

N-body Simulation – an Example for High-Performance Computing and Visualization

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Outline:

[**Astrophysics** at the Research Center Jülich
(current status, ongoing projects...)

[**New project:** Decay of Star Clusters in the
Galactic Center

[Why do we need **Supercomputers**?

[Why do we need **Visualization**?



Astrophysical projects using Jump:

1. Dr. Ralf Klessen (**AIP**): Star Formation & Protoplanetary Discs
2. Dr. Stefan Gottloeber (**AIP**): Galaxy Formation & Evolution
3. Dr. Hans-Thomas Janka (**MPA Garching**): Supernova Explosions
4. Dr. Susanne Pfalzner (**U Köln**): Protoplanetary Discs
5. Prof. Stephan Rosswog (**U Bremen**): Stellar Encounters with BH's
6. Dr. Gyula Bene (**U Budapest**): Expansion of the Universe
7. Prof. Rainer Spurzem (**U Heidelberg**): N-body Simulations





Collaboration Project:

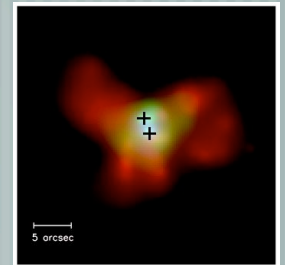
with ARI Heidelberg, Prof. Rainer Spurzem, experimental Stellar Dynamics, N-body Models with **nbody6++**

Patrick Glaschke (**ARI**): Planetary dynamics, Formation of Protoplanets out of Planetesimals



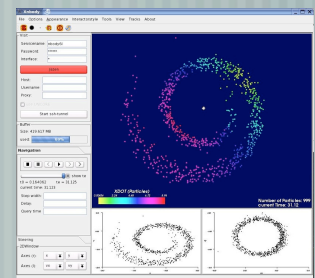
Dr. Andrea Borch (**ARI**): N-body & Stellar Population Synthesis

Christoph Eichhorn (**ARI**): Evolution of massive Black Hole Binaries in Active Galactic Nuclei



Andreas Ernst (**ARI/NIC**): Rotating Star Clusters

Sonja Dominiczak (**NIC**): Visualization (xnbody)



New project: Decay of Star Clusters in the Galactic Center



Burning Question: How can we explain the presence of young, massive He I stars in the central parsec of the Milky Way?

— [Star formation in the central parsec (impossible?)

— very strong tidal field of the supermassive Black Hole ($3 \times 10^6 M_{\text{Sun}}$)

— [Inspiral of a massive Star Cluster in a few Myrs (O. Gerhard 2001)

