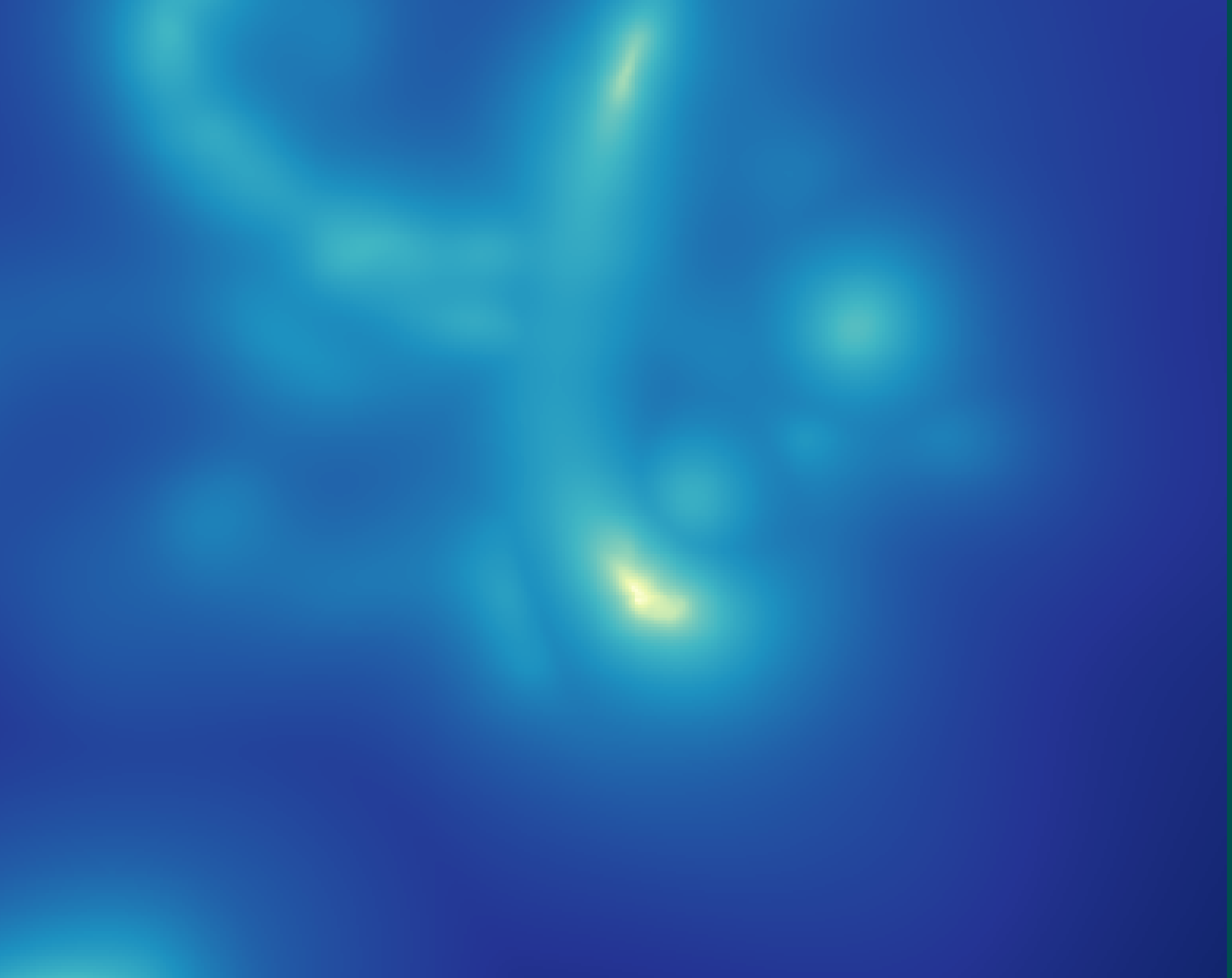
Black-hole accretion from stellar winds in star clusters using AMUSE



Nora Lützgendorf, MODEST14

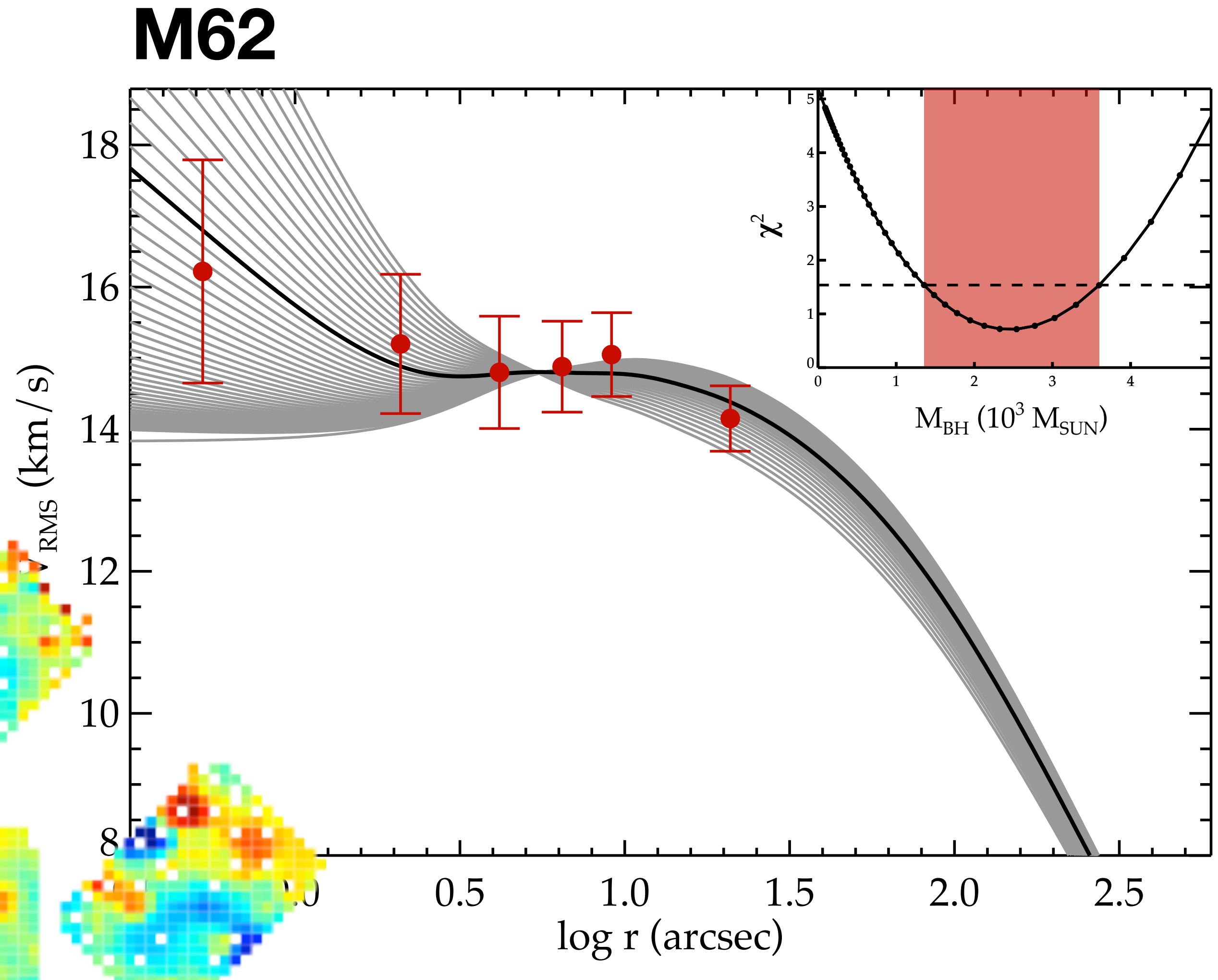
Edwin van der Helm, Inti Pelupessy, Simon Portegies Zwart

AMUSE

Motivation

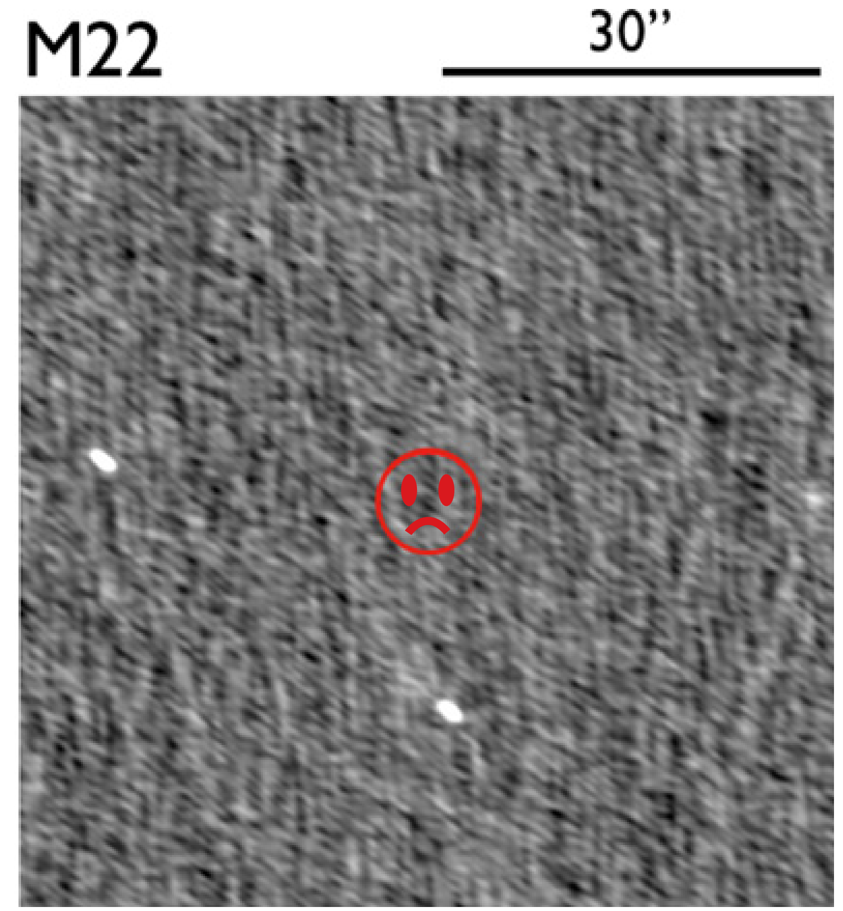
Intermediate-Mass Black Holes

PRO (Kinematics)



Lützgendorf et al., 2013a

CON (Radio Flux)



Strader et al., 2012

Motivation

?

