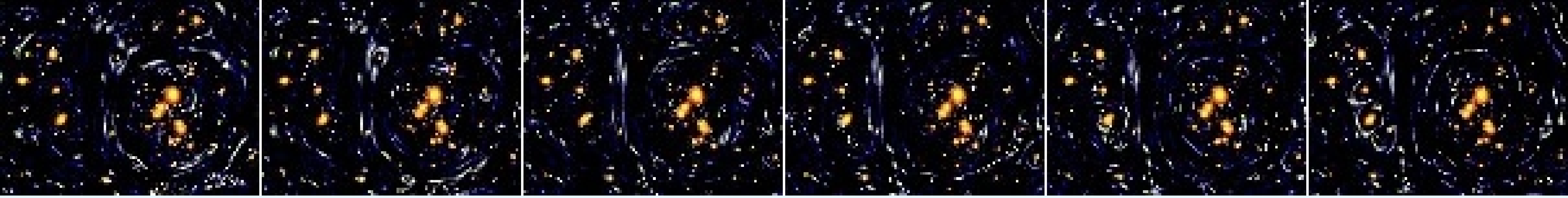


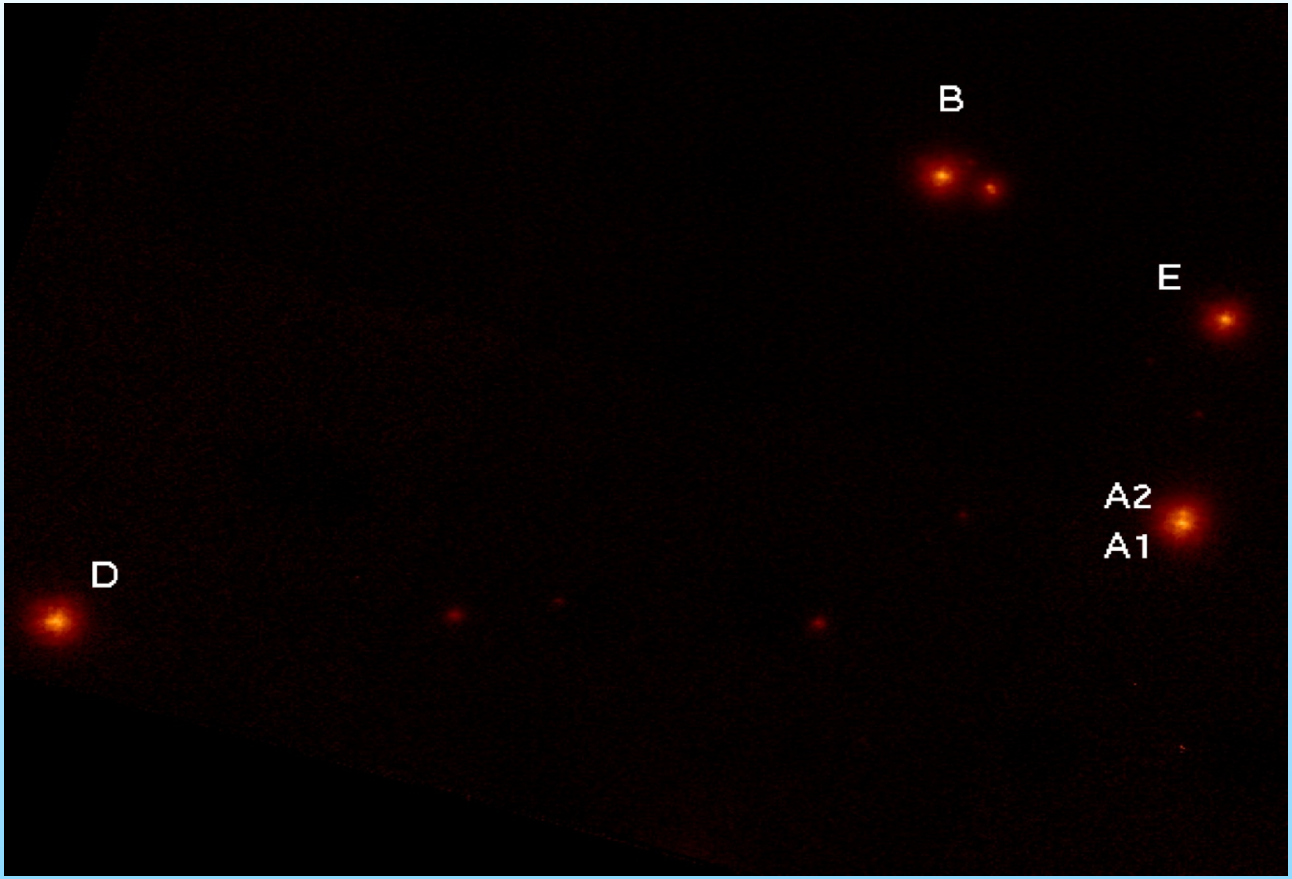
Theta 1 Ori B: a quintuple (sextuple?) system less than 30,000 years old