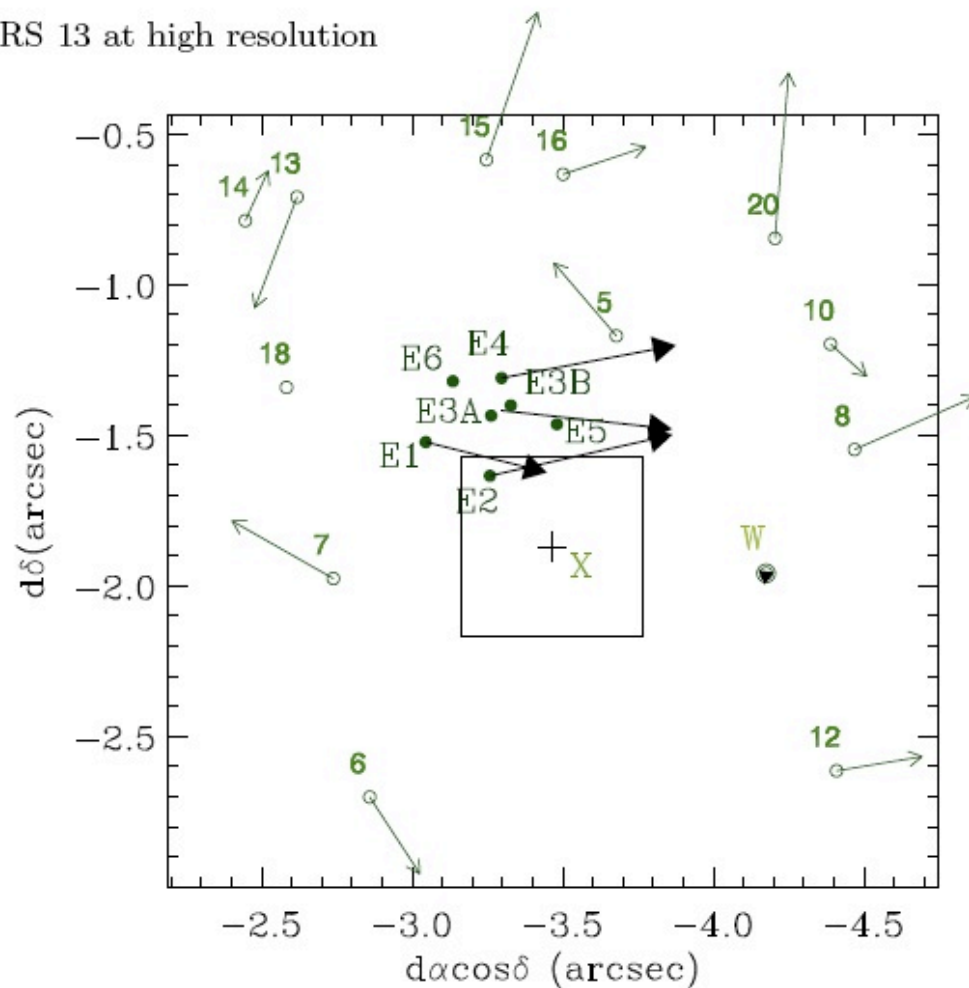
