > v_s \gg 30$ km/s (Hyper-runaways)
    - $v_s > v_{esc}$ (Hyper-velocity stars)
  - Multiple type populations
    - MS-O,B,A..
    - sdOB (US708)
    - White Dwarfs as Type Ia remnants
    - White Dwarfs as Type Iax remnant
  - Compact objects show higher space velocities



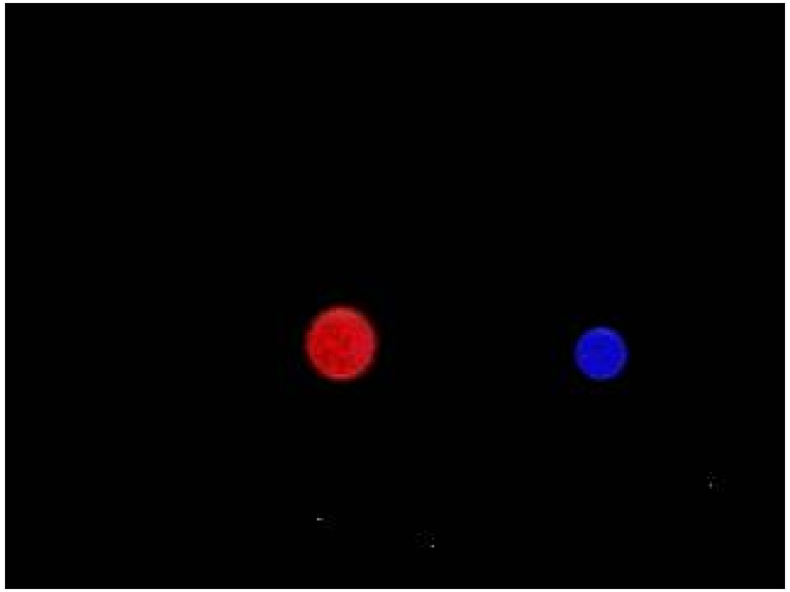
Formation Mechanism: Open Clusters/Associations

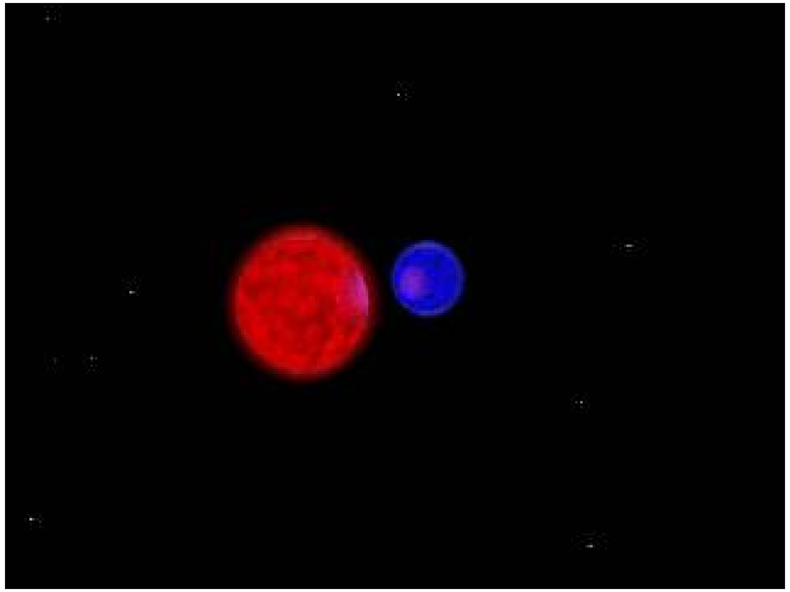
- All Stars formed in clusters. Single, Binary, Triples..
- Proto-clusters are violent. Many stars taking part in dynamics.
- Gravitationally stable structure formed, but has there been mass loss?

Space Telescope Science Institute using HST

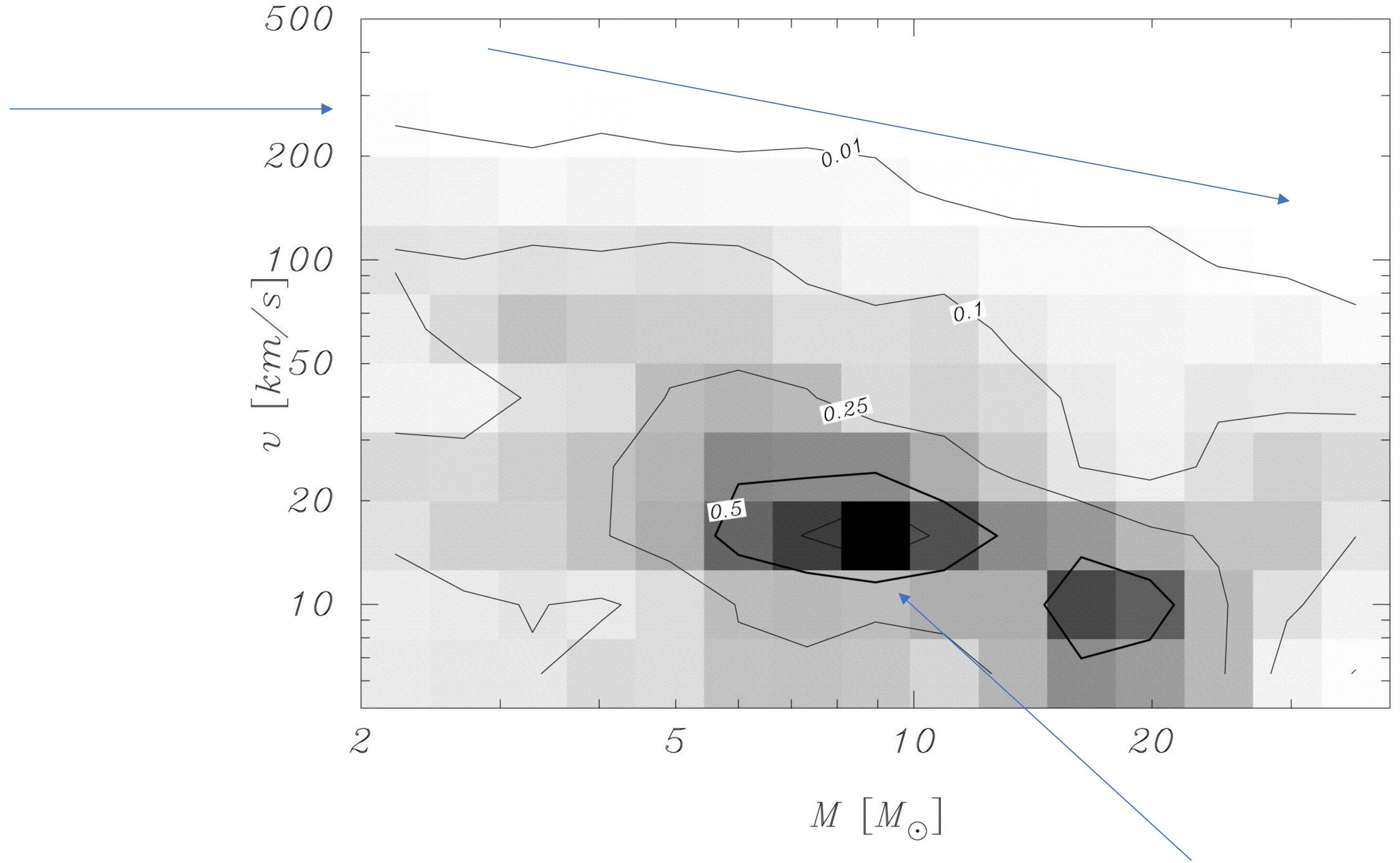
Bally J.
Overview of the Orion Complex (2008)

