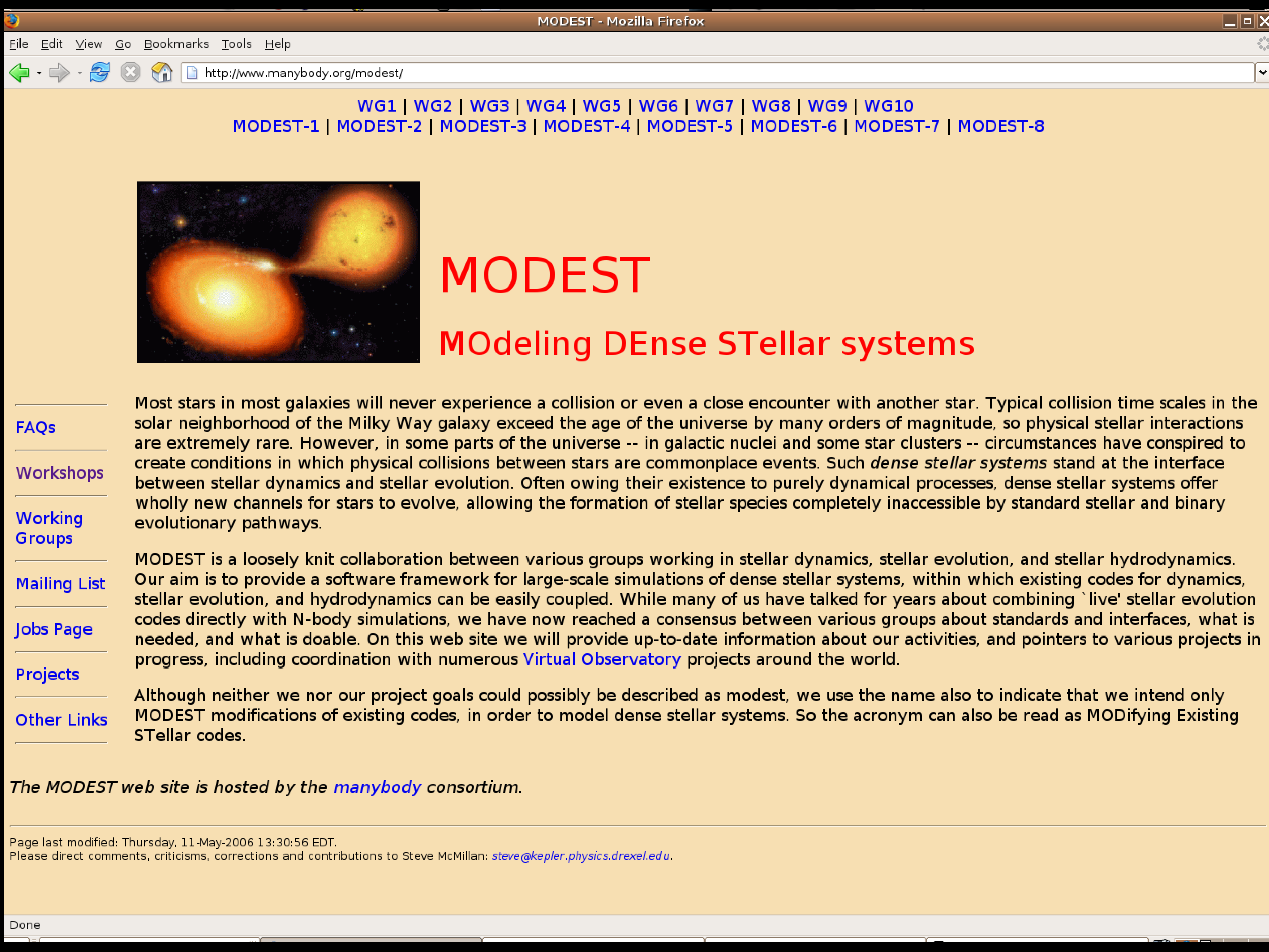
MODEST-7a

MODEST and MUSE

Steve McMillan


MODEST - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://www.manybody.org/modest/
Done

WG1 | WG2 | WG3 | WG4 | WG5 | WG6 | WG7 | WG8 | WG9 | WG10
MODEST-1 | MODEST-2 | MODEST-3 | MODEST-4 | MODEST-5 | MODEST-6 | MODEST-7 | MODEST-8

MODEST

MOdeling DEnse STellar systems

- FAQs
- Workshops
- Working Groups
- Mailing List
- Jobs Page
- Projects
- Other Links

Most stars in most galaxies will never experience a collision or even a close encounter with another star. Typical collision time scales in the solar neighborhood of the Milky Way galaxy exceed the age of the universe by many orders of magnitude, so physical stellar interactions are extremely rare. However, in some parts of the universe -- in galactic nuclei and some star clusters -- circumstances have conspired to create conditions in which physical collisions between stars are commonplace events. Such *dense stellar systems* stand at the interface between stellar dynamics and stellar evolution. Often owing their existence to purely dynamical processes, dense stellar systems offer wholly new channels for stars to evolve, allowing the formation of stellar species completely inaccessible by standard stellar and binary evolutionary pathways.

MODEST is a loosely knit collaboration between various groups working in stellar dynamics, stellar evolution, and stellar hydrodynamics. Our aim is to provide a software framework for large-scale simulations of dense stellar systems, within which existing codes for dynamics, stellar evolution, and hydrodynamics can be easily coupled. While many of us have talked for years about combining `live' stellar evolution codes directly with N-body simulations, we have now reached a consensus between various groups about standards and interfaces, what is needed, and what is doable. On this web site we will provide up-to-date information about our activities, and pointers to various projects in progress, including coordination with numerous Virtual Observatory projects around the world.

Although neither we nor our project goals could possibly be described as modest, we use the name also to indicate that we intend only MODEST modifications of existing codes, in order to model dense stellar systems. So the acronym can also be read as MODifying Existing STellar codes.

The MODEST web site is hosted by the manybody consortium.

