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N-body and hydrodynamical simulations of star clusters and star forming regions

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OUTLINE

1. Introduction: why young star clusters
   and star forming regions?

2. N-body simulations without gas and with gas

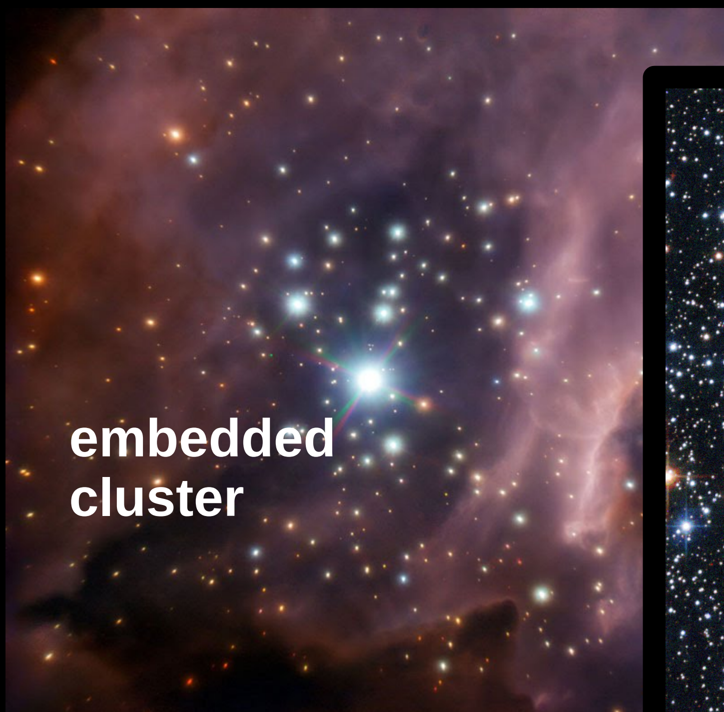
3. Synergy between simulations and data of young /
   open clusters (Gaia ESO survey, Gaia, VISTA
   Magellanic Cloud survey, …)

4. What we use and what we need

1. Why young star clusters and star forming regions?

~ 80 % of stars thought to form in star clusters (Lada & Lada 2003)

→ BUILDING BLOCKS OF GALAXY DISCS



open cluster

young dense
star cluster

OPEN QUESTIONS:

HOW DO STAR CLUSTERS FORM?

HOW DO STAR CLUSTERS EVOLVE?

Modelling star clusters requires 3 ingredients (not necessarily in the same simulation):

i- dynamics

most star clusters have shorter two-body relaxation time than lifetime

ii- stellar evolution

most properties of star clusters depend on interplay between dynamics and stellar evolution
e.g. mass loss by massive stars changes star cluster potential → affect dynamics

iii- gas physics:

clue to understand embedded star clusters and infant mortality

2. N-Body simulations with gas / without gas

i- Dynamics of star clusters: Direct N-body simulations

- solve Newton equation directly
  → high accuracy dynamics

- special purpose hardware
  such as graphics processing units (GPUs)

- 1:1 correspondence star-particle

DETAILS ALREADY IN MARIO'S TALK

(e.g. MM+ 2013; MM & Bressan 2013; Trani, MM, Bressan 2014; Ziosi, MM+ 2014; MM+ 2015)

