The Challenge of the Globular Clusters

1. Size (particle number)
2. Gaseous component
3. Stellar/binary evolution; collisions

AMUSE Workshop
5-7 October 2009

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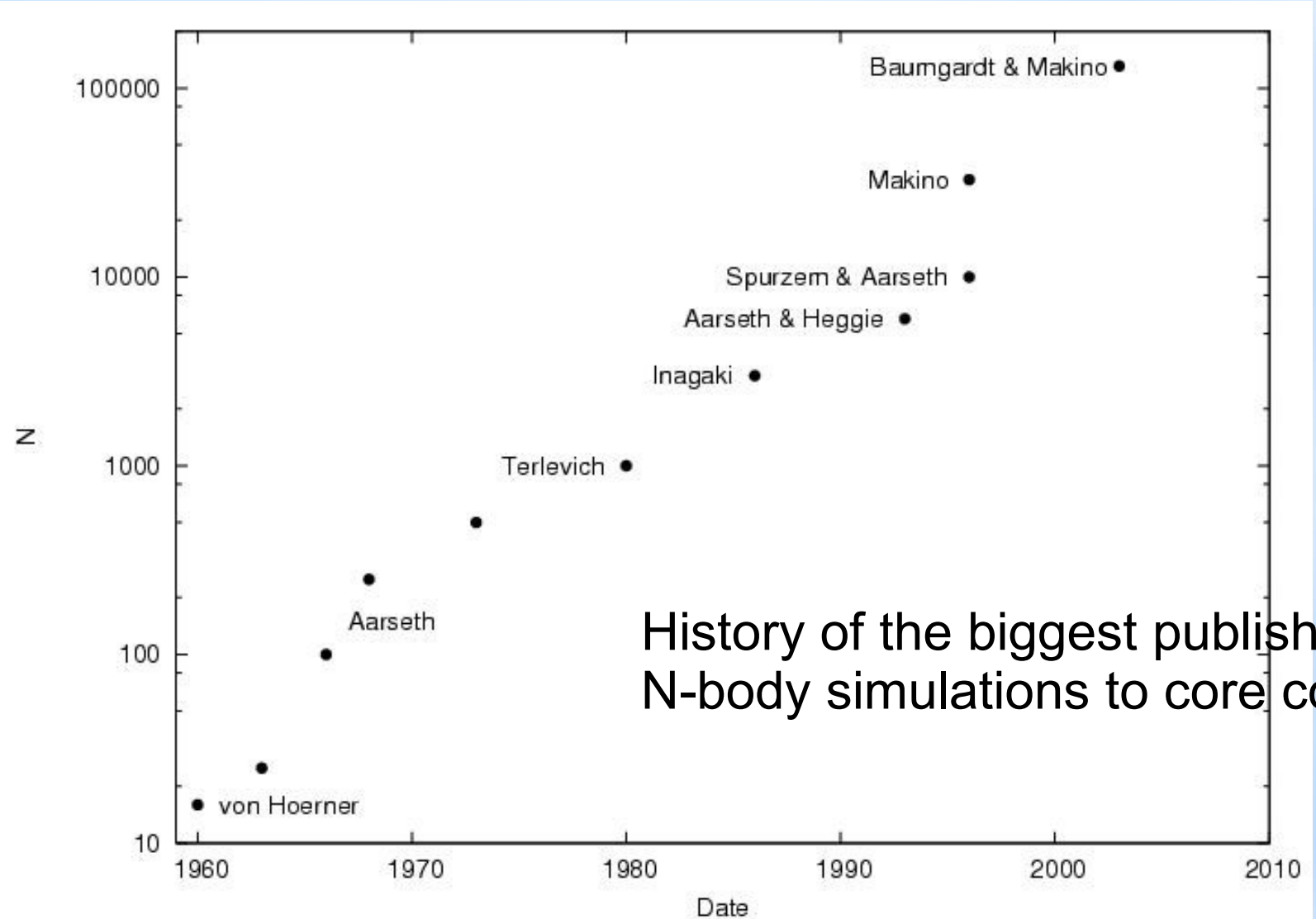
1. N



History of the biggest published N-body simulations to core collapse

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1. N (continued)

NGC6397 (eso)

The next grand challenge:

When will we see the first star-by-star *N*-body model of a globular cluster?

