Center for Computational Astrophysics

Progress Report for FY2018-2019

Eiichiro Kokubo (Director)

CfCA Missions

CfCA

- Center for Computational Astrophysics (C-Type Project)

Missions

(a) Operate an open-use high-performance computing system that consists of a supercomputer, the special-purpose computer for gravitational many-body problems and other computers to store and analyze data. Support domestic and international users to perform astronomical simulation research.

(b) As a base for computational astrophysics, develop original hardware and software and accomplish world-leading astronomical simulation research.

(c) Develop 4D2U (4-Dimensional Digital Universe) contents based on the latest research outcomes. By providing the 4D2U contents, support astronomers to carry out research and promote astronomical education and public outreach.

Members (Tenured)

Professors (2)

- E. Kokubo (Director), K. Tomisaka

Assistant Professors (5)

- T. Ito (Deputy Director), K. Iwasaki, A. Kataoka, T. Moriya, T. Takiwaki

Research Engineer (1)

- T. Ishikawa

(joint appointment from DoS and Mizusawa)

Members (Fixed-Term)

Research Expert (1)

- H. Nakayama

Specially Appointed Senior Specialists (3)

- H. Hohokabe, T. Kato, H. Fukushi

Specially Appointed Research Staffs (3)

- S. Ishikawa, Y. Ohtani, T. Taki

Research Supporters (2)

- K. Kano, S. Hasegawa

Administrative Supporter (1)

- K. Mashiko

Specially Appointed Assistant Professor (1)

- T. Kawashima

(4D2U)

FY2019 Operating Members

(2019.4)

FY Goal (1)

Goal (1)

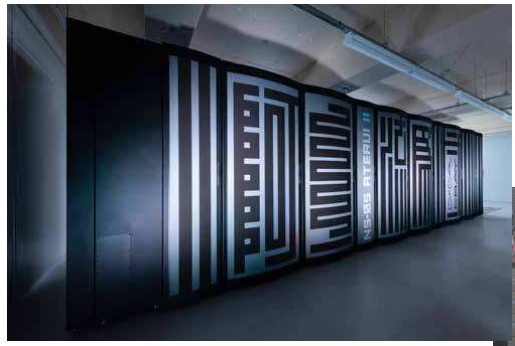
- スーパーコンピュータを中心とした共同利用計算機システムを安定に運用し、日本全国の研究者の共同利用に供する。

Results

- new system installation in FY2018
- system reinforcement in FY2019
- more users and papers

Stable operation and more results!

CfCA HPC System

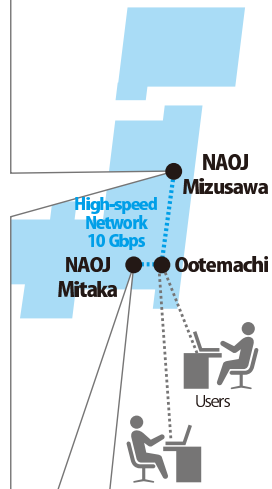


Supercomputer "ATERUI II" (Cray XC50)

Theoretical Peak Performance: 3.087 Pflops
Main Memory: 385.9 TB
Nodes: 1,005
CPU: Intel Xeon Skylake 6148
2.4 GHz, 40 cores
Total Core Number : 40,200

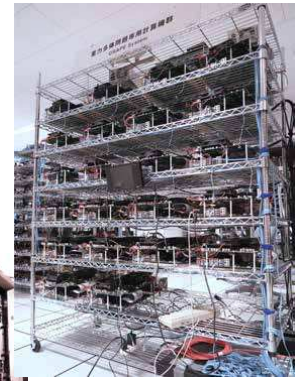
File Server (DDN EXA Scaler)

Disk Capacity: 6.5 PB



GRAPE (GRAvity PipE)

GRAPE-DR : 16 nodes
GRAPE-9 : 8 nodes



Analysis Server

Nodes: 9
CPU : AMD Opteron
2.1 GHz 12 cores

PC Cluster

Nodes: 224

CPU : Intel Core i7-2600K 3.4 GHz 4 cores (64 nodes)
Intel Core i5-4670 3.4 GHz 4 cores (128 nodes)
Intel Core i5-7500 3.4 GHz 4 cores (32 nodes)

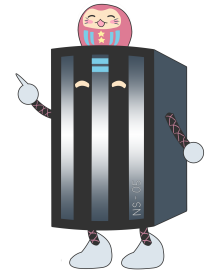
File Server

Disk Capacity: 6 PB

Not only supercomputer but also simulation infrastructure!

NS-05 ATERUI II (Cray XC50)

Peak Performance: 3 Pflops
TOP500 139 (2019.11)



CfCA HPC System (2019.12)

Cray XC50 (ATERUI II)

- Massively parallel scalar computer (40200 cores, 3.087 Pflops, 385.9 TB)

GRAPE-DR/9 (DIY)

- Special-purpose computer for many-body problems

GPU Cluster (DIY)

- PC cluster with GPUs (NVIDIA Tesla K20 x 8 nodes)

PC Cluster (DIY)

- Small-scale non-parallel calculation (1408 cores)

File Server (DIY)

- Parallel RAID (7 PB)

Data Analysis Server (DIY)

- (36 cores, 1 TB memory) x 6 nodes

FY Goal (2)

Goal (2)

- 大規模シミュレーション用ハードウェア・ソフトウェアの開発・運用を通じて、日本のシミュレーション天文学拠点として活発な研究開発活動を推進し、質・量ともに十分な成果を挙げる。

Results

- Stable operation of the computer system
- Development of GPU system, PC cluster, file server, and analysis server
- More papers than the last year

System development and more papers!