Christine Allen

Instituto de Astronomía, UNAM, Mexico

Collaborators: Rafael Costero, Miroslava Hernández

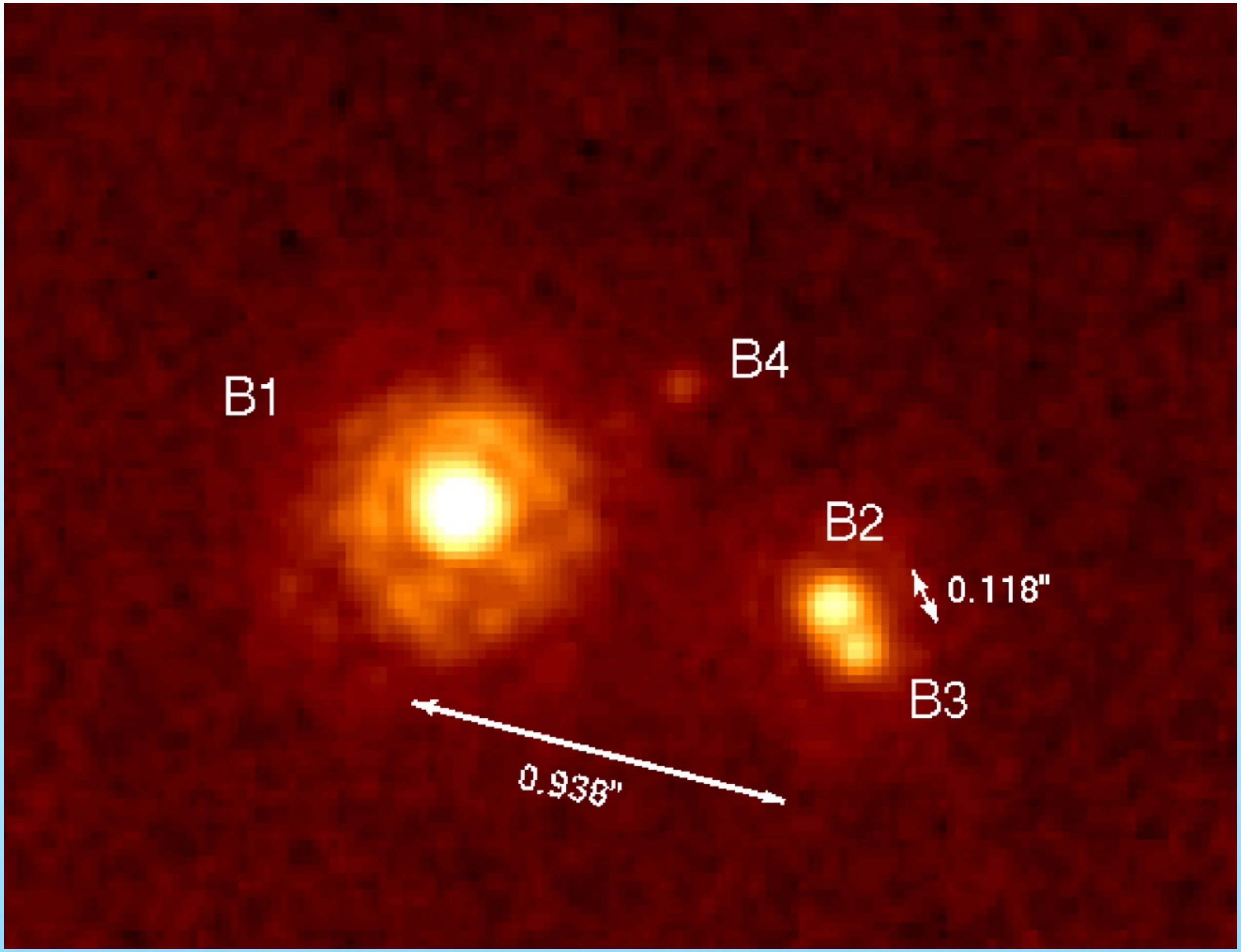
The system Theta 1 Ori B



Upper part of the Theta 1 Ori cluster as imaged over 30" × 30" FOV at Gemini with the Hokupaa AO system. Color scale is logarithmic. North is up, and east is to the left. Note that the object "A1" is really a spectroscopic binary (A1-A3), where the unseen companion A3 is separated from A1 by 1 AU (Bossi et al. 1989).

=> A: TRIPLE

Also E: escaping spectroscopic binary (Costero et al. 2008)



Detail of the Theta1 Ori B group as imaged at 0".077 resolution (in the H band) with the MMT AO system and the Indigo IR camera. Color scale is logarithmic. North is up, and east is left. Note that the object "B1" is really an eclipsing spectroscopic binary (B1-B5), where the unseen companion B5 orbits B1 every 6.47 days (Abt et al. 1991). Hokupaa Gemini. (Close et al. 2003)

=> B: QUINTUPLE. Also C: DOUBLE, D: possible double (speckle)

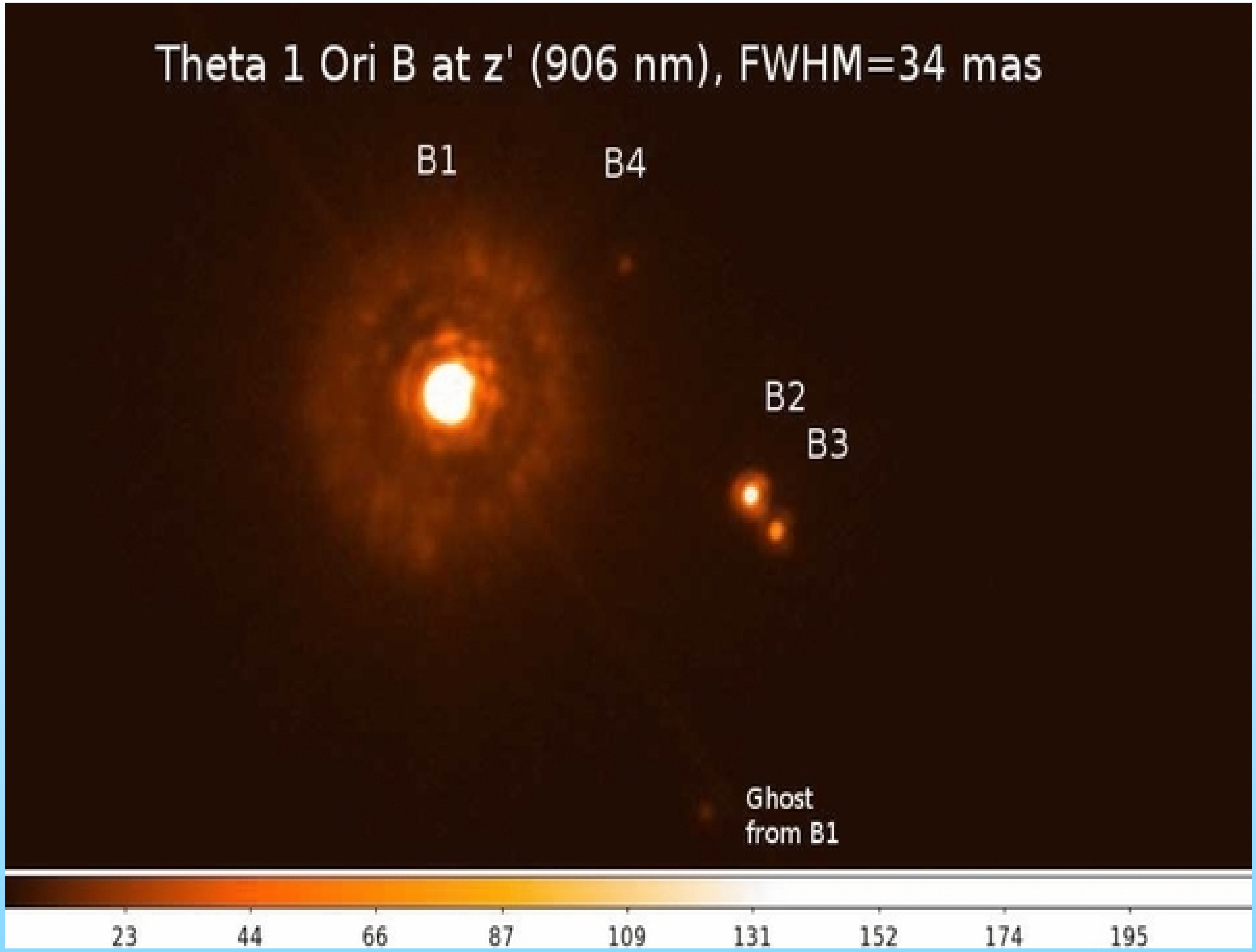


Figure 9. MagAO z' (0.91 µm) images of the θ1 Ori B group. Resolution 0034. Linear color scale. North is up and east is to the left. Note that this image is ~2 × sharper than that of the 8.4 m LBT at Brγ (2.16 µm; see Figure 8). This is clear evidence that AO in the "blue" allows a smaller 6.5 m telescope to outperform the resolution of an 8 m in the NIR. Close et al, 2012

