Center for Computational Astrophysics

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CfCA Members

2025.12.4

Assignments

1. CfCA の設置目的と現在の体制
2. これまでの活動状況
3. スパコン開発の世界的情勢および post 富岳時代の CfCA のスパコンに対する長期的ビジョン
4. 計算機資源の整備に関する (SAC などを通じた) ユーザーからの要求と将来計画 (SRM 掲載計画提案書との重複は問題ありません)
5. 計算機資源の整備や運営体制についての長期的ビジョン
6. 国立天文台の他プロジェクトへの関与の状況 (あれば)
7. サイエンスロードマップ (11 月初旬頃に公表予定) に対するご意見 (あれば)

Outline

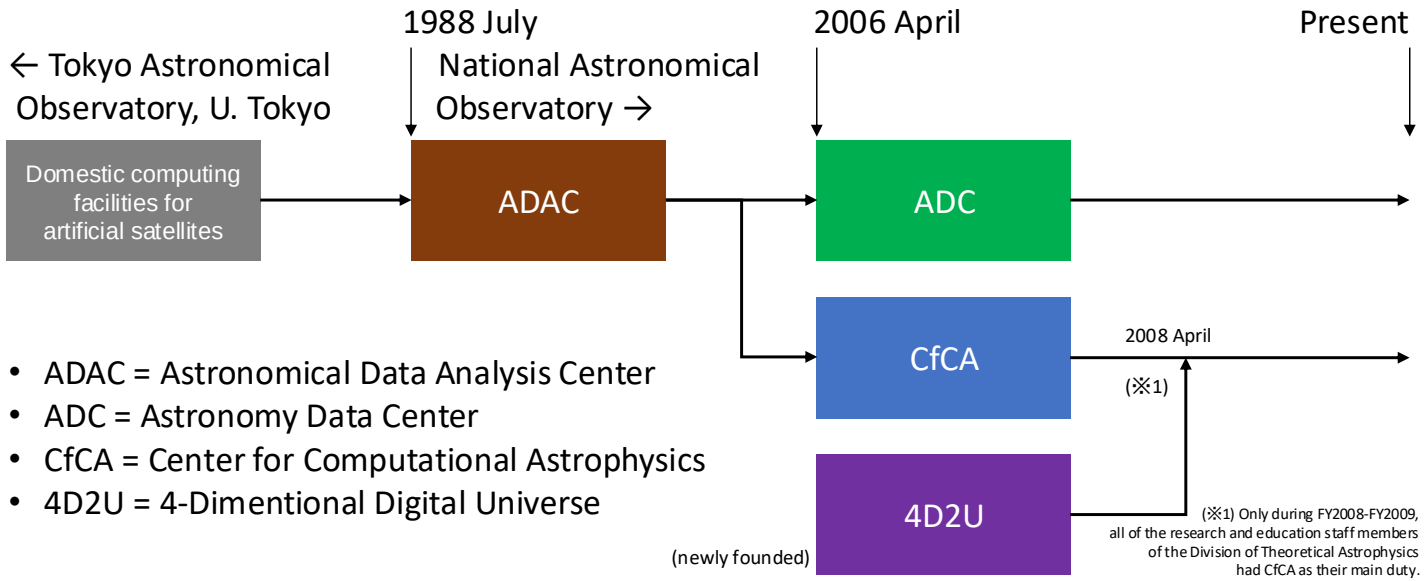
Center for Computational Astrophysics: Overview

- assignments: (1), (2), (6)

Responses to Individual Assignments

- assignments: (3), (4), (5)

Brief History to Date



Center for Computational Astrophysics (CfCA)

- Established in 2006 as a C-type project when ADAC was split into ADC and CfCA
- Used to be a ”center” (ADAC) until 2006
- Proposed names
  - English: Center for Computational Astrophysics
  - Japanese: 計算科学センター

Scientific Goals and Missions (1)

Purpose

- The Center for Computational Astrophysics (CfCA) promotes computational astrophysics to explore the Universe as a Center of Excellence (COE) of this research area in Japan.

Missions

The missions of this project are:

1. to operate diverse computing resources, provide them to the Japanese astronomy community on an open-use basis, and support the progress of research activity in astronomy and astrophysics;
2. to produce first-rate research achievements in the area of computational astrophysics; and
3. to develop cutting-edge contents with astronomical data, and publicize the latest achievements in astronomy.

Scientific Goals and Missions (2)

Primary Scientific Goals

The primary scientific goals of this project are:

1. maintain stable operation of the open-use computing facilities, and serve as a COE for this research field in Japan;
2. carry out research and development of the hardware/software dedicated to computational astrophysics, and obtain a substantial amount of first-rate academic achievements in astrophysics; and
3. develop cutting-edge contents for the advanced 4-Dimensional Digital Universe (4D2U) program for visualization of astronomical data.