Number of Users and Publications

FY	# of users	# of publications	XC30/50 OR
2014	187	88	88%
2015	210	114	86%
2016	225	129	$\simeq$ 90%
2017	252	137	94%
2018	256	141	93%

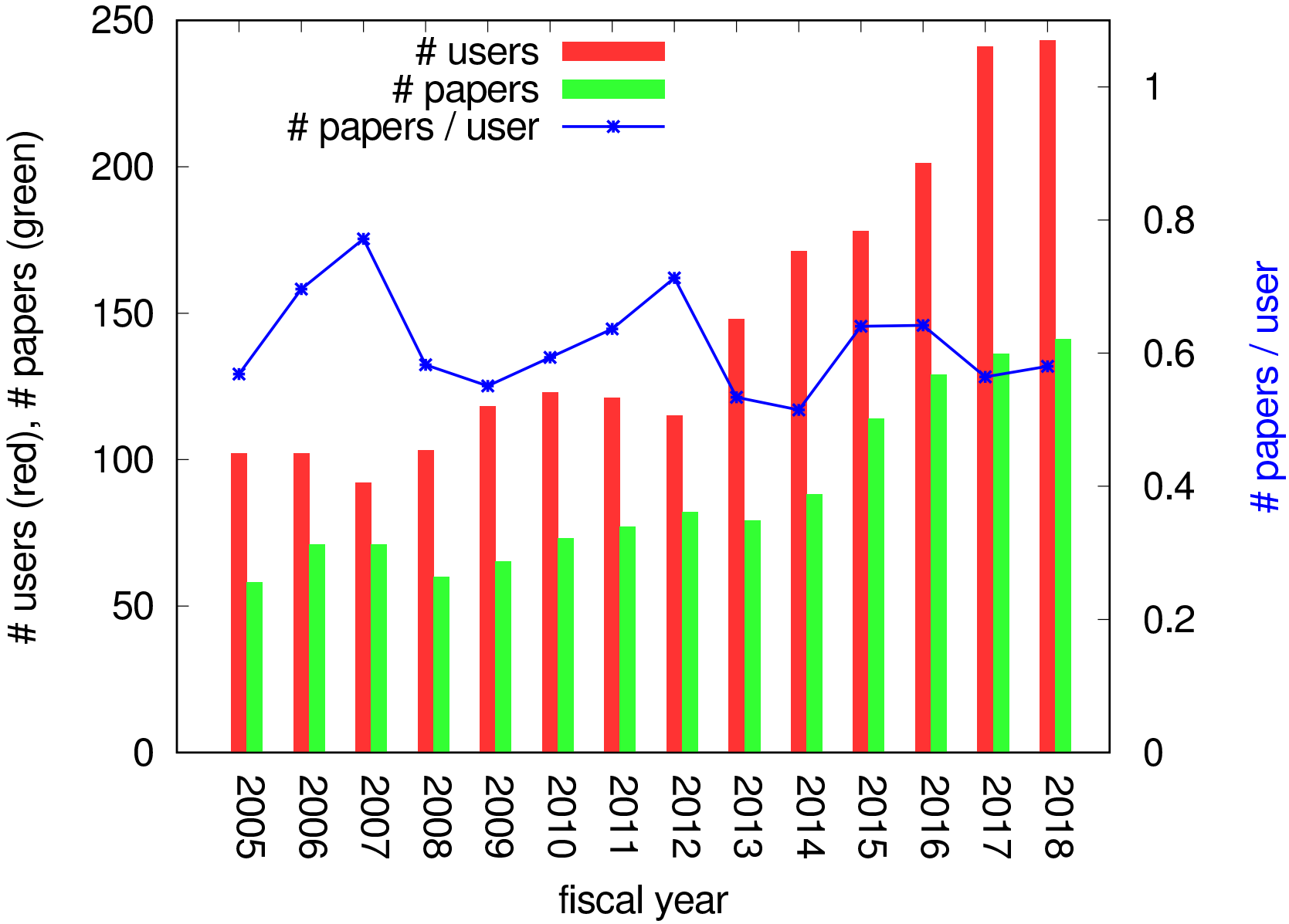
10 Nature/Science papers in 2014-18

FY2018	total	XC50	GRAPE	PC cluster
users	255(30%)	205	5	45
