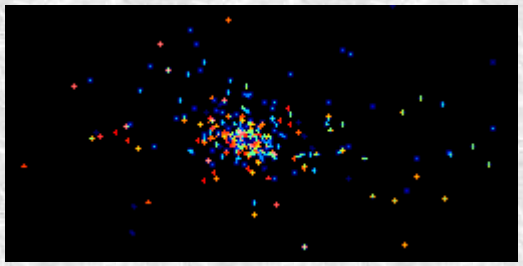

Starlab: A Software Environment for Collisional Stellar Dynamics
Steve McMillan
Simon Portegies Zwart
Piet Hut
Jun Makino

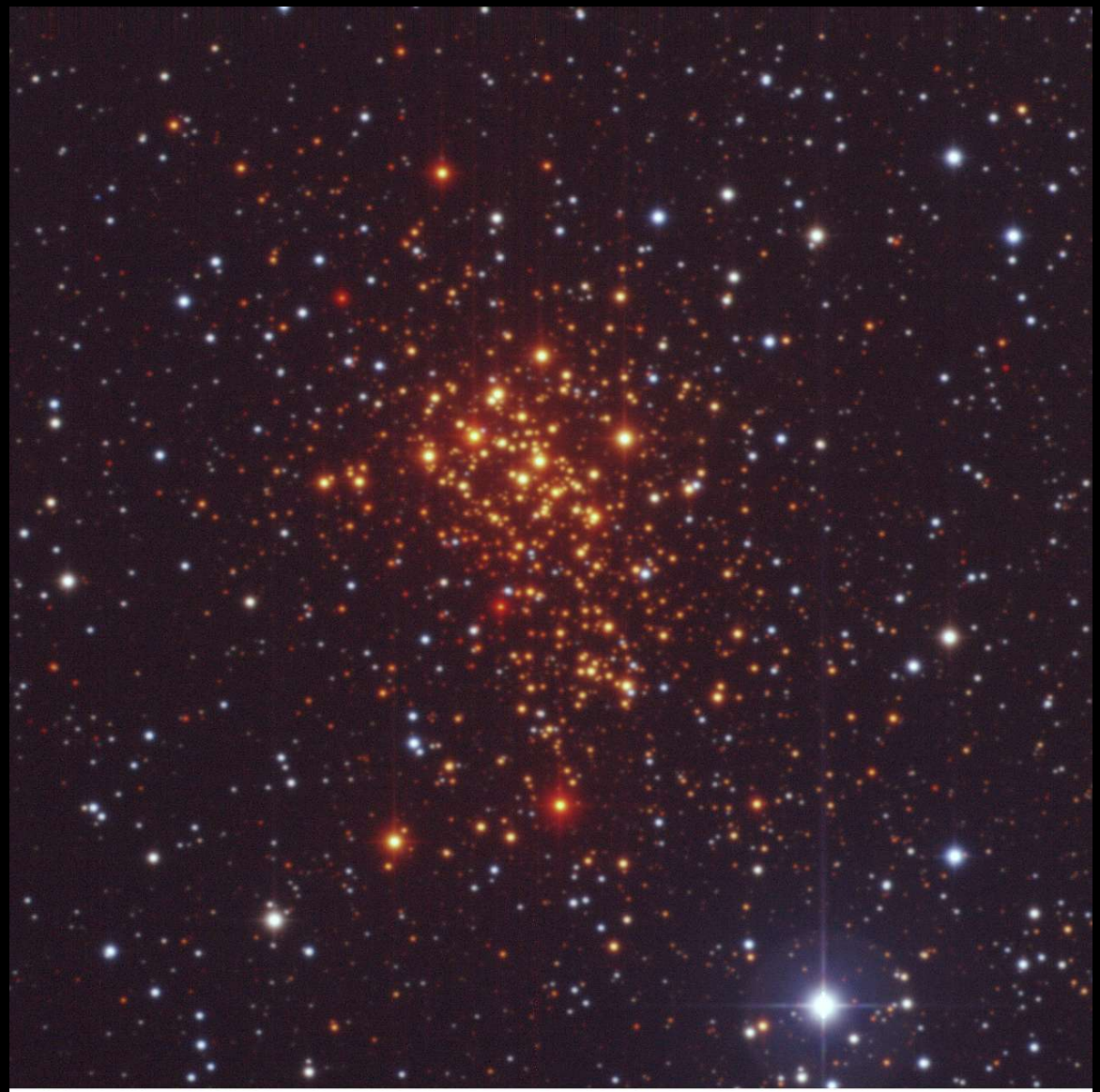
The Starlab Project

- Goal: to simulate the dynamics and stellar evolution of collisional/dense stellar systems
  - stellar dynamics
  - stellar and binary evolution
  - stellar collisions and mergers
  - external potentials