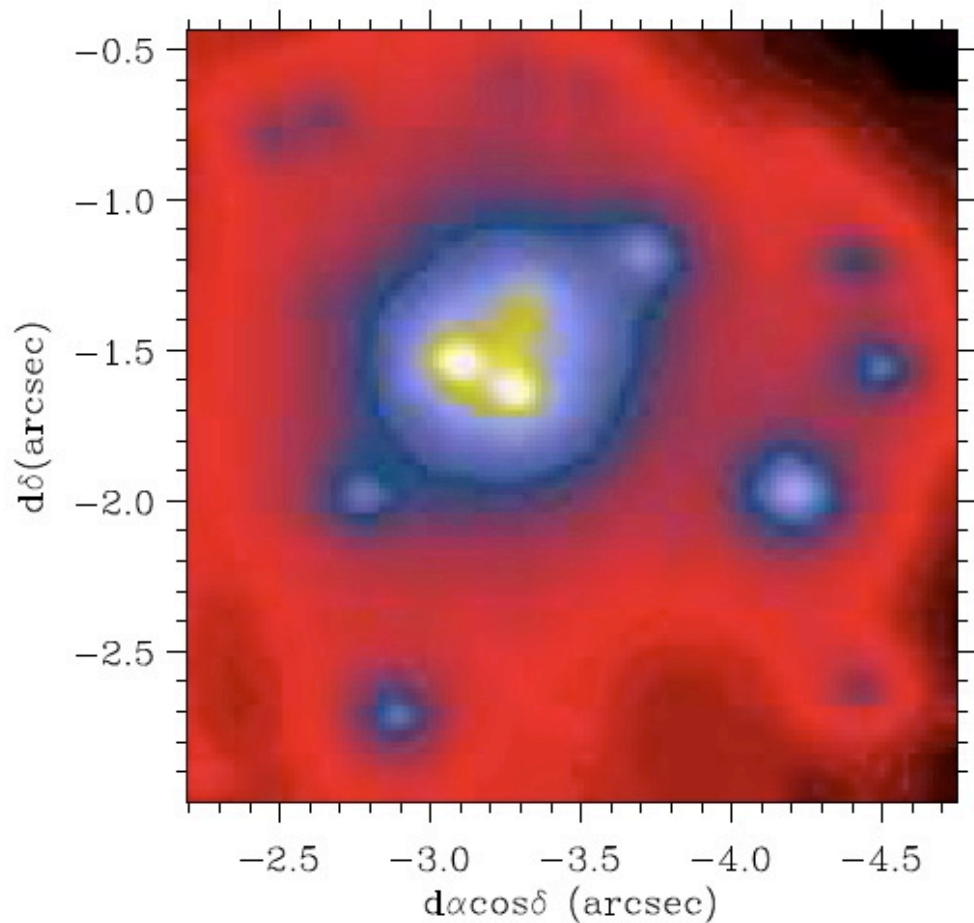
— Dynamical friction