Main Operation Members

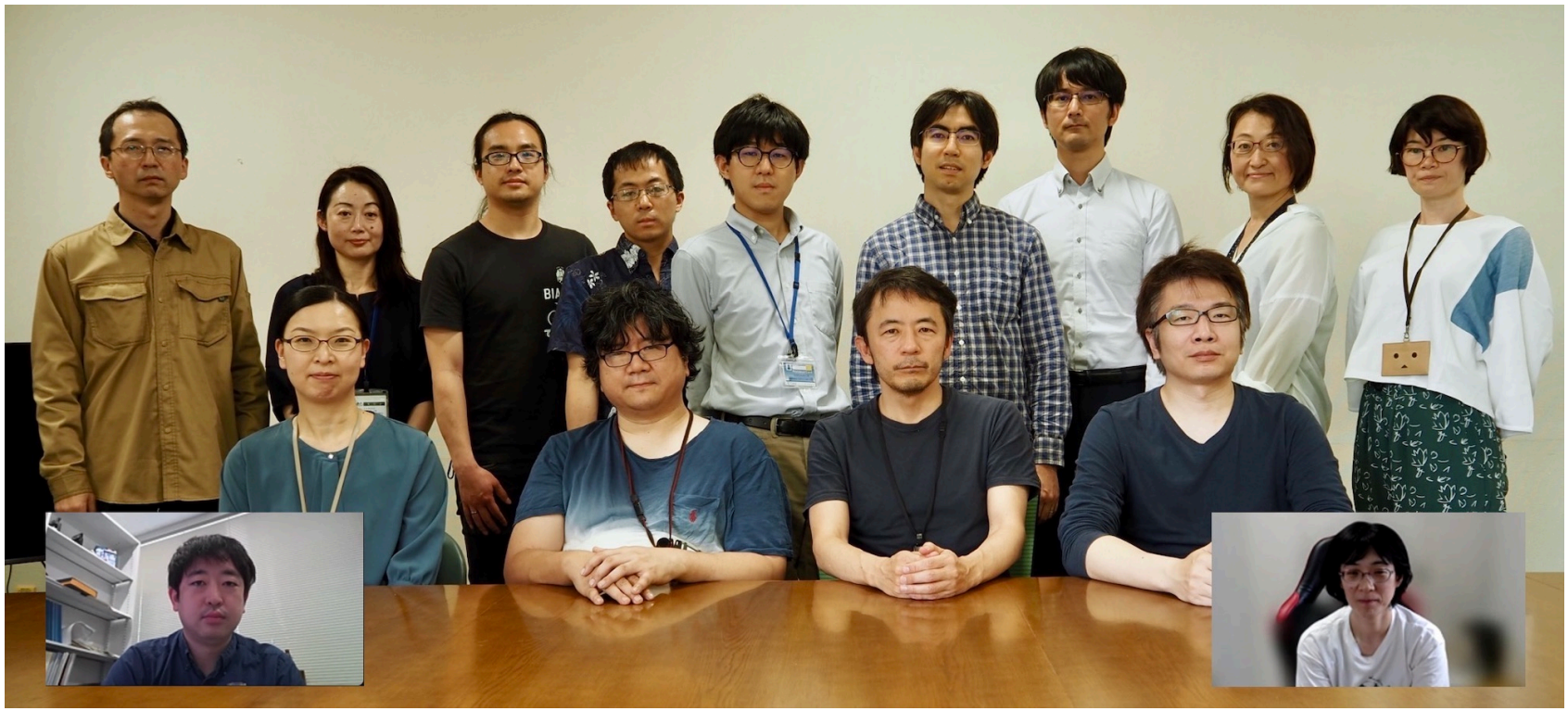
15 Members ($\simeq$ 10 FTE)

- Kokubo, Takiwaki, Ito, Iwasaki
- Tominaga, Machida, Moriya (10% from DoS)
- Fukushi, Hohokabe
- Ideguchi, +2 (50%)
- Kano, +1
- Masuyama
  attending weekly operation meeting

Issue

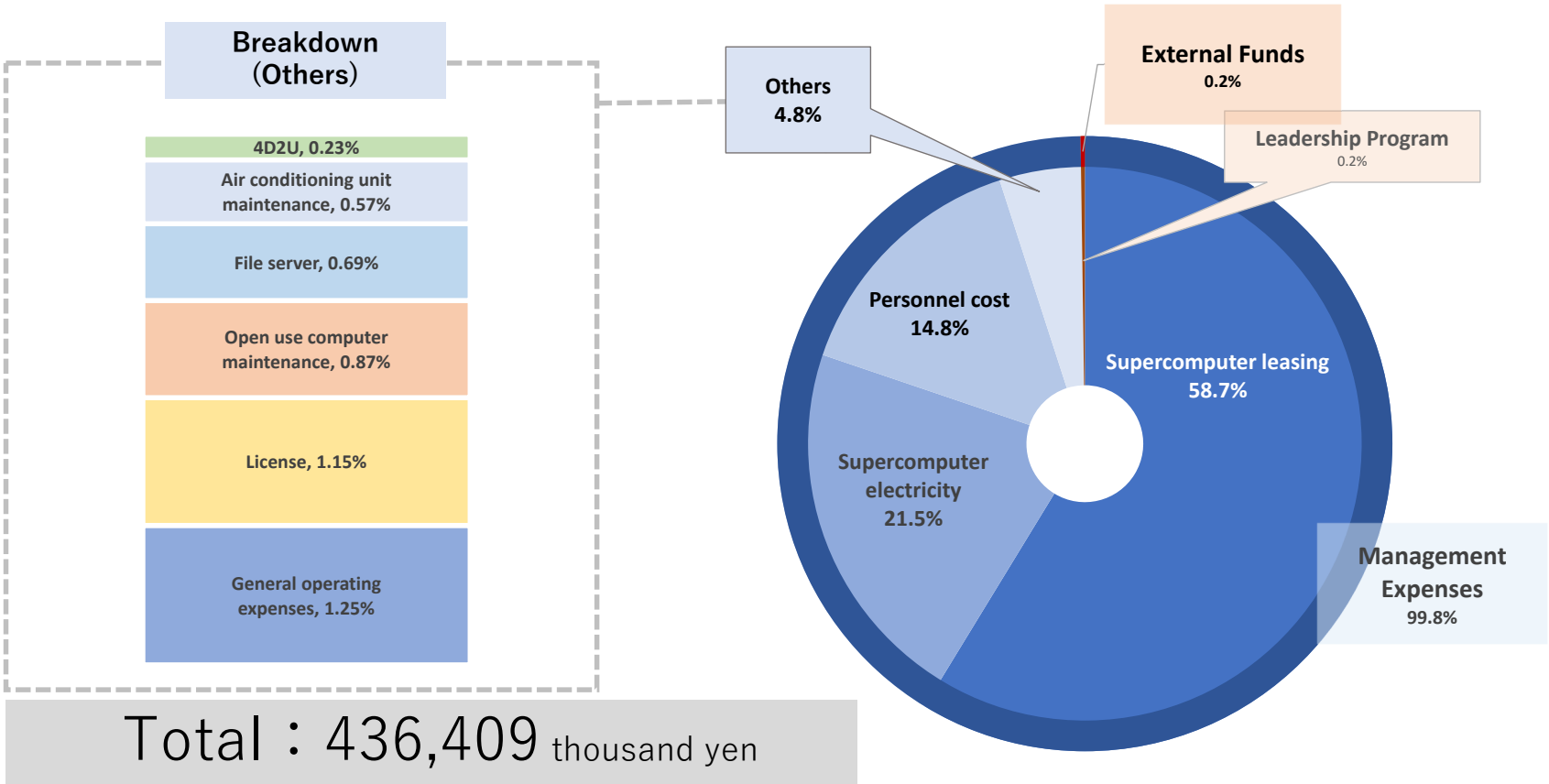
- No engineer is assigned to CfCA full-time. Operations rely on partial FTEs (Shizugami/ALMA 12%, Takahashi/Mizusawa 5%)

