Progress report

2D simulation for circus-stellar disks

R. Matsukoba
(astronomical institute)

Theoretical Astrophysics
Tohoku University

GPPU
GRADUATE PROGRAM ON PHYSICS FOR THE UNIVERSE

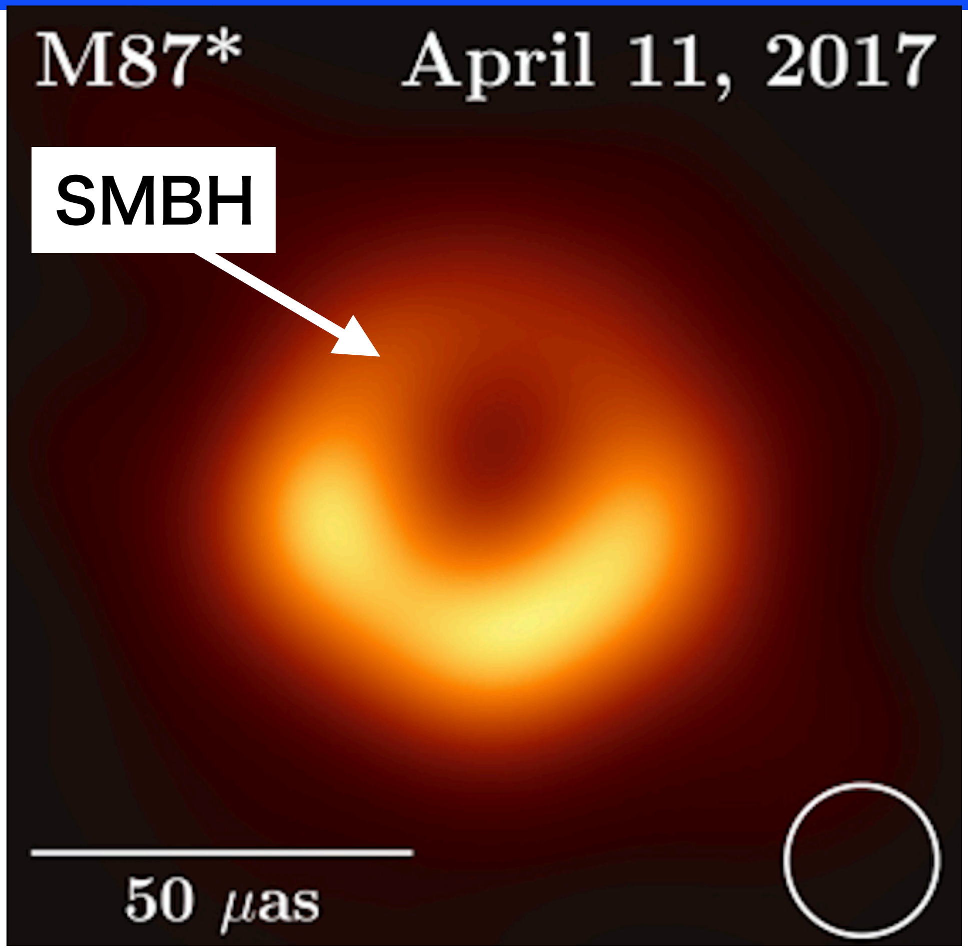
Outline

1. Progress of my study

2. Course status

1. Progress of my study

Supermassive Black Holes (SMBHs)



The Event Horizon Telescope Collaboration

- very massive ~ 10^6 - 10^{10} M_{sun}
- exists in the center of most galaxies
- affects a galaxy evolution