— Dissolution in the tidal field

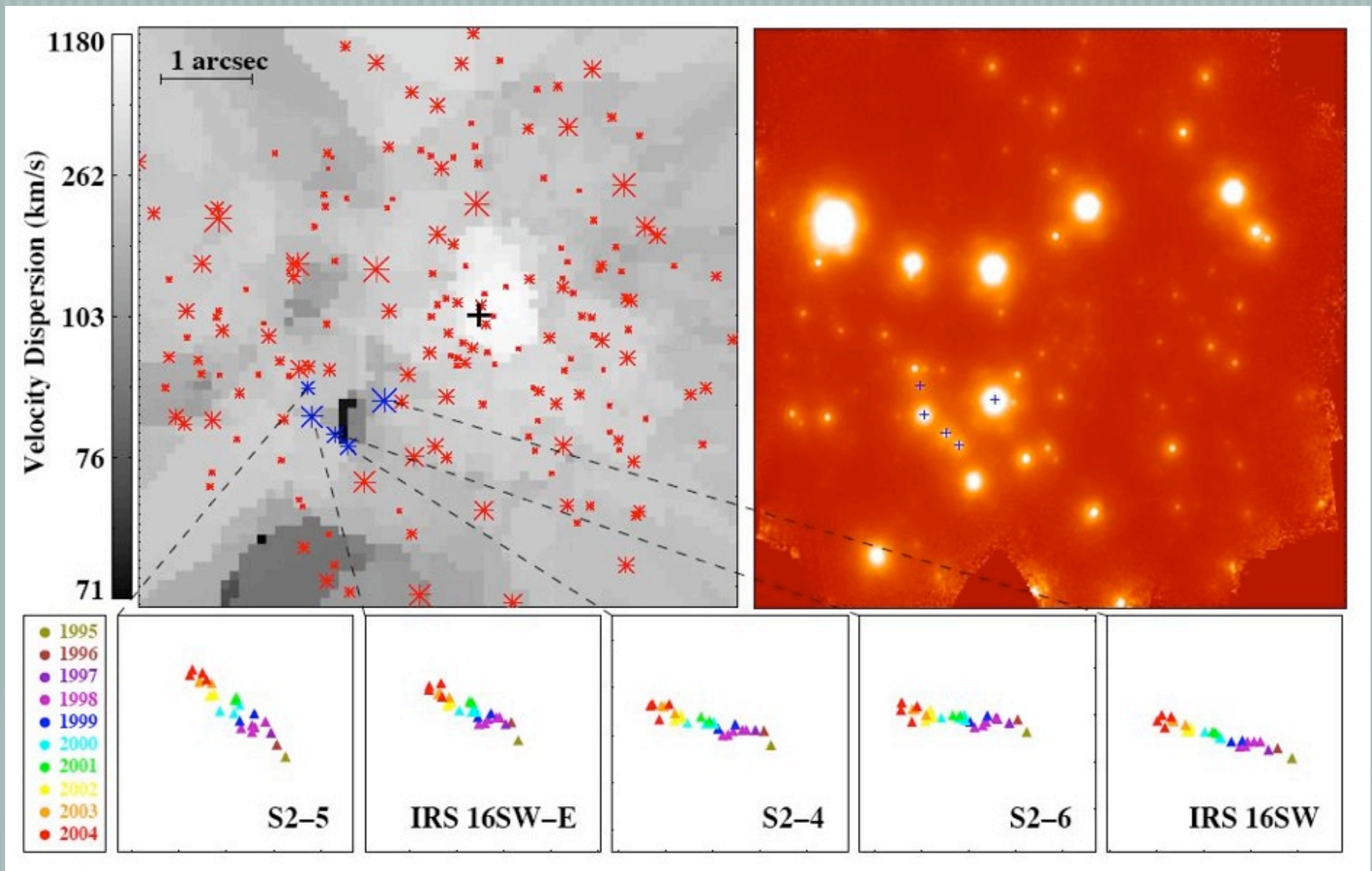
— Remnant: IRS 13 / IRS 16SW ?