papers	141	109	1	40

(): % of students

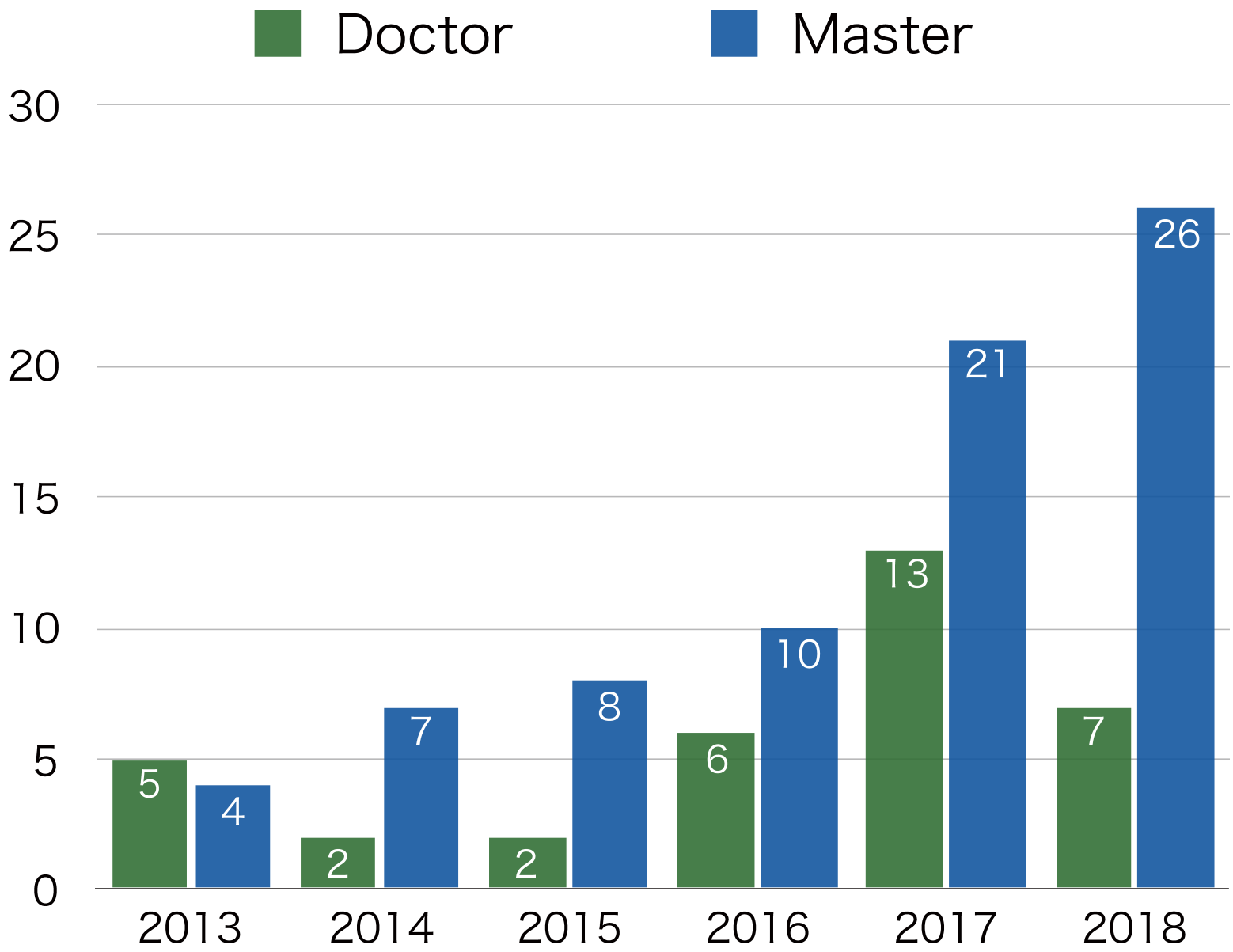
Both numbers of users and papers increase with time!

Number of Users and Publications



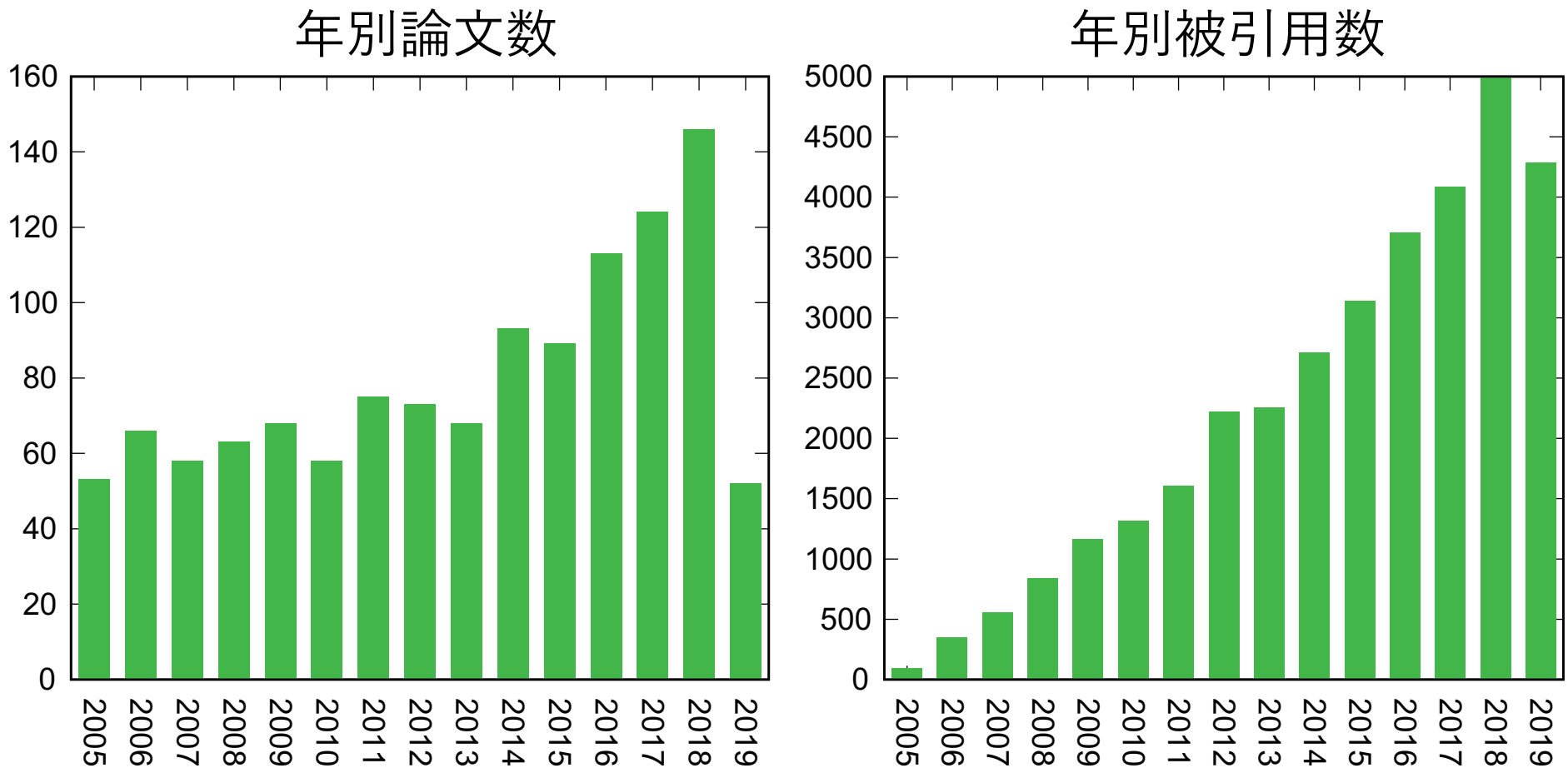
# of papers/user is constant

Thesis



More and more students are using CfCA!