- SMBHs in the early universe

  dozen of SMBHs within 1 Gyr from Big Bang

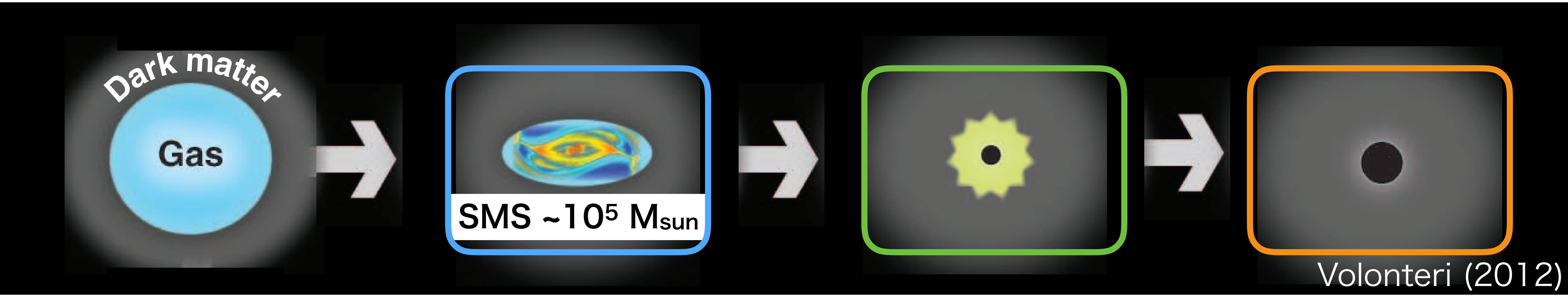
  most distant: 0.7 Gyr after Big Bang with 8×10^8 M_{sun} Bañados et al. (2017)

→ **How did SMBHs form in a short time?**

need massive seed BHs?

Formation scenario

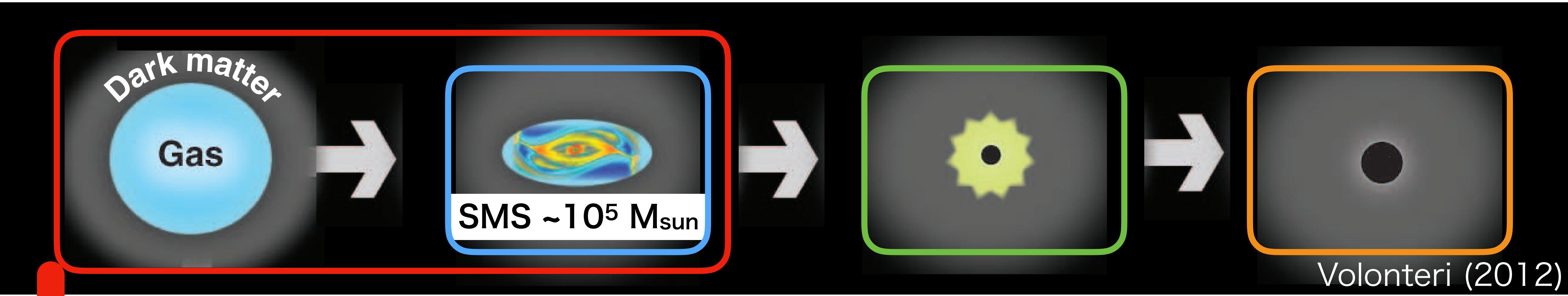
direct collapse (DC) scenario



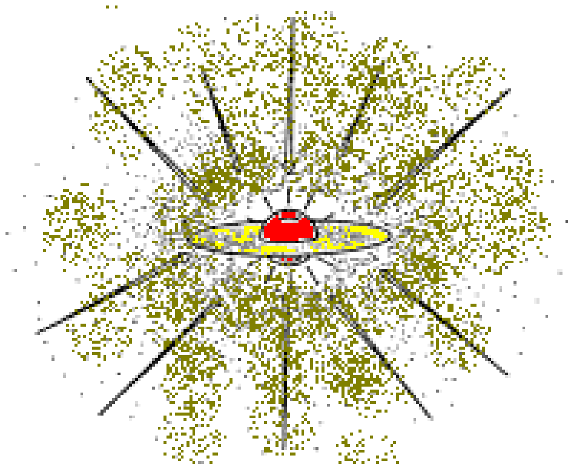
- ✔ Supermassive star (SMS) with 10^5 M_{sun} forms.
- ✔ SMS collapses into a black hole (BH) by GR effect.
  The black hole with the same mass as SMS is left.
- ✔ The BH grows by accretion and merger.

Formation scenario

direct collapse (DC) scenario



- ✔ Supermassive star (SMS) with 10^5 M_{sun} forms.
- ✔ SMS collapses into a black hole (BH) by GR effect.
  The black hole with the same mass as SMS is left.
- ✔ The BH grows by accretion and merger.