How much accretion would we expect from an IMBH in a Globular Cluster?

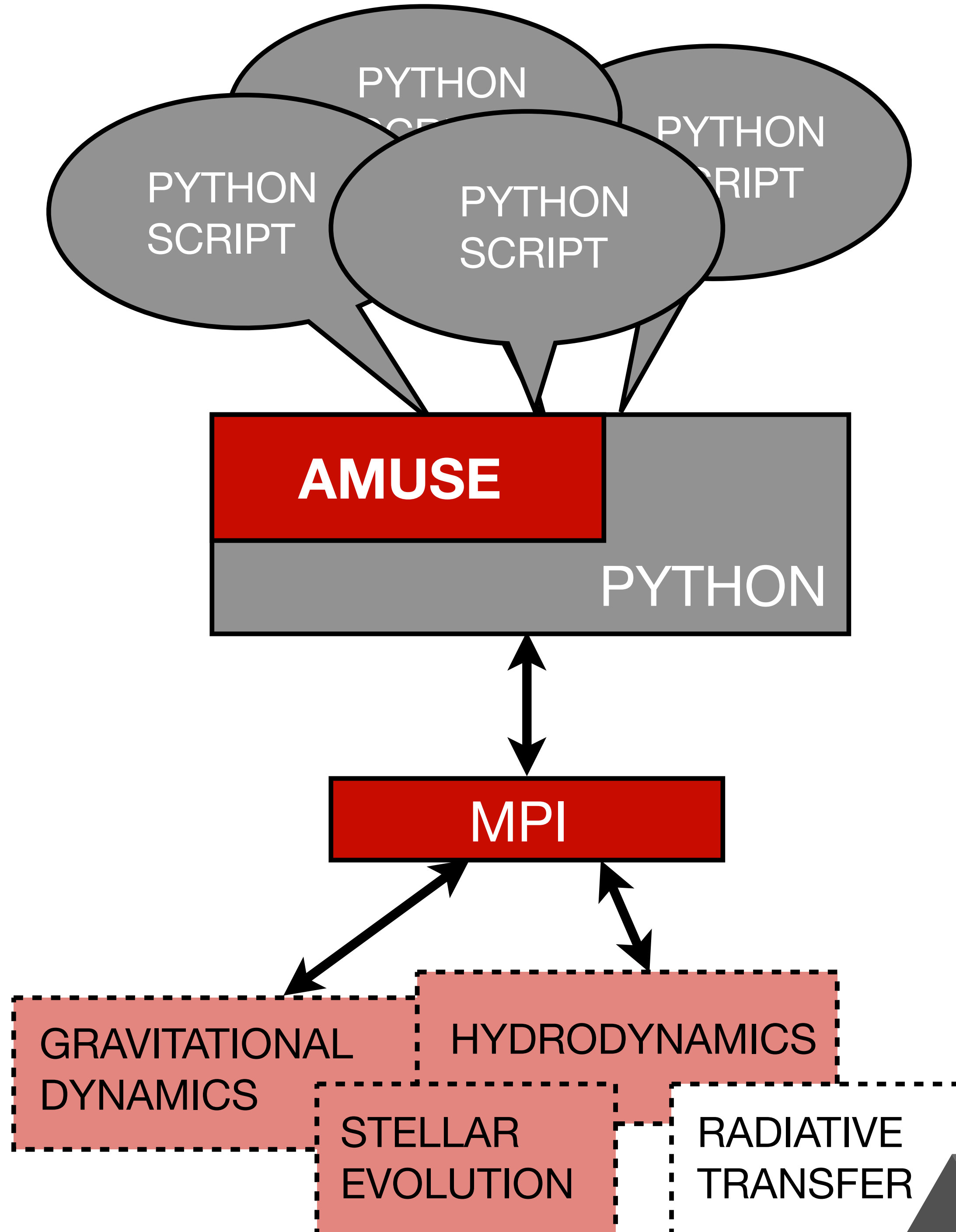
Simulate accretion from stellar winds onto the IMBH!

AMUSE

Astrophysical Multipurpose Software Environment

AMUSE

www.amusecode.org



Codes - Gravity

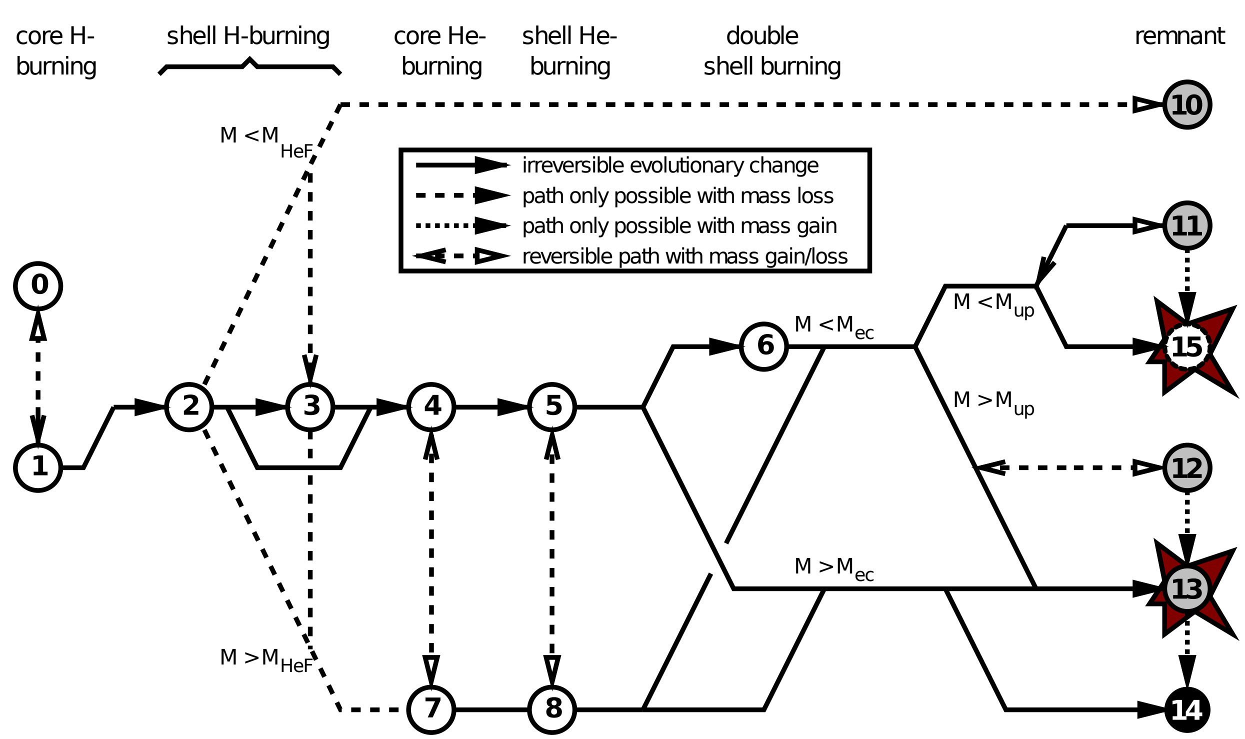
Gravity Codes in AMUSE:

name	type of code	language	$N_{\min}$	$N_{\max}$	softening	parallel	GPU
Hermite	direct	C++	1	10^3	no/yes	yes	no
ph4	direct	C++	1	10^4	no/yes	yes	no
PhiGRAPE	direct	F77	1	10^4	no/yes	yes	no
HiGPUs	direct	C++	1	10^4	no/yes	yes	yes
Brutus	direct	C++	2	10	no	yes	no
SmallN	direct	C++	2	10	no/yes	yes	no
Twobody	Kepler	Python	2	2	no	no	no
Mikkola	PN direct	F77	2	100	no	no	no
MI6	PN direct	C++	2	10^5	no/yes	yes	yes
Huayno	symplectic	C	2	10^3	no	no	no
Mercury	sympelctic	F77	2	10^4	no	no	no
octgrav	treecode	C++	10^4	10^6	yes	yes	yes
Bonsai	treecode	CUDA	10^4	10^9	yes	yes	yes

Codes - Stellar Evolution

Stellar Evolution Codes in AMUSE:

name	type of code	language	binary evolution	internal structure
MESA	Henyey	F95	no	yes
EVTWIN	Henyey	F77	yes	yes
SSE/BSE	parameterized	F77	yes	no
SeBa	parameterized	C++	yes	no