BSS: Binary Supernova Scenario





Credit: Andreas Irrgang

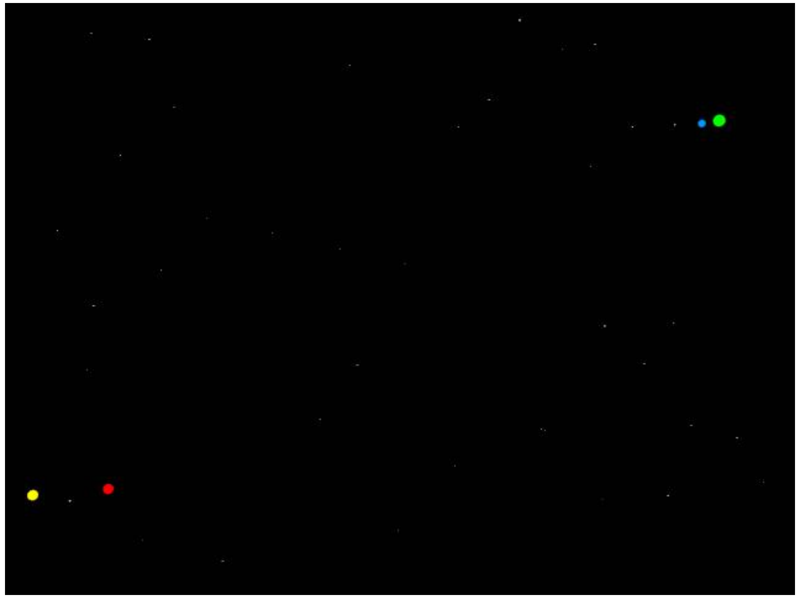


500
200
100
50
20
10
v [km/s]
2
5
10
20
M [M$_\odot$]
0.01
0.1
0.25
0.5

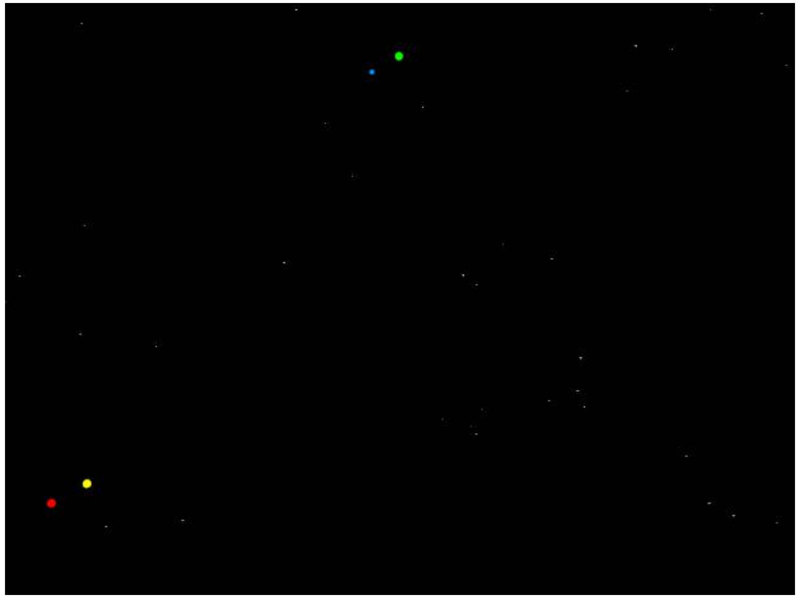
Zeta Ophiuchi

Credits: NASA

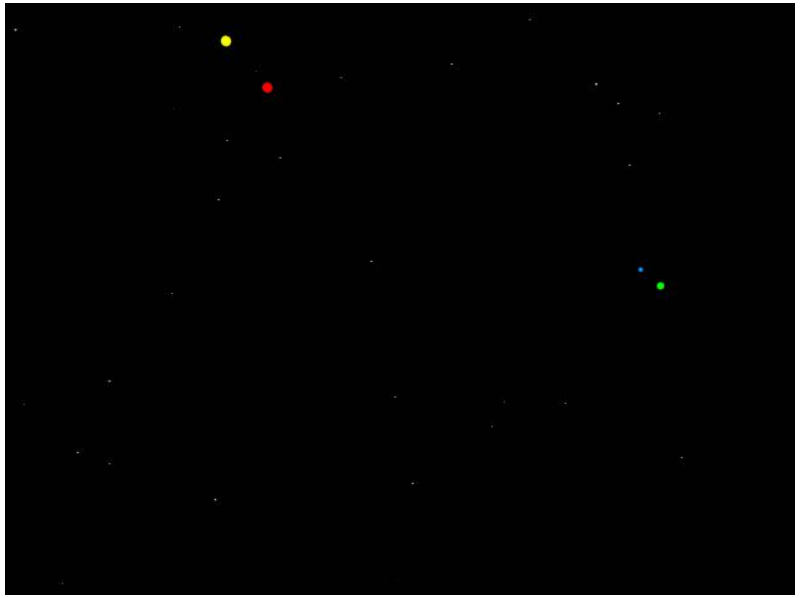
DES: Dynamical Ejection



Exchange

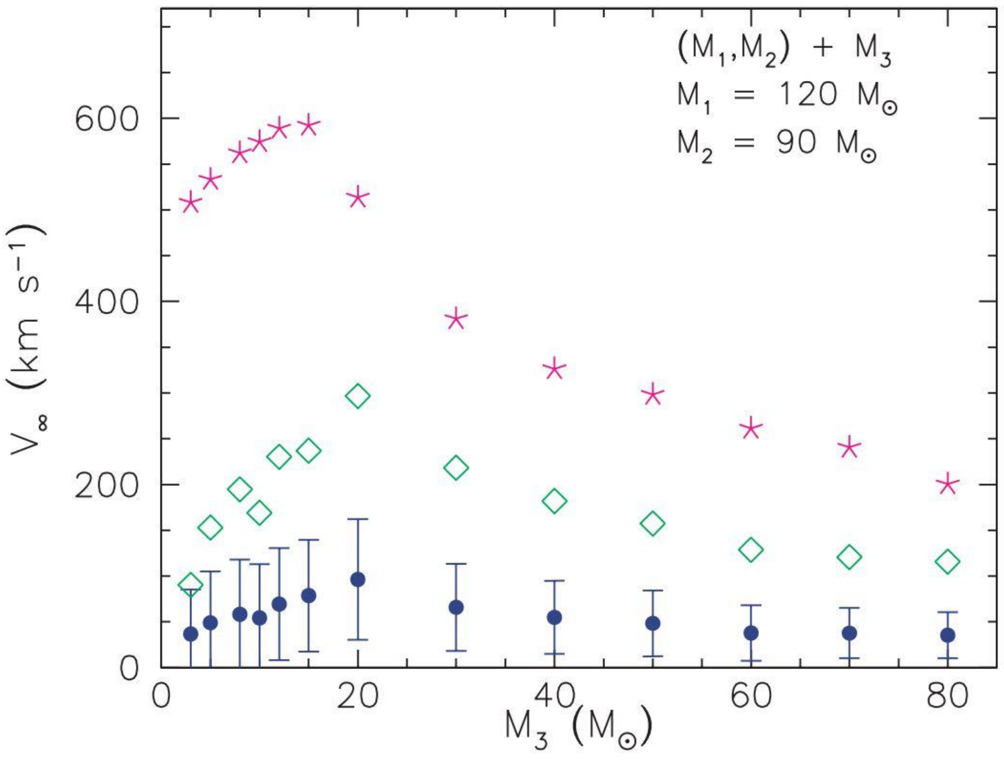


2 Runaways

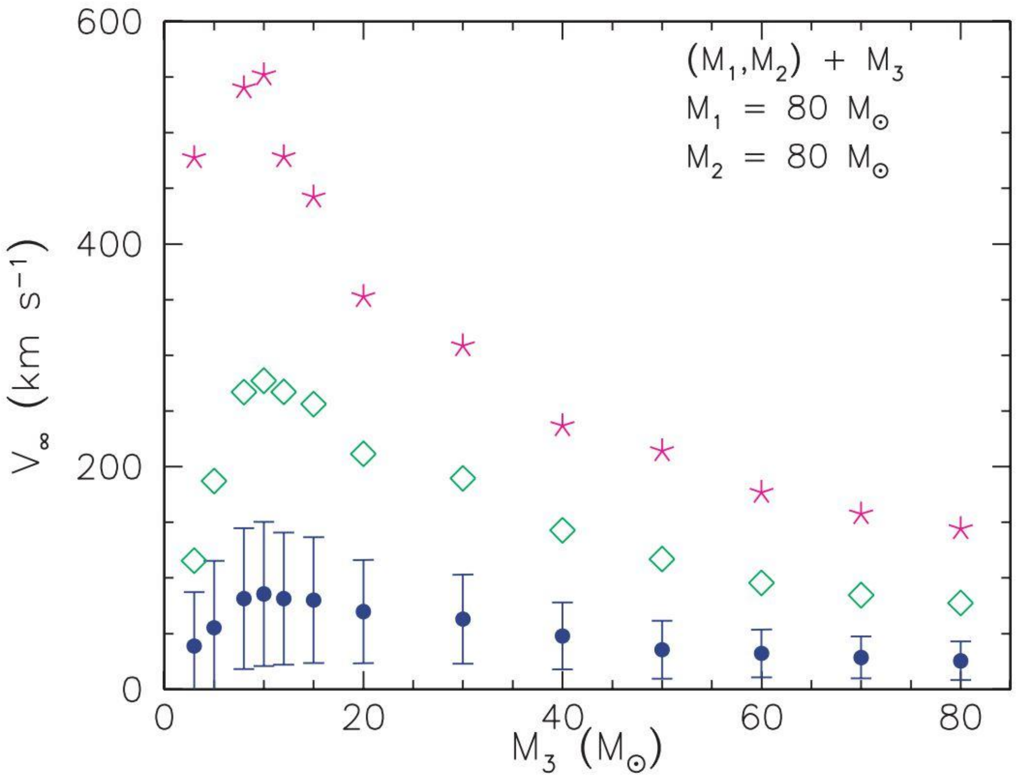


1 Runaway

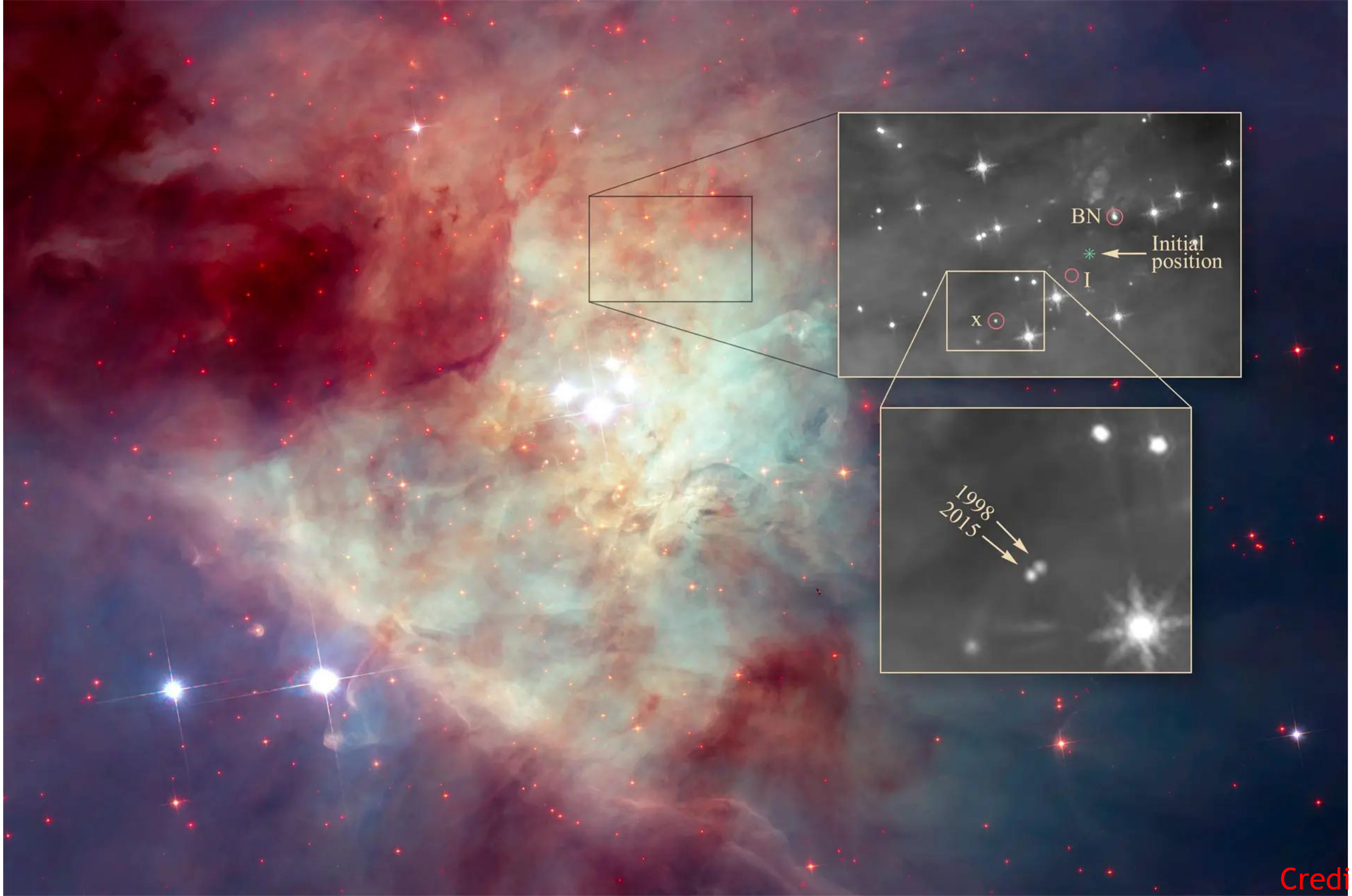