Simulation of NGC 6397 at present day (Heggie & Giersz 2009, MNRAS, 397L, 46):

- 1 month/Gyr on multicore PC with GPU

But

- N6397 now : $N \approx 110\,000$
  initially: 500 000

Extract from my summary of KITP January conference:

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Key Question: When will we see the first star-by-star *N*-body model of a globular cluster?

- Honest N-body simulation
- Reasonable mass at 12 Gyr (~$5 \times 10^4 M_\odot$)
- Reasonable tide (circular galactic orbit will do, ~few kpc)
- Reasonable IMF (e.g. Kroupa)
- Reasonable binary fraction (a few percent)
- Any initial model you like (Plummer will do)
- A submitted paper (astro-ph will do)

An inducement: a bottle of single malt Scotch whisky worth €50

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A dishonest way of winning?

Use a tree code, with stellar evolution

See McMillan & Aarseth, 1993, ApJ, 414, 200

Arabadjis & Richstone, 1998, astro-ph/10192 & 10193

Is the high accuracy of a direct N-body simulation essential for the evolution of all globular clusters?

Do binaries matter?

Would this be faster than NBODY6/GPU?

A natural project for AMUSE

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Another dishonest way of winning?

Use a Monte Carlo code (Fregeau, or Giersz)

Main Limitations:

- Non-rotating clusters
- Static galactic tide

Not a winner, but it is the best we can do at the moment

M4: H & Giersz 2008, MNRAS, 389, 1858
NGC 6397: Giersz & H 2009, MNRAS, 395, 1173
47 Tuc: G&H in draft

AMUSE should incorporate a MC code (ask Arek)

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2. The gaseous component

Westerlund 2
Age ~ 2 Myr

apod.nasa.gov/apod/ap080131.html

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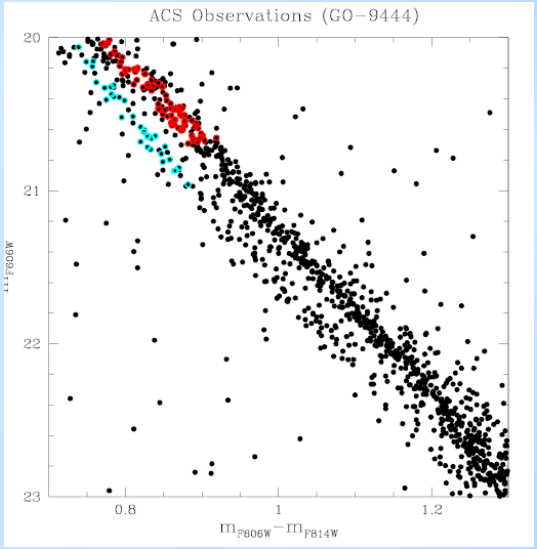
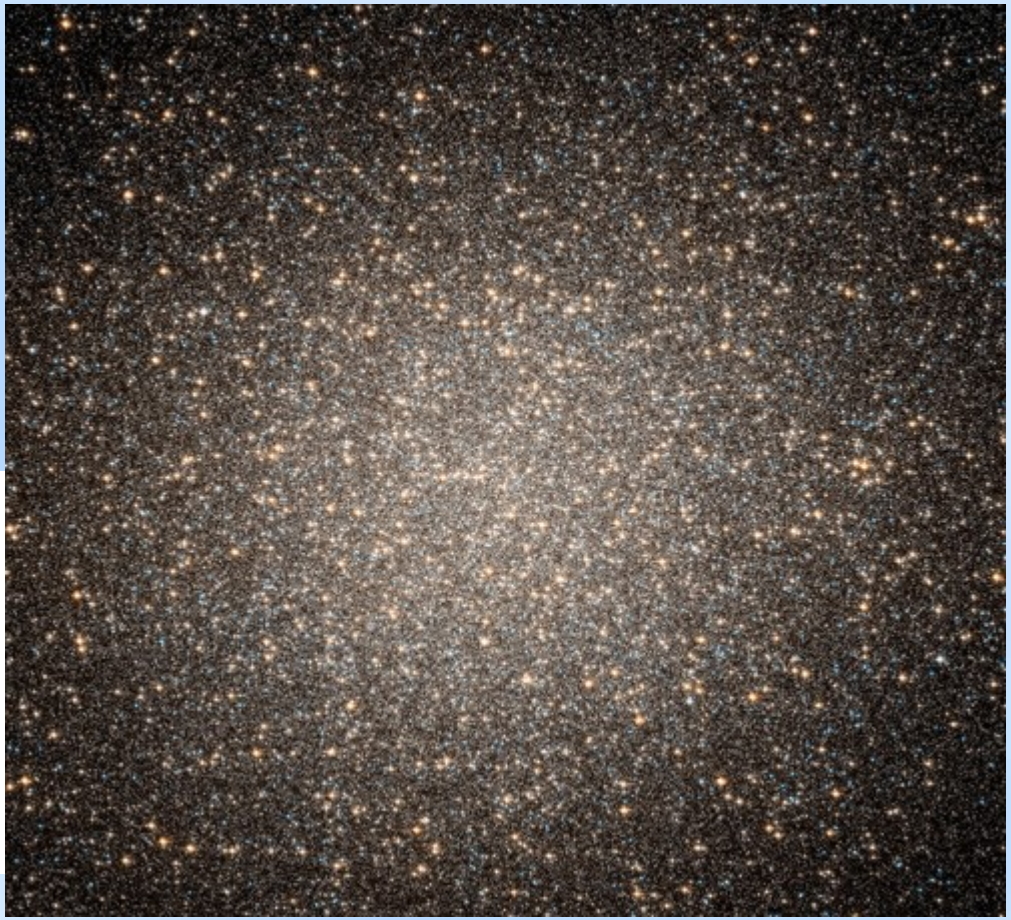
Another gaseous component?