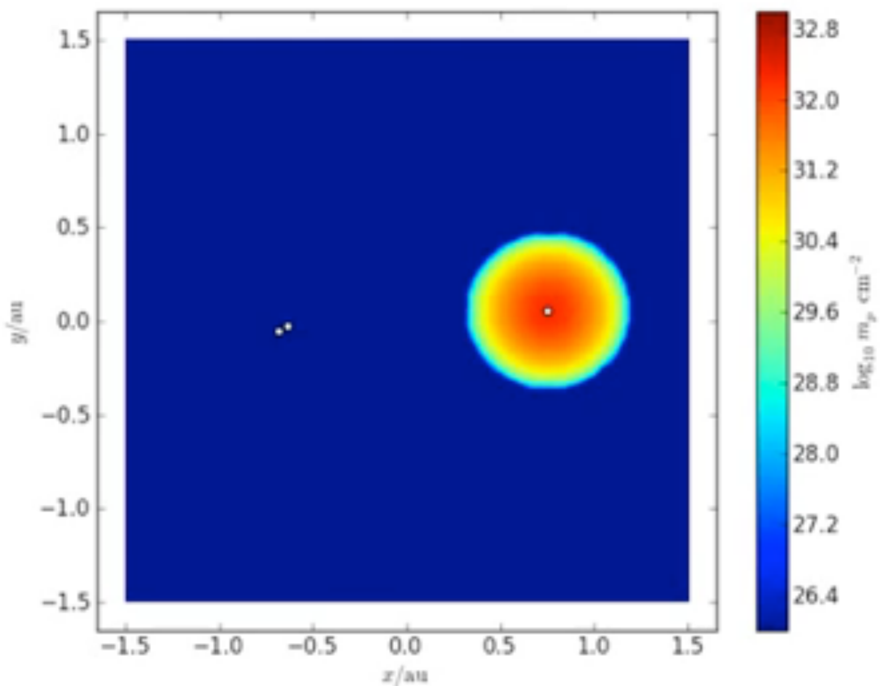


0 = main sequence $M < 0.7\ M_\odot$
1 = main sequence $M > 0.7\ M_\odot$
2 = Herstzsprung gap / subgiant
3 = first-ascent red giant
4 = horizontal branch / helium-burning giant
5 = early asymptotic giant / red supergiant
6 = thermally pulsating asymptotic giant
7 = naked helium main sequence
8 = naked helium (sub) giant
10 = helium white dwarf
11 = carbon/oxygen white dwarf
12 = oxygen/neon white dwarf
13 = neutron star
14 = black hole
15 = no stellar remnant

Codes - Hydrodynamics

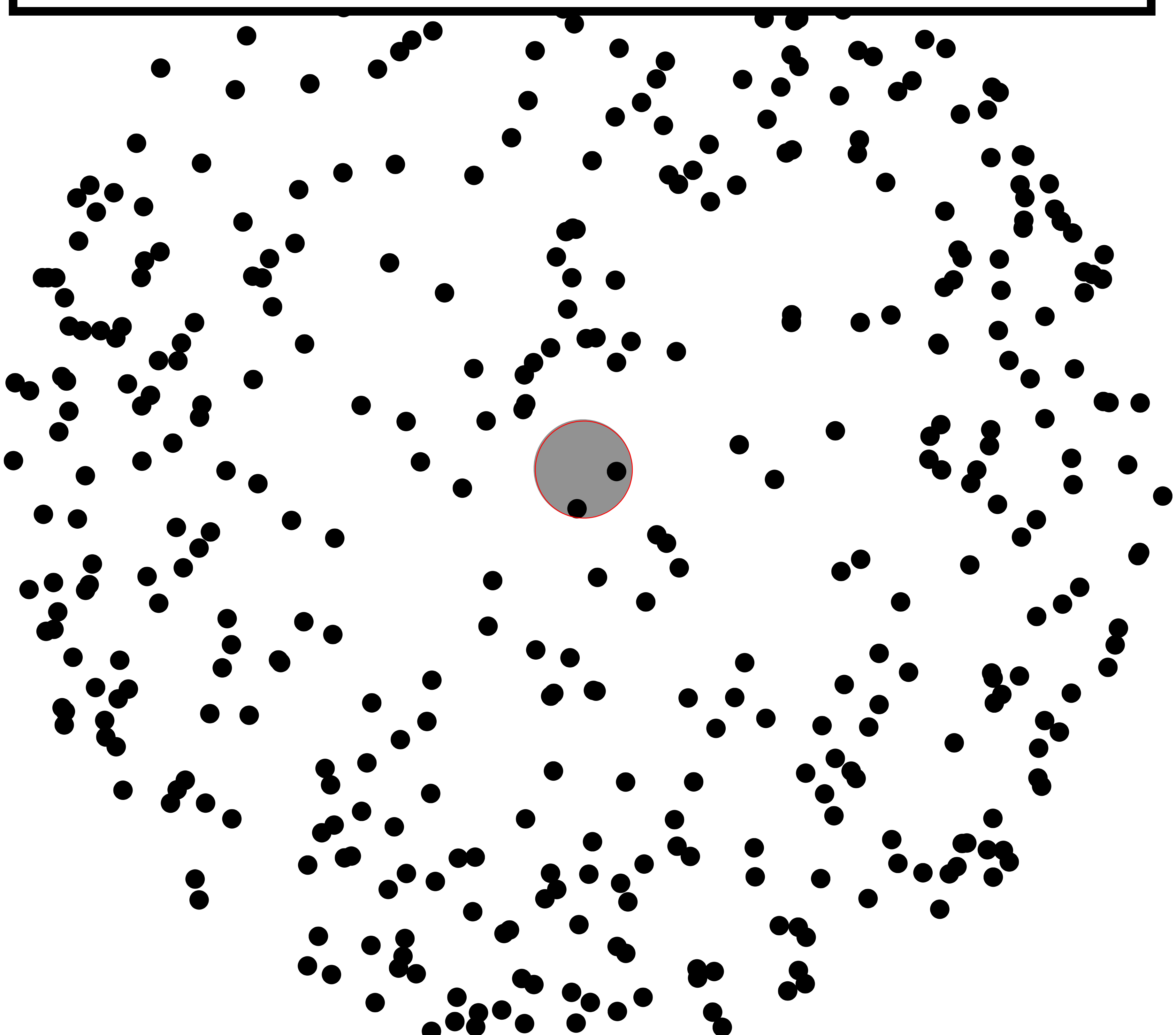
Hydrodynamics Codes in AMUSE:

name	type of code	language	parallel
Gadget-2	TreeSPH	C	yes
Fi	TreeSPH	F95	yes
Capreole	grid	F95	yes
Athena3D	AMR	C	yes
AMRVAC	AMR	F95	yes