Citation



Average Citation Count: 28

(Web of Science 2019.12.5)

School and Meeting

FY2019

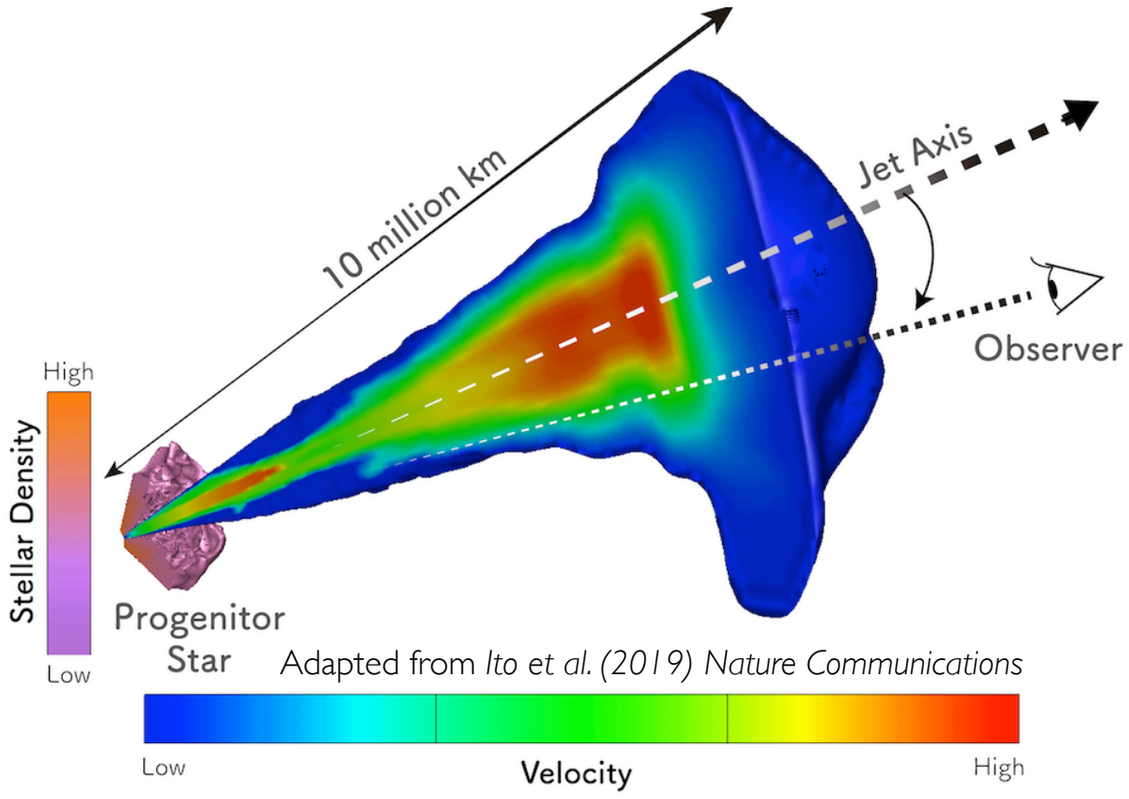
Name	Date	# of participants
XC50 beginner course	10.8	5
iSALE school	7.30-8.1	12
Users' meeting	1.20-21	-
N-body school	1.22-24	-
SPH school	12.23-24	-