Gvaramadze et. Al.



The more massive the intruding star the greater its ability to affect the binding energy of the binary system and thereby to increase the kinetic energy of the system

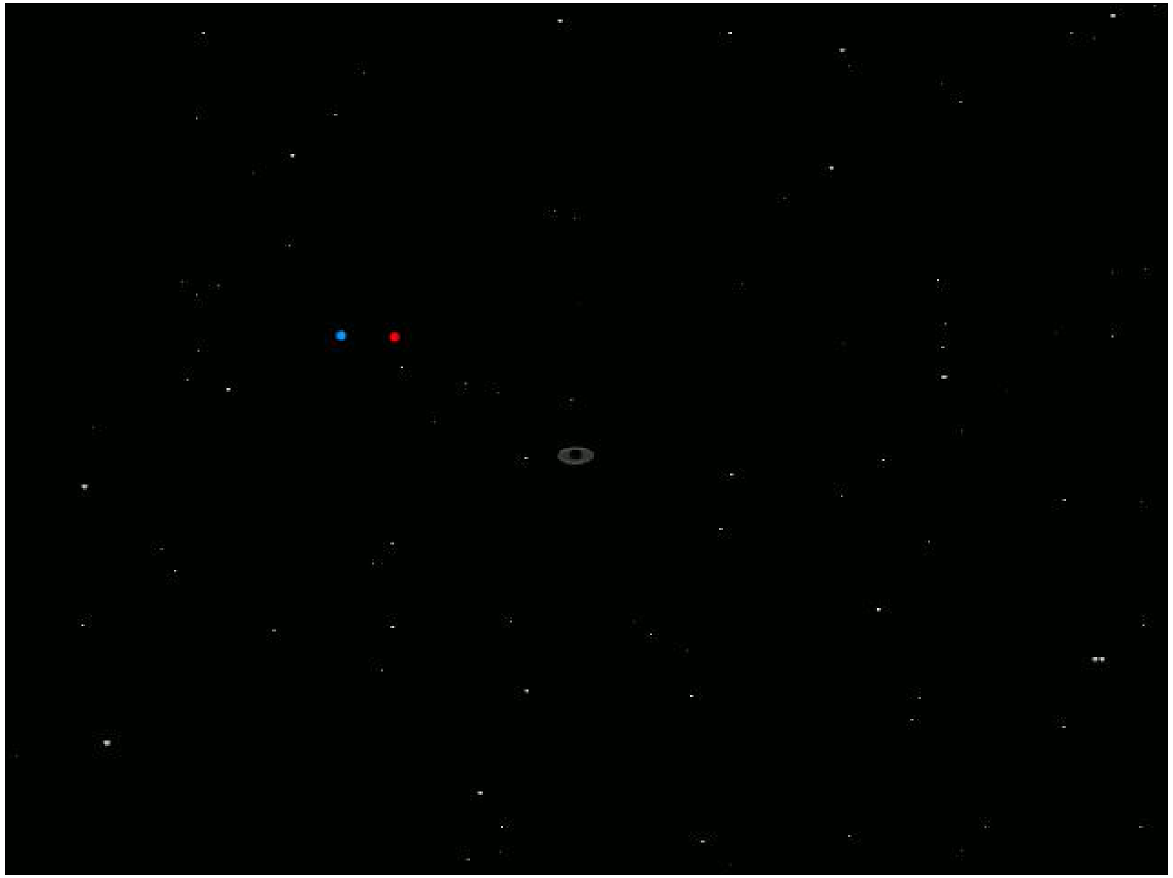


The more massive the intruding star the larger the recoil velocity of the binary and the smaller the velocity of the ejected star relative to the centre of mass



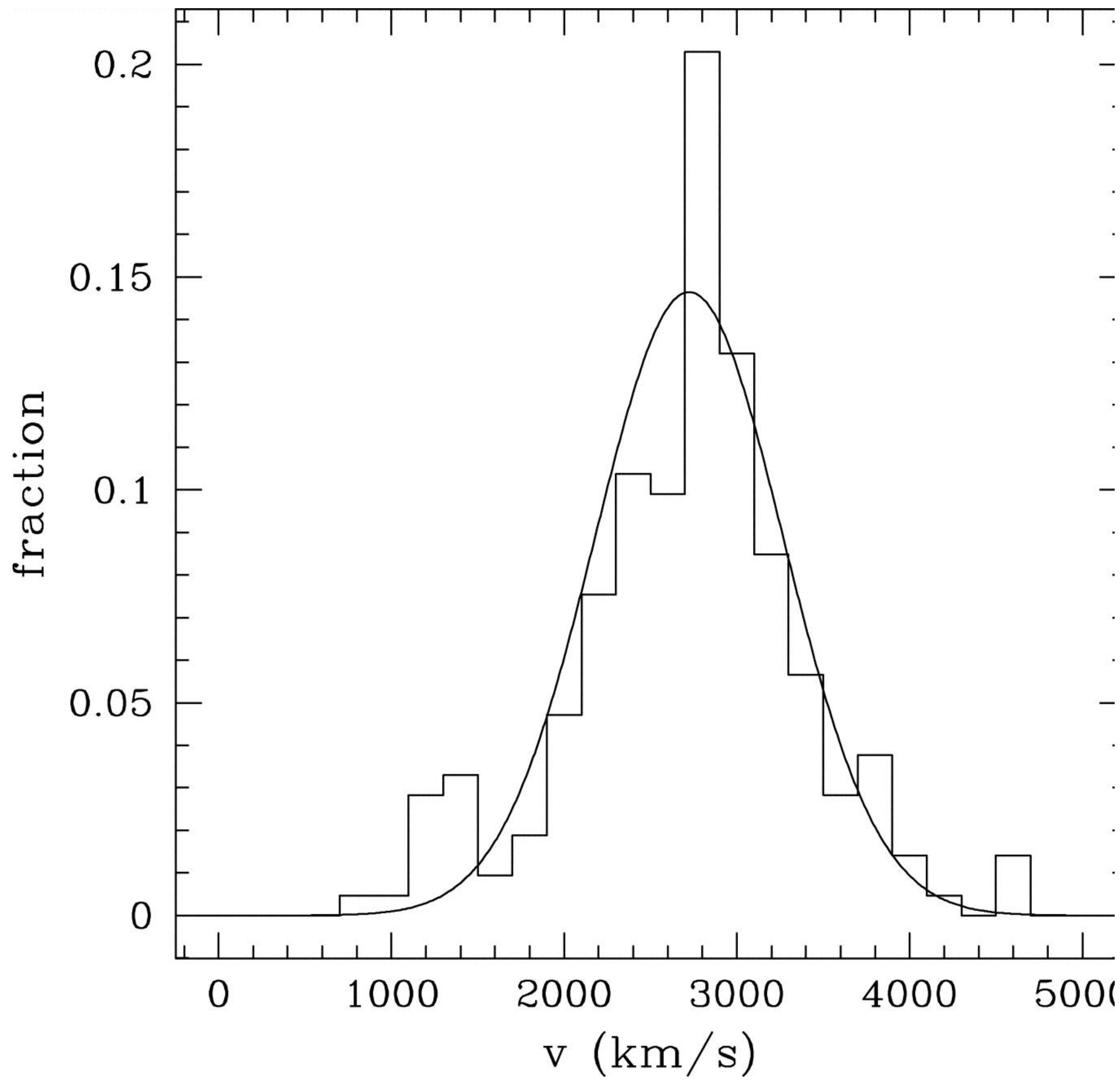
Credit:

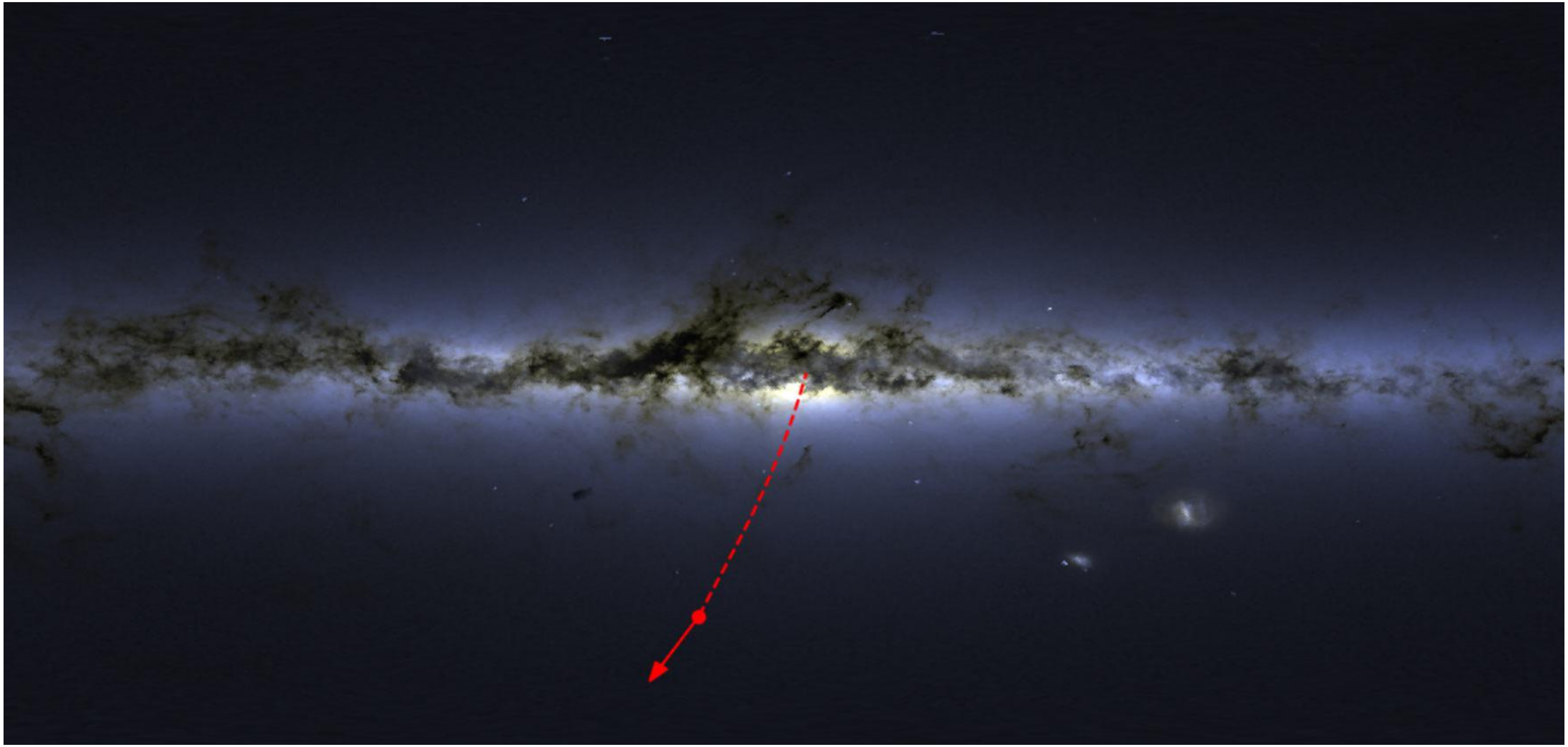
Hills Mechanism: SMBH



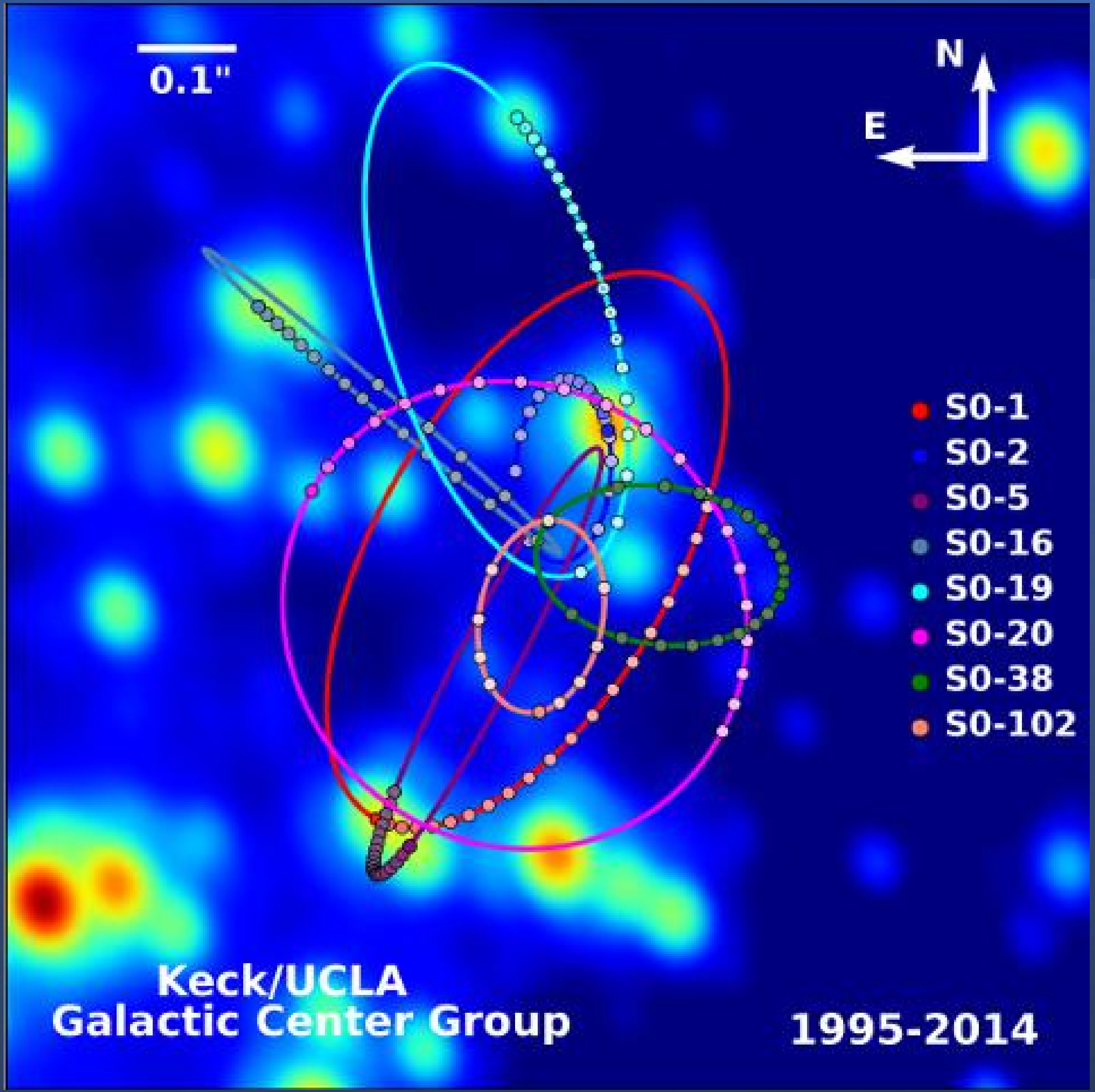
Hills Mechanism: SMBH

- The Milky Way has an SMBH at its center
- Binary goes near the SMBH
- Tidal Forces disrupt the binary
- Hypervel + S-type





Koposov et. al.