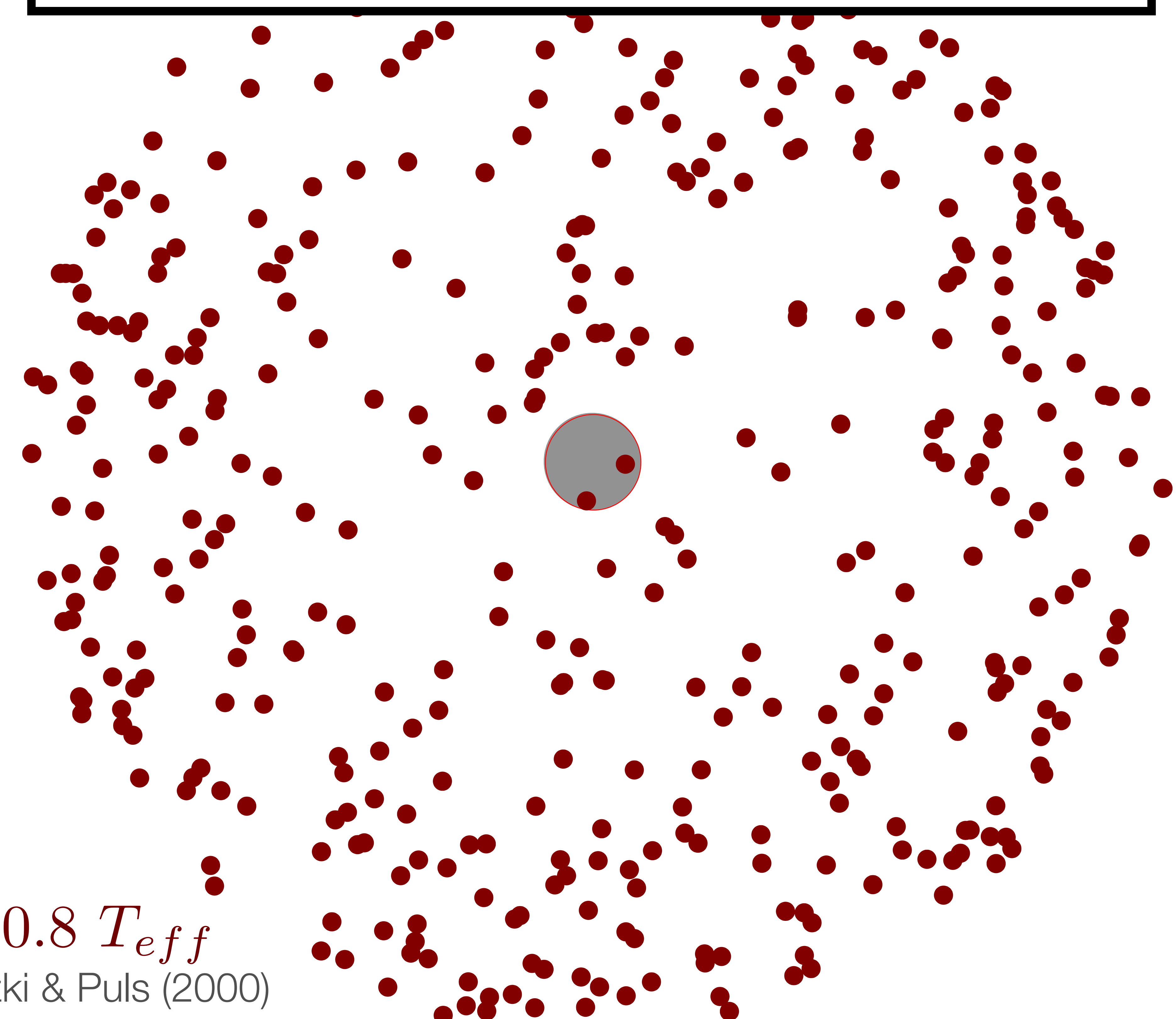


Bridge

Stellar Wind



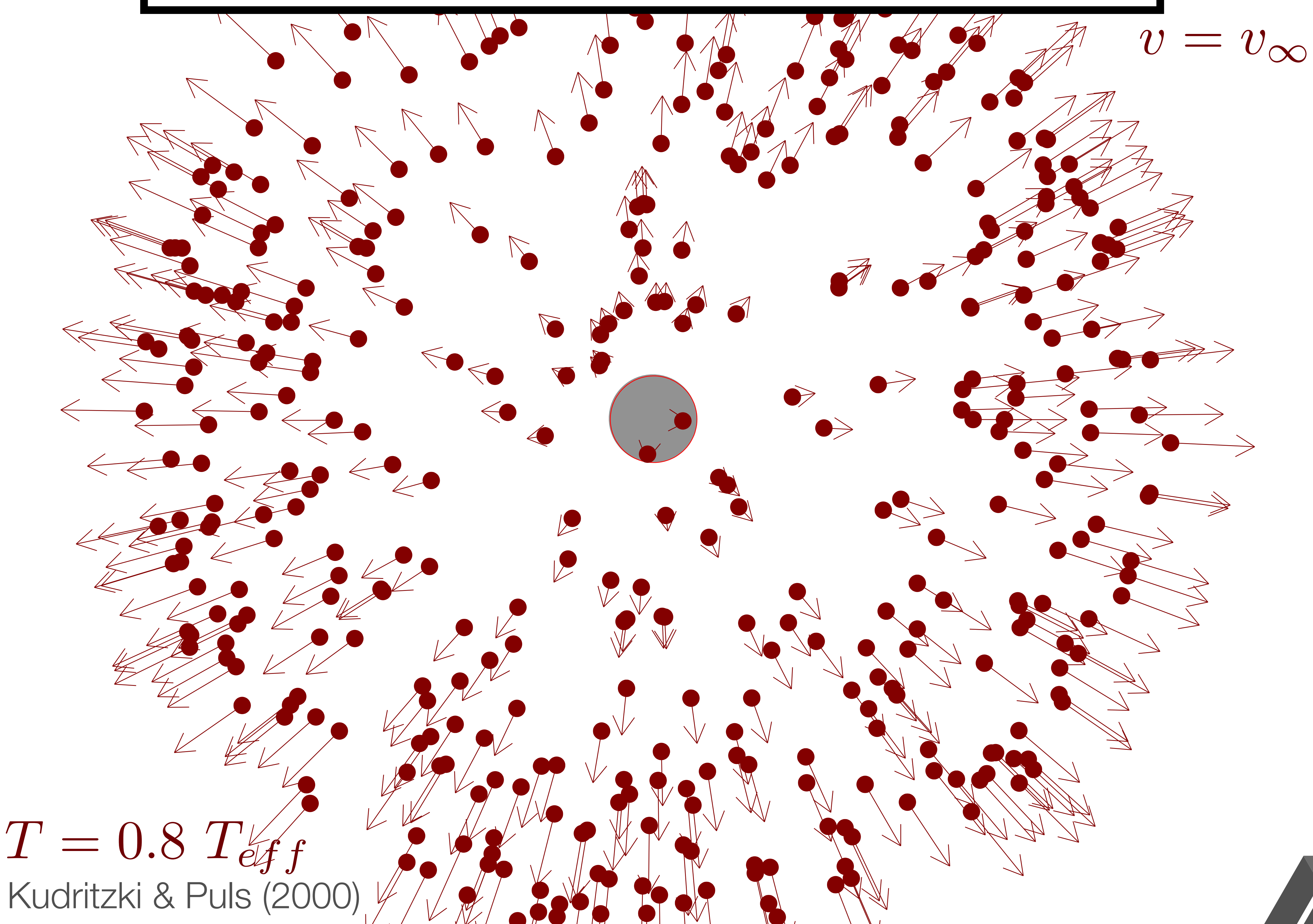
Stellar Wind



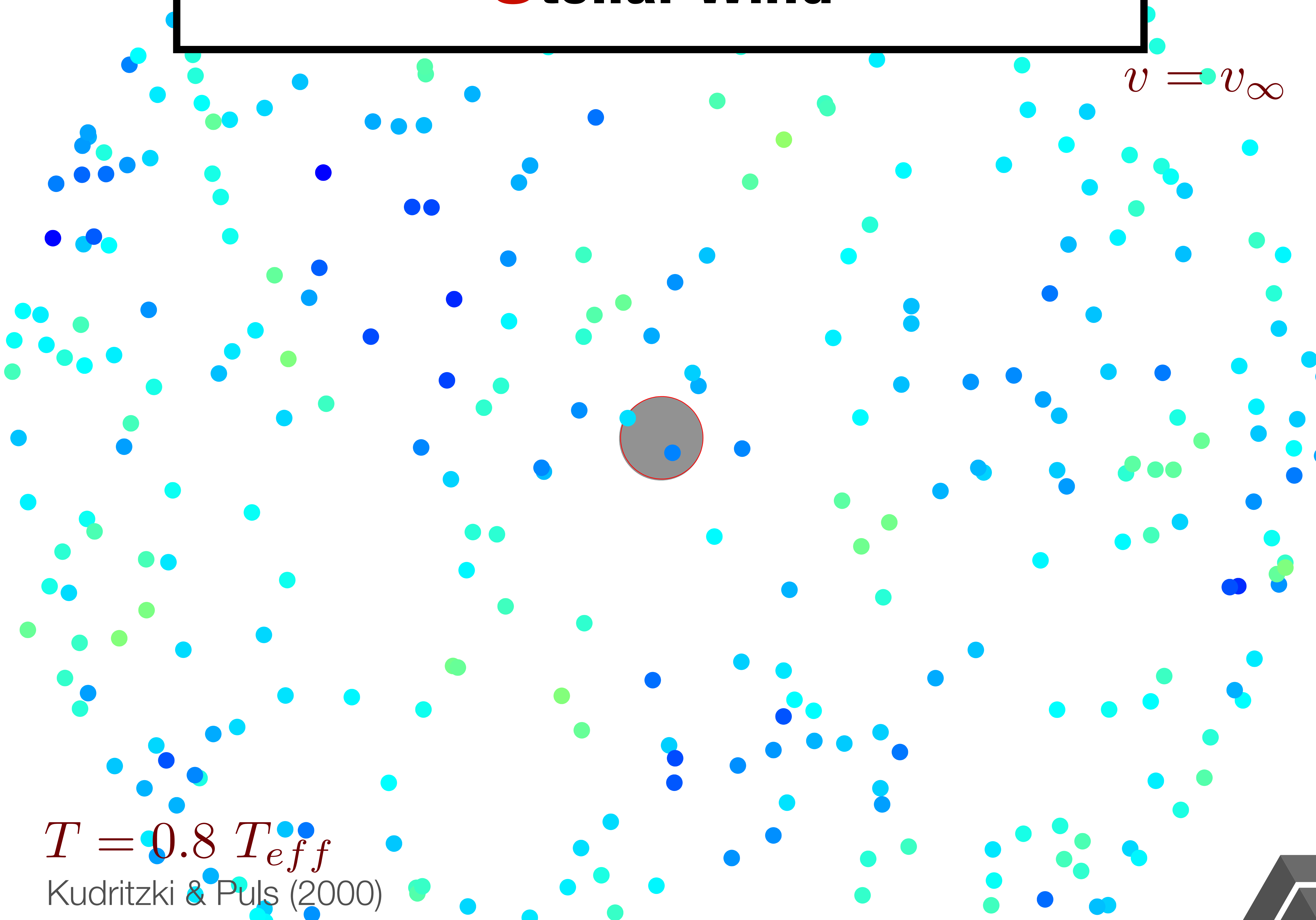
$T = 0.8\ T_{eff}$

Kudritzki & Puls (2000)