Export PowerPoint slide

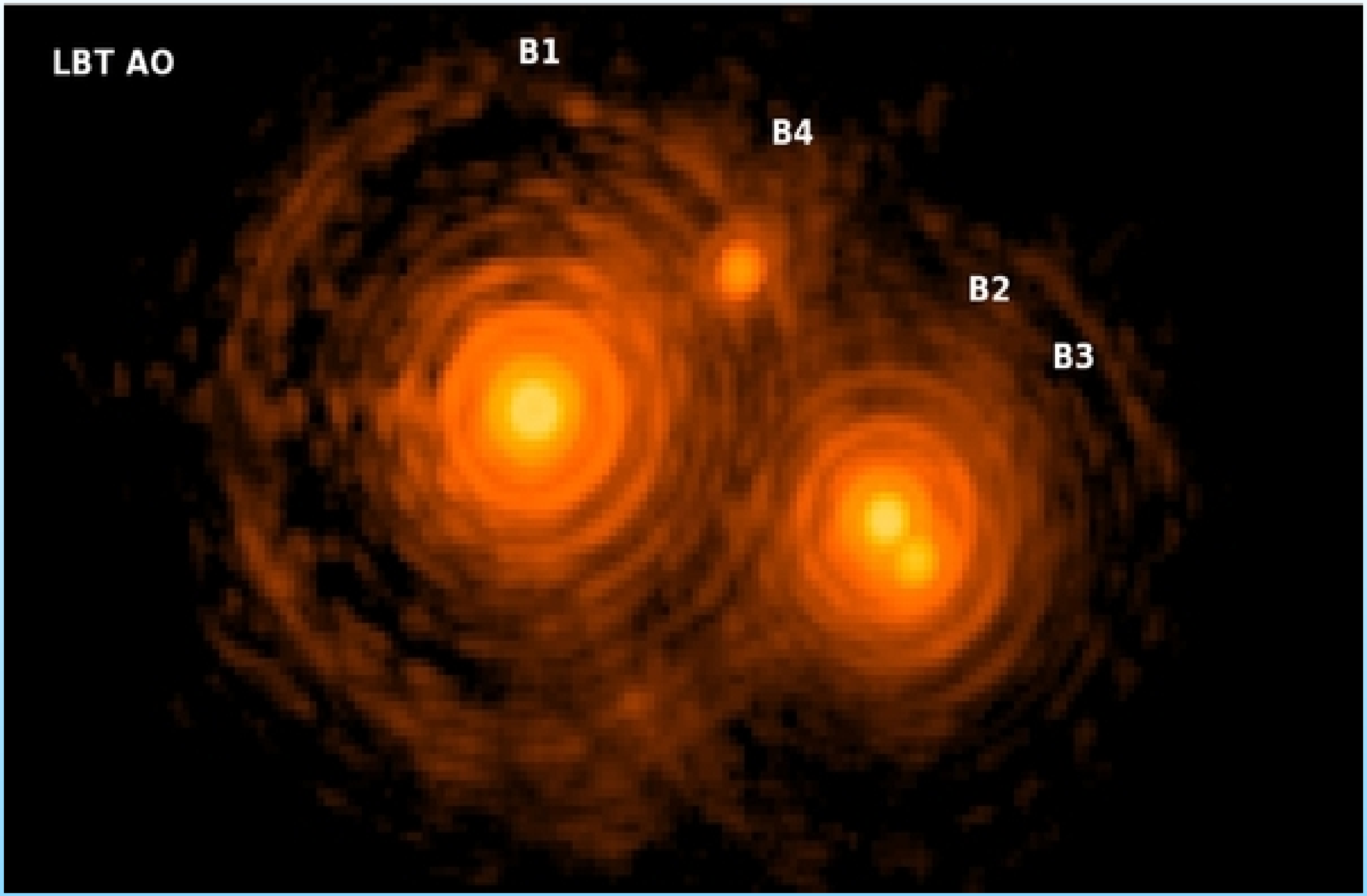
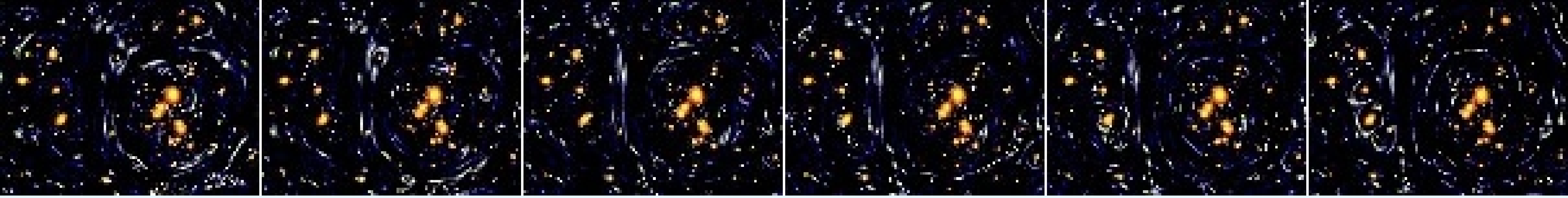


Figure 8. LBT AO Brγ (2.16 µm) images of the θ1 Ori B group. Resolution 006. Logarithmic color scale. North is up and east is to the left. Strehl is ~75% (Close et al. 2013).



The system Theta 1 Ori B

Close et al.(2013) ask:

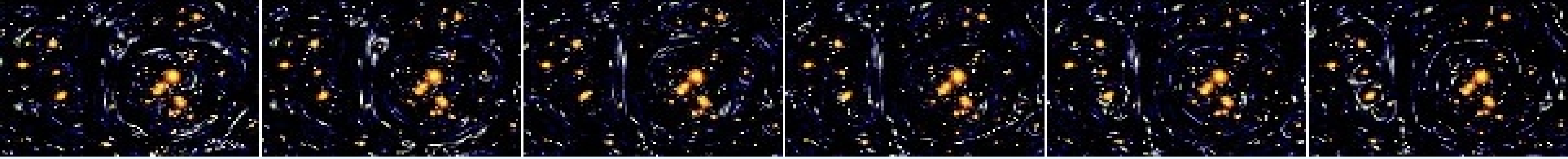
Is the group Theta 1 Ori B long-term stable?