2. N-Body simulations with gas / without gas

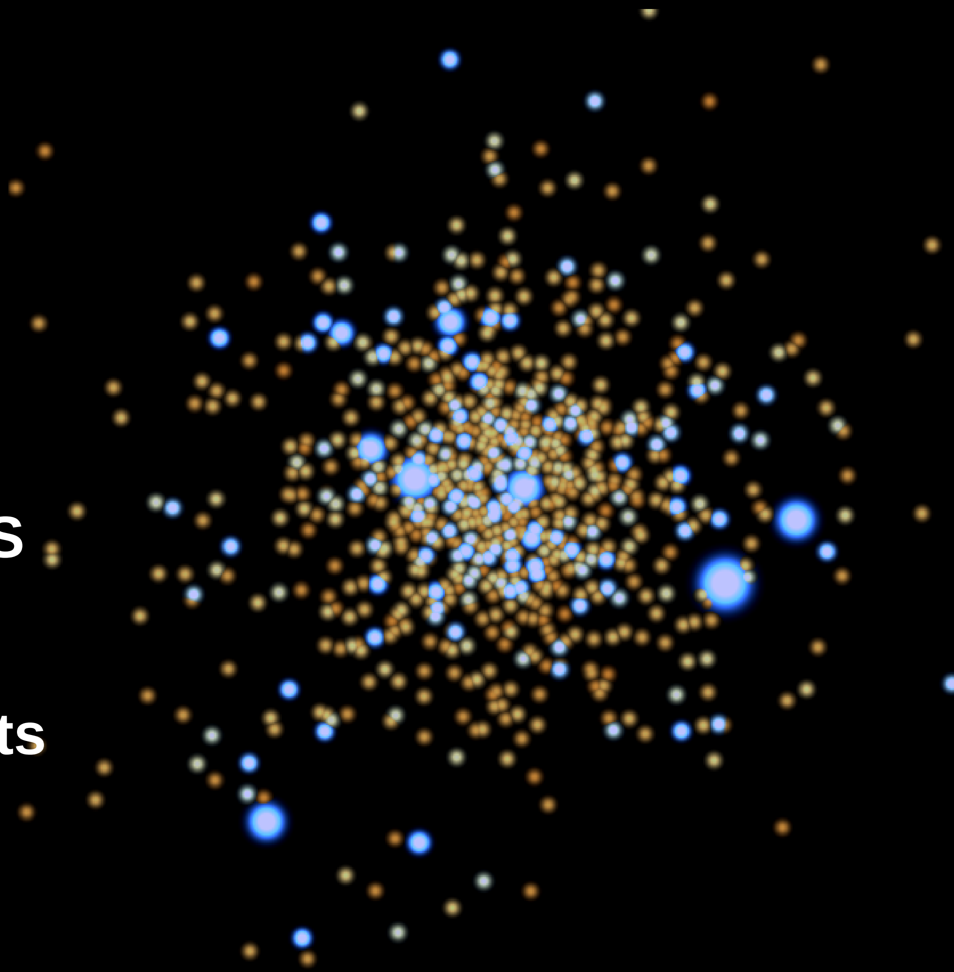
i- Dynamics of star clusters: Direct N-body simulations

ii – Stellar evolution:
stellar evolution can be added
in direct-N-body simulations:

- each particle is a star
  with physical mass, radius,
  luminosity, temperature,
  metallicity changing in time