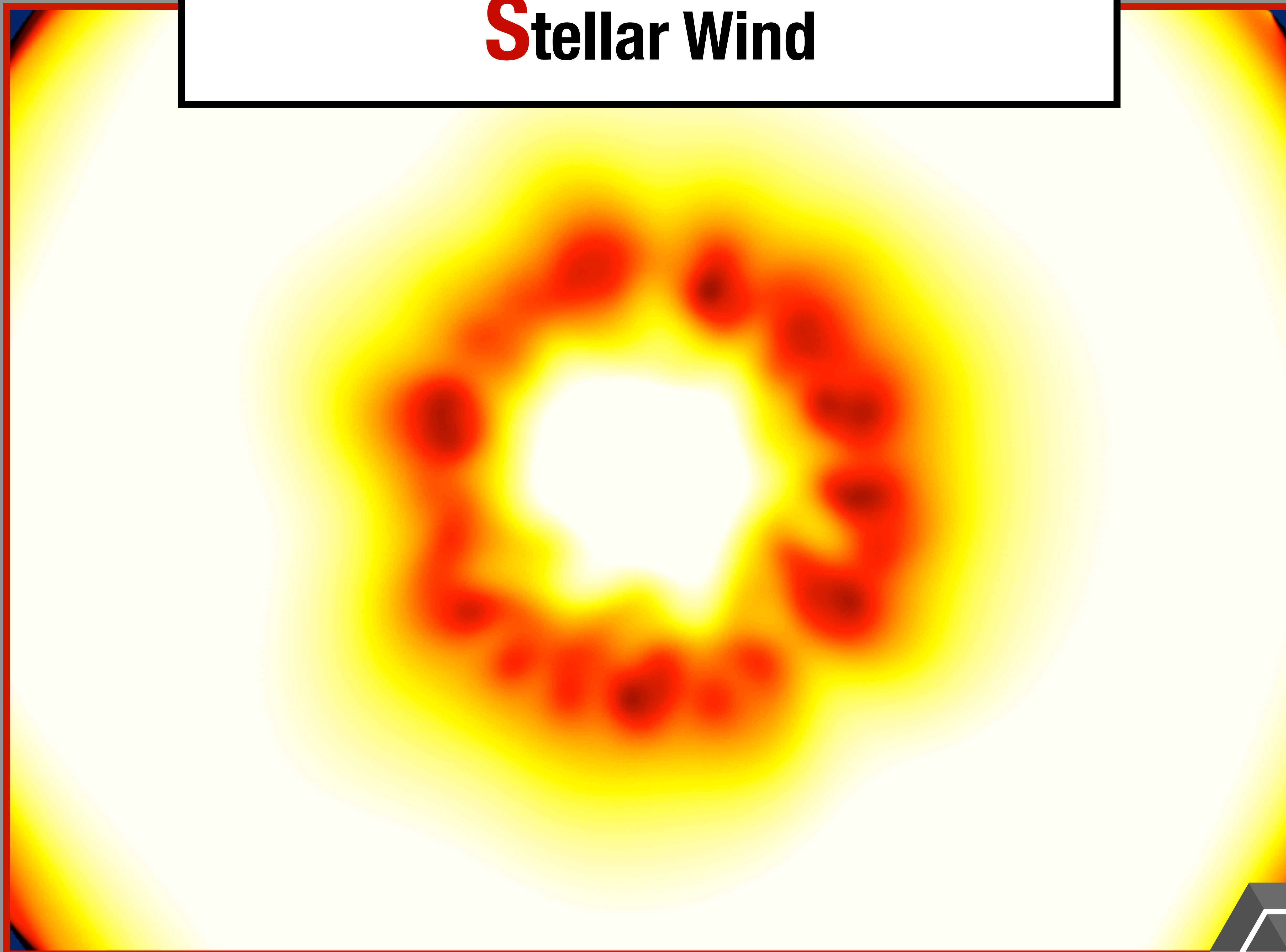
Stellar Wind



Stellar Wind

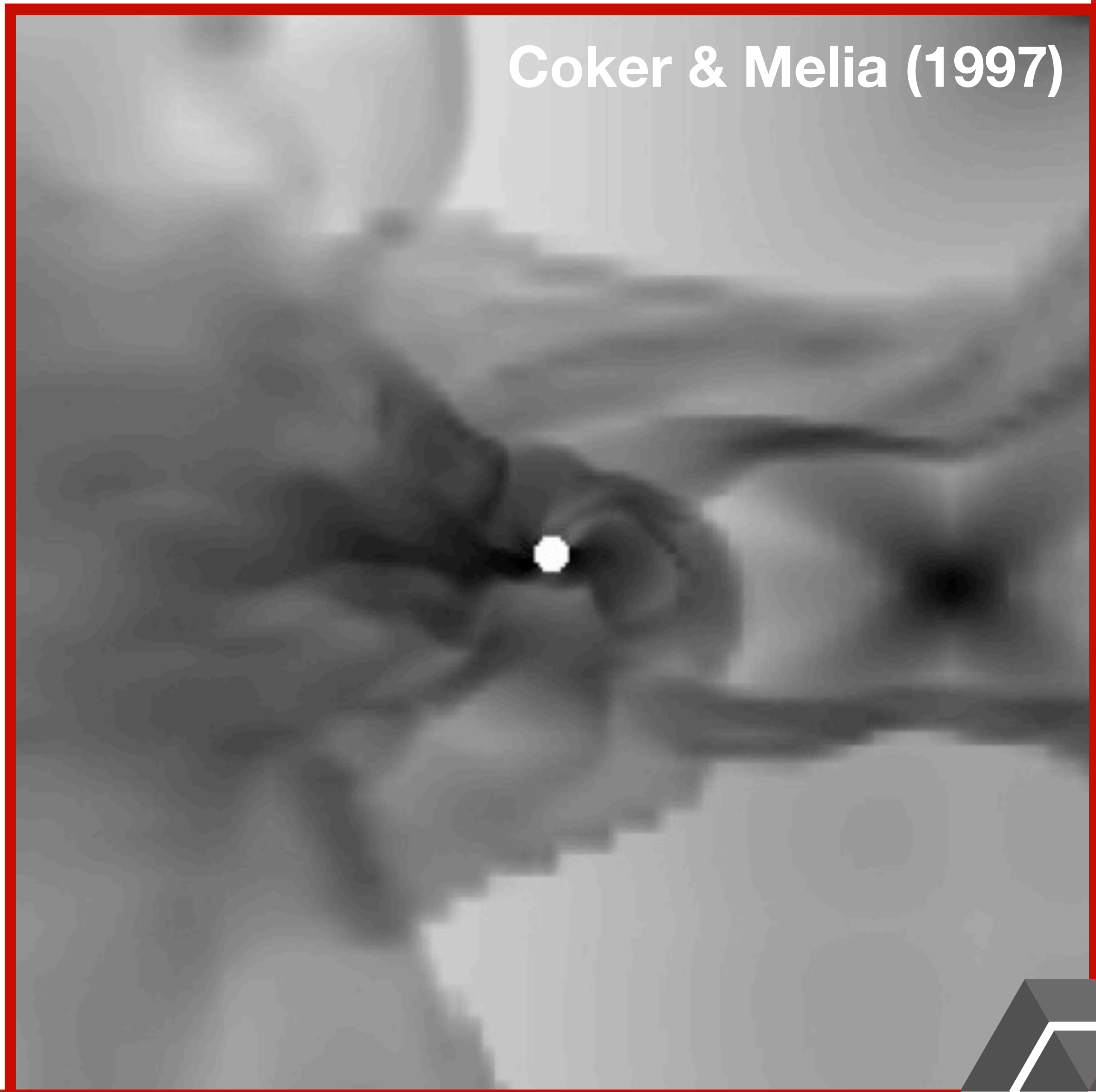


Stellar Wind

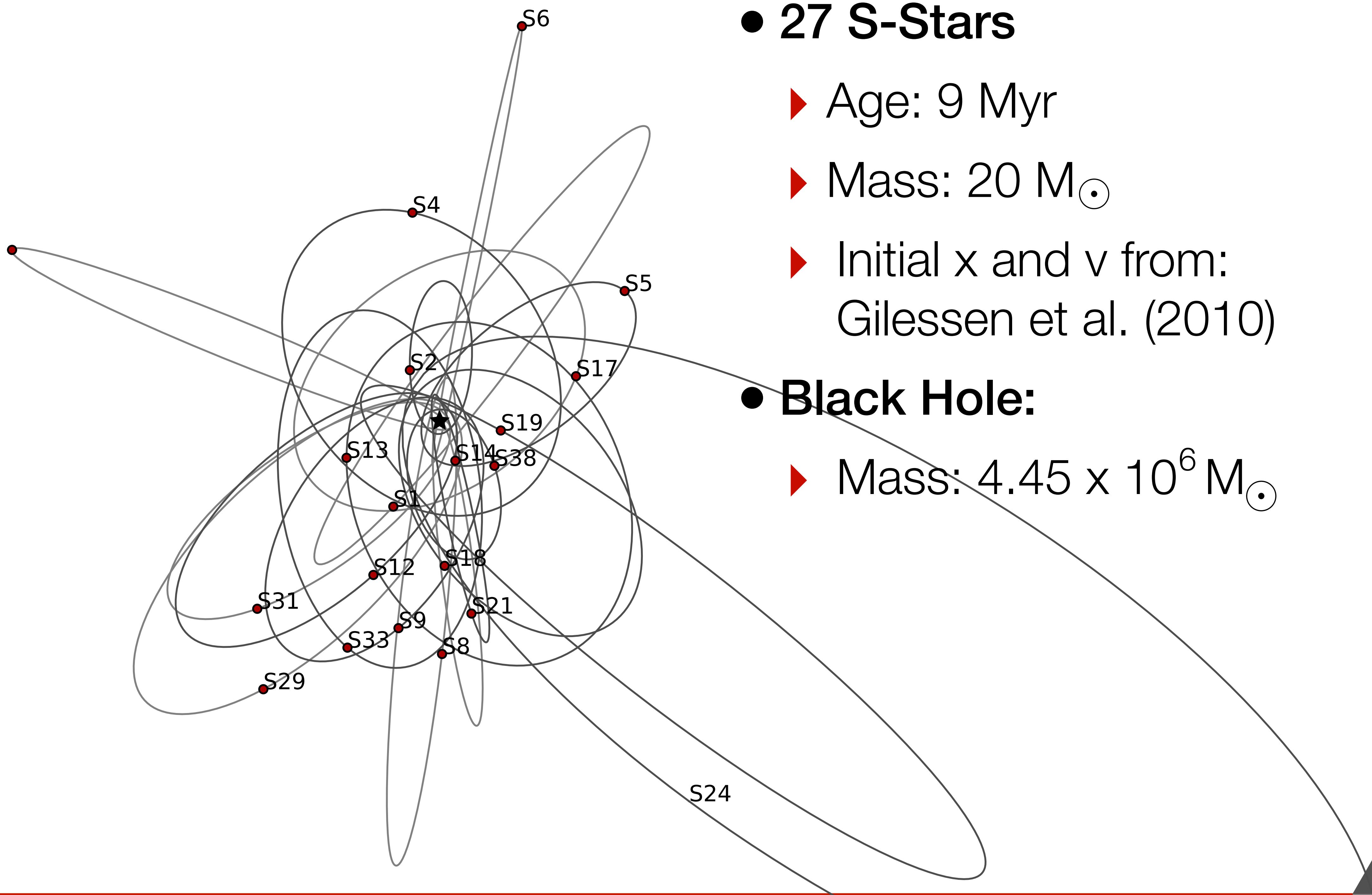


Accretion

- **Spherical sink particle (Black Hole)**
  - Infall from all directions
- **Bondi - Hoyle Accretion**
  - $R_{acc} = 0.05 \times R_B$
  - COMPROMISE: Computational Efficiency - Point-Mass Accreter
  - (Moeckel et al., 2009)