Main Operation Members



2023.5

FY2025 Budget Profile



Total：436,409 thousand yen

Present Open-Use Computer Facilities

CfCA Open-use Computer System

Last update: December 2 2025

HPE Cray XD2000 "ATERUI III"

Numerical simulation using over 40 cores

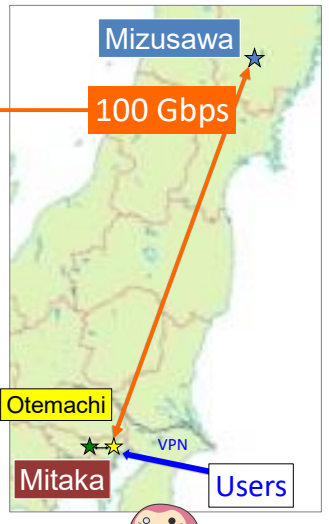
Theoretical Peak Performance : 1.989 Pflops
Total number of nodes : 288 (System M: 208, System P: 80)
Total number of cores : 32256
Specs for each node
System M : Intel Xeon CPU Max 9480 (56 cores, 1.9 GHz, 3.4 TFlops) x 2
System P : Intel Xeon Platinum 8480+ (56 cores, 2.0 GHz, 3.6 TFlops) x 2
Memory: 67.6 TB (System M: 128GB/node, System P: 512GB/node)

/home 100TB (Lustre)

/work 14.6PB (Lustre)
DDN EXA Scaler

Login node x 2
Intel Xeon 8480+ , 256GB

CfCA HPC network



GPU clusters

Computer with calculation accelerator

AMD EPYC 7742 (64 cores) x 2, NVIDIA A100 SXM 40GB 8 units / node, 2 nodes
AMD EPYC 7402P (24 cores) x 1, NVIDIA A100 PCIe 40GB 4 units / node, 2 nodes
AMD EPYC 7453 (28 cores) x 1, NVIDIA A100 PCIe 80GB 4 units / node, 2 nodes
AMD EPYC 7443 (24 cores) x 1, NVIDIA A100 PCIe 80GB 1 unit / node, 1 node

Analysis servers

Analysis and visualization of simulation data

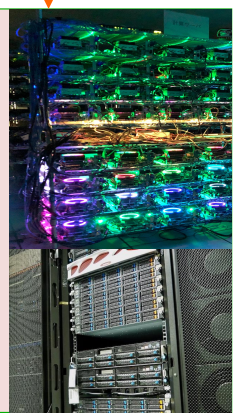
an[09-14] Common Specs for each server
10Gbps or 25Gbps
Total number of cores : 216
Memory: 1 TB/node
an[09-12] Intel Xeon CPU E5-2697 v4 (2.3 GHz,18 cores) x 2
an[13, 14] AMD EPYC 7713 64 core x 1

GP-PC (General-purpose PCs)

Numerical simulation using 1 – 4 or 48 cores

Total number of nodes : 114
Total number of cores : 2272
Memory : 4 GB/core (Average value of all nodes)
AMD Ryzen9 3950X (3.5GHz, 16(32) cores),128GB (29 units)
AMD Ryzen9 3800X (3.9GHz, 8(16) cores), 64GB (11 units)
AMD Ryzen9 3700X (3.6GHz, 8(16) cores), 64GB (30 units)
AMD Ryzen7 5800X (3.8 GHz, 8(16) cores), 64 GB (4 units)
AMD Ryzen7 5700 (3.8 GHz, 8(16) cores), 64 GB (16 units)
AMD Ryzen7 2700X (3.7GHz, 8(16) cores), 64GB (8 units)
AMD Ryzen7 2700 (3.2GHz, 8(16) cores), 64GB (4 units)
AMD EPYC 7713 (2.0 GHz, 64(128) cores), 512 GB (2 units)

Part of former **SPC** (Small Parallel Computers)
Total number of nodes : 11
Total number of cores : 528
Memory : 512 GB/node
AMD EPYC 7402 (24 cores) x 2 / node, 6 nodes
AMD EPYC 74F3 (24 cores) x 2 / node, 3 nodes
AMD EPYC 74F3 (24 cores) x 1 / node, 1 node
AMD EPYC 7443 (24 cores) x 2 / node, 1 node



Storage

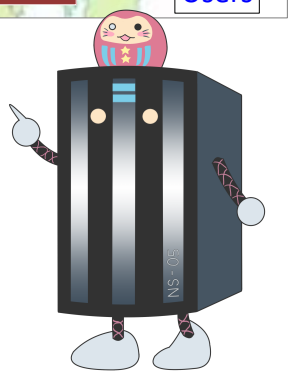
/cfca-work 121TiB
DDN EXAScaler
ES200NVX

/home 349 TiB

File servers

Storage of calculation results

Capacity 11.5 PB
10 GbE, RAID6
120 TiB(cfcafs[26-36],[38-48])
1.6 PiB (fs50, fs51)
2.1 PiB (fs52, fs60)
1.5 PiB (glv0)



Center for Computational Astrophysics

(2025.12)

Not only a supercomputer, but also a simulation infrastructure!