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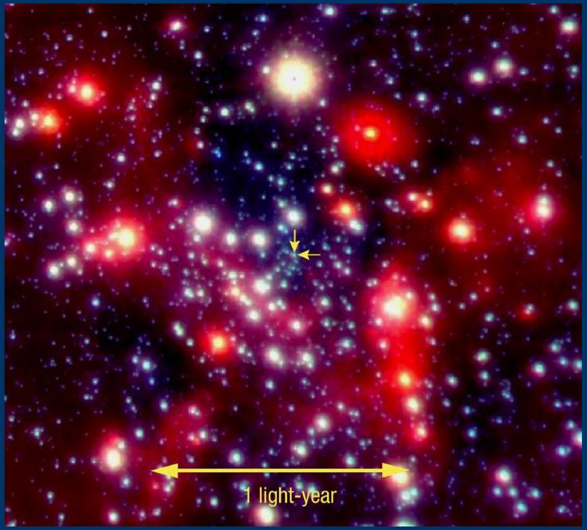
Please direct comments, criticisms, corrections and contributions to Steve McMillan: *steve@kepler.physics.drexel.edu*.

MODEST research

- star clusters, galactic nuclei
- physical processes
  - stellar dynamics
  - stellar evolution
  - stellar encounters and collisions
  - gas dynamics?
  - radiative transfer?
- broad range in scales
  - most stars evolve in isolation most of the time
- physical interactions among stars drive software integration

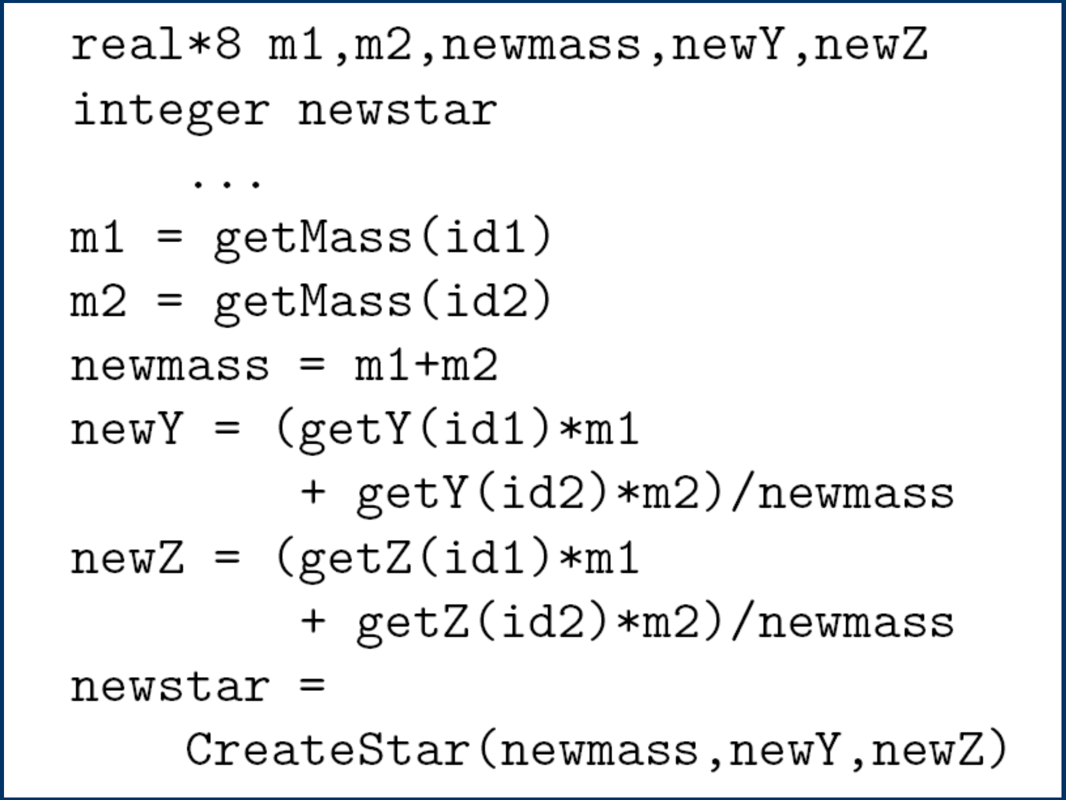


MODEST-1

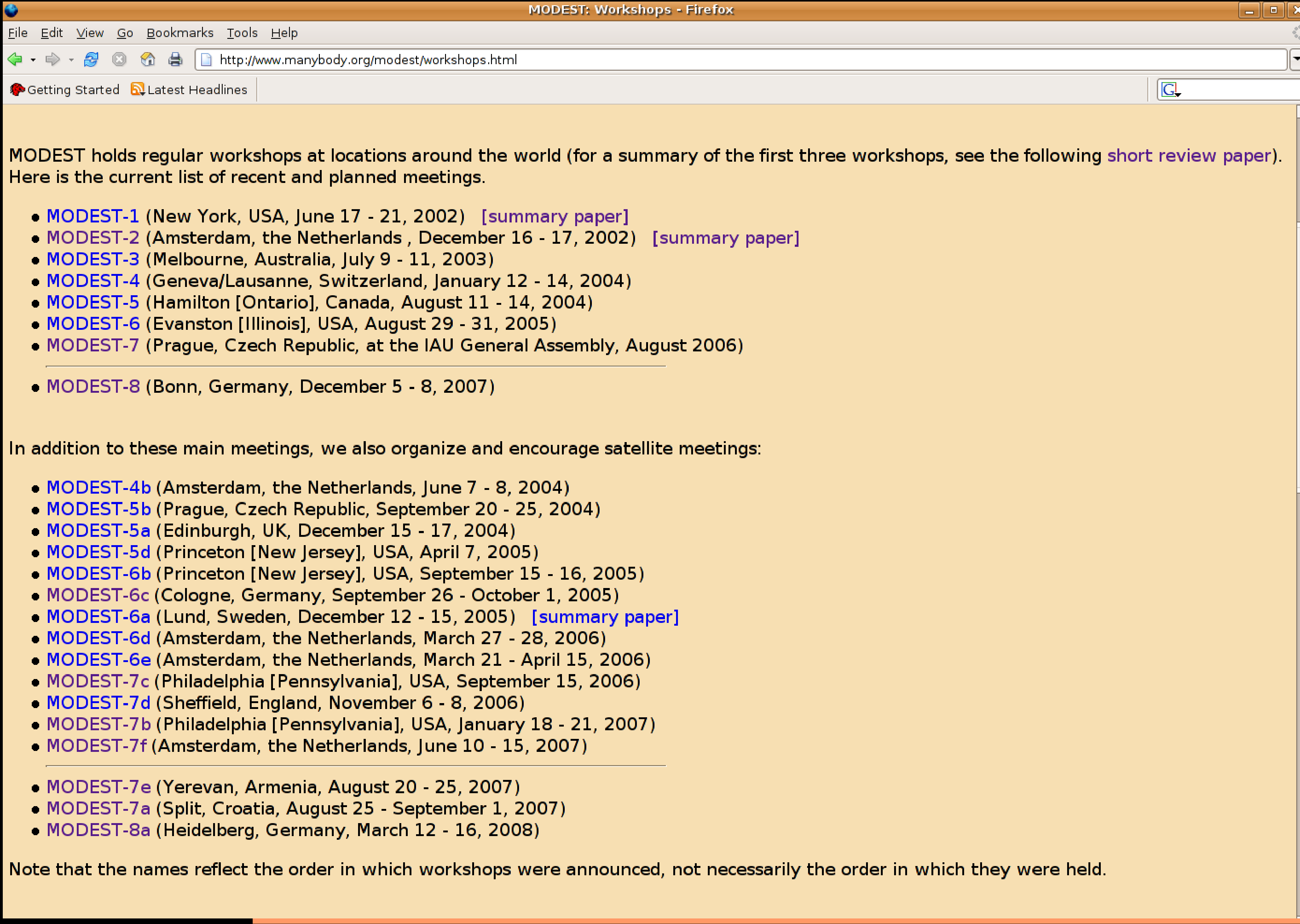
- no agenda, no speakers!
- recognition of basic issues
- working groups and software modules
- integration of live stellar evolution?
- integration of live stellar collisions?
- MODEST name!