Increasing users and fostering next generations

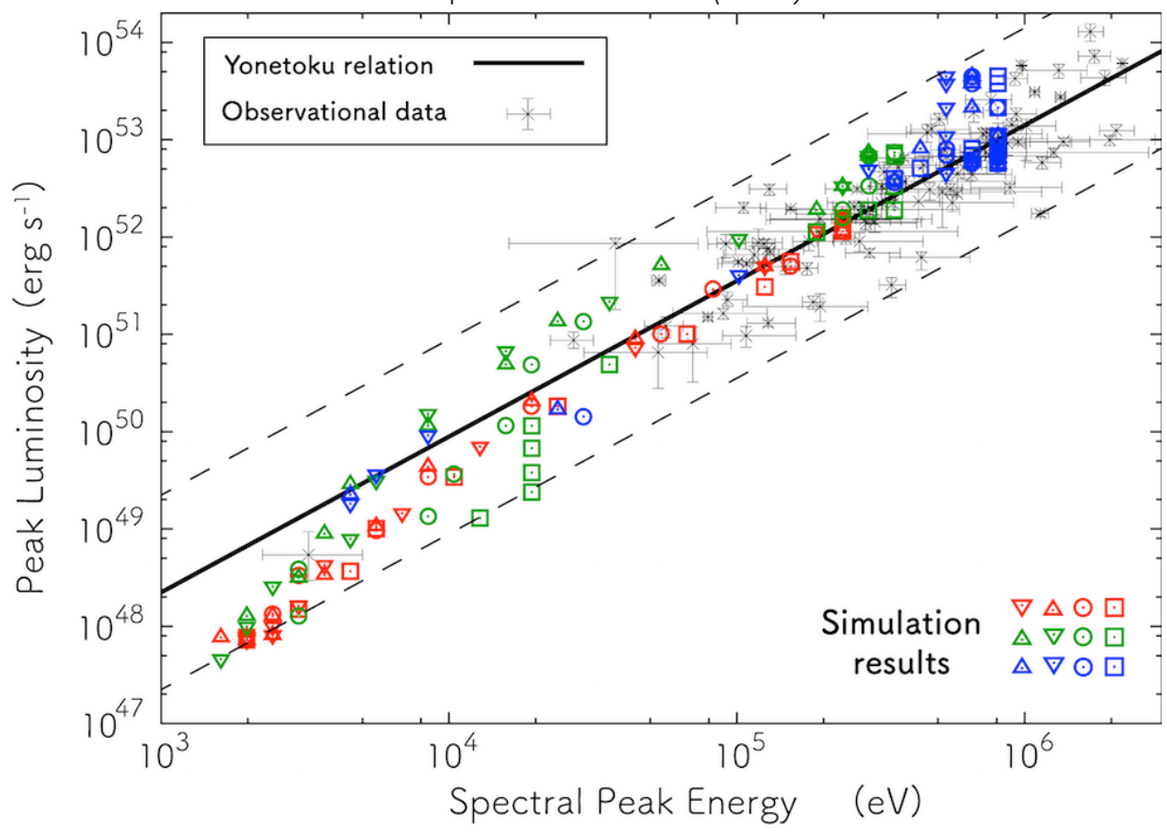
Center for Computational Astrophysics

The photospheric origin of the Yonetoku relation in GRBs

April 3, 2019 Press Release
Ito et al. (2019), Nature Communications
Result of ***ATERUI & ATERUI II***



Adapted from *Ito et al. (2019) Nature Communications*



- There was no consensus on the emission mechanism of long GRBs.
- **ATERUI & ATERUI II** performed 3D hydrodynamical simulations and post-process radiation transfer calculations of photospheric emission from a relativistic jet.
- **ATERUI**'s simulations reproduced an empirical law from observations, the "Yonetoku relation", correlations between the peak energy of gamma-ray spectrum and the luminosity of photospheric emission. It is a natural consequence of viewing angle.
- This result strongly suggests that the photospheric emission is the dominant component of the prompt phase of GRBs.

Center for Computational Astrophysics

Black Hole Shadow Simulation Around M87*

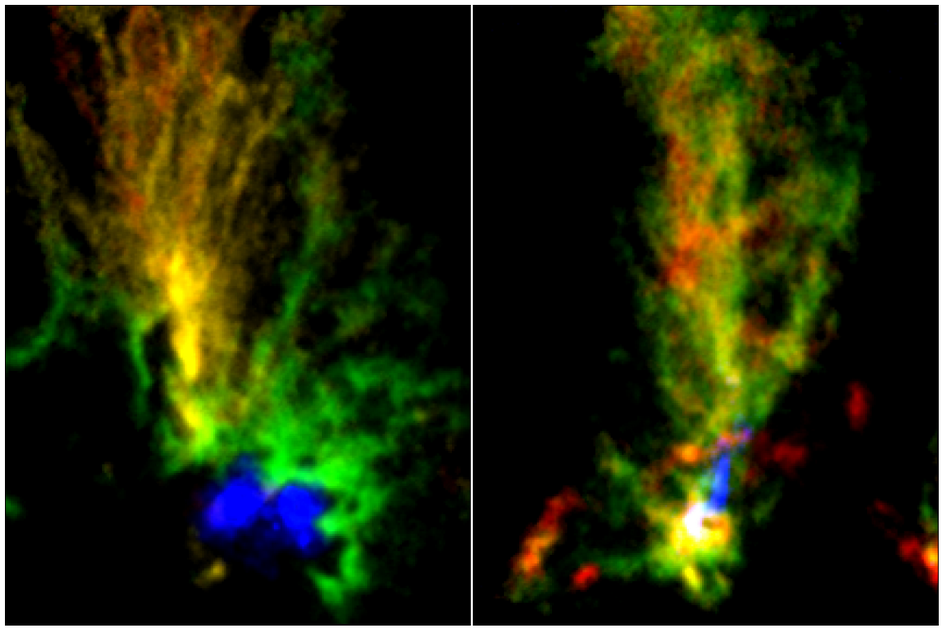
April 10, 2019 Press Release
EHT Collaboration (2019), ApJL
Using ***ATERUI II*** *by* ***Tomohisa Kawashima (CfCA)***

Credit: Tomohisa Kawashima, Masanori Nakamura

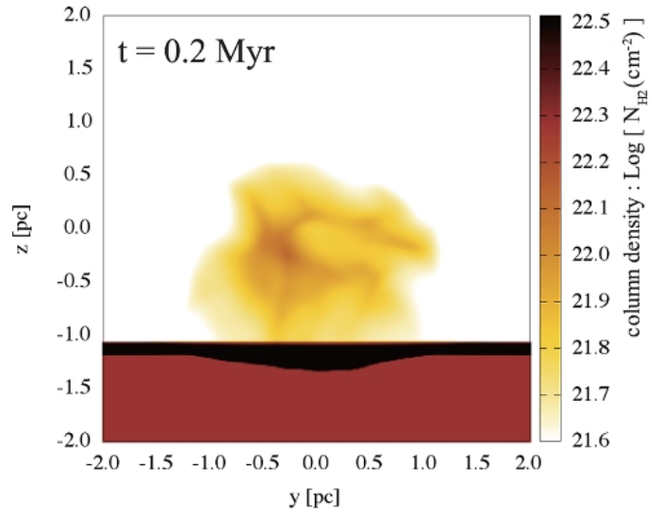
- **ATERUI II** performed general relativistic ray-tracing radiative transfer simulations of the supermassive black hole at the center of M87.
- **Tomohisa Kawashima** at CfCA, a member of the EHT theoretical and simulation working group, developed an advanced and accurate general relativistic radiative transfer code used in one of the EHT simulations, and compared the simulated models with the observational data.
- In addition, the Japan-Taiwan simulation team including **Kawashima** also calculates the general relativistic magneto-hydrodynamics and radiative transfer (by **ATERUI II**) to explain the observational features including jet from M87's black hole.