- stellar winds for MS and post-MS

- recipes for formation of
  black holes and other remnants



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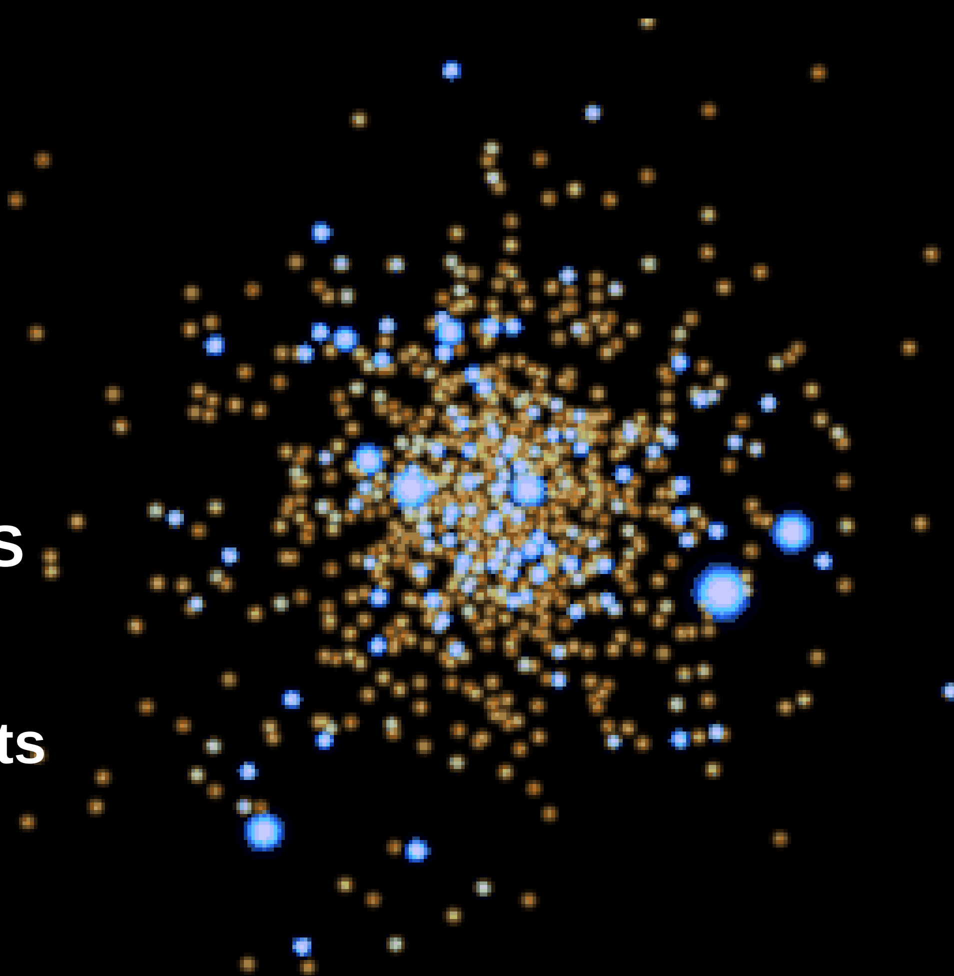

Example: movie of dynamics+stellar evolution
KIRA for dynamics (Portegies Zwart+ 2001) +
SEVN code for stellar evolution (Spera, MM & Bressan 2015)

2. N-Body simulations with gas / without gas

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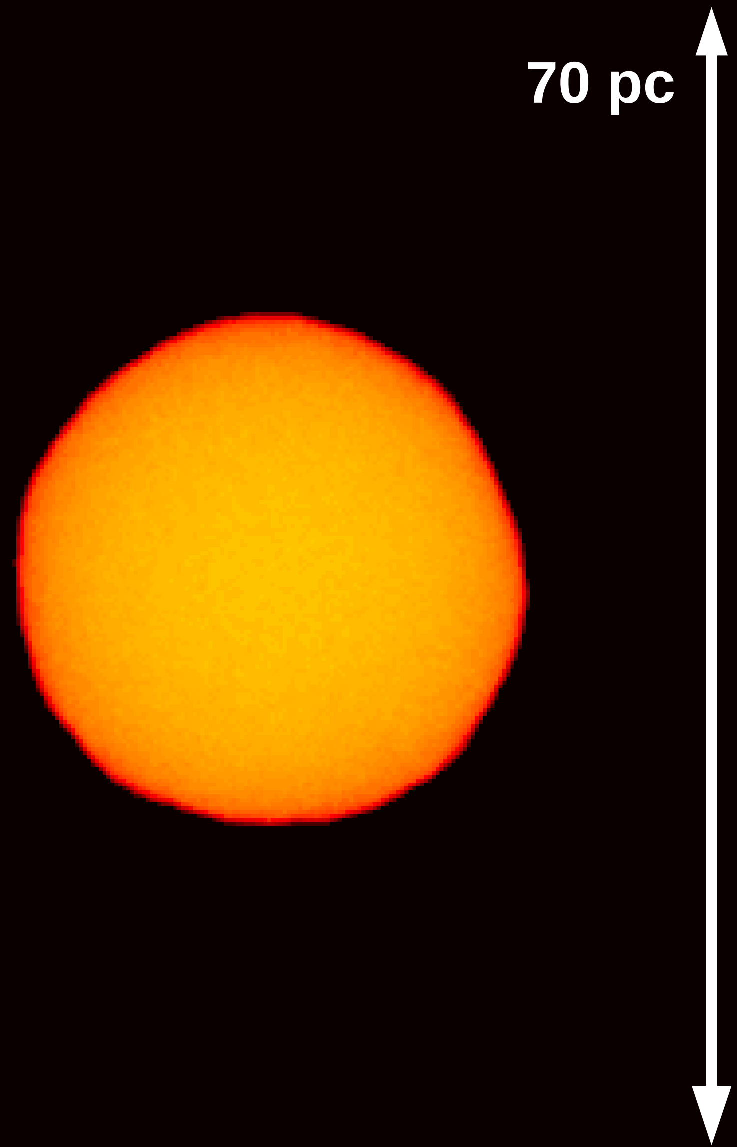
iii – Gas physics