Early Successes

- general discussion of interfaces
- definition of some interfaces
- “toy” stellar evolution/collision implementation (Makino & Hut, in the “proceedings”)



```
real*8 m1,m2,newmass,newY,newZ
integer newstar
    ...
m1 = getMass(id1)
m2 = getMass(id2)
newmass = m1+m2
newY = (getY(id1)*m1
        + getY(id2)*m2)/newmass
newZ = (getZ(id1)*m1
        + getZ(id2)*m2)/newmass
newstar =
    CreateStar(newmass,newY,newZ)
```


MODEST: Workshops - Firefox
File Edit View Go Bookmarks Tools Help
Getting Started
Latest Headlines

http://www.manybody.org/modest/workshops.html

MODEST holds regular workshops at locations around the world (for a summary of the first three workshops, see the following short review paper). Here is the current list of recent and planned meetings.

- MODEST-1 (New York, USA, June 17 - 21, 2002) [summary paper]
- MODEST-2 (Amsterdam, the Netherlands , December 16 - 17, 2002) [summary paper]
- MODEST-3 (Melbourne, Australia, July 9 - 11, 2003)
- MODEST-4 (Geneva/Lausanne, Switzerland, January 12 - 14, 2004)
- MODEST-5 (Hamilton [Ontario], Canada, August 11 - 14, 2004)
- MODEST-6 (Evanston [Illinois], USA, August 29 - 31, 2005)
- MODEST-7 (Prague, Czech Republic, at the IAU General Assembly, August 2006)

- MODEST-8 (Bonn, Germany, December 5 - 8, 2007)

In addition to these main meetings, we also organize and encourage satellite meetings:

- MODEST-4b (Amsterdam, the Netherlands, June 7 - 8, 2004)
- MODEST-5b (Prague, Czech Republic, September 20 - 25, 2004)
- MODEST-5a (Edinburgh, UK, December 15 - 17, 2004)
- MODEST-5d (Princeton [New Jersey], USA, April 7, 2005)
- MODEST-6b (Princeton [New Jersey], USA, September 15 - 16, 2005)
- MODEST-6c (Cologne, Germany, September 26 - October 1, 2005)
- MODEST-6a (Lund, Sweden, December 12 - 15, 2005) [summary paper]
- MODEST-6d (Amsterdam, the Netherlands, March 27 - 28, 2006)
- MODEST-6e (Amsterdam, the Netherlands, March 21 - April 15, 2006)
- MODEST-7c (Philadelphia [Pennsylvania], USA, September 15, 2006)
- MODEST-7d (Sheffield, England, November 6 - 8, 2006)
- MODEST-7b (Philadelphia [Pennsylvania], USA, January 18 - 21, 2007)
- MODEST-7f (Amsterdam, the Netherlands, June 10 - 15, 2007)

- MODEST-7e (Yerevan, Armenia, August 20 - 25, 2007)
- MODEST-7a (Split, Croatia, August 25 - September 1, 2007)
- MODEST-8a (Heidelberg, Germany, March 12 - 16, 2008)

Note that the names reflect the order in which workshops were announced, not necessarily the order in which they were held.

MODEST-2

- no agenda, a few speakers!
- first MUSE-like, hands-on workshop
  - integration of dynamics, stellar evolution, and hydrodynamics
  - runaway mergers
  - blue stragglers
  - application to specific clusters

- MMAS/Triptych/Tripletych (Lombardi)
- working groups!

MODEST Themes...