NS-06 ATERUI III (HPE Cray XD2000)

Supercomputer Dedicated to Astronomy

CfCA Open-Use Computer System

Hardware Features

- massively parallel scalar computer (ATERUI series)
- GPU cluster (DIY)
- PC cluster (DIY)
- analysis server (DIY)
- file server (DIY)
- infrastructure dedicated to computational astrophysics

Operation Features

- open for researchers affiliated with Japanese institutions and with degrees from Japanese universities
- single-year individual-based proposal
- peer-review system
- user category $\rightarrow$ unlimited use (not credit-based)
- category for graduate students
- free of charge
- support for publication fee up to JPY 200,000 or 100,000
- user-friendly easy-to-use operation

Roles of CfCA Supercomputer

MEXT HPCI Program

- National Flagship System (NFS) (e.g., Fugaku)
  - cutting-edge simulations
- National Infrastructure System (NIS) (e.g., ATERUI)
  - middle-scale simulations
  - code development
  - education

Tier-based terms (e.g., 第三階層) are no longer used in HPCI community.

Systems are defined by roles: NFS and NIS, and selected by user needs.

Theoretical "Telescope" or "Laboratory"

- high-resolution simulations with realistic physics
  - to predict what we observe
  - to interpret what we observe

Recent Activities (1)

FY2020-2024

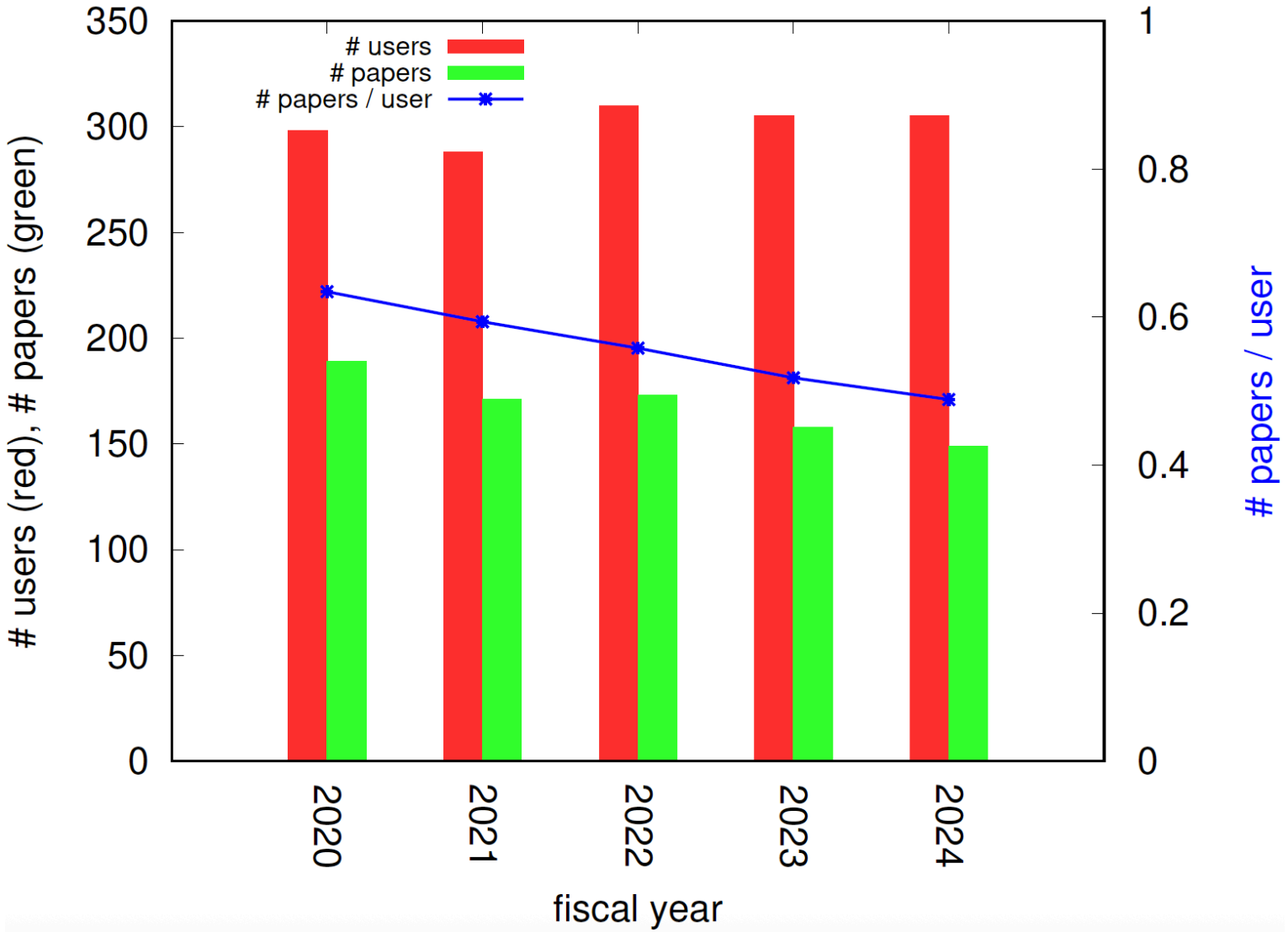
FY	# of users	# of publications	XC-A adoption rate	XC50 operating ratio
2020	298	189	13/63	93%
2021	288	171	16/52	96%
2022	310	173	15/51	95%
2023	305	158	15/38	97%
2024	305	149	14/39	90%

- 14 Nature/Science papers
- 20 press releases
- Average citation per paper: 41.77 (Web of Science 2025.12.1)

FY2024

FY2024	total	XC50/XD2000	GPU	PC cluster
users	305	224/241	21	66
papers	149	122	6	41