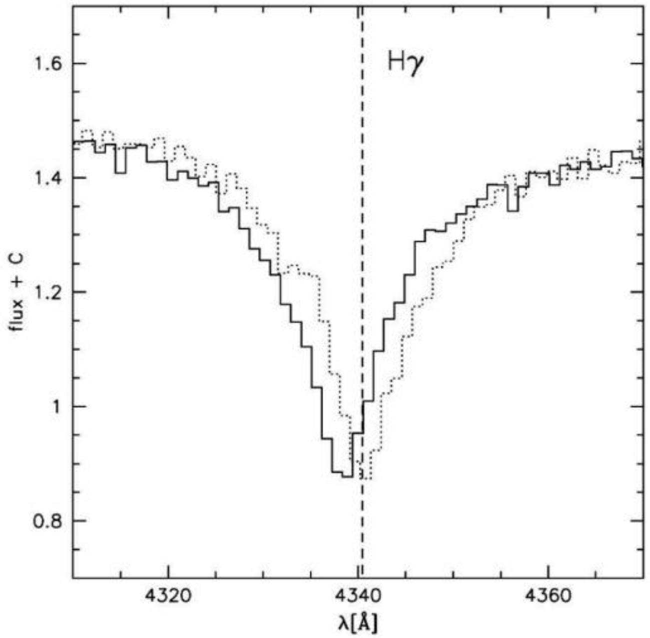


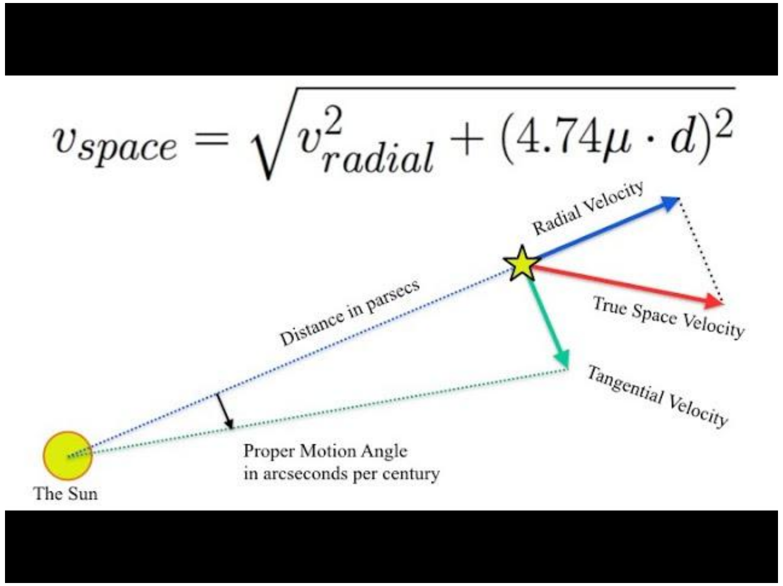
Credit: UCLA Astronomy

RECAP

- Runaway stars are stars with velocities >30 km/s and velocity vectors pointing away from the disk.
- There are multiple ways of creating main-sequence runaways:
  1. Binary Supernova Scenario
  2. Open Cluster Dynamical ejection
  3. Hills Mechanism
- There are differences:
  - Hills produces the fastest stars which point directly to the center
  - DES implies that the age of the star must be similar to the age of cluster
  - BSS produces stars with imprints of binary interaction: High Rotation, He