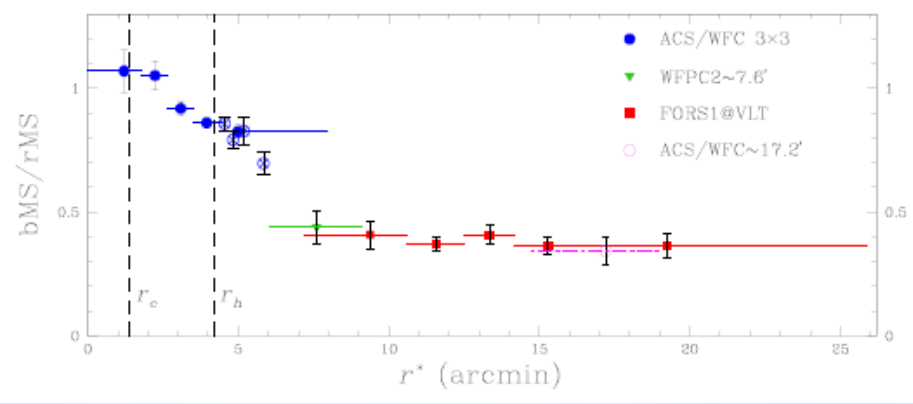


Bedin et al 2004 MSAIS,5,105

Omega Centauri (and probably many other globular clusters)



Bellini et al astro-ph/0909.4785



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One scenario for multiple populations

See d'Ercole et al 2008, MNRAS, 391, 825
for hydrodynamical/dynamical study, and background

1. First generation (either very massive or with anomalous MF)

2. FG stars between ~4-8M$\odot$ eject processed gas in winds or planetary nebulae at $\sim 10^8$yr; possibly mixing with pristine gas