- generally not coupled with direct N-body
  but with collisionless N-body

- essential to model collapse of cloud

- recipes for cooling, radiative transfer,
  chemistry, magnetic fields



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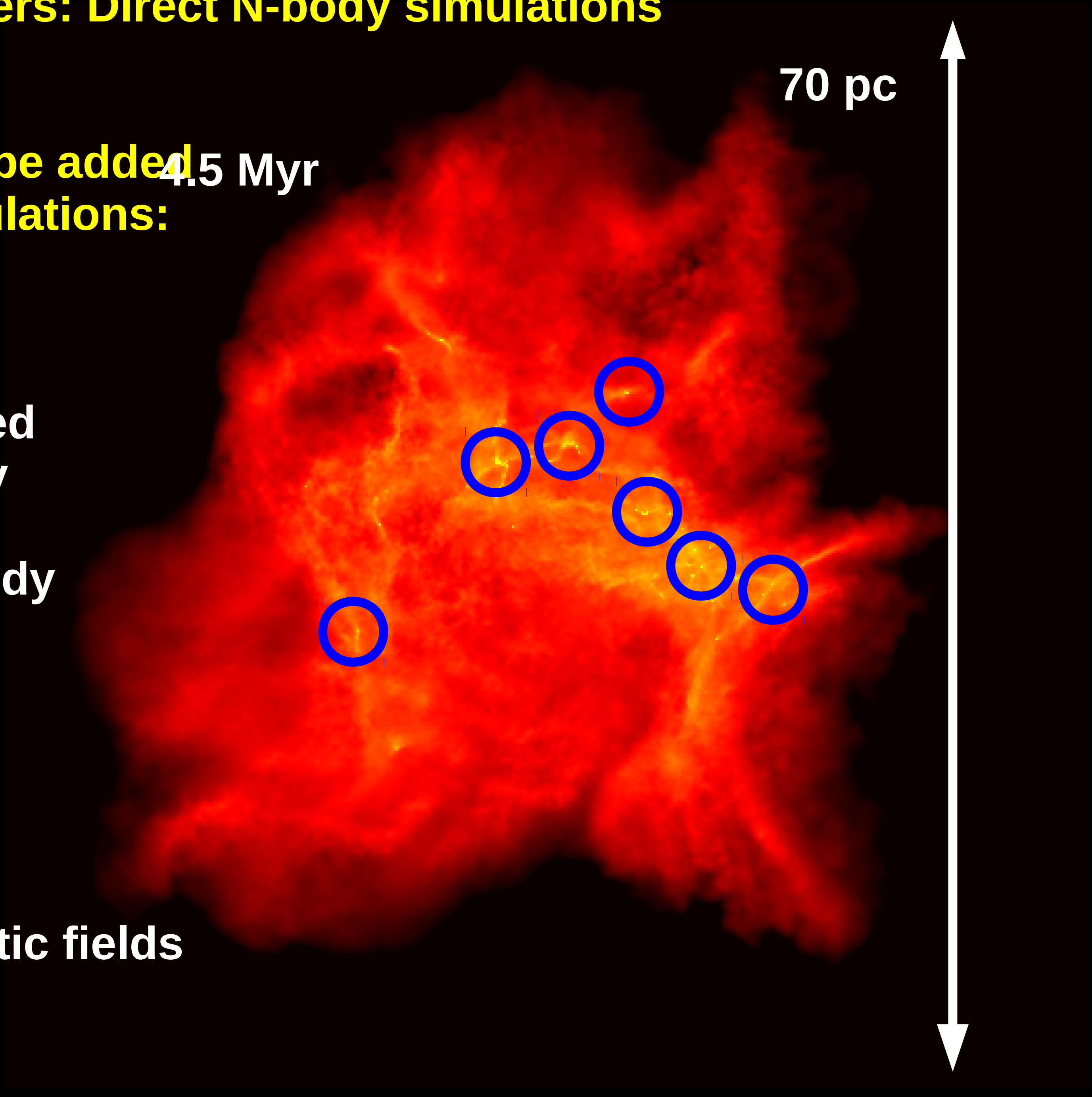