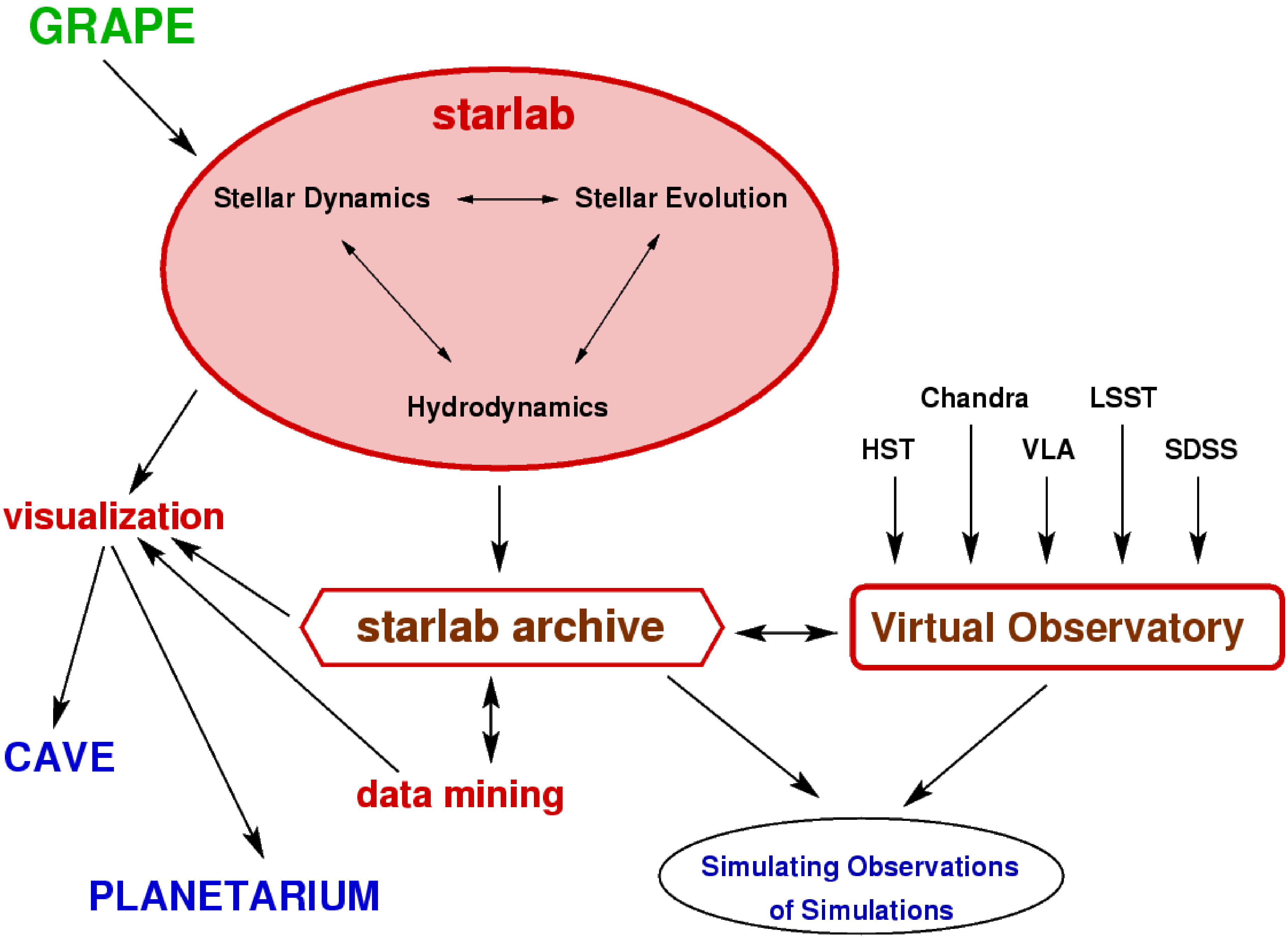
- stellar dynamics and stellar evolution
- stellar mergers and stellar evolution
- blue stragglers in clusters
- runaway mergers in clusters
- modeling individual clusters

⋮

...and MUSE Modules

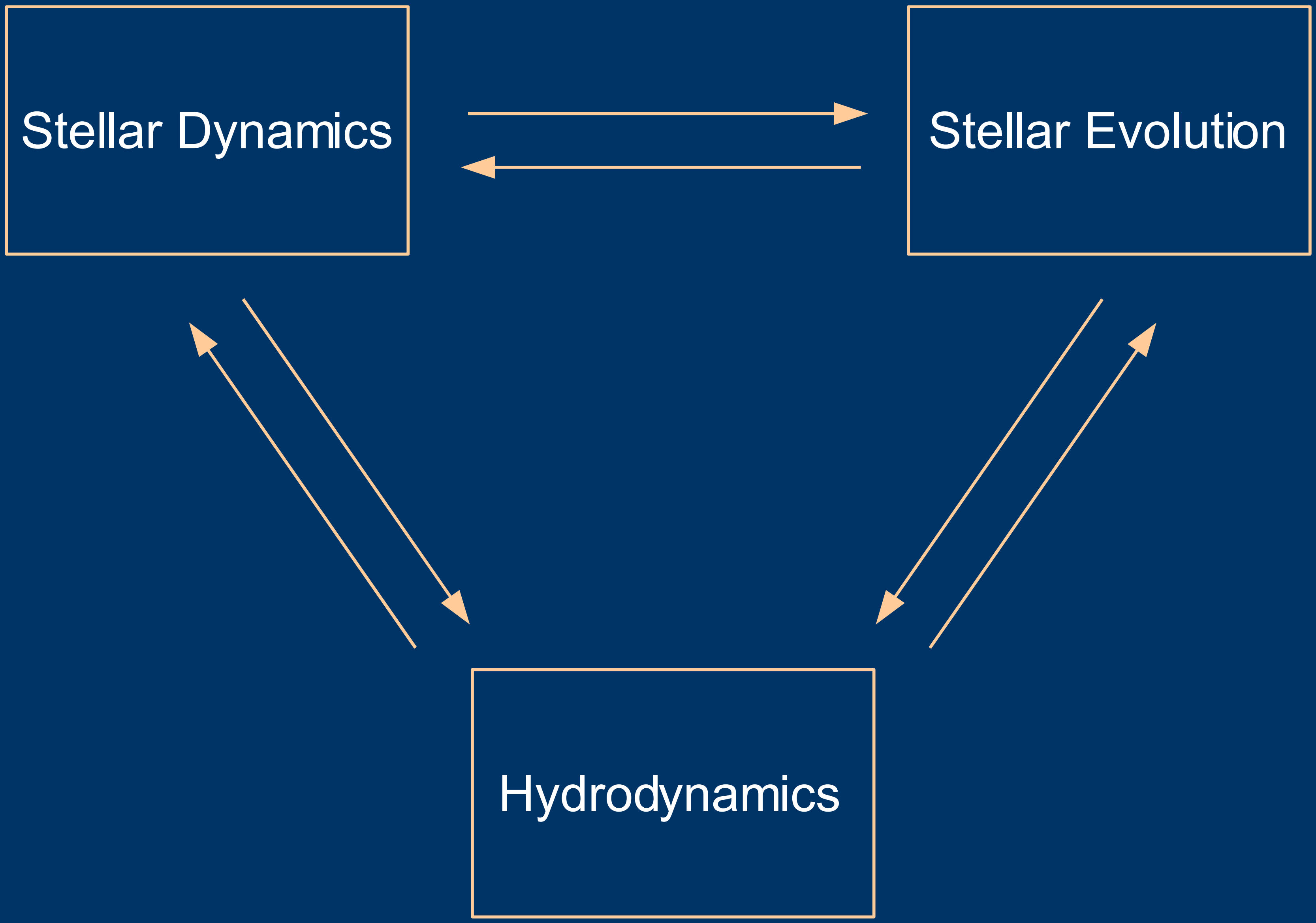
- particle pushing
- stellar evolution recipes
- binary evolution recipes
- live stellar evolution
- MMAS recipes
- live SPH