3. Gas falls to centre in cooling flow, and form second generation

4. Mass loss by stellar evolution of SG causes expansion, and preferential loss of FG stars

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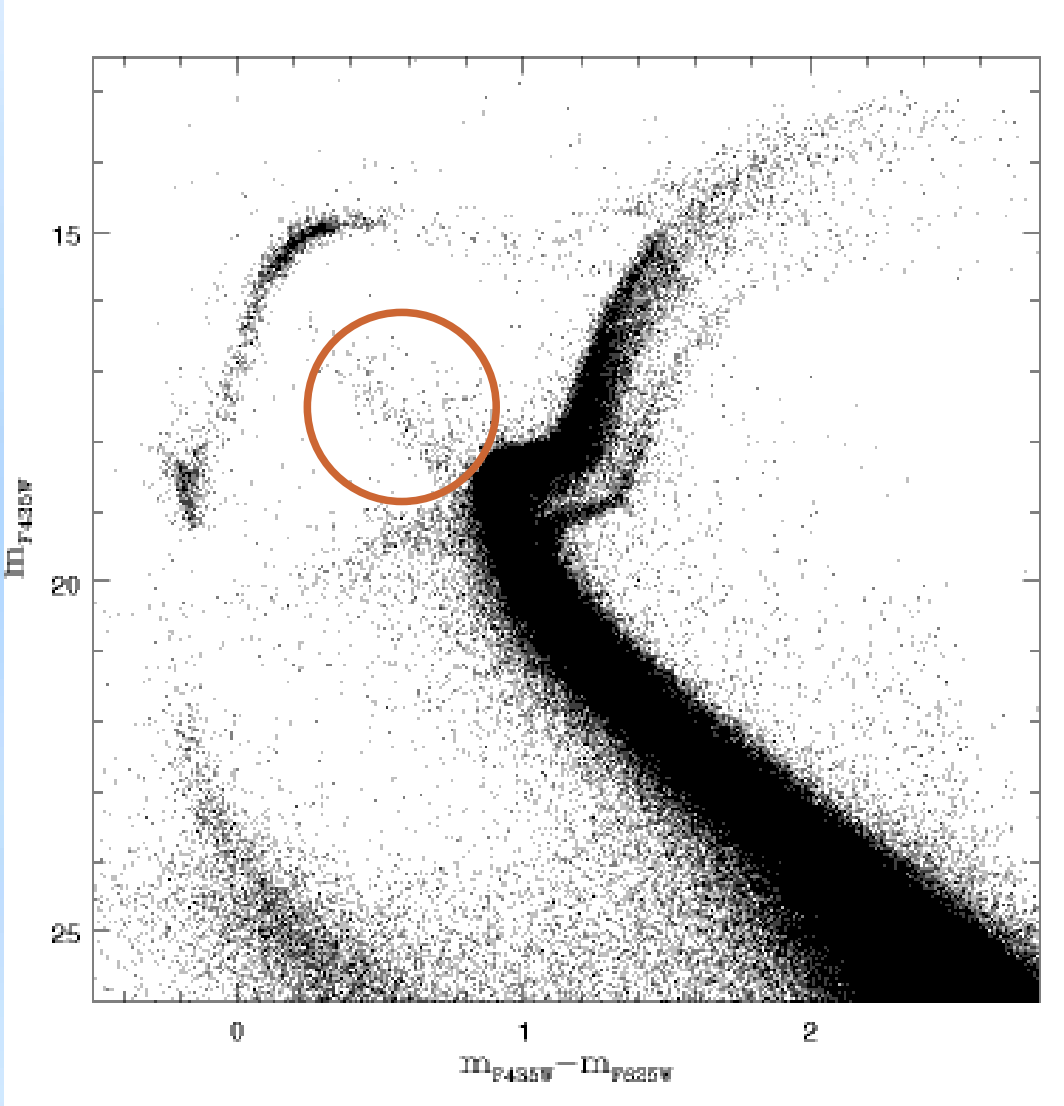
Stellar and binary evolution; collisions

Need to incorporate

1. Hydrodynamics for collisions (MUSE)
2. Live stellar/binary evolution (Church PhD thesis 2006)



ω Cen
Villanova et al
2007, ApJ, 663, 296

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A natural problem for AMUSE

Code needs to incorporate

- Stellar dynamics
- Stellar evolution with weird abundances, and outflows
- Gas dynamics
- Star formation
- Feedback from stellar evolution
- Collisions

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