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Maillard *et al.*: GC source IRS 13 at high resolution



IRS 13: Maillard *et al.*, A&A 423, 155 (2004)



IRS 16SW: J.R. Lu et al., ApJ 625, L51 (2005)

How can we test Gerhard's 2001 proposal?



Direct N-body Models

Challenge: Models must be very realistic (no simplifying idealizations!)

Ingredients:

- Dynamical Friction
- Tidal field
- Mass spectrum (IMF),
- Stellar evolution,



Does the central Black Hole grow through Star Cluster Accretion?

Why do we need **Supercomputers**?

— [Models must be realistic!

— [Simulations show that the mass of the inspiraling Star Cluster must be of the order of $M \approx 10^6 M_{\text{Sun}}$ and very compact

(Kim & Morris 2003, Hansen & Milosavljevic 2003, McMillan & Portegies Zwart 2003, Kim et al. 2004, Gürkan & Rasio 2005)

— [$T_{\text{CPU}} \approx C \cdot N^2$

— [Reduced particle number leads to a shifting of the stellardynamical processes (Relaxation, Stellar evolution, Processes depending on the orbital time scale)

IBM Regatta p690+ (Jump)



Cray XD1 (with 6 FPGAs)



IBM Blue Gene/R (Jubl)

FPGAs in the Cray XD1

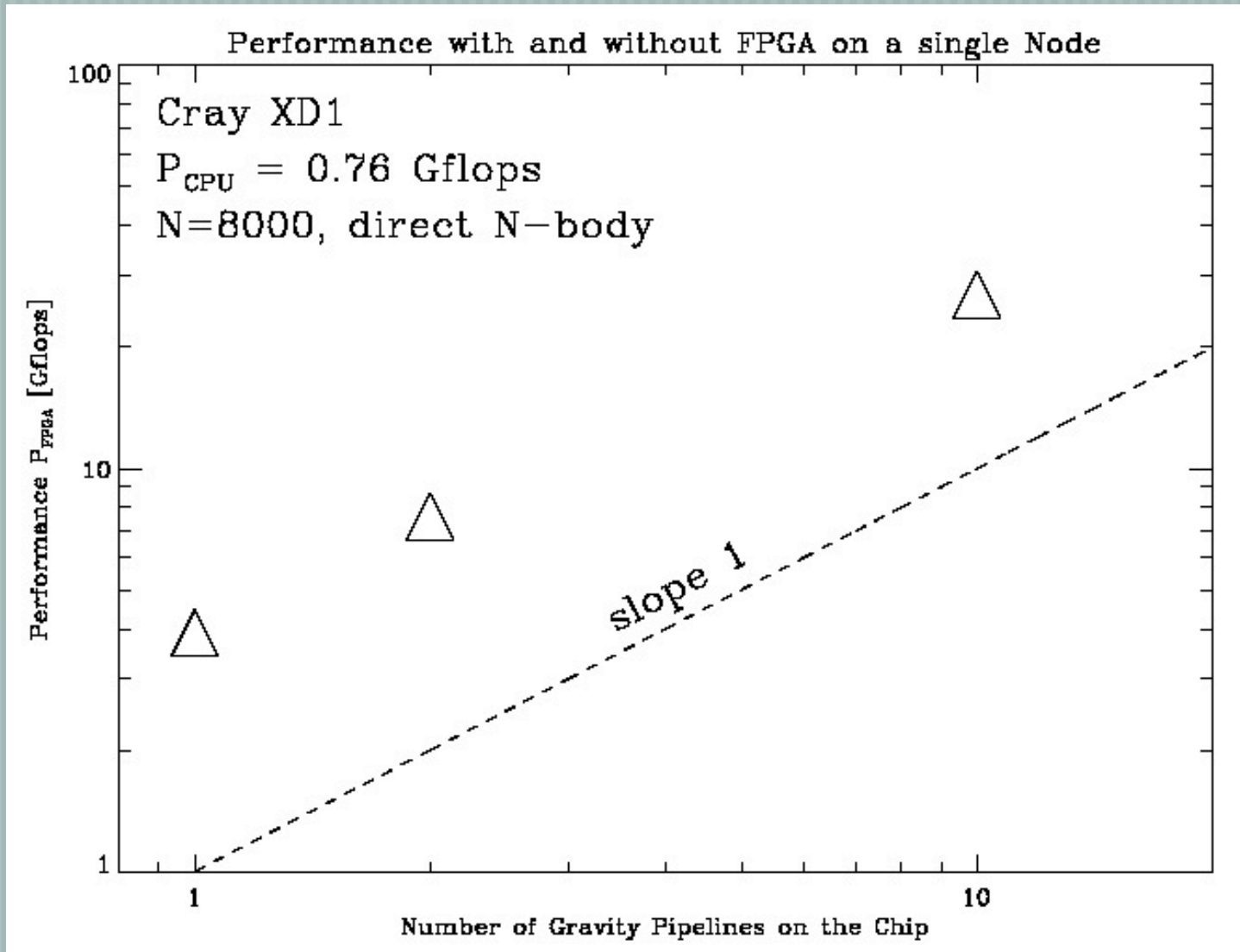
Collaboration with N. Nakasato,
T. Hamada (**RIKEN Institute, Japan**)