6-d Kinematics





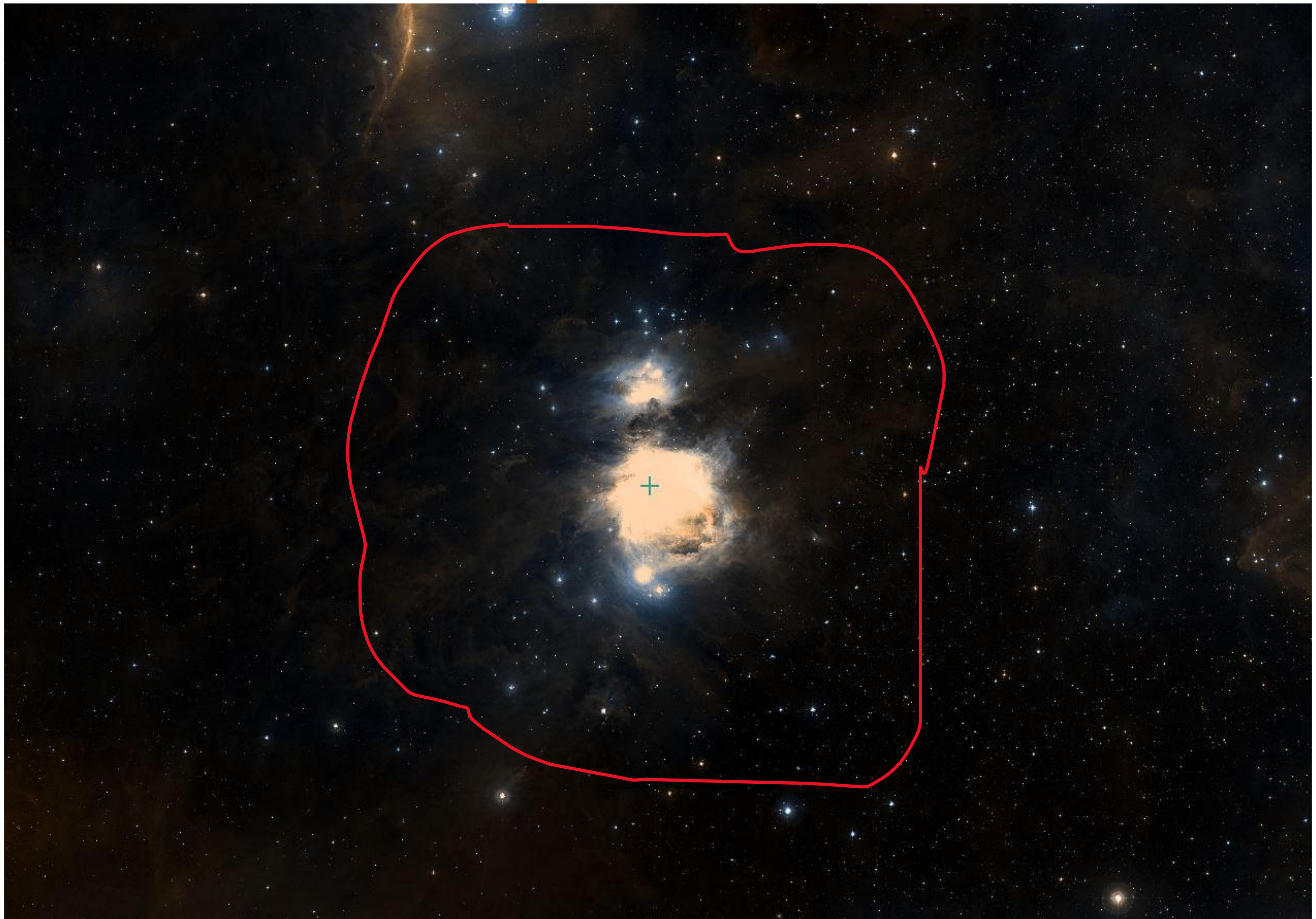
Jason Kendall on Youtube

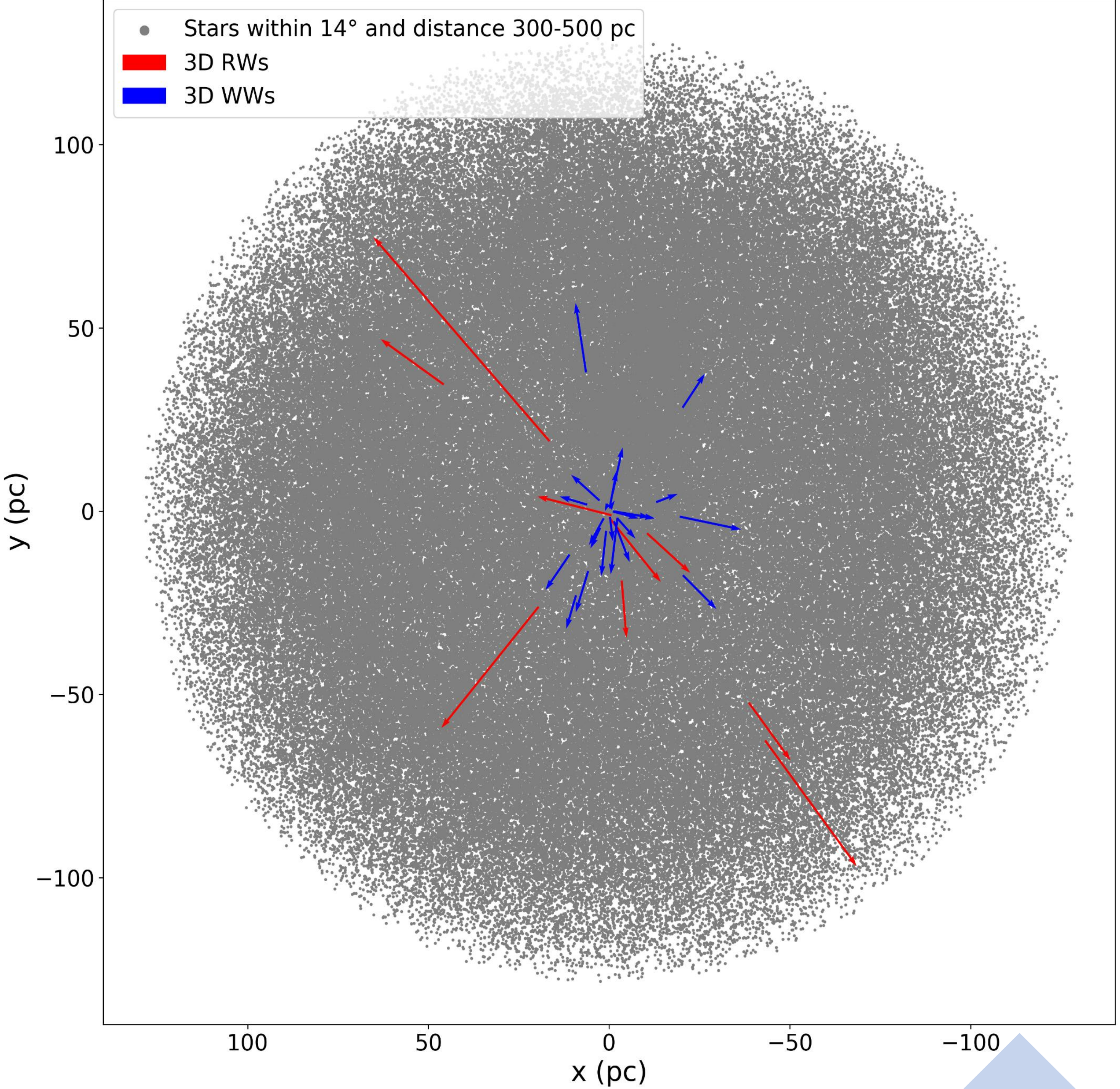
4d + α,δ

- $v_R = \frac{\Delta\lambda}{\lambda} c$
- d=1/parallax
- Proper motion measured by change in angular position

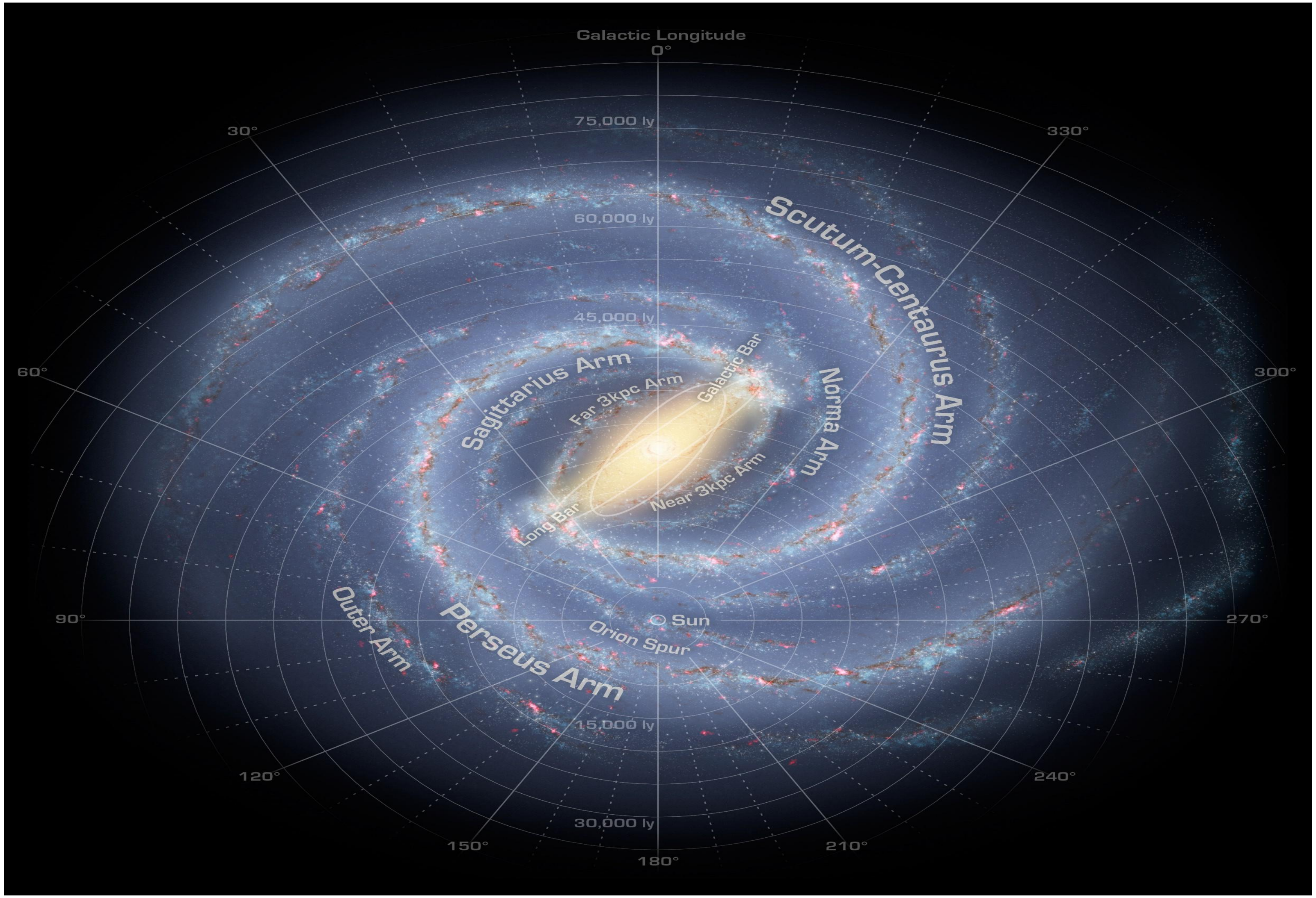
How to study them?

- We can use runaways in two ways
    1. Study a cluster and find runaways from it