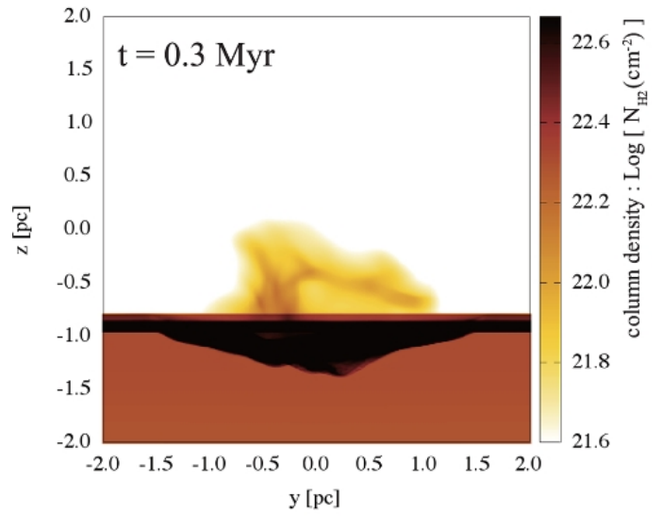
Formation of Massive Molecular Filaments and Massive Stars Triggered by a Shock Wave

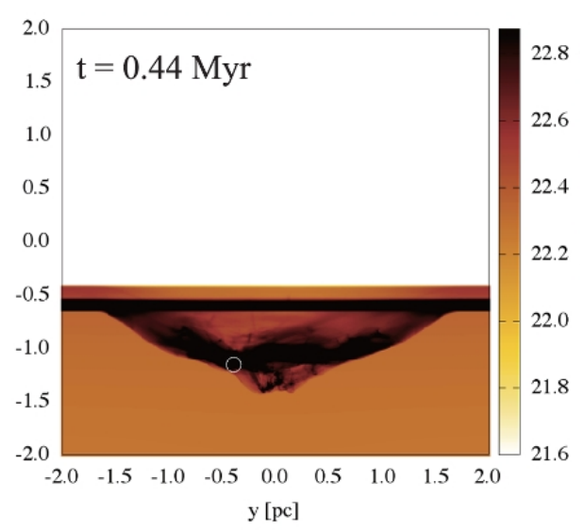
- **ATERUI** calculated long time evolutions of shock compressions caused by cloud-cloud collisions with isothermal magneto-hydrodynamics simulations.
- Simulations show that the shock compression of a turbulent inhomogeneous molecular cloud creates massive filaments, which lie perpendicularly to the background magnetic field.
- ALMA found very similar structures in the LMC (Fukui et al., 2019 & Tokuda et al., 2019). They interpreted that these features are the evidences of cloud-cloud collisions in the LMC.

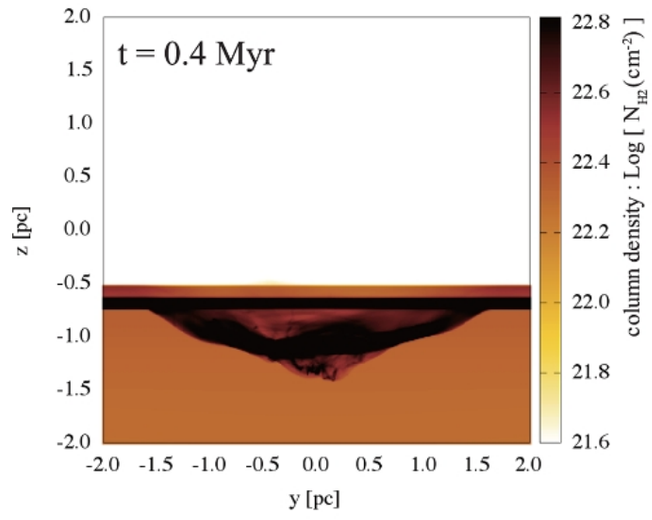


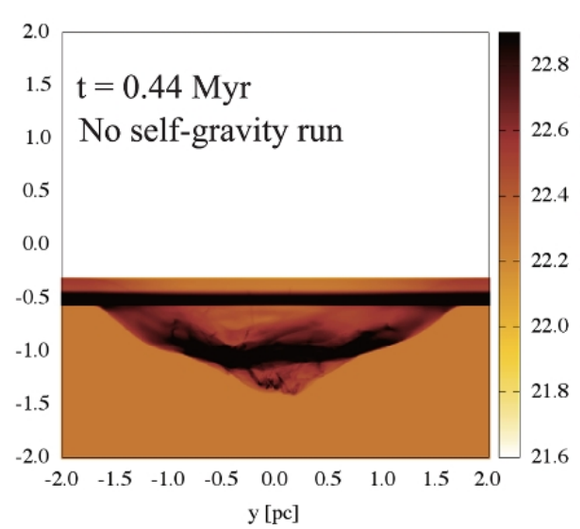
Credit: ALMA (ESO/NAOJ/NRAO)/Fukui et al./Tokuda et al./ NASA-ESA Hubble Space Telescope











Inoue et al. (2018), PASJ
*Result of **ATERUI***
Related researches were released in November, 2019.