→ To form SMS requires very rapid accretion rate $> 10^{-1}$ M_{sun} yr^{-1}

High accretion-rate disk tends to be gravitationally unstable

Our previous work

We study the structure of circum-stellar disks

with detailed treatment of **chemical** and **thermal** processes.

➡ **If $\dot{M} > 0.1\ M_{\odot}\ \mathrm{yr}^{-1}$, disk fragmentation occur.**

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **484,** 2605–2619 (2019) doi:10.1093/mnras/sty3522
Advance Access publication 2018 December 31

Gravitational stability and fragmentation condition for discs around accreting supermassive stars

Ryoki Matsukoba,[1★] Sanemichi Z. Takahashi ,[2,3] Kazuyuki Sugimura[1] and Kazuyuki Omukai[1]

[1] *Astronomical Institute, Tohoku University, Aoba, Sendai, Miyagi 980-8578, Japan*
[2] *Department of Applied Physics, Kogakuin University, Nakano, Hachioji, Tokyo 192-0015, Japan*
[3] *National Astronomical Observatory of Japan, Osawa, Mitaka, Tokyo 181-8588, Japan*

published in MNRAS

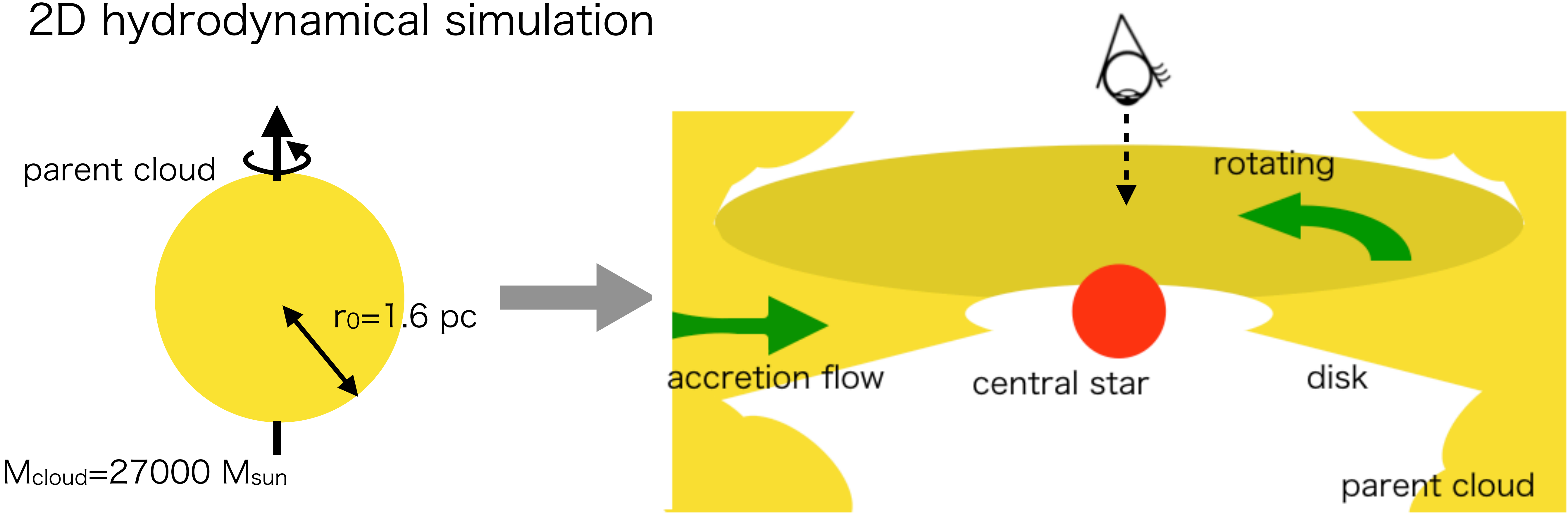
last December

We need to study the circum-stellar disk with time variation

and fragment evolution.