N-body with
10 parallel
Gravity Pipelines
on one FPGA

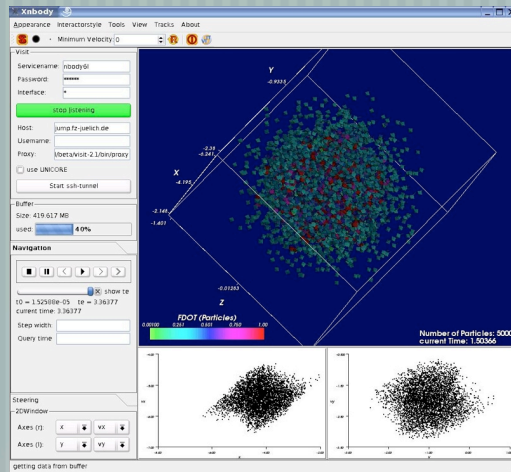


Without FPGA:
0.76 Gflops
With FPGA:
27 Gflops

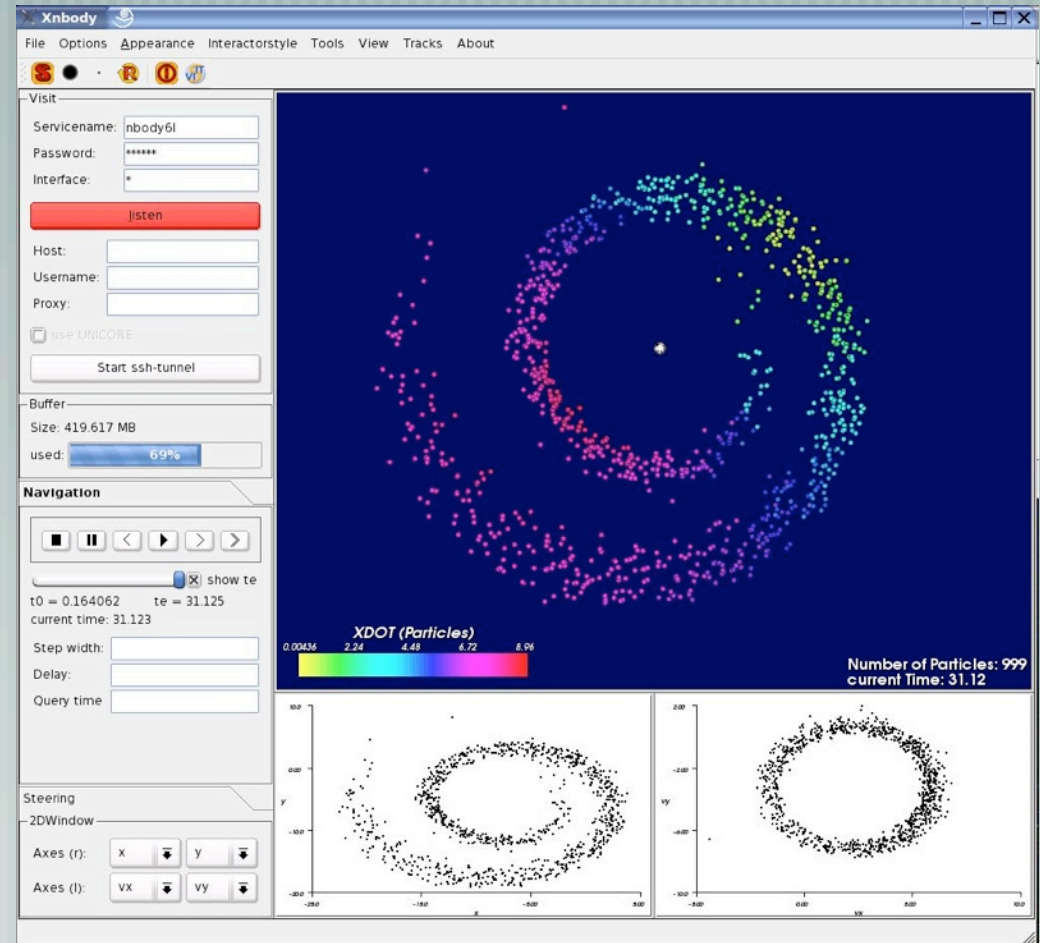


Why do we need **Visualization**?

We want to see the Dynamics in the Galactic Center!



xnbody - written by
Sonja Dominiczak
(NIC Jülich)



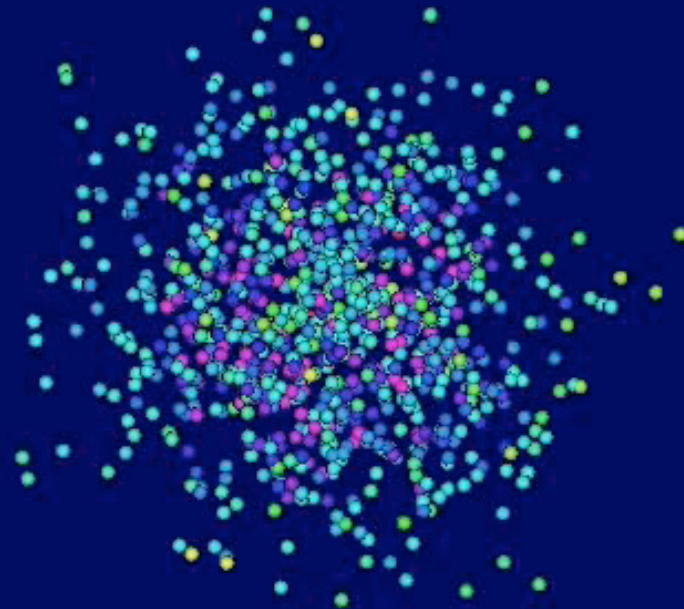
Online-Visualization

GRID-enabled by UNICORE (EU Project UniGrids)