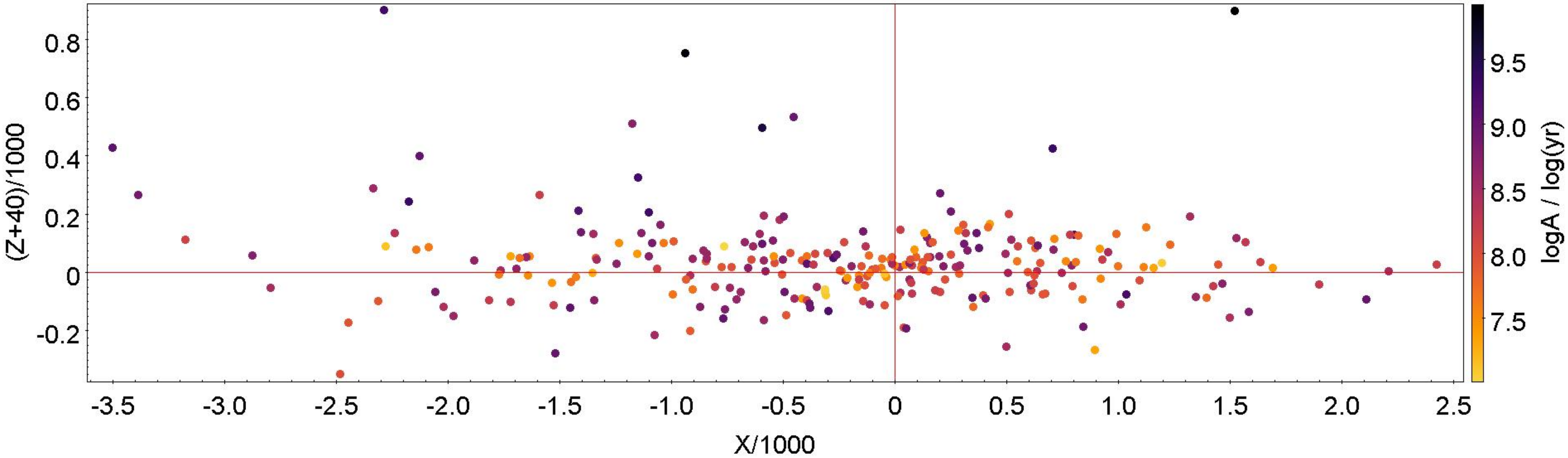


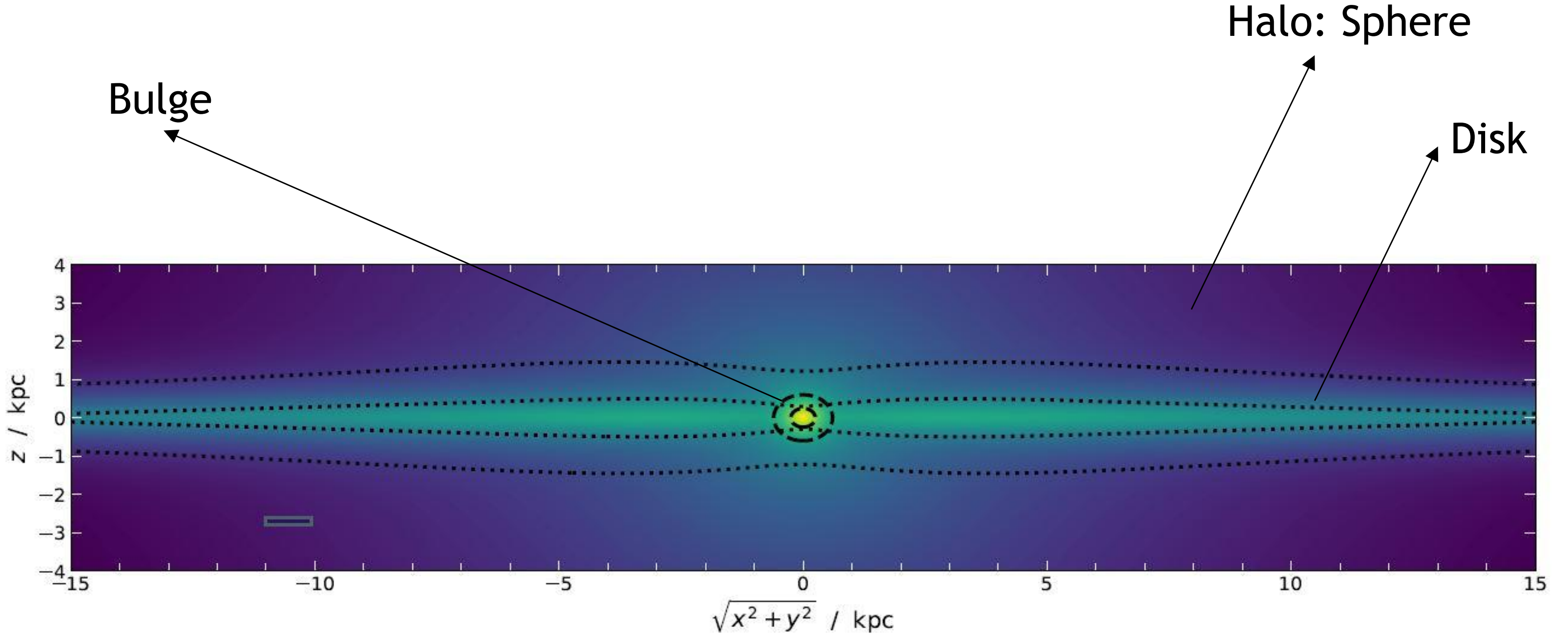


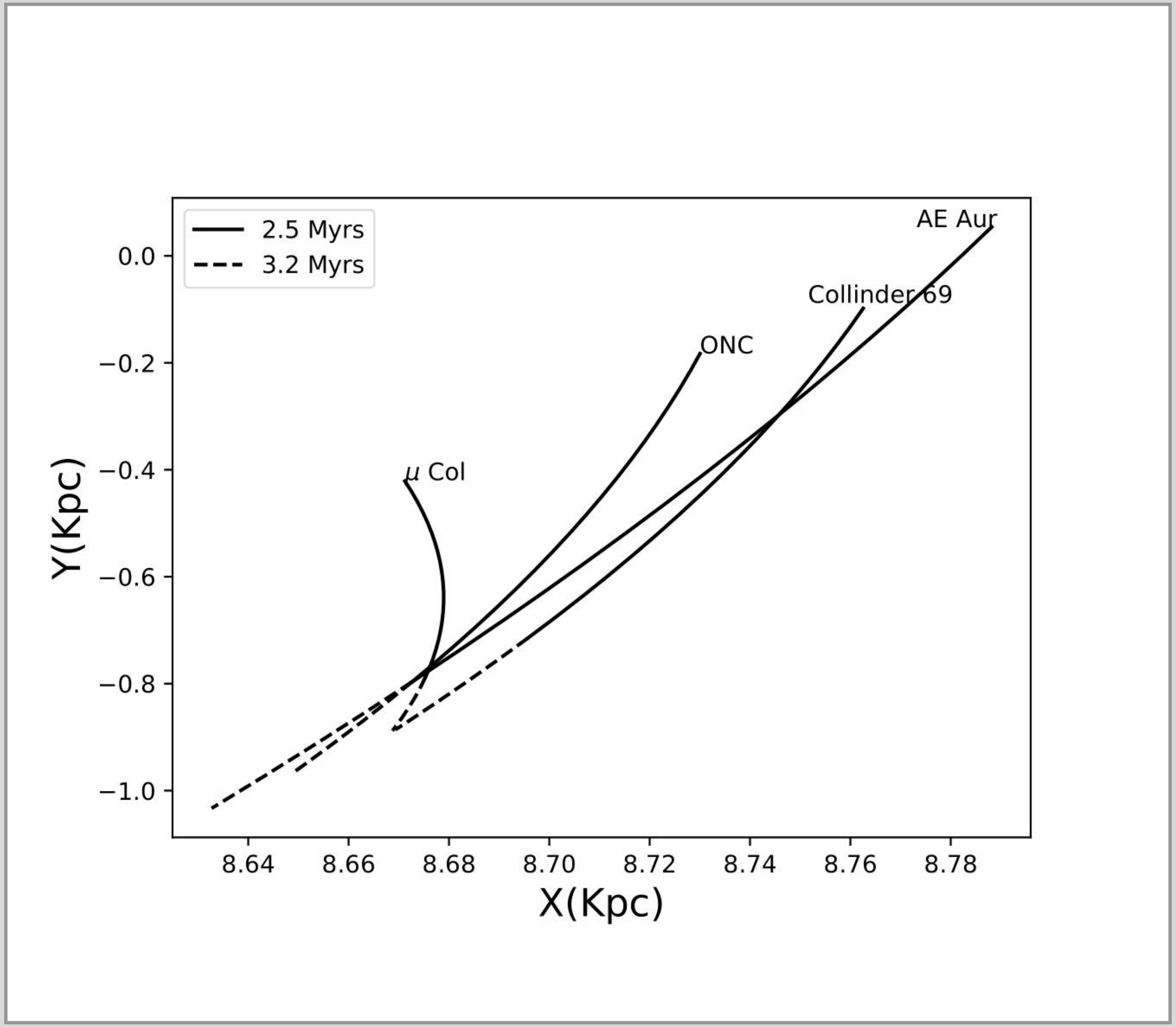
Orion by Farias and Schöttler

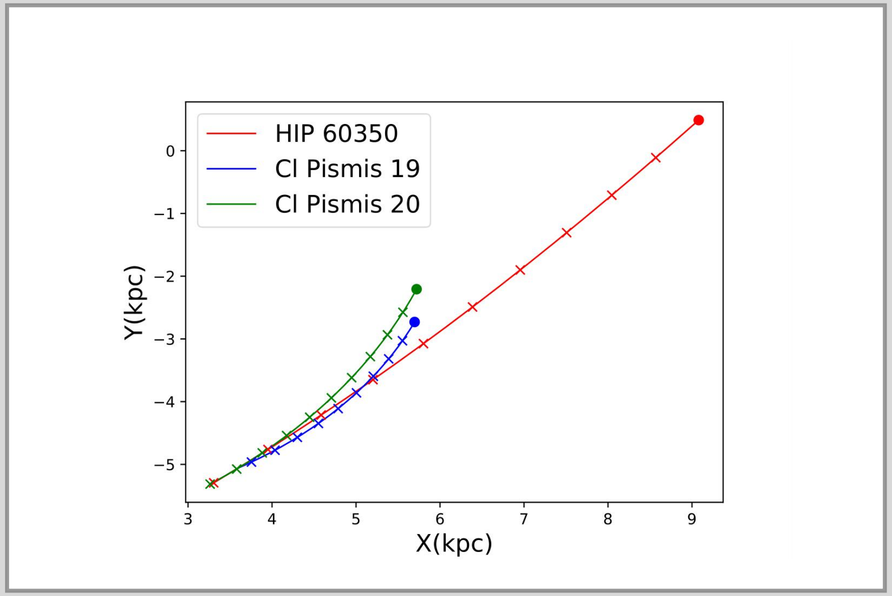


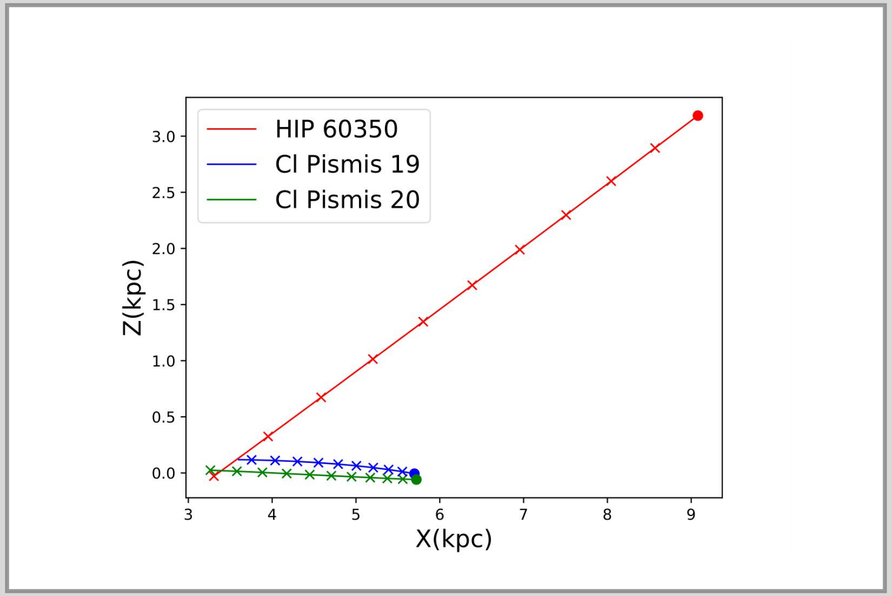
Method 2: Study Runaways and find their clusters