Numerical model

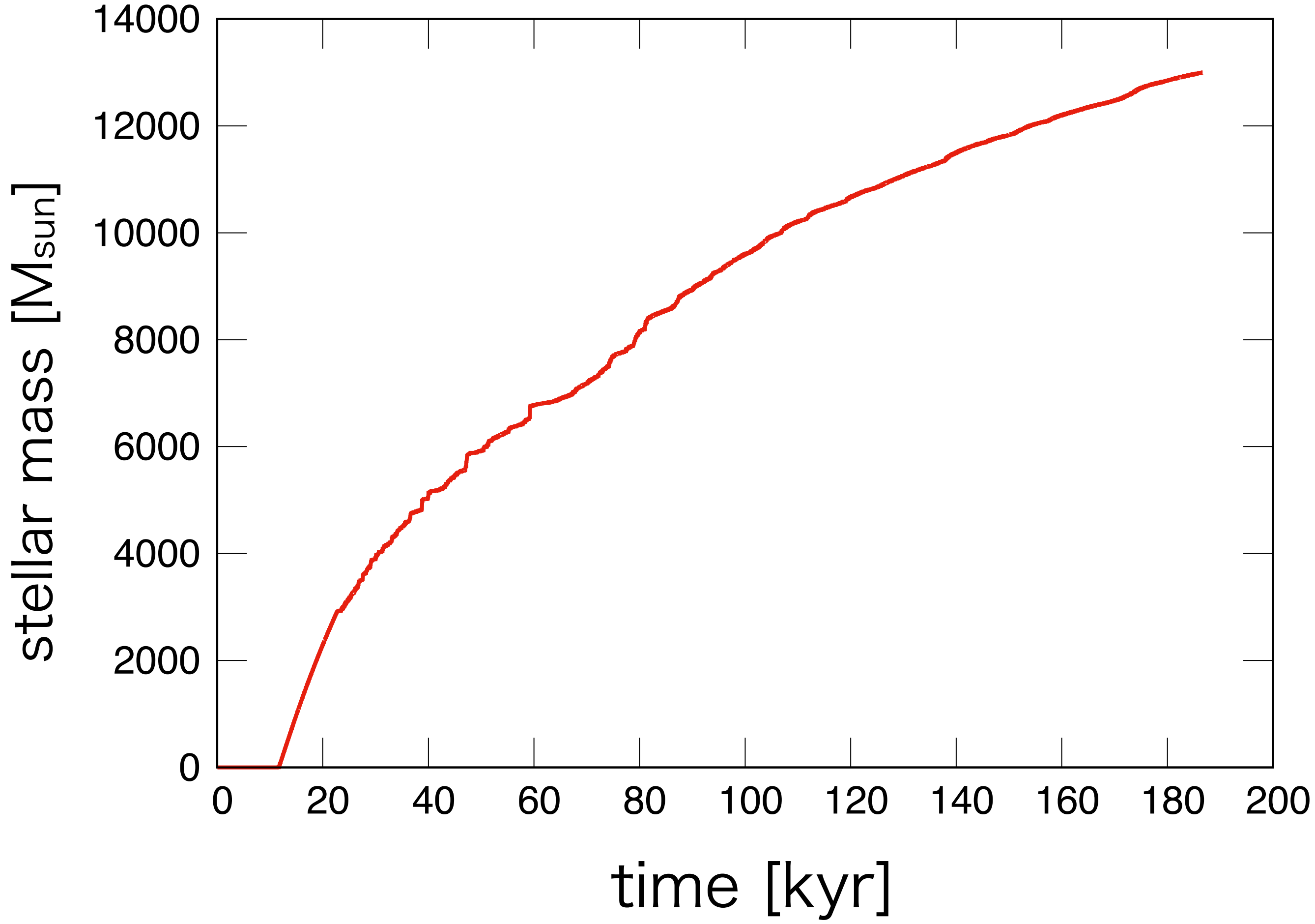
2D hydrodynamical simulation

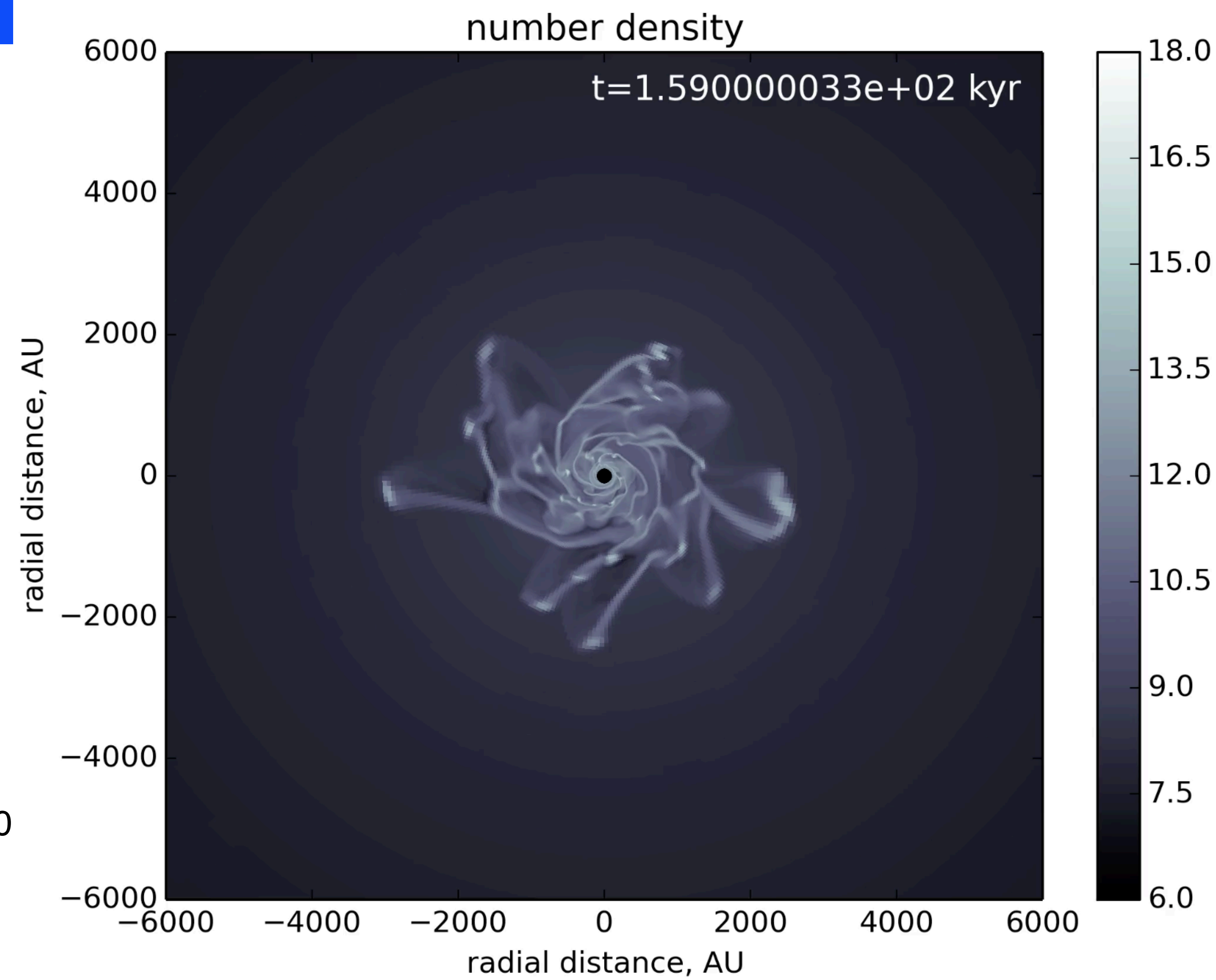


- ✔ cylindrical coordinate (r, ϕ) see the face-on disk
- ✔ calculate the thermal and chemical evolutions in each grid
- ✔ setup (test calculation)
  - grid number (r, ϕ)=(512, 256) and set the sink cell at the center
  - The parent cloud has uniform density and temperature.

    $n_0 = 10^5$ cm^{-3}, T = 7000 K

Result





We stopped the calculation when the stellar mass becomes half the mass of the parent cloud.

→ We confirmed that the numerical calculation works without problems.

Next, we will calculate with more realistic initial condition and high resolution.

2. Course status

Course status

- Advanced Lecture on Physics for the Universe I

GSP: 7p + GASP: 3p → **total: 10p**

- Advanced Experiments on Physics for the Universe

GEP 8P (remaining points: 5p)

N2: Scintillator hodoscope array read by MPPC

A1: Measurements on optical aberrations in an optical observation system