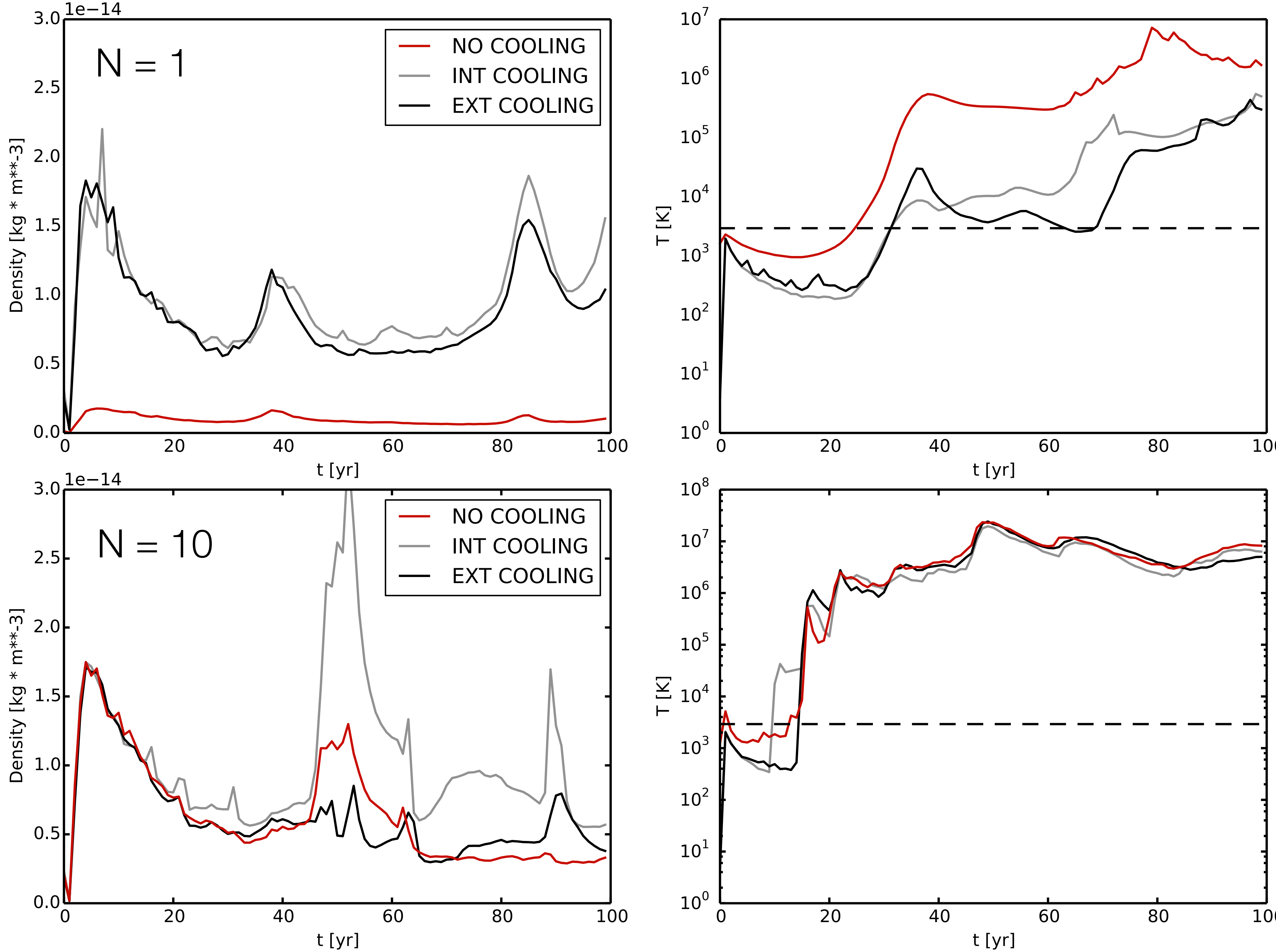


Setup



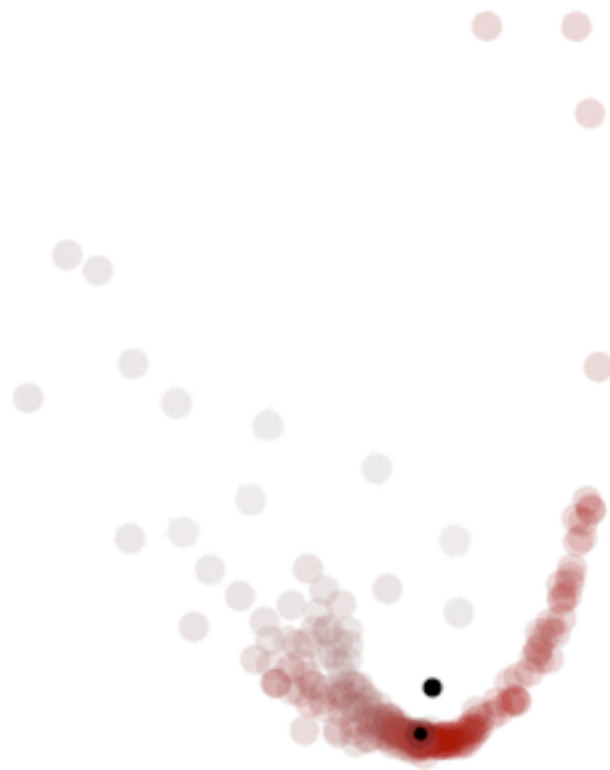
- **27 S-Stars**
  - Age: 9 Myr
  - Mass: 20 $M_\odot$
  - Initial x and v from: Gilessen et al. (2010)
- **Black Hole:**
  - Mass: 4.45 x 10^6 $M_\odot$