Number of Users and Publications

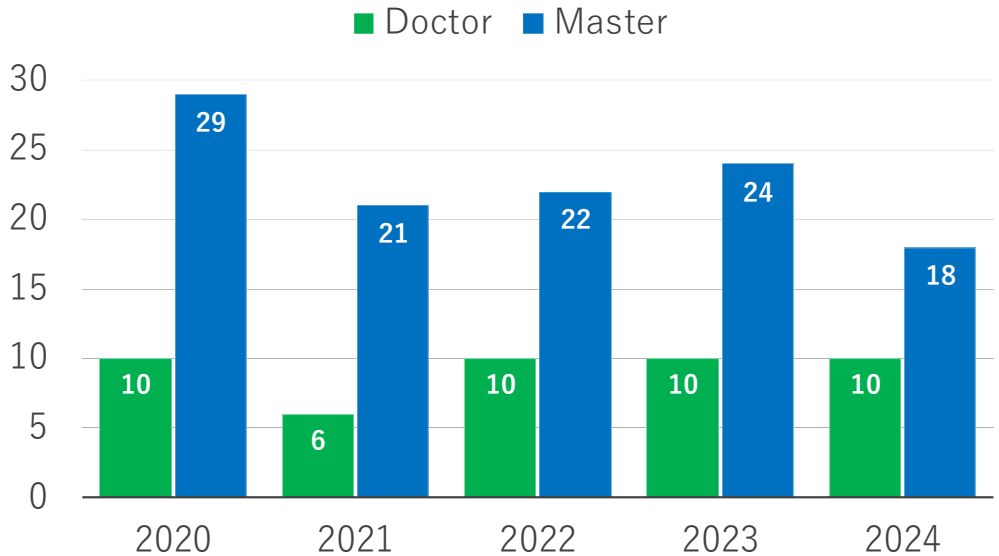


# of papers/user is almost constant

Recent Activities (2)

Graduate Students

- FY2024: 35% are students
- $\simeq 10$ PhD and $\simeq 20$ master theses / year



Schools and Workshops

- parallel computing, GPU computing
- schools for *N*-body simulation, hydrodynamics simulation, collision simulation (iSALE)

Internal Collaborations

- ADC (Subaru HSC), TMT, JASMINE, ...

Item 3

Assignment

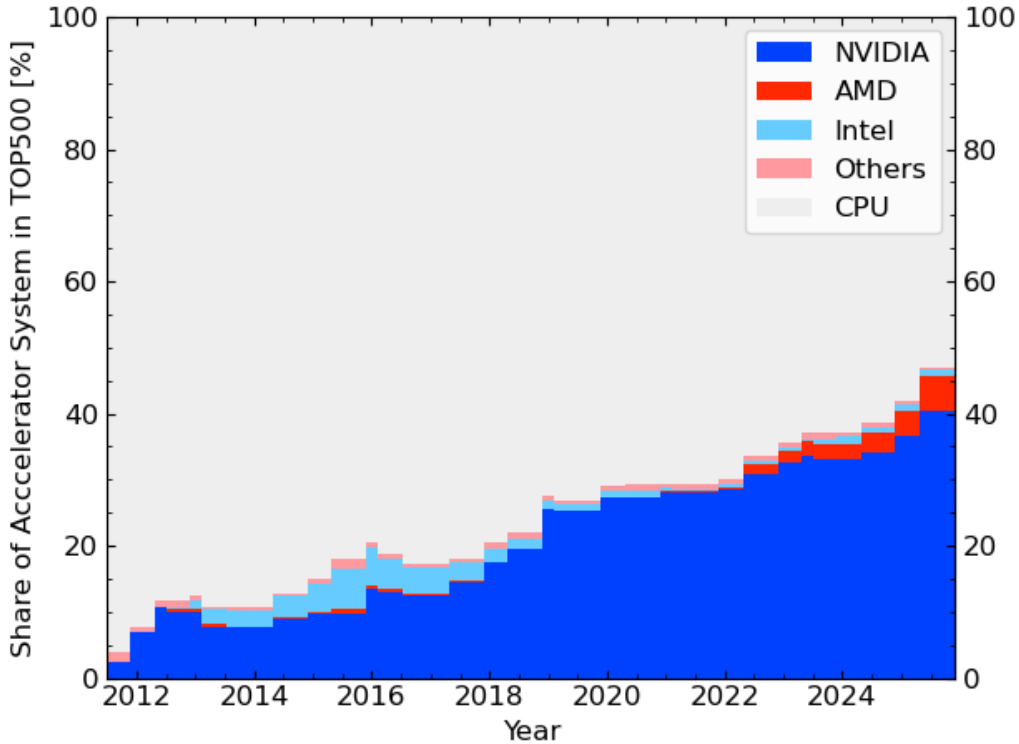
- スパコン開発の世界的情勢および post 富岳時代の CfCA のスパコンに対する長期的ビジョン

Answer

- global trends in supercomputer development
- roles of CfCA in the post-Fugaku era

Global Trends in Supercomputer Development

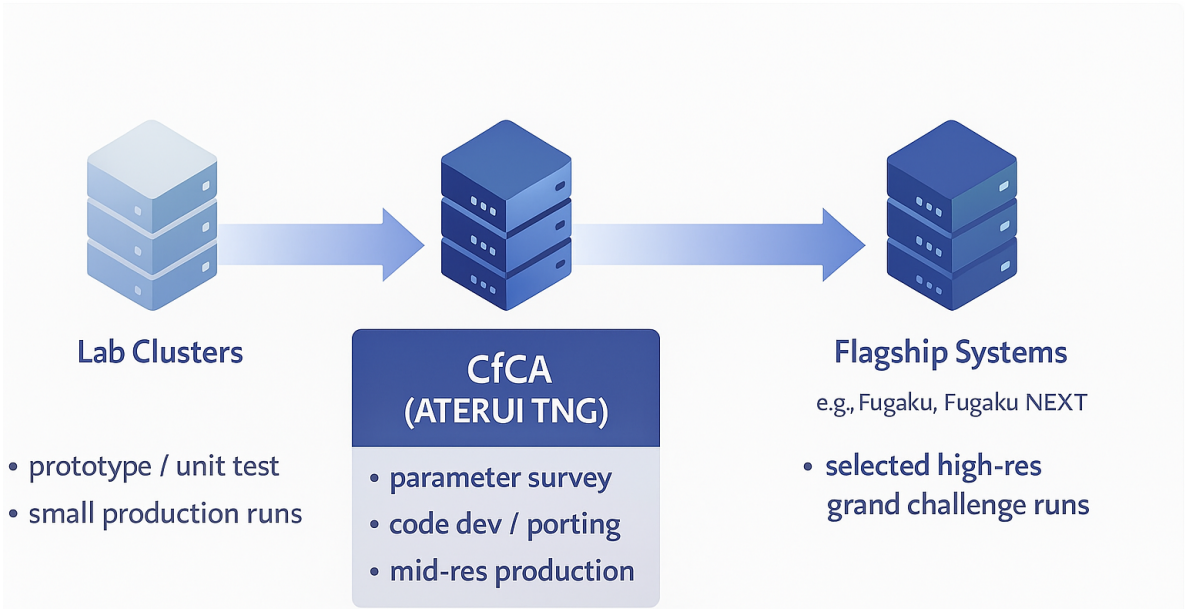
Global Rapid Shift toward GPU-based Computing