$N = 1000$

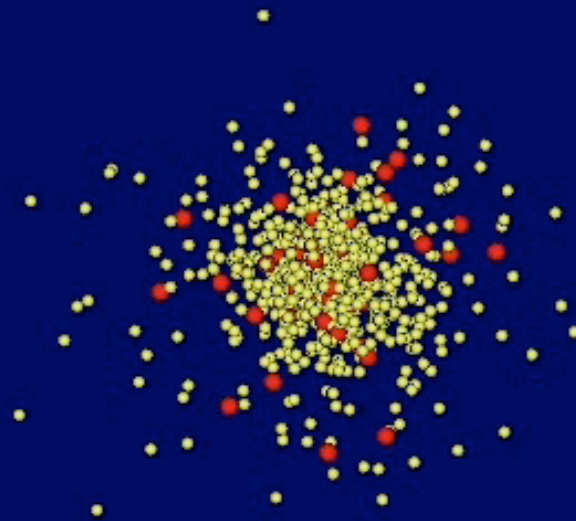
$W_0 = 6$

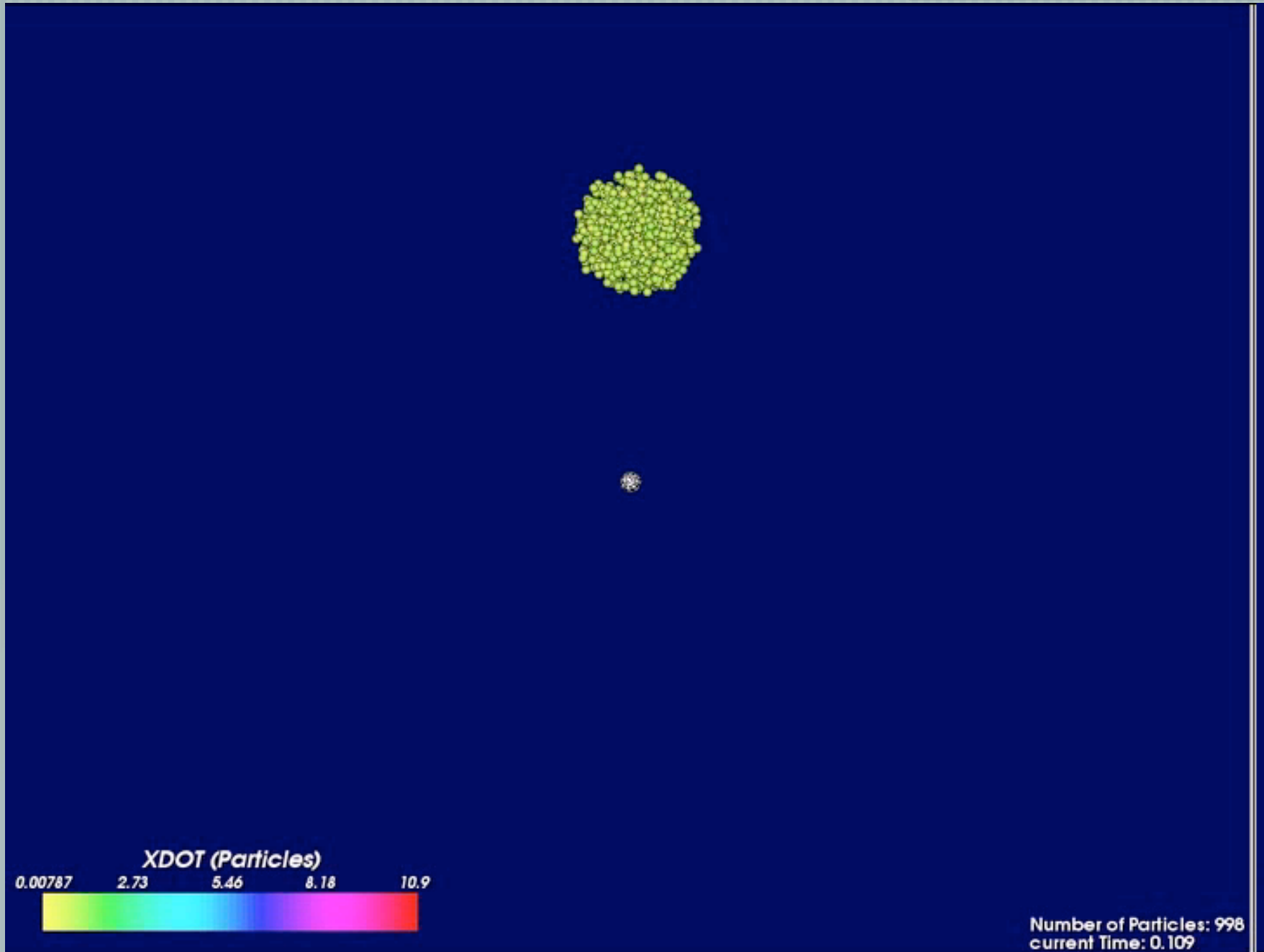
$\omega_0 = 0.9$



Number of Particles: 100
current Time: 0.605

$m_2/m_1 = 100$
 $M_2/M_{tot} = 0.1$





Conclusions:

Several working groups from all over Germany do **astrophysical** calculations on Jump, but there is no real cooperation...

So far, there is only **one** **astrophysical** cooperation project between NIC Jülich and ARI Heidelberg related to N-body simulations

LOFAR might be the **next** large **astrophysical** cooperation project!