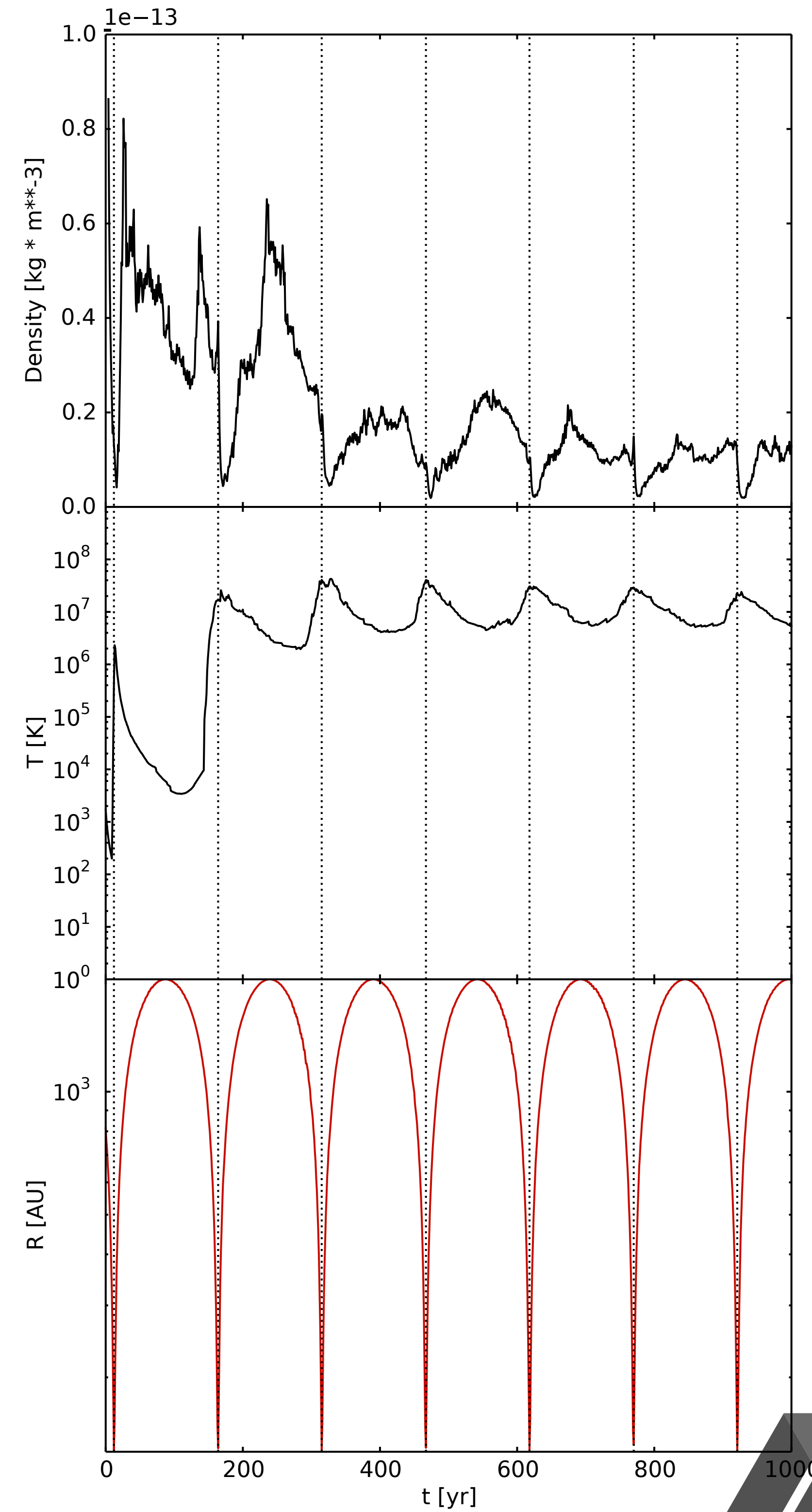
Cooling



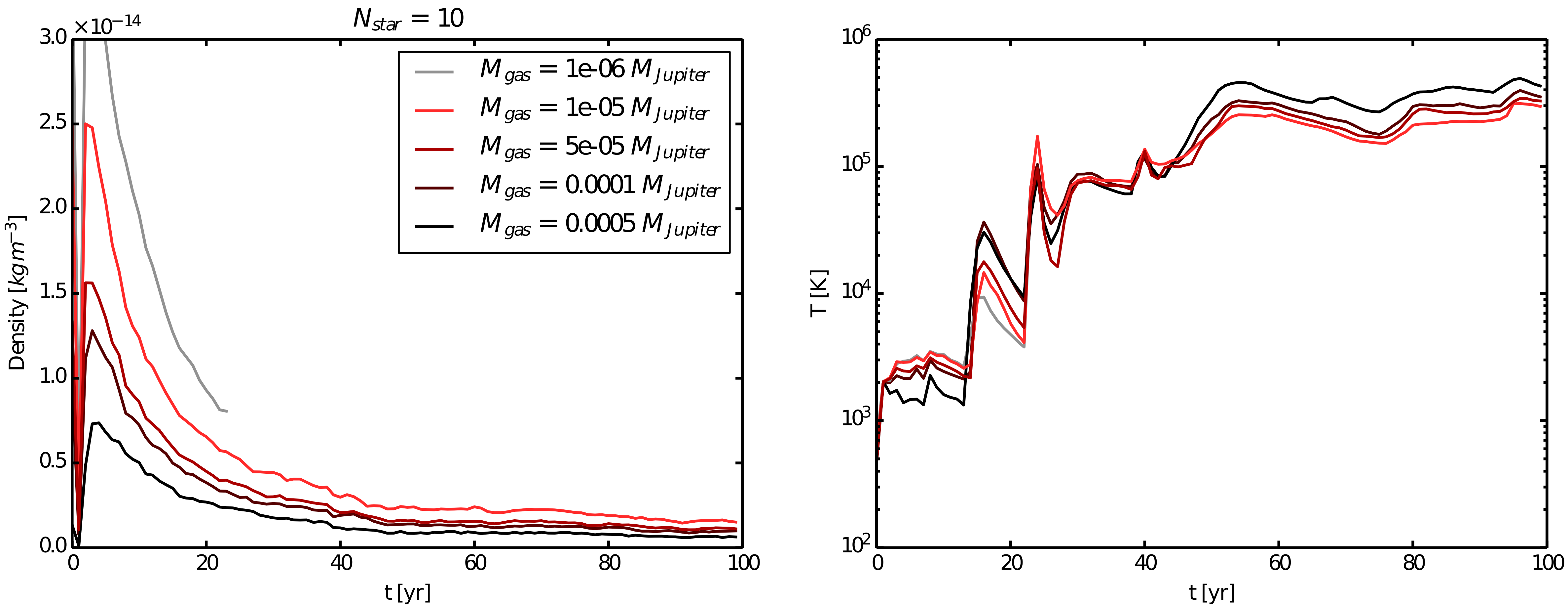
N = 1
NO COOLING
INT COOLING
EXT COOLING
1e−14
Density [kg * m**-3]
t [yr]
T [K]
N = 10
NO COOLING
INT COOLING
EXT COOLING
1e−14
Density [kg * m**-3]
t [yr]
T [K]