3. Synergy between simulations and major current surveys

EXAMPLE: Gaia ESO Survey (GES)

sample of embedded, young and open star clusters
(all stages of star cluster life are included in the same survey)

Rho ophi

NGC2264

EMBEDDED

Cha I

NGC6705

Berkeley 81

NGC2516

OPEN CLUSTERS
>100 Myr

Trumpler20

NGC4815

Gamma Vel

NGC3293

YOUNG
<100 Myr

IC 4665

NGC2451

IC 2391

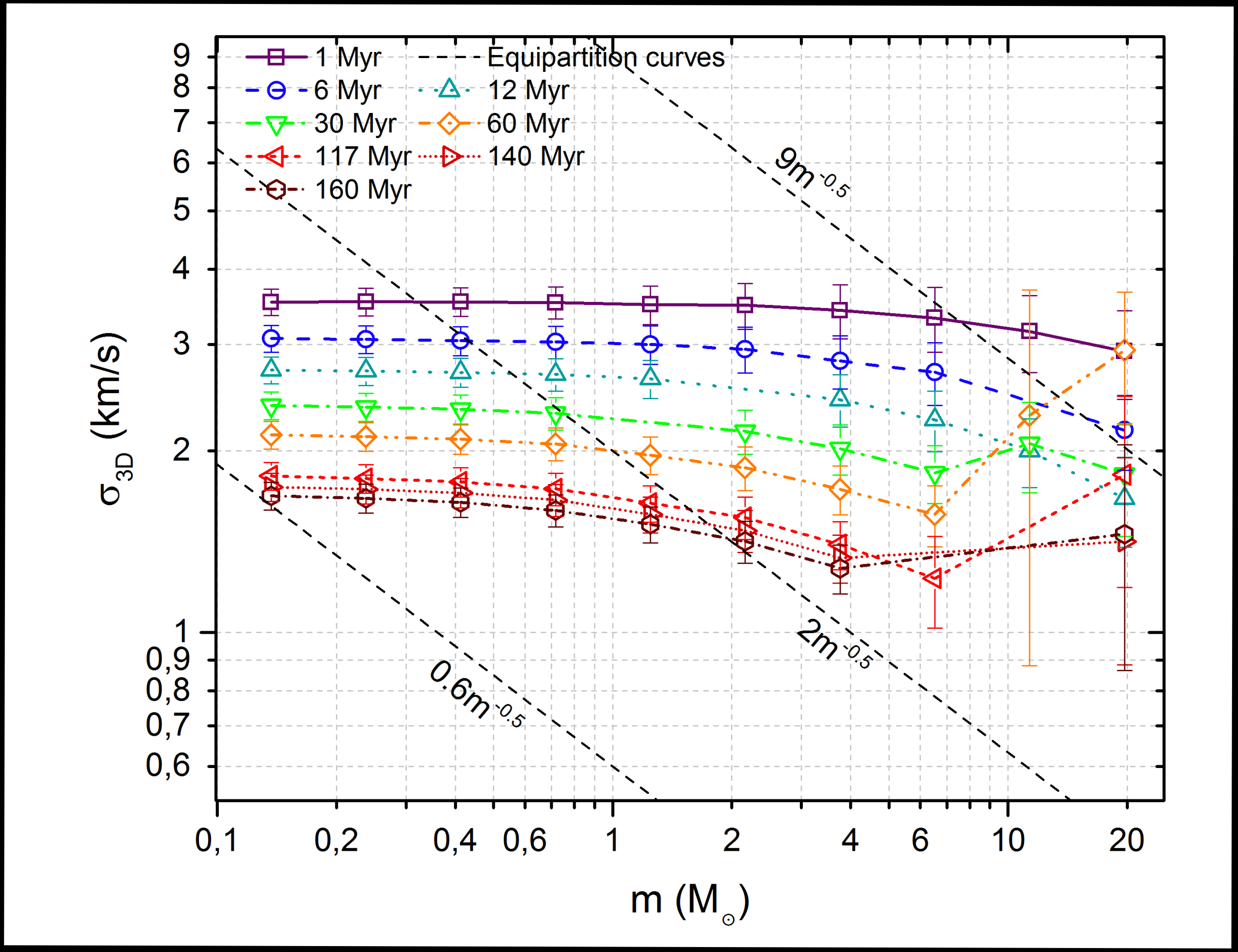
NGC2547

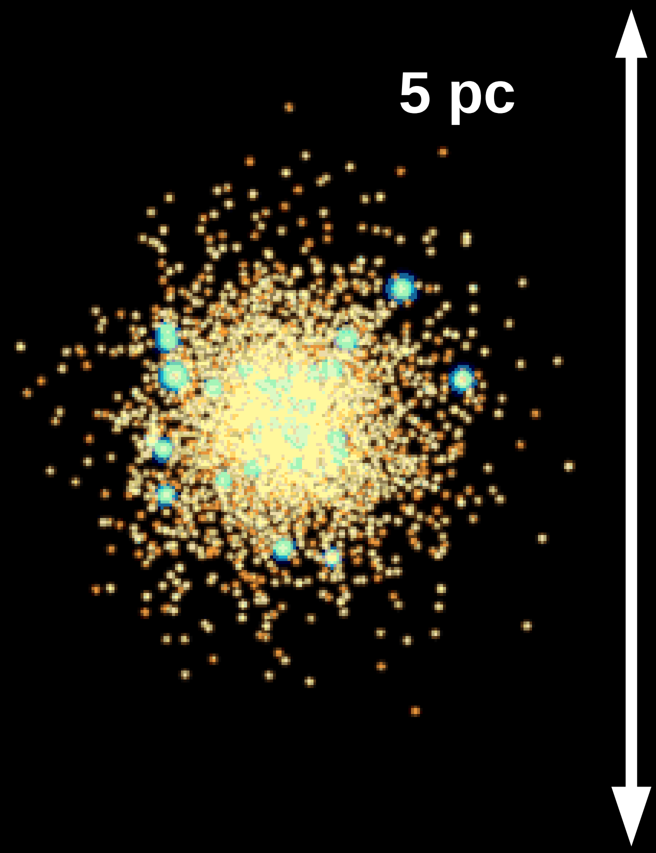
- Radial velocities (accuracy better than 1 km/s!!!)
- Chemistry
- Age

3. Synergy between simulations and major current surveys

Our simulations predict NO ENERGY EQUIPARTITION in OPEN CLUSTERS (Spera, Mapelli & Jeffries 2016, MNRAS)