Are orbits B2-B3, (B2+B3)- (B1+B5) long-term stable?

-They have precise astrometry over a time base of 15 years

-So, positions and relative (planar) velocities are known. But z-positions and radial velocities are unknown.

- N-body Monte Carlo simulations can provide insight.



As initial conditions we take:

-Separations, relative positions and planar velocities as in Close et al. 2013

-Masses: B1+B5: 14 Mo (point mass)

B2: 3 Mo

B3: 2.5 Mo

B4: 0.2 Mo

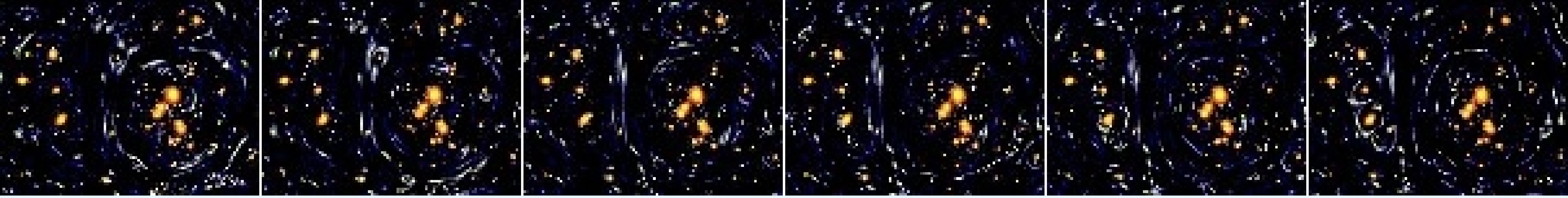
-Random radial velocities (sigma = 1-3 km/s)

-Random z-positions (10-40% of the group radius)

-Planar positions and velocities randomly perturbed, according to uncertainties in Close et al. (0.2-1.4 km/s)

-Used Mikkola & Aarseth code with chain regularization.

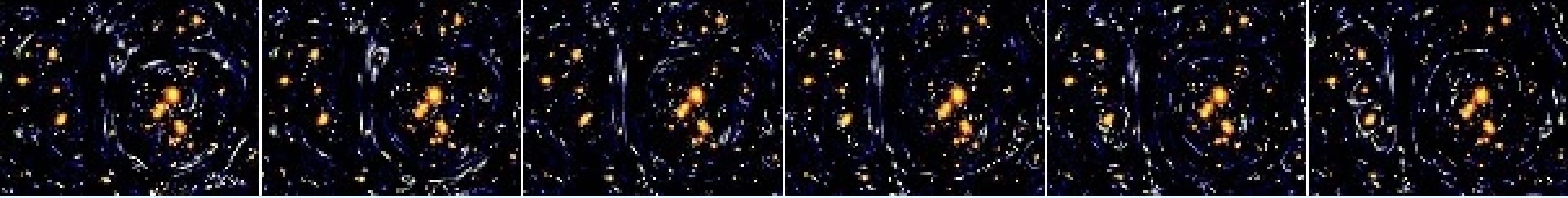
-All groups turned out to be bound.



Results

1st series: 100 cases , TC = 5, 10, 100 (1500-30 000 years)

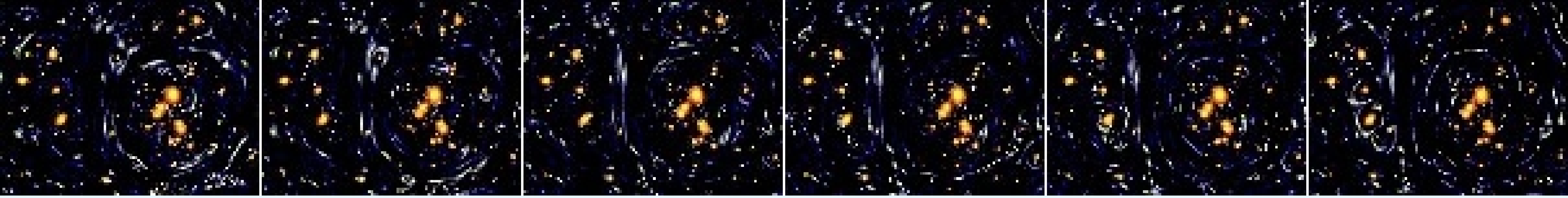
	5	10	100
Stable	29	18	1
Triple	43	42	19
Dissolved*	28	40	80
*Double^2	6	6	7



Results

2nd. Series: 100 cases , Tc = 5, 10, 100 (1500-30 000 yr)
4x z-perturbations, 3x Vz-perturbations

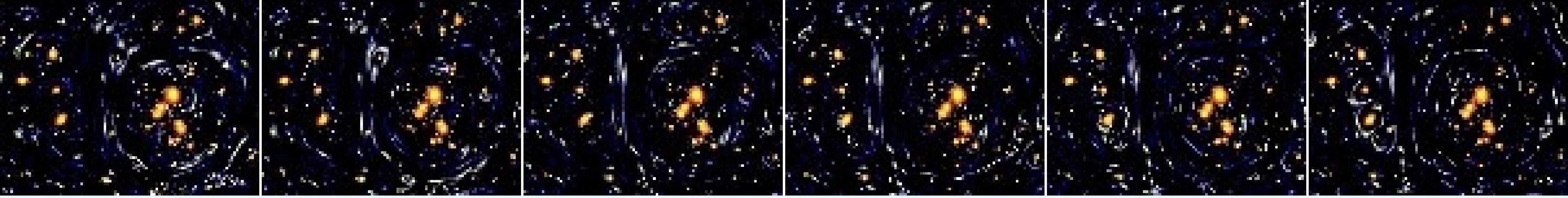
	5	10	100
Stable	39	26	1
Triple	40	46	28
Dissolved*	21	28	71
*Double^2	1	4	5



Results

3rd. Series: 100 cases , Tc = 5, 10, 100 (1500-30 000 yr)
perturbations as in 2nd, but similar V for 2-3