Uchuu simulation

2018,19 XC-S

PI T. Ishiyama (Chiba Univ)

z=0.0

$N = 12{,}800^3 = 2{,}097{,}152{,}000{,}000$

$L = 2.0$ Gpc/h

$m = 3.27 \times 10^8$ Msun/h

Planck Cosmology

Data size
(50 snapshots):
Raw particle : ~2PB
Merger tree: ~50TB

One of the largest
cosmological
N-body simulation
in the world

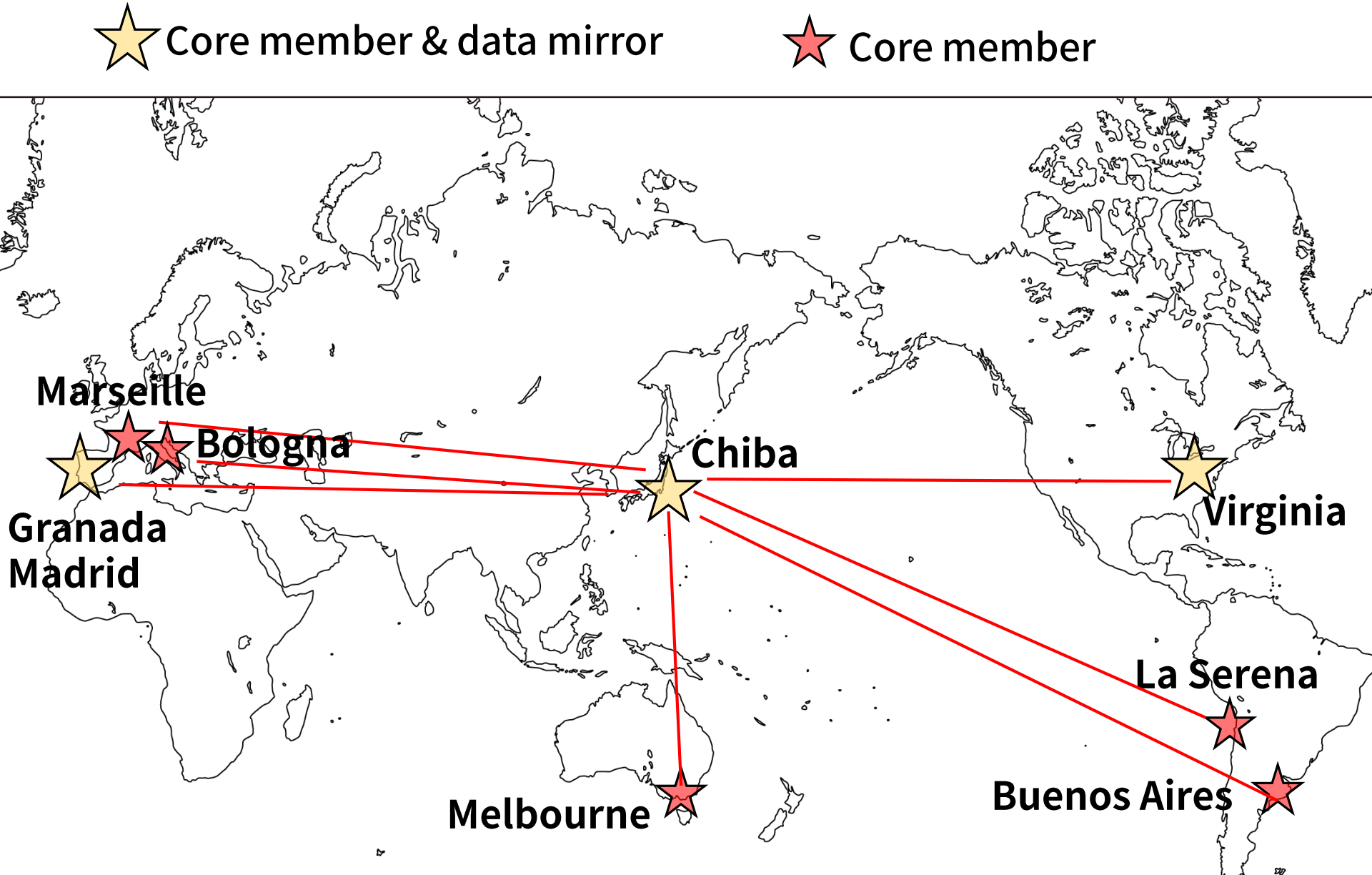
64 x larger volume,
3 x better mass res,
compared to
Millennium Run
(WMAP1 cosmology)

Gpc scale mock galaxy/AGN catalogs

- Ongoing/future wide/deep surveys (e.g., HSC, PFS) give extremely large dataset of galaxies/AGN
  - Survey areas are over 1Gpc
  - bright AGNs at high redshift is rare ($\sim 10^{-6}$ Mpc^{-3})

- **Large mock catalogs (Gpc scale)** are needed to compare with each other
  - Applying semi analytic galaxy/AGN formation model to huge cosmological N-body simulations
  - We are planning to make catalogs publicly available
    - DR1: April 1st, 2020, dark halo catalogs
    - DR2: Q4 2020, mock galaxy/AGN catalogs

Big international collaboration based on simulations conducted on Aterui-II



Scientific targets

- Thanks to large volume, we can study the formation and evolution of a number of objects at high-z probed by HSC and PFS

- Origin of AGNs/QSOs and co-evolution with galaxies
- Emission line galaxies and large scale structures
- Statistics of galaxy clusters and proto-clusters
- Cosmological probes including weak lensing and galaxy surveys
- and many other

FY Goals (3) & (5)

Goal (3)

- 天文学における計算科学発展の観点から、関係コミュニティとも意見交換しながら国立天文台における将来のスーパーコンピュータのあり方についての検討を継続する。

Goal (5)

- 計算基礎科学連携拠点やHPCIコンソーシアムでの活動を通し、日本の数値天文学業界の意見集約窓口として政府機関などとの交渉や連絡・広報業務を実施する。

Results

- Discussion with simulation astronomy community
- Discussion with HPC community

Keeping discussion on future supercomputers

Collaboration within NAOJ

TMT

- Usuda: Seismic isolation analysis of TMT by ANSYS (ATERUI II)

HSC/Subaru

- Development of analysis cluster for the SSP data

Collaboration proposals are welcome!