⋮


GRAPE
starlab
Stellar Dynamics
Stellar Evolution
Hydrodynamics
Chandra
LSST
HST
VLA
SDSS
visualization
starlab archive
Virtual Observatory
CAVE
data mining
PLANETARIUM
Simulating Observations
of Simulations

MODEST begets MUSE

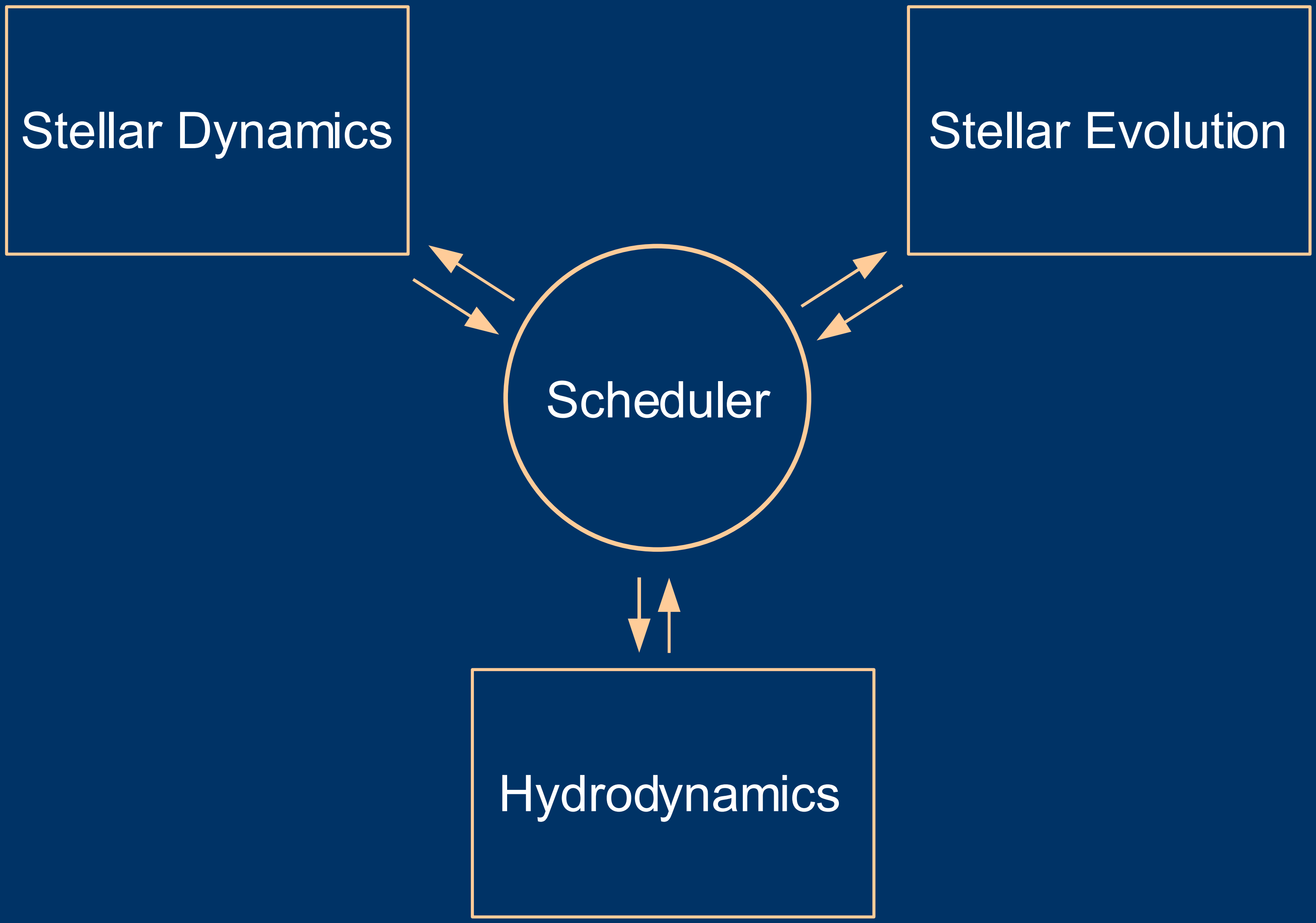
- MODEST 6a: Lund, December 2005
  - live stellar evolution (Church)
  - evolution of MMAS products (Pols/Glebbeek/Lombardi)
  - renewed discussion of software frameworks
- MODEST 6d: Amsterdam, April 2006
  - first “framework” workshop
  - modules, interfaces, and C++ glue
  - name MUSE coined