- Result (10+ years later): a flexible software environment allowing the user to create, modify, evolve, and analyze models of stellar clusters


Arches Cluster
Quintuplet Cluster
1 light year
2 light years



The Super Star Cluster Westerlund 1
(2.2m MPG/ESO + WFI)

ESO PR Photo 09a/05 (22 March 2005)

Starlab Tools

- Starlab provides tools to perform basic operations
  - making and modifying model clusters
  - adding stellar properties
  - evolving clusters
  - analyzing and visualizing cluster evolution
- Tools are connected via UNIX pipes, or users can link their own programs with the Starlab libraries

Making Model Clusters

- Standard dynamical models

```
makecube, makesphere, makedisk
makeplummer
makeking, make_aniso_king
makepowerlaw
makepyth
```

- Attributes

```
makemass, makesecondary, makebinary
add_tidal/plummer/power_law
scale
flatten, freeze, set_com, ...
set_radius, add_star
```

Measuring Cluster Properties

- Analysis tools

```
compute_com, compute_density
lagrad
energy, sys_stats, star_stats, ...
hop, kingfit, ...
```

- Visualization

```
xstarplot, xhrdplot
starcluster
snap_to_image
partiview
```

Examples

- Create a 500-particle $W_0 = 5$ King model, with numbered stars, unscaled

```
makeking -n 500 -w 5 -i -u
```

- Same, with a Kroupa mass function and stellar properties, scaled to standard units

```
makeking -n 500 -w 5 -i -u \
    | makemass -F Kroupa -l 0.1 -u 100 \
    | add_star -T 10 \
    | scale -s
```

- Now add some binaries and display the cluster

```
makeking -n 500 -w 5 -i -u \
    | makemass -F Kroupa -l 0.1 -u 100 \
    | makesecondary -f 0.1 \
    | add_star -T 10 \
    | scale -m 1 -e -0.25 -q 0.5 \
    | makebinary -l 1 -u 10 \
    | sys_stats -o \
    | xstarplot
```

Evolution

- Simple systems

  `leapfrog`

  `flat_hermite`

- More complex systems

  `kira`

  `kira_smallN`

  `SeBa`

- Scattering experiments

  `low_n(3)_evolve, scatter(3)`

  `SeBa_scatter3`

  `sigma3, rate3`

Examples

- Simple dynamics

```
makeplummer -n 100 -i | kira -D 0
```

- Turning on stellar evolution

```
SeBa
makeplummer -n 100 -i \
    | makemass -l 1 -u 10 \
    | add_star -T 10 | scale -s \
    | kira -S -D 0 -d 10
```

- GRAPE runs

```
makeplummer -n 10000 -i -u | hscale -s \
    | kira -D 0
```

Images and Animations

- GIF/PNG images and movies

```
makepyth -i \
    | flat_hermite -e 0 -a 0.01 -D 0.125 -d 10 -t 80 \
    | hxstarplot -b

makepyth -i \
    | flat_hermite -e 0 -a 0.01 -D 0.125 -d 10 -t 80 \
    | snap_to_image -a -p 3 -N 3 -s 400 -d -o movie

makeking -w 12 -n 256 -i \
    | makemass -l 0.5 -u 10 \
    | scale -s \
    | kira -t 10 -D -5 \
    | snap_to_image -s 400 -a -m -p -2 -a -d -o movie
```

More Visualization Tools

- Starcluster
- Partiview
- Examples/demos

Writing your own...

- Modifying the Starlab distribution
  - recommended for experts only
  - CVS source may change and local modifications could be lost
- Compiling using the Starlab headers and libraries
  - need a Makefile containing the following lines

```
CXXFLAGS = -I$(STARLAB_INSTALL_PATH)/include/starlab -DHAVE_CONFIG_H
LDLIBS   = -L$(STARLAB_INSTALL_PATH)/lib/starlab ldyn -lnode -lstd -lm
```

  - details of classes and libraries on the Starlab website (http://www.sns.ias.edu/~starlab)
  - example