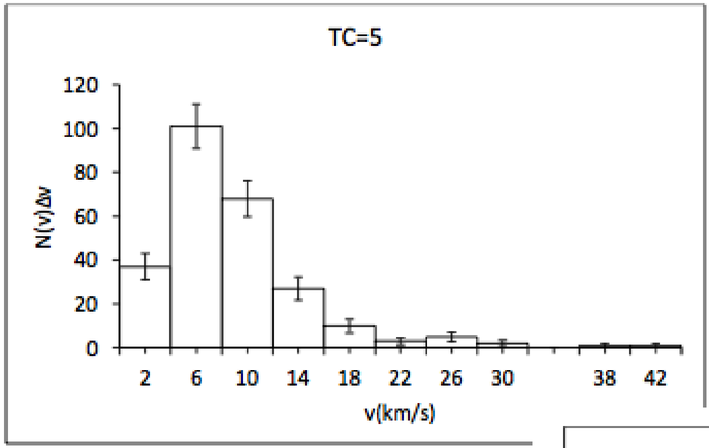
	5	10	100
Stable	35	22	4
Triple	49	55	31
Dissolved*	16	23	45
*Double^2	0	4	9



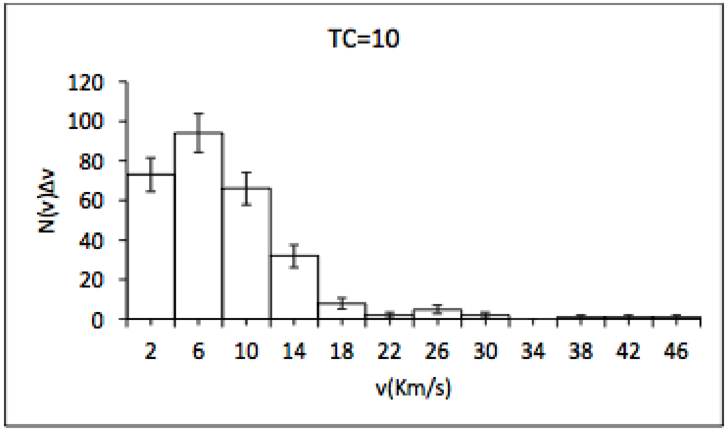
Results (Summary)

Three series, Tc= 5, 10, 100 (1500-30 000 years)

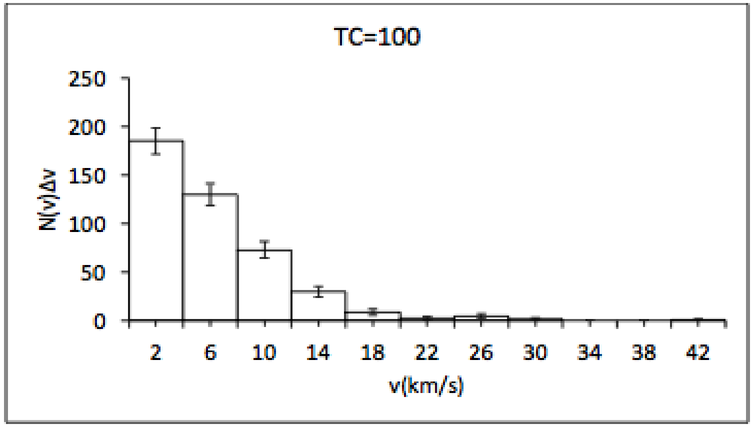
	5	10	100
Stable	29, 39, 35	18, 26, 22	1,1, 4
Triple	43, 40, 49	42, 46, 55	19, 28, 31
Dissolved*	28, 21, 16	40, 28, 23	80, 71, 45
*Double^2	6, 1, 0	6, 4, 4	7, 5, 9



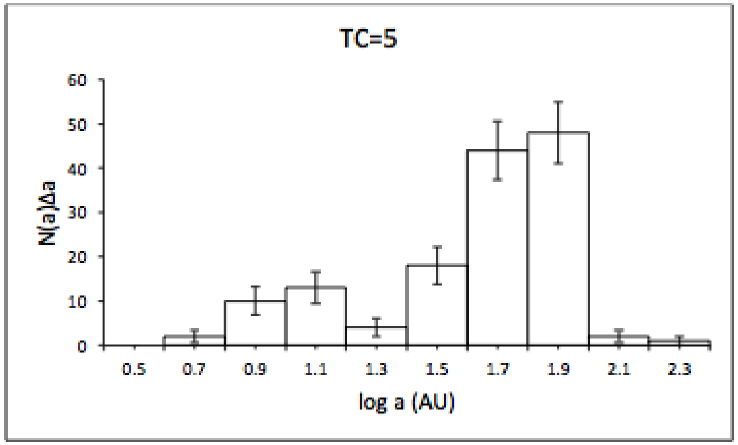
Distribution of velocities of ejected stars

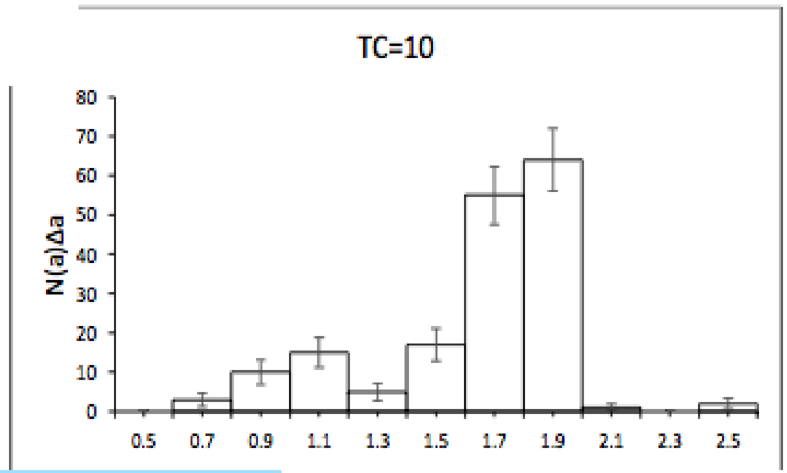


Sum of all series

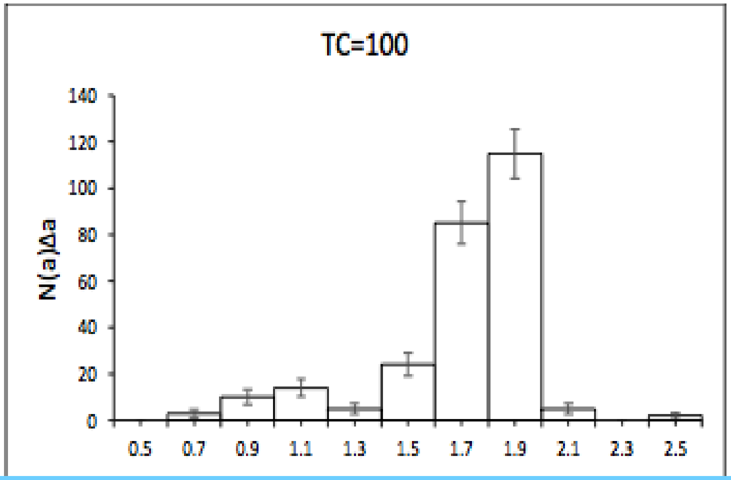


Distribution of major semiaxes of 142, 172, 263 binaries formed during integrations