Stellar Dynamics

Stellar Evolution

Hydrodynamics

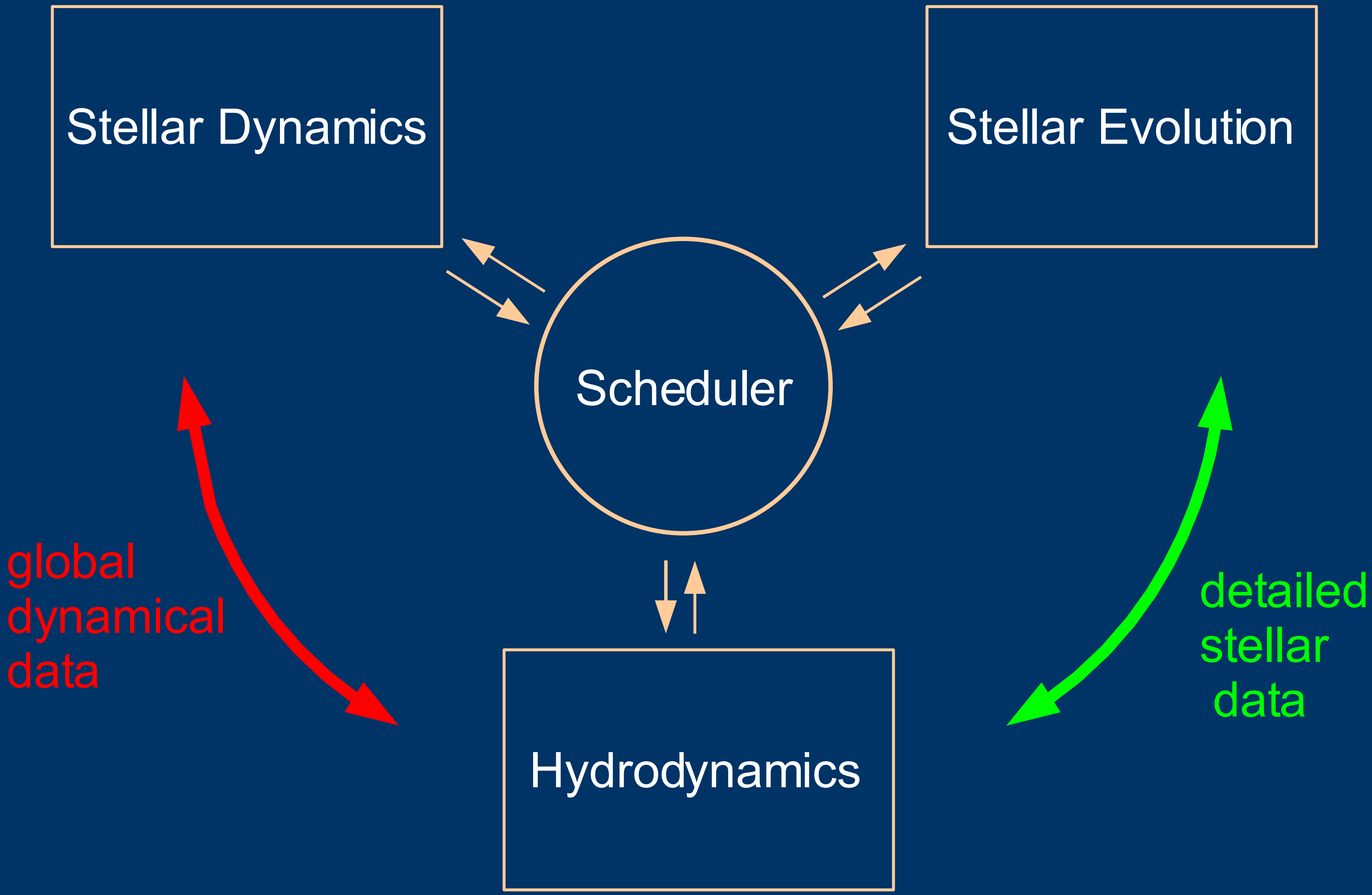


Stellar Dynamics

Stellar Evolution

Scheduler

Hydrodynamics



Stellar Dynamics

Stellar Evolution

Scheduler

Hydrodynamics

global dynamical data

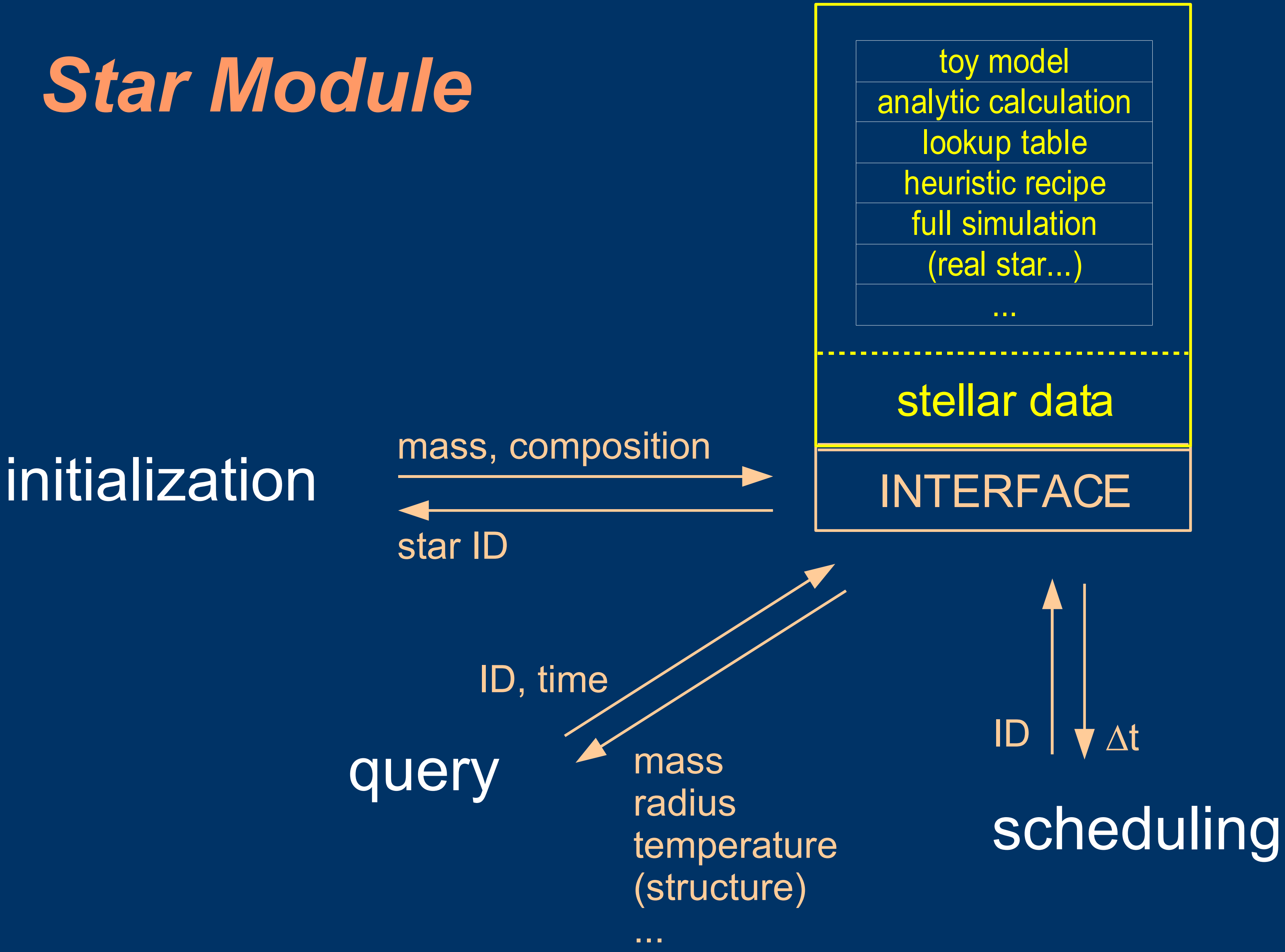
detailed stellar data

MUSE (Multiscale Multiphysics Scientific Environment)