- The main challenge is porting the code. The programming model strongly depends on the hardware vendor.
  - NVIDIA remains the most likely main choice. In preparation for future collaboration with Fugaku NEXT, we will promote the use of OpenACC.
  - AMD systems are often cheaper, while code development can become more difficult.

Roles of CfCA in the Post-Fugaku Era

Strengthen the Established Research Flow

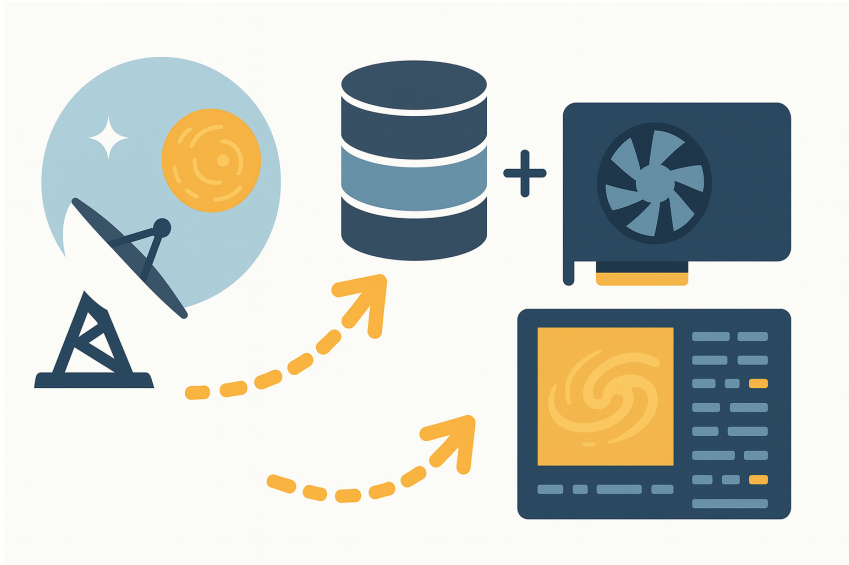


- Middle-resolution multi-parameter surveys reveal qualitative differences, helping us distinguish competing formation and evolution scenarios of astrophysical objects.
- Essential step before high-resolution studies at the optimal parameters, which aim for quantitative precision.
- Offering an ideal environment for porting, code development, and performance tuning providing both CPU and GPU resources.

Roles of CfCA in the Post-Fugaku Era (cont'd)

Facilitate Data-Driven Astronomy

- Providing large-scale storage and GPU-enabled analysis platforms for data-intensive observational astronomy.
- Offering GPU resources and software environments for machine learning in both simulation and observation.
- In collaboration with ADC, CfCA will standardize and share how-tos of storage and GPU software/hardware.



Item 4

Assignment

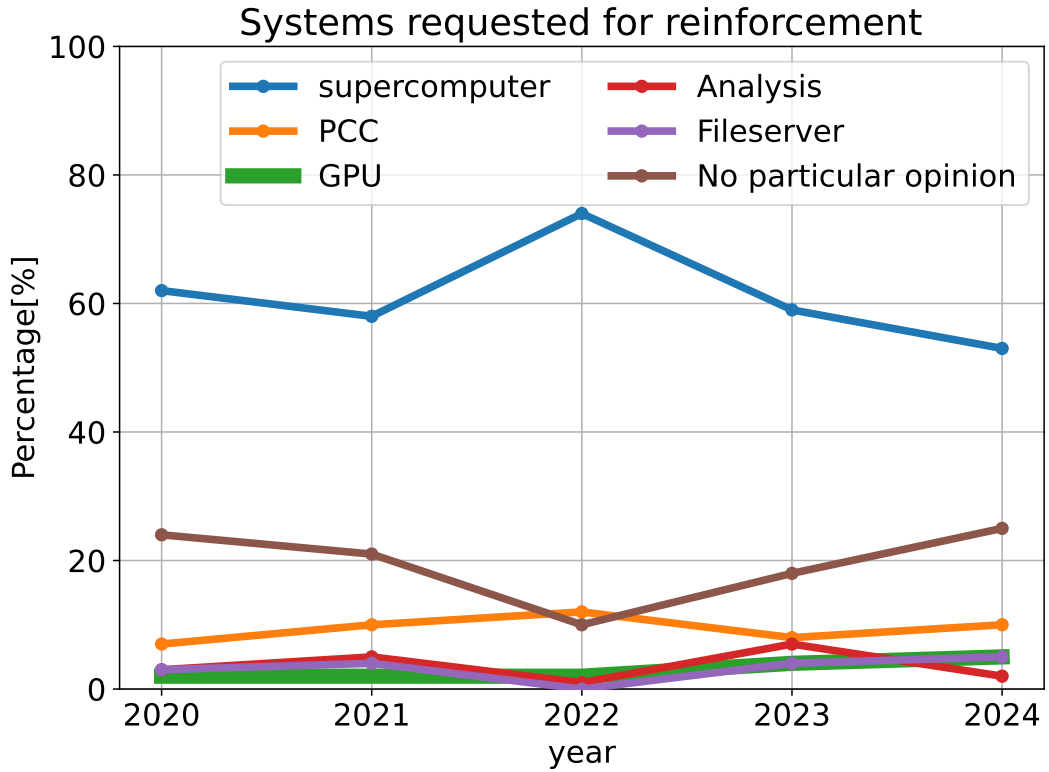
- 計算機資源の整備に関する (SAC などを通じた) ユーザーからの要求と将来計画

Answer

- requests from users and Rirokon
- future plan

Requests from Users

Which systems should be prioritized for upgrades?