FY Goal (4)

Goal (4)

- 4D2U デジタル宇宙プロジェクトに関する活動を継続して行う。

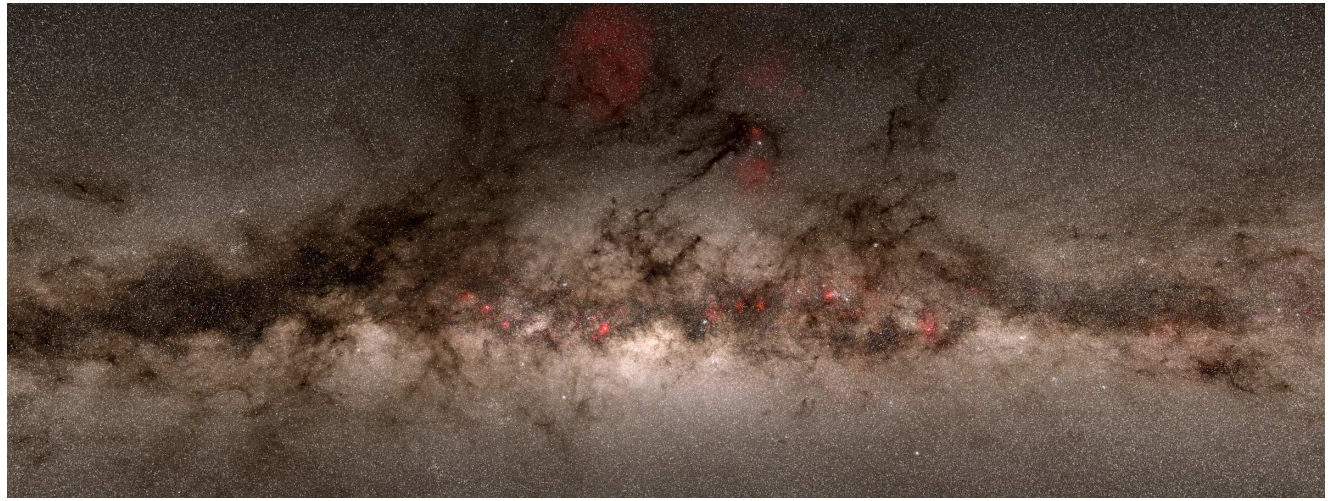
Results

- “Mitaka” update
- New dome movies

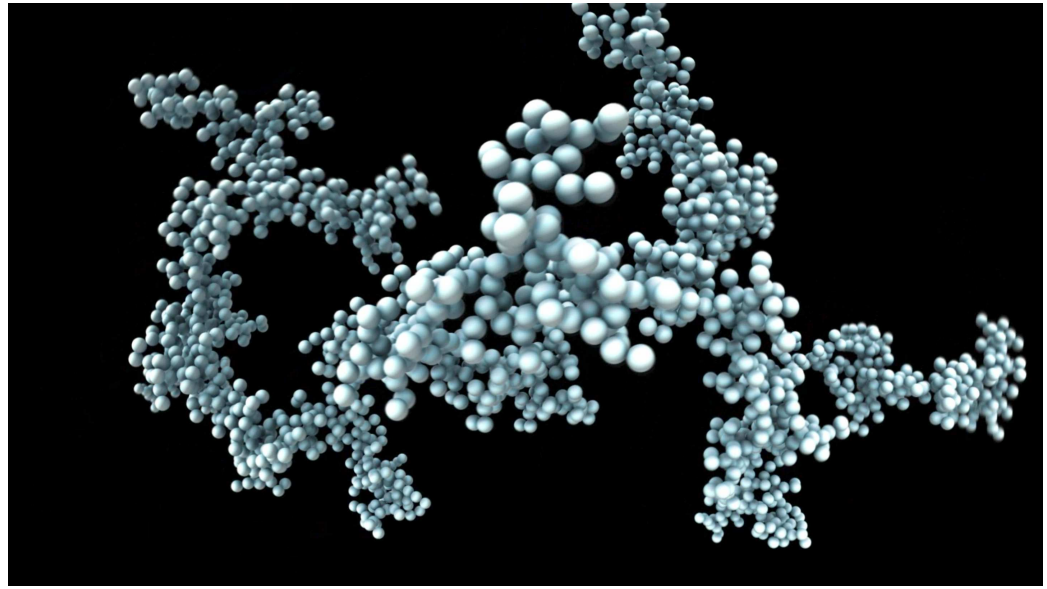
More realistic and beautiful 4D2U contents!

New Contents

Milky Way from GAIA (Mitaka)



Growth of Dust Aggregates (Dome Movie)



Plan for FY2020

DIY System Reinforcement

- File Server
- GRAPE $\rightarrow$ GPU
- PC Cluster
- ...

Collaboration with Fugaku 富岳

- Star formation
- Supernova explosion
- Formation of planetary systems
- ...

4D2U

- “Mitaka” update
- Movies (Relativistic Jet, Ryugu Formation, ...)