- wiki: `http://muse.li`

- modules for stars, dynamics, collisions, etc.
- implemented as “black boxes” with wrappers
- all modules provide prediction time scales
- coordinated by “blind” scheduler
- top level “glue” — swig/f2py/python

Star Module



toy model
analytic calculation
lookup table
heuristic recipe
full simulation
(real star...)
...

stellar data

INTERFACE

initialization

mass, composition

star ID

query

ID, time

mass
radius
temperature
(structure)
...

scheduling

ID

Δt

```
import gravity.hermite.muse_dynamics as dyn
import stellar.EFT89.muse_stellar as star
import collisions.sticky_spheres.muse_hydro as coll
.
.    (initialization)
.
while time < t_max:

    time += dtime
    dyn.evolve_dynamics(time)
    star.evolve_stellar(time)

    for i in range(nd):
        id = star.get_stellar_identity(i)
        dyn.set_mass(id, star.get_mass(id))
        dyn.set_radius(id, star.get_radius(id))

    id1, id2 = dyn.get_colliding_pair()
    if id1 >= 0 and id2 >= 0:
        nd, ns = collide_stellar_pair(nd, id1, id2)

print "end at t = ", time, ", Ndyn = ", nd, ", Nstars= ", ns
```

Current Gravity Interface

```
int initialize_dynamics(void);
int add_dynamics(dynamics_state d);
int set_mass(int id, double m);
int set_radius(int id, double r);
int set_pos(int id, double pos[]);
int set_vel(int id, double pos[]);
int delete_dynamics(int id);
int get_n_dynamics();
double get_dynamics_time_scale();
double get_dynamics_time();
double get_dynamics_next_time();
int initialize_timestep();
int finalize_timestep();
int evolve_dynamics(double t_end);
int find_colliding_primary();
int find_colliding_secondary(int id);
dynamics_state get_dynamics_state(int id);
double get_mass(int id);
double get_radius(int id);
double get_kinetic_energy();
double get_potential_energy();
int get_escaper();
```

```
typedef struct {
    int id;                   /// identifier
    double mass;              /// mass
    double                    /// radius
    double x, y, z;           /// position
    double vx, vy, vz;        /// velocity
} dynamics_state;
```

MUSE Development History

- 6d/e: Amsterdam, Apr 2006
  - MUSE conception; elementary modules
- 7c: Philadelphia, Sep 2007
  - software frameworks
- 7b: Philadelphia, Jan 2007
  - MUSE expansion; “Noah's ark” goal
- 7f: Amsterdam, Jun 2007
  - consolidation and further expansion
- 7a: Split, Aug 2007
  - ???

MUSE Software Goals

- “collaborative competition”
- high-performance applications
- interoperation of software
- calibration and comparison of codes
- visualization of results
- comparison of simulations with observations

Collaborative Software Development

- software engineering
  - modules
  - data structures
  - interfaces
  - schedulers
- legacy codes
  - language choices
  - programmer burden