NO EQUIPARTITION MEANS NO DYNAMICAL EQUILIBRIUM



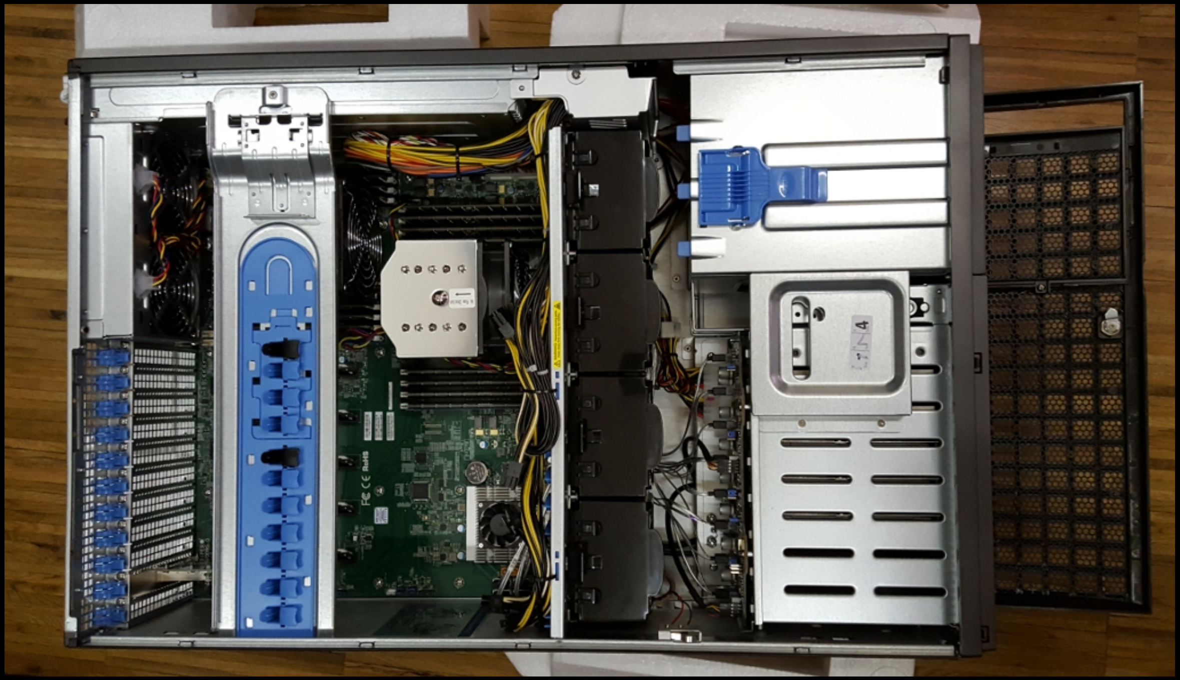


A PREDICTION THAT THE GES CAN TEST IN MANY NEARBY CLUSTERS

4. What we use and what we need?

- WITHOUT GAS: WE NEED GPUs

- WITH GAS: GPUs or >16 CPUs per run (>128 Gb RAM)



@ INAF - Padova we have
- 3 NVIDIA Tesla GPUs
- 1 small SERVER
(64 cores, 256 Gb RAM)
- 40 Tb storage

TOTAL EXPENSE ~ 30 000 EUR

ALL BOUGHT BY OUR TEAM (PI: Mapelli) thanks to COMPETITIVE GRANTS (FIRB, Merac, PRIN-INAF)
not a single EURO from FFO (apart from electricity)

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@ CINECA we obtained
>4 M CPU/GPU hours through
COMPETITIVE PROPOSALS
(100% success rate)

BUT CINECA IS
NO LONGER INVESTING
IN NVIDIA GPU
+
QUEUES ARE LOOOOONG
(> 1 week for a small job)

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OUR DREAM: A Tier2 or Tier1 machine @ INAF

- equipped with at least 2 NVIDIA GPUS per NODE
- RAM > 128 Gb per NODE

It is expensive (1-2 M EUR x Tier 1) but better than each observatory (or each single groups) buying its own small machines

OUR BACKUP SCENARIO:
At least try to negotiate with CINECA for the choice of its future machines

Our team:ForDyS (Formation and Dynamics of Stars)

http://web.pd.astro.it/mapelli/group.html

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