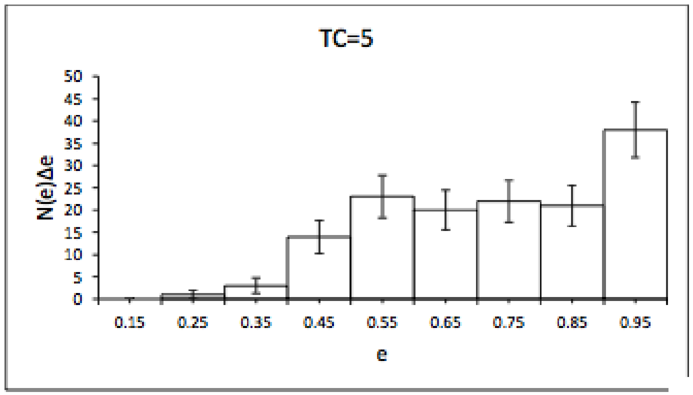


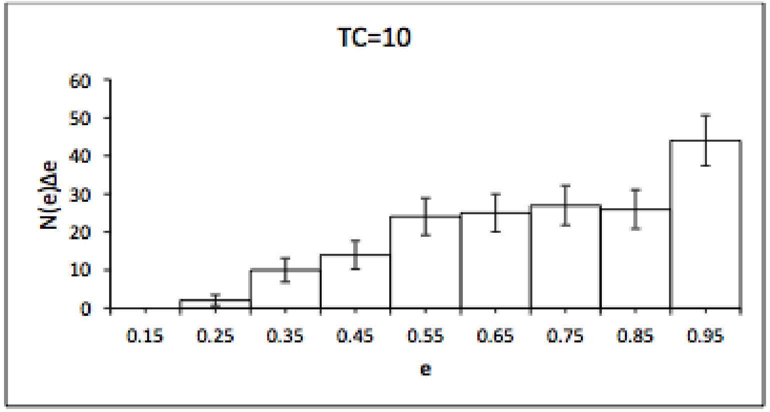


Sum of all series

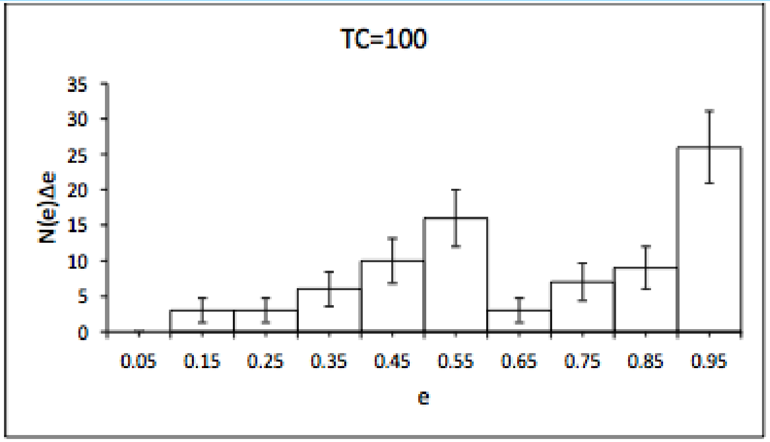


Eccentricity distribution of 142, 172, 263 binaries formed during integrations

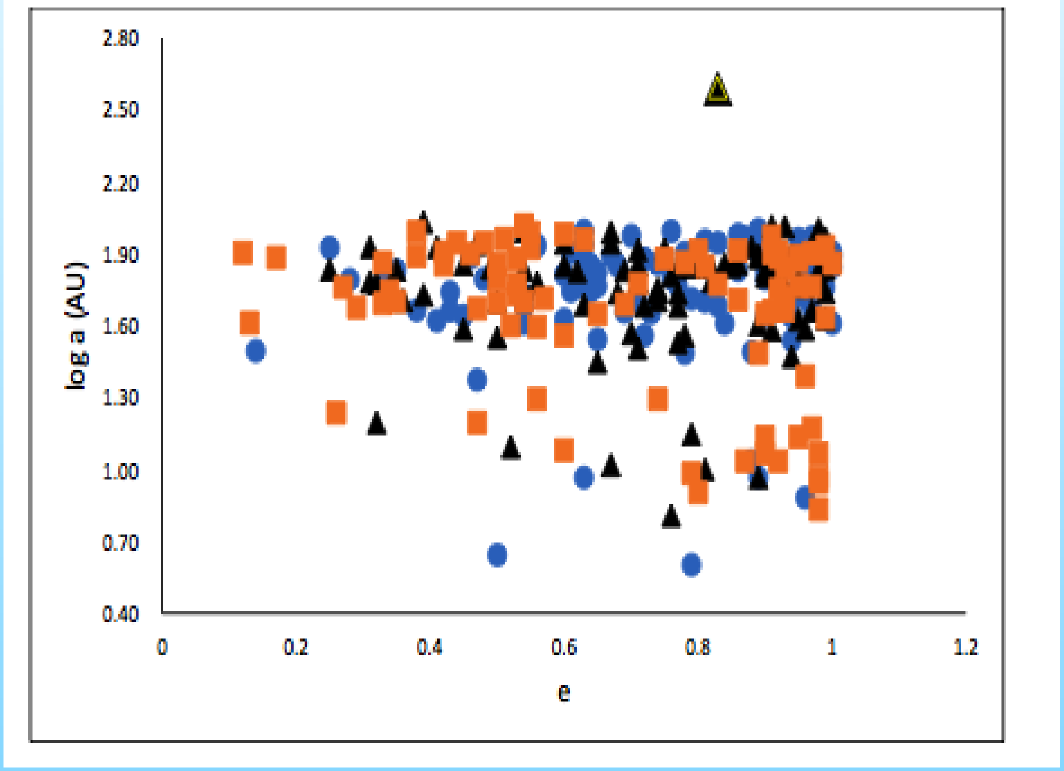




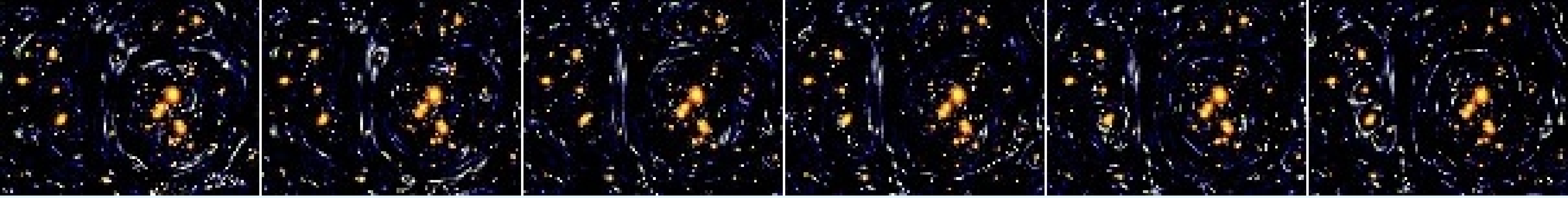
Sum of all series



Major semiaxes as a function of eccentricities for 263 binaries

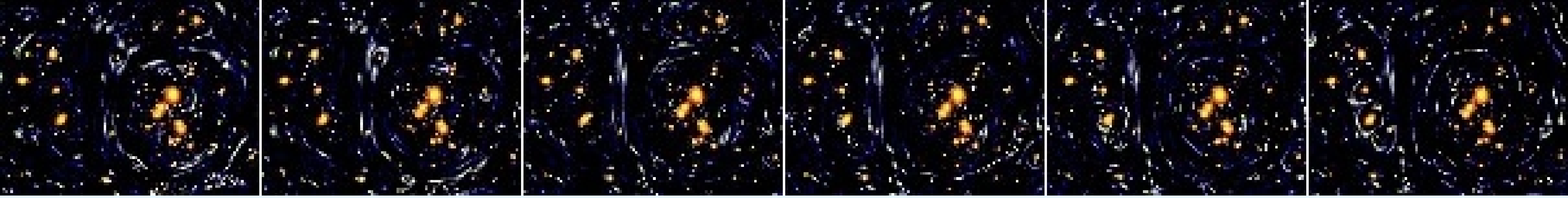


Triangles: 1st Series
Dots: 2nd Series
Squares 3rd Series



Other results, some expected, some surprising:

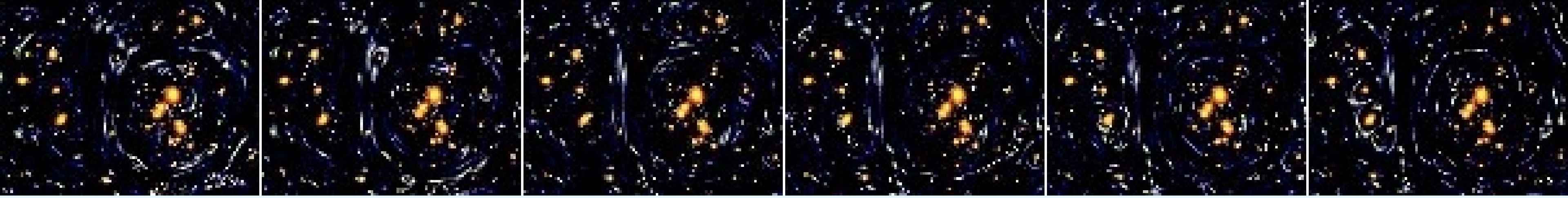
- Groups evolve and disintegrate in very short times.
- Most massive stars (B1+B5)-B2 form a close, stable binary in 49-60 % of the cases. Very close pairs are formed with major semiaxes as small as 6 AU
- The putative initial binary (B2-B3) survives (even at TC=5) only in 5% of the cases (14% in Series 3)
- Dissolved systems have sometimes a double-double configuration, very wide and stable.
- Most escaping stars are low mass, but in 2-5% of the cases the most massive star (B1+B5) escaped.