Tests - One Star

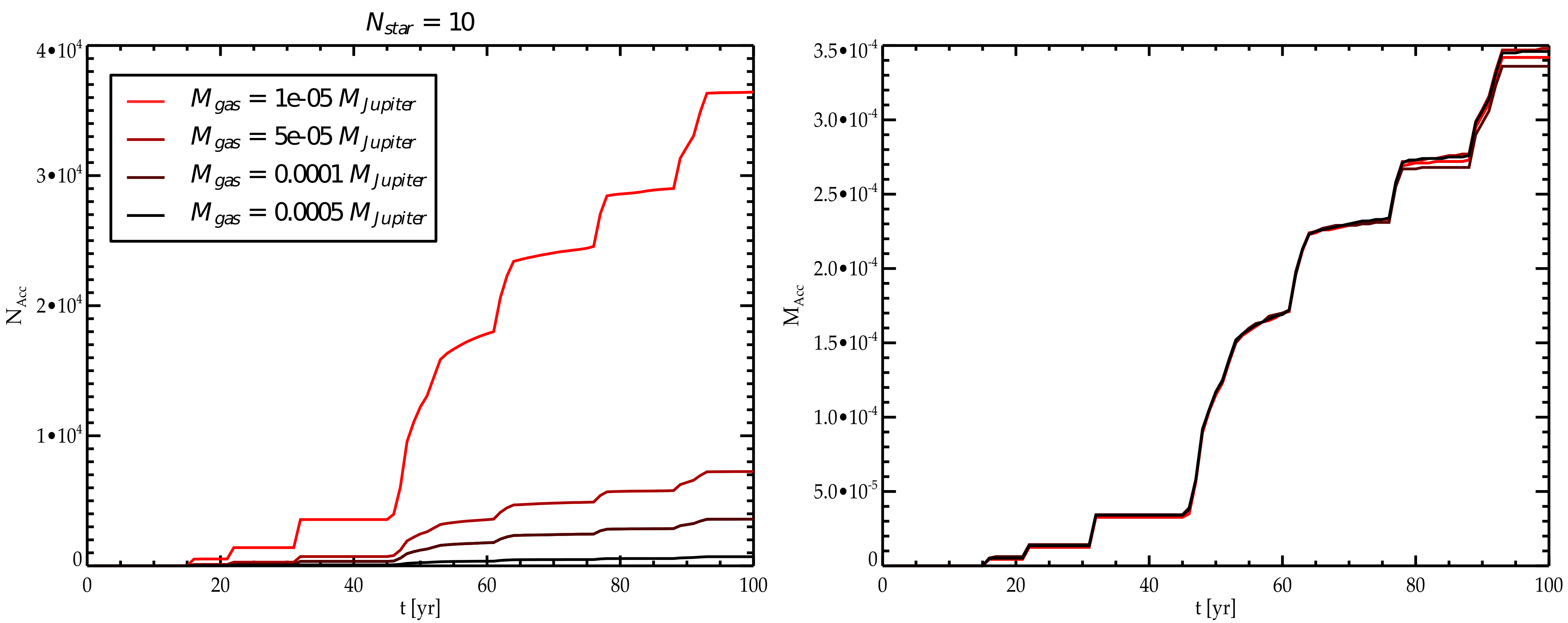




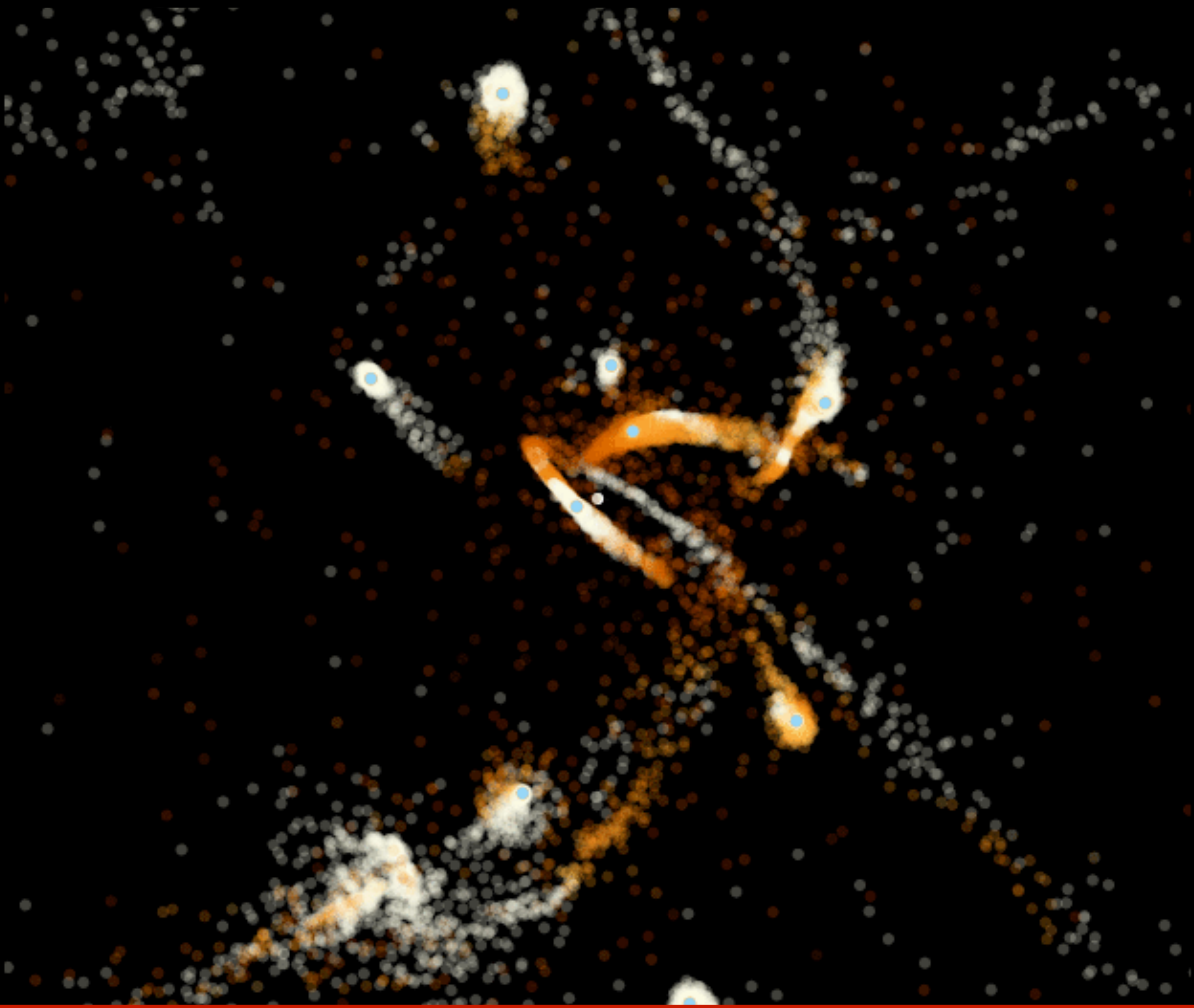
Tests - Convergence



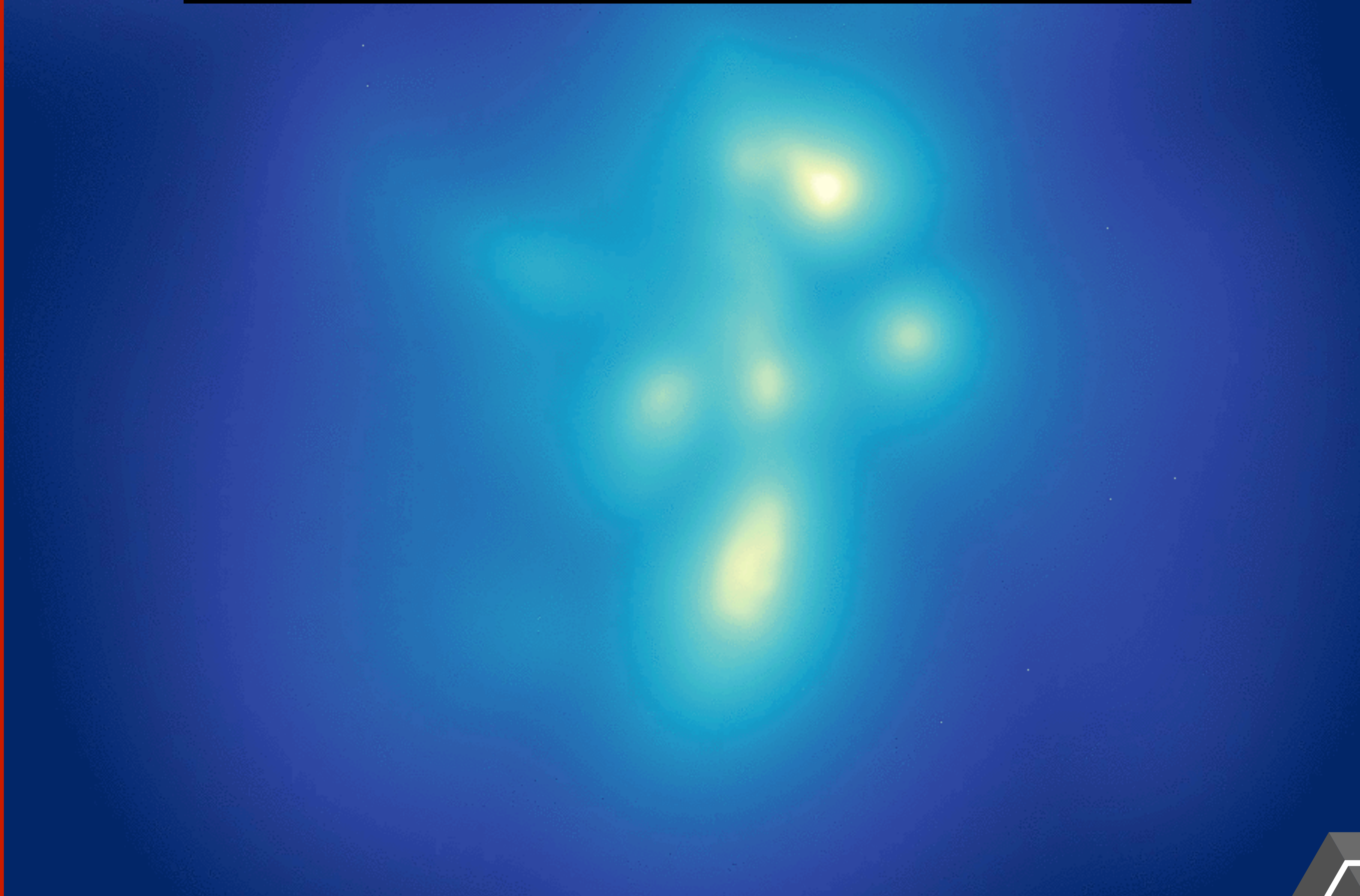
Tests - Accretion



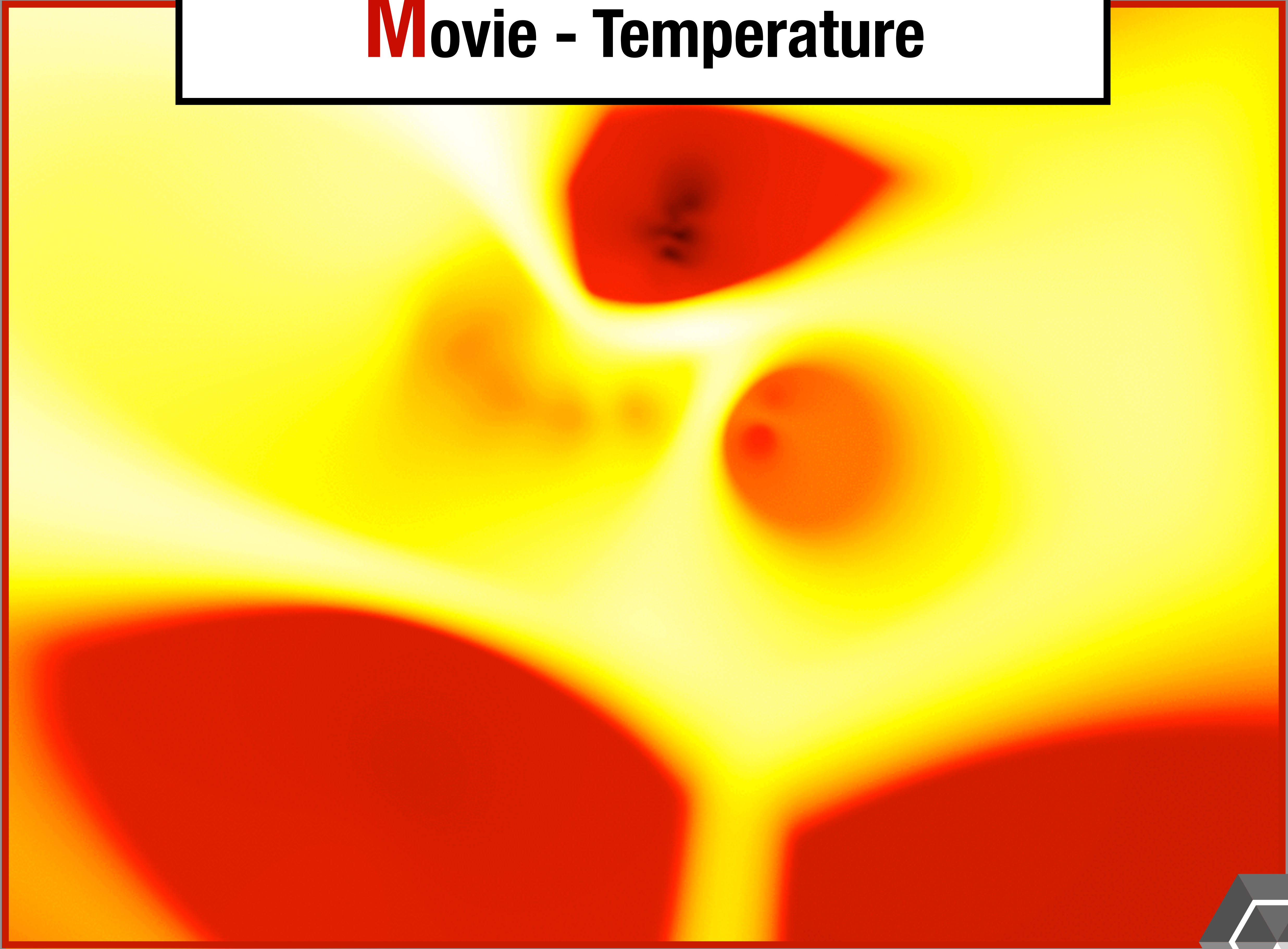
Movie - Particles



Movie - Density



Movie - Temperature



Next Steps

1. **FINISH TESTS**
2. **REFINE ACCRETION**
   - Accretion Radius
   - Fractions of gas particles
3. **MOVE TO SUPERCOMPUTER**
   - i.e., SARA
4. **COMPARE TO OBSERVATIONS**
5. **EXTEND TO GLOBULAR CLUSTERS AND IMBHs**

Summary

- **AMUSE - combining physics**
  - Gravitational Dynamics
  - Stellar Evolution
  - Hydrodynamics
- **Testing accretion of stellar wind with S-Stars**
  - 27 Stars
  - Supermassive Black Hole ($M = 4.45 \times 10^6 M_\odot$)
- **Next Steps:**
  1. Refine Accretion
  2. Run on supercomputer
  3. Extend to Globular Clusters and IMBHs

THANK YOU