- Many requests to enhance the supercomputer resources that individual lab workstations cannot replace.
- Request for the GPU cluster, which is used not only for simulations, but also for observational data analysis and machine learning.
- Small-scale computing resources (PCC), as well as analysis and file servers for data analysis, are also requested.

Support from Rironkon Committee

System Replacement & Maintenance

- Maintain competitive CPU/GPU configurations and high-speed storage through systematic replacement every 5–6 years.
- Secure long-term funding for system upgrades and stable operations.

Enhancing User Support

Continue and expand support for:

- Hands-on workshops on GPU optimization and large-scale parallelization to actively support users in porting their codes to GPUs.
- Development of template codes and shared libraries
- Individual consulting for performance tuning

Future Plan

Exploring the Universe by The Next Generation (TNG) Simulations

- Period: FY2031-
- Goal: Explore the formation and evolution of the universe through astrophysical simulations with TNG supercomputers
- Instrument: ATERUI TNG - supercomputer dedicated to astronomy
  - parallel scalar computer with accelerators?
  - budget: $\gtrsim$ 350 Myen/year?
  - joint procurement with other institutes?
- Key issue: how to leverage GPU and AI

Item 5

Assignment

- 計算機資源の整備や運営体制についての長期的ビジョン

Answer

- future of CfCA as a “center”
- internal and external collaborations

Future of CfCA as a “Center”

- CfCA aims to become a center for a larger variety of computational sciences related to astronomy beyond just conventional numerical simulations.
  - This encompasses broader ingredients, such as big-data science, including machine learning, directly related to observational outcomes.
  - Synergy with the activity of ADC would be huge.
- To function as a true center for computational astronomy, CfCA will continuously operate not only supercomputers but also the diverse computing facilities.
  - Examples: GPUs, small to medium-sized PC clusters, servers for various data analysis, large-scale storage, and high-speed networks connecting them.
- Since 2023, we have proposed to the NAOJ’s executive board to change the Japanese name of CfCA from 天文シミュレーションプロジェクト to 計算科学センター, which is strongly supported by the international review board.

Deeper Collaborations with ADC

- As an effort for this matter, we have allocated a portion of the FTE of staff engaged in technical work at Astronomy Data Center (ADC) to CfCA as well, promoting the sharing of technical knowledge and expertise.
  - ADC and CfCA operate similar computing facilities of similar scale with a certain amount of overlap in their user base.
  - On the other hand, each entity (ADC or CfCA) possesses unique knowledge and equipment. Example: CfCA operates GPUs, while ADC does not do it, although there is a demand for GPUs among ADC's user body.
- Increasing the areas of interaction and integration between ADC & CfCA will undoubtedly generate significant synergy.
- We also welcome collaboration with computer teams from other projects.

NINS-Integrated Computing Center?

- Under the increasingly tight budgetary constraints, it may be necessary for NAOJ to consider integration and joint operation of computing facilities not only inside NAOJ but also with other computer centers within NINS.
- Discussions on this matter have already begun among relevant parties.
- These discussions continue to focus on the specific possibility that the operation of the next-generation supercomputer, to be introduced in several years, may involve joint operation by the entire NINS or multiple institutes under it.

CfCA

Purpose

- The Center for Computational Astrophysics (CfCA) promotes computational astrophysics to explore the Universe as a Center of Excellence (COE) of this research area in Japan.

Missions

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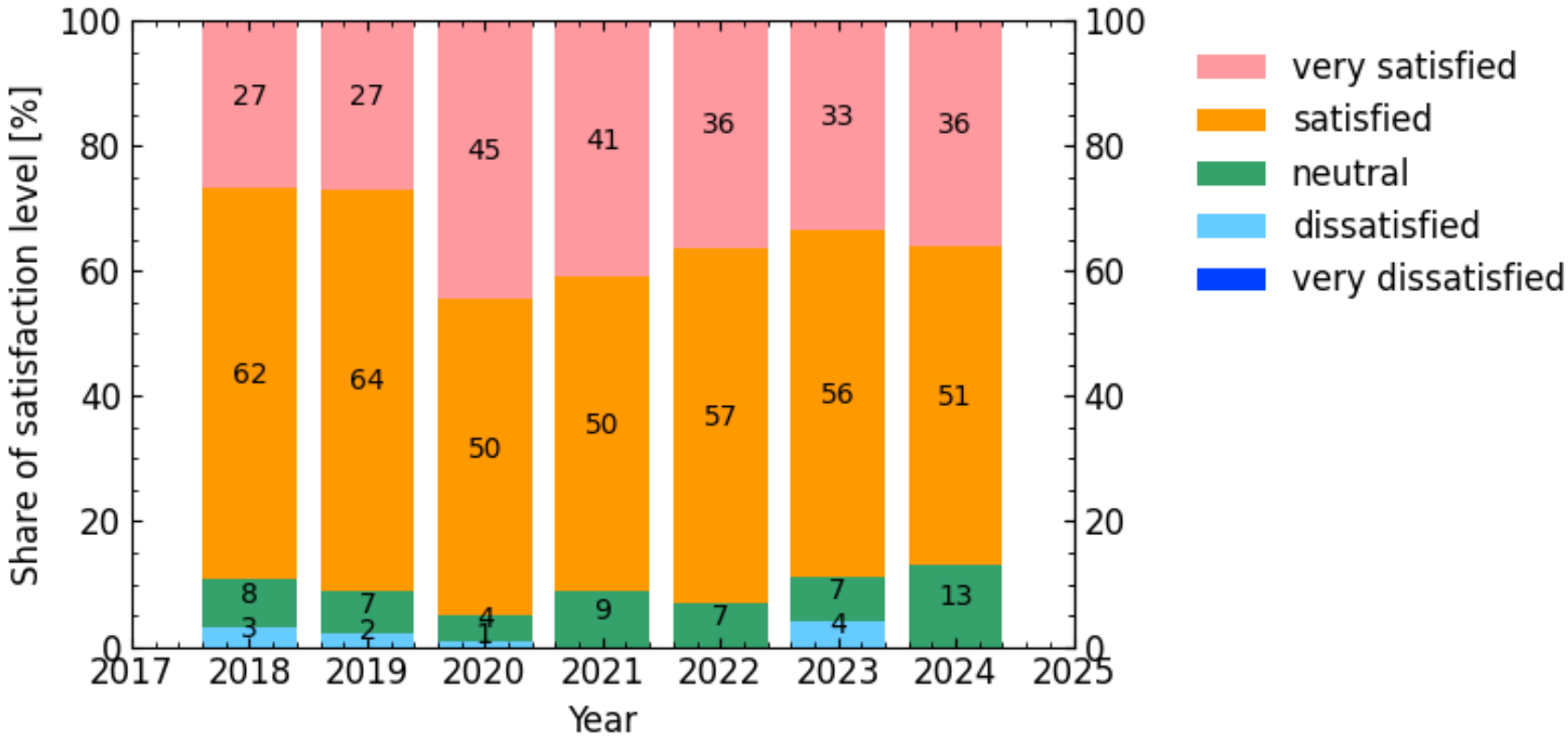
User Survey Results (1)