- Most escapers are low V, but some (7%) stars with V > 3Ve (21 km/s) are produced, both early and late in the evolution of the clusters.



Conclusions

- The quintuple, low mass system (sub-trapezium) Theta 1 Ori B is a bound group, but extremely unstable dynamically. We have shown that it will probably disintegrate in less than 30,000 yr, producing low velocity escapers and perhaps a runaway star, both early and late in its dynamical evolution.

- The Orion region has been a source of at least a few runaway stars. Recent examples are the system BN-I-n, and the escaping spectroscopic binary Theta 1 Ori E. Another example could be the sub-trapezium Theta1 Ori B whose disintegration in the near future could produce a runaway star.



Discussion

A possible problem: is the disintegration too rapid?

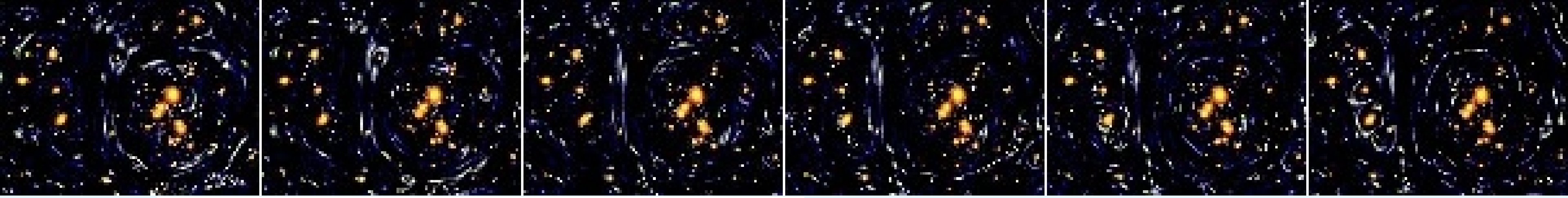
-There are other extremely young structures in the Orion region e.g. the BN-I-n object (500 yrs), the Nebula itself (illumination age about 15,000 yr, O´Dell et al. 2009)