(Z+40)/1000
X/1000
logA / log(yr)
0.8
0.6
0.4
0.2
0
-0.2
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0
0.5
1.0
1.5
2.0
2.5
9.5
9.0
8.5
8.0
7.5


Halo: Sphere
Bulge
Disk
z / kpc
$\sqrt{x^2+y^2}$ / kpc
4
3
2
1
0
−1
−2
−3
−4
−15
−10
−5
0
5
10
15


2.5 Myrs
3.2 Myrs
AE Aur
Collinder 69
ONC
μ Col
Y(Kpc)
X(Kpc)
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
8.64
8.66
8.68
8.70
8.72
8.74
8.76
8.78

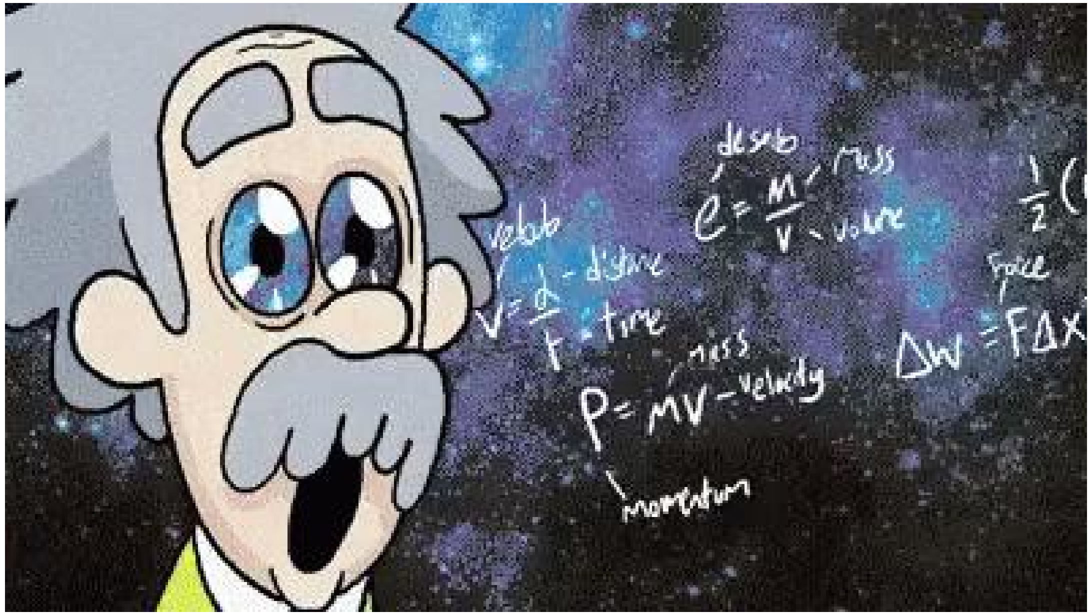

HIP 60350
Cl Pismis 19
Cl Pismis 20
Y(kpc)
X(kpc)
0
−1
−2
−3
−4
−5
3
4
5
6
7
8
9


HIP 60350
Cl Pismis 19
Cl Pismis 20
Z(kpc)
X(kpc)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3
4
5
6
7
8
9

What is different about this project?

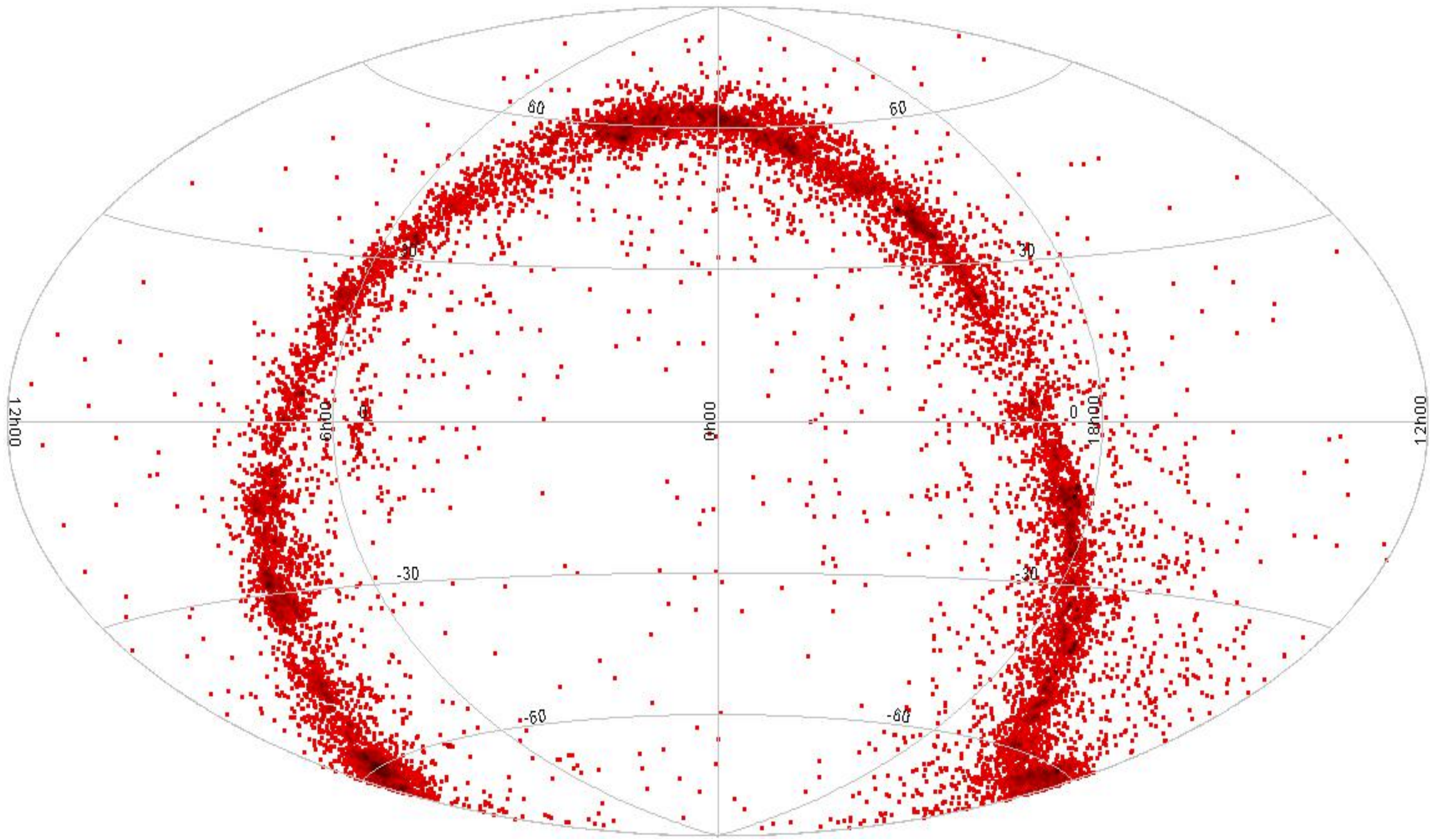
- So far, we have studied well known stars and collected kinematics based on literature values. These tend to be bright, nearby, high declination objects.
- But if we want to find the missing runaways, we need to start from scratch: Find our own targets, take our own measurements, do our own spectral analysis.
- And if we are lucky, we might find something unique!

What can we learn?



- Stellar Evolution (Life, Death, Afterlife)
- Cluster formation
- Galactic structure (Mass Function)
- Supernova rates and star formation
- If lucky, common enevlope/accretion

How to find the Target without RV?? Use other 5 kinematic values



- We can use Gaia and Simbad (5 arcsec each) to get:
  - Tangential Velocity: 4.74*pm/parallax>25 km/s
  - Galactic Z coordinate: >150 parsec (0.15 kpc) (icrstoGal(polarXYZ(ra,dec,1/parallax)))
  - RUWE <1.4 (Is our Parallax reliable? Especially bad if stars are binaries)
  - Parallax>0.1 and parallax_over_error>3
  - Literature search in Simbad
  - To prioritize make your list increasing order by vtan and by main_type=„star“