User Satisfaction

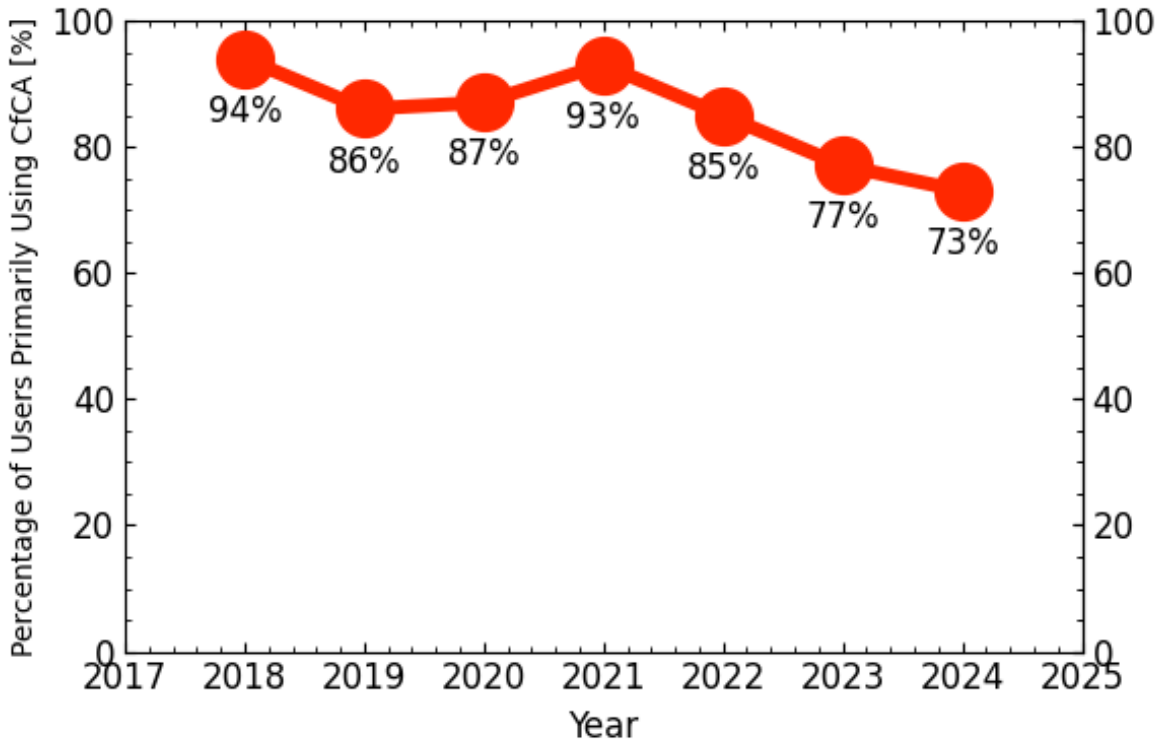
- Most users are satisfied with our services.



User Survey Results (2)

Percentage of Users Primarily Using the CfCA System

- The fraction of users primarily using the CfCA computing system is high, but it is decreasing after FY2021.



Open Source Codes Developed by CfCA

gpuhydro

- Mesh-based 2D/3D MHD code
- Fortran/C++
- MPI, OpenMP(CPU), OpenACC(GPU), OpenMP(GPU)
- The key porting techniques are explained by documentation

CfCA_HydroSchool_FVM

- Mesh-based 1D/2D MHD code
- Fortran
- Visualization by python/gnuplot
- Used in School. 48 page documents are attached

mpi-io

- Mesh-based 3D code
- Fortran
- An example of MPI-IO is shown

These codes are publicly available on CfCA's GitHub

Computational Resources for Astrophysicists

ATERUI III

- 2 Pflops, employing HBM, computational efficiency should be high

Fugaku

- 500 Pflops, ~ 20% is used for particle physics, nuclear physics, and astronomy (2023). Assuming a 7% usage, ~ 35 Pflops

Yukawa-21

- 1.3 Pflops

Miyabi

- Miyabi-G (GPU), 78.8 Pflops, 30% is used for HPCI, the ratio for astronomical use is unknown
- Miyabi-C (CPU), 1.2 Pflops, 30% is used for HPCI, the ratio for astronomical use is unknown

It is risky to compare systems solely on peak performance, as computational efficiency can vary substantially.