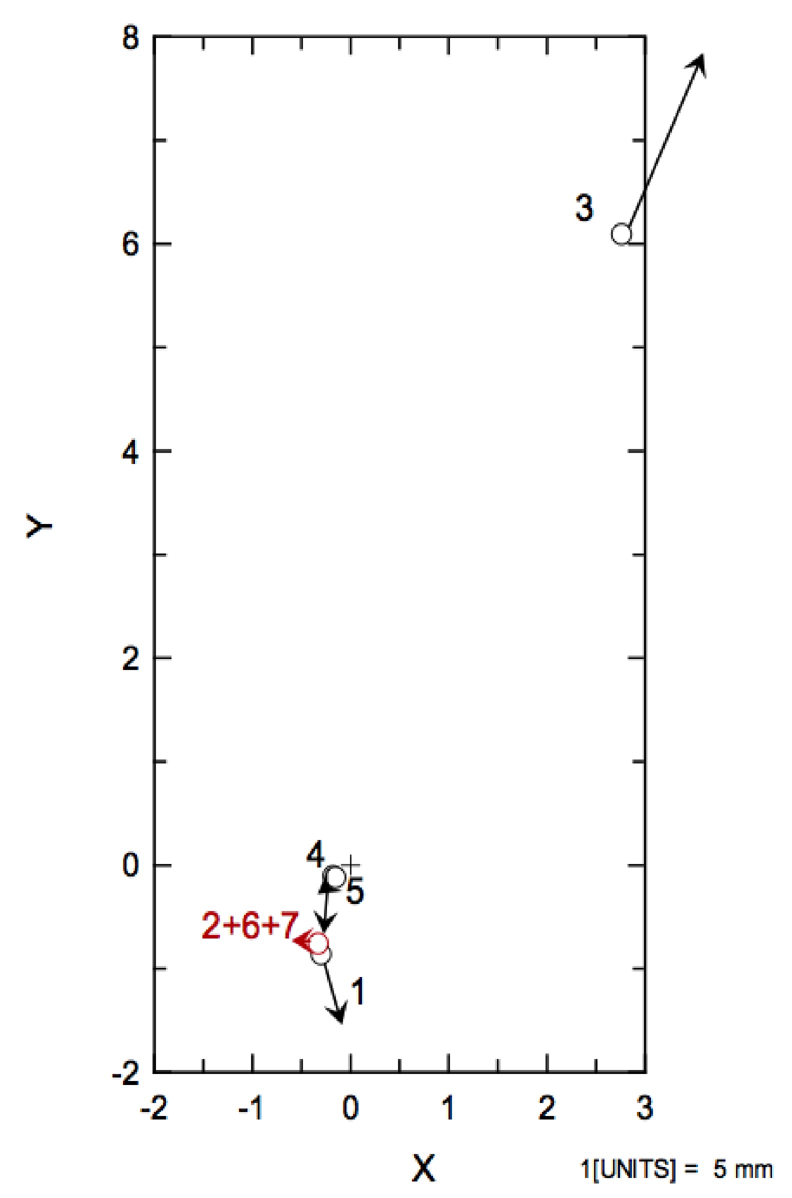
-One or more of its components could be optical (unlikely)

-Masses (especially B1, B5) are very uncertain

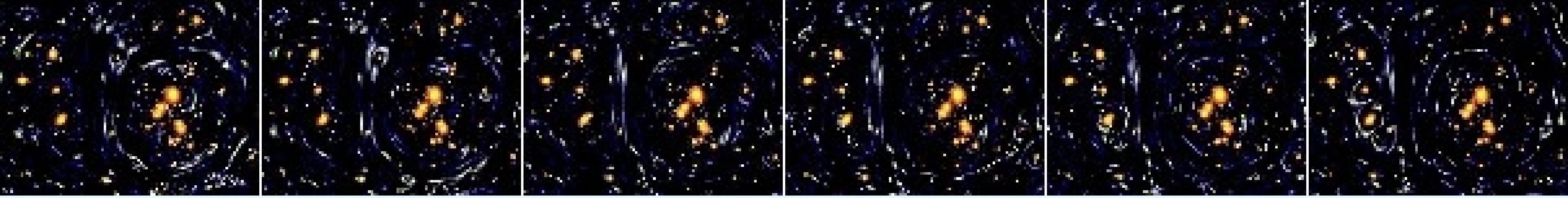
-Binary B1+B5 could have another, not very close, companion (B6?)

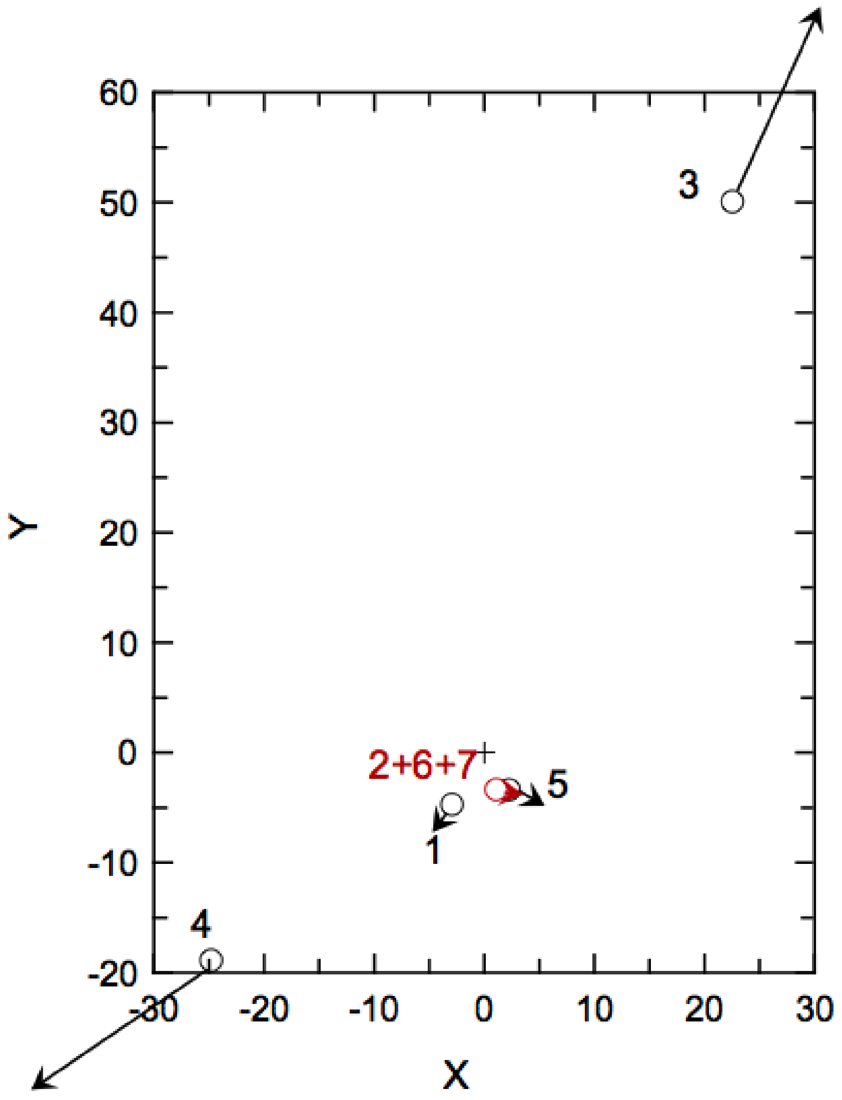
-Perhaps Theta 1 Ori B is the remnant of a more numerous group, already well evolved dynamically and on its way to total dissolution.





Case 87
7 stars
T = 2TC
(600 years)





Case 87
7 stars
T = 10 TC
(3000 years)

NB: at T= 100Tc the group is dissolved, leaving only a binary 2-7

Muchas gracias