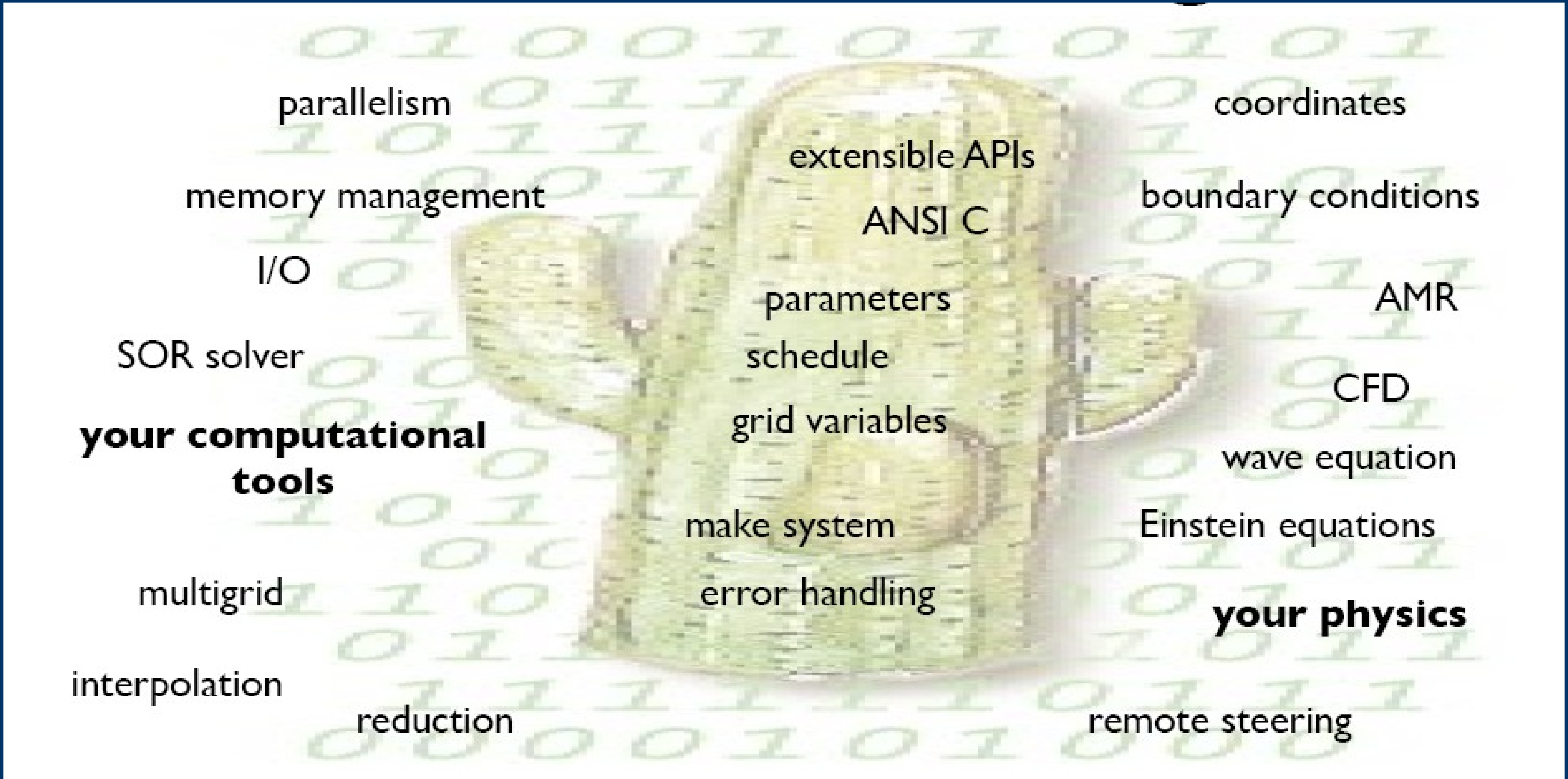
Collaborative Software Management

- social engineering
  - broad range in programming styles
    - “legacy programmers”
    - modularity and structure
  - generational and cultural differences
- open source
- contributed software
- access to source code

MODEST-7c: We Are Not Alone...

- software frameworks in astrophysics and elsewhere
  - cactus
  - climate modeling
  - common component architecture (CCA)
- need to define a common interface
- need to provide a means of data transfer between modules
- restrictions on language and data types?

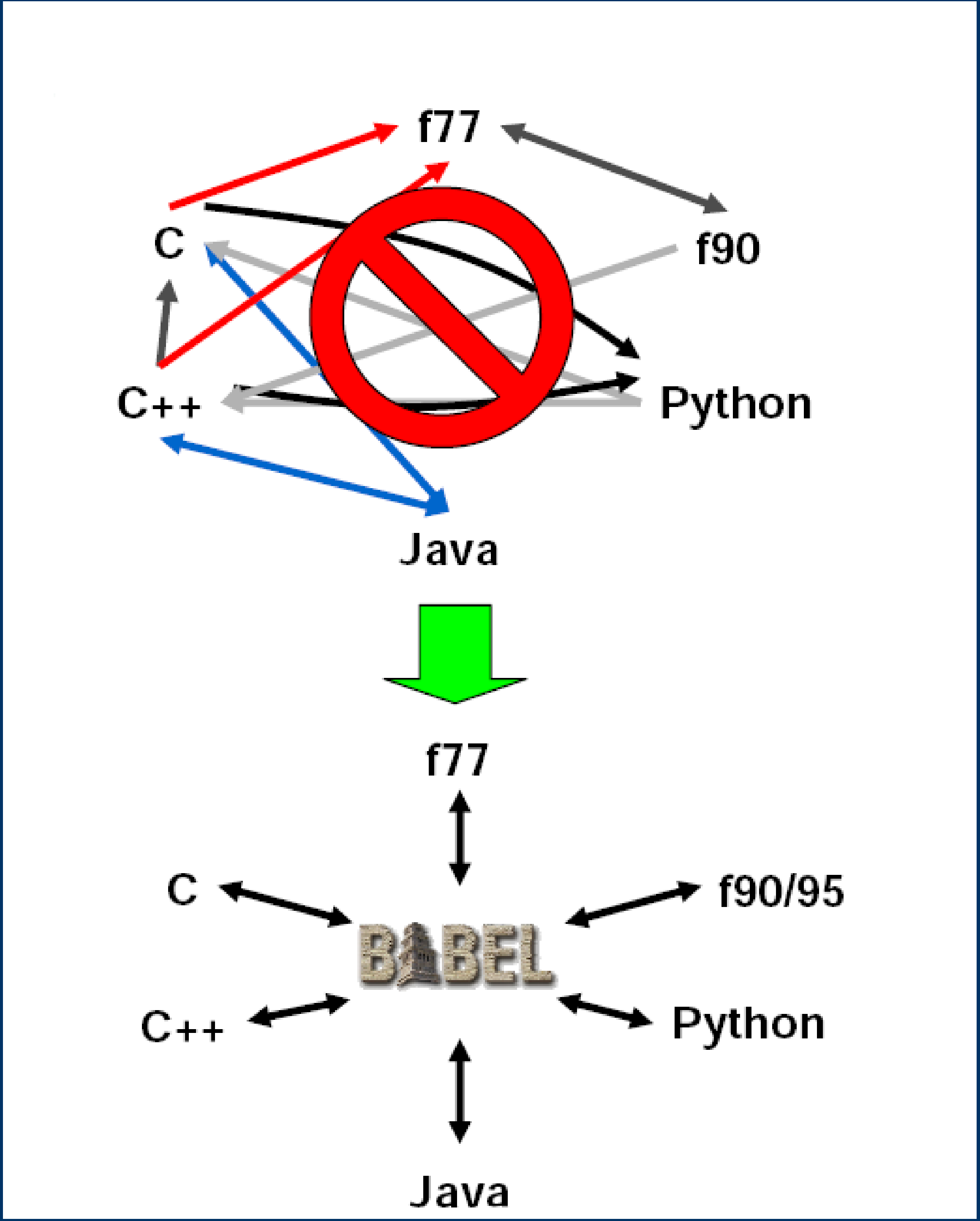
Cactus



Core *flesh* with plug-in *thorns*

CCA

- BABEL tool provides a means of communication between modules written in different languages
- Scientific Interface Definition Language provides a language-neutral way of writing interfaces



MODEST-7b: Expanding the Base

- cleaned up interfaces
- Noah's ark—(at least) two of everything
- wrapping legacy codes
- porting to other platforms (MacOS X)
- f77/f9x/f2py support

MODEST-7f: Consolidation

- repaired structure broken after Philadelphia!
- further integration of modules
- standardized dynamical interface
- multiple dynamical modules
- grid module

MUSE: Current Status

- dynamics
  - shared time step hermite0
  - Barnes-Hut treecode
  - Aarseth's NBODY1H
  - Monte-Carlo
- stellar evolution
  - EFT89
  - HPT00

MUSE: Current Status

- stellar hydrodynamics
  - sticky spheres
  - MMAS
- radiative transfer (placeholder)
- grid enabled
- initialization modules
- documentation!

MUSE Summary

- clean separation of functionality
- modular design encourages experimentation
- “easily” incorporates legacy code

- is it efficient?
- can it be extended to more complex physics?

- are there better ways of interfacing programs and sharing data?
- what strategies should we employ in extending MUSE?