Chemodynamical Evolution of Elliptical Galaxies

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1. Abstract

We discuss the chemodynamical evolution of elliptical galaxies using our GRAPE-SPH code. To make comparison with the observational data, we introduce detail models of the physical processes; radiative cooling, star formation, feedback of Type II and Ia supernovae (SNe II and SNe Ia), and stellar winds (SWs), and chemical enrichment. We simulate the formation and evolution of more than 100 elliptical galaxies from the CDM initial fluctuation, and reproduce the tight relation among global properties and a variety of the internal structures.

2. N-body+SPH

We solve the hydrodynamics with Smoothed Particle Hydrodynamical (SPH) method and compute the gravity by the special purpose computer GRAPE. We use GRAPE5 MUV system (NAOJ) and GRAPE6 (Univ. of Tokyo). Our GRAPE-SPH code (Nakasato 2000) is highly adaptive in space and time by means of individual smoothing length and individual timestep.

$$\frac{D\rho}{Dt} + \rho\nabla\cdot\mathbf{v} = 0$$

$$\frac{D\mathbf{v}}{Dt} = -\frac{1}{\rho}\nabla P - \nabla\Phi$$

$$\frac{Du}{Dt} = \frac{P}{\rho^2}\frac{D\rho}{Dt} + \frac{\nabla\cdot(\kappa\nabla T)}{\rho} + \frac{\Gamma-\Lambda}{\rho}$$

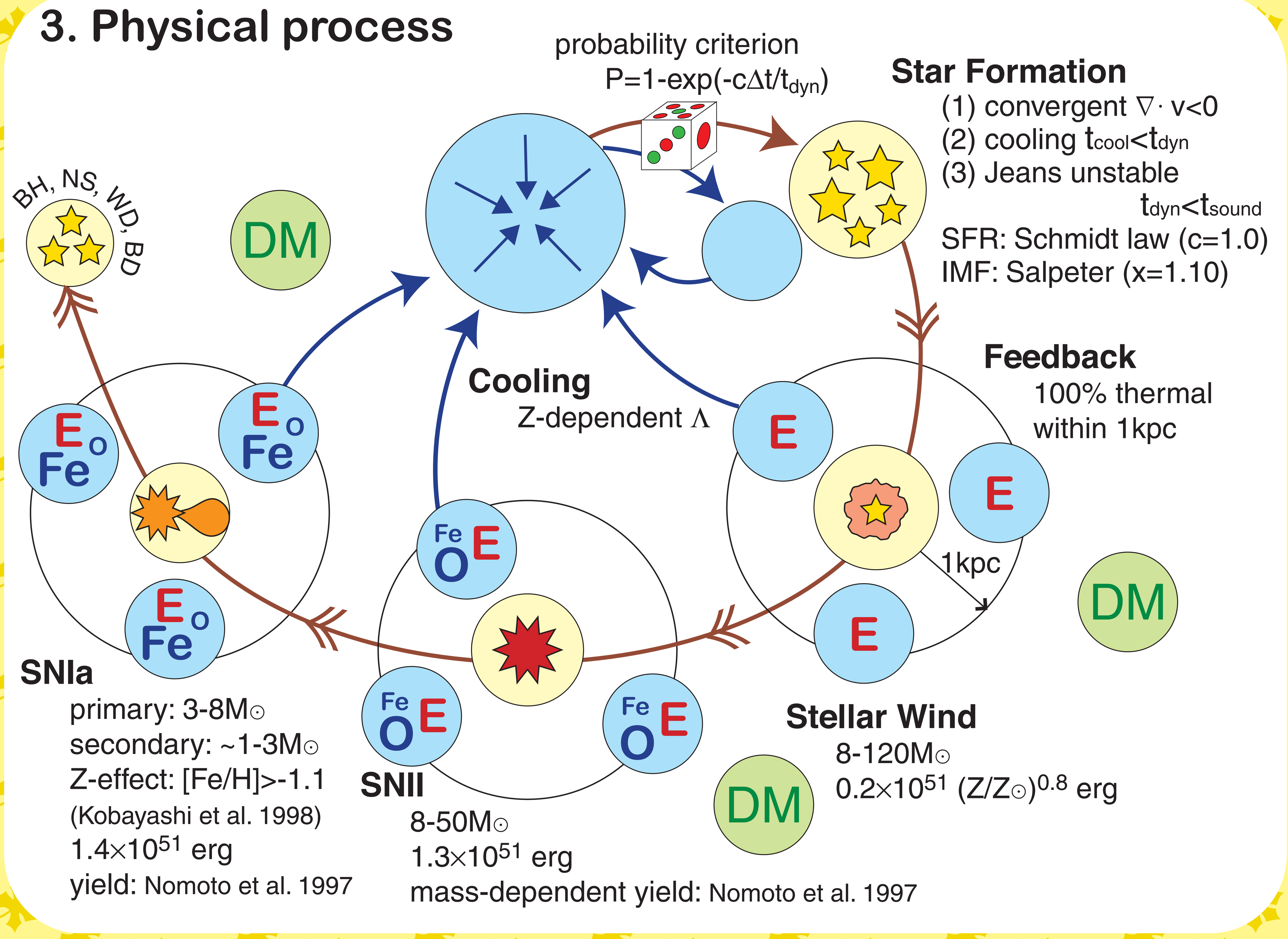
$$\nabla^2\Phi = 4\pi G\rho$$

$$\rho_i = \sum m_j W(\mathbf{r}_i - \mathbf{r}_j; h)$$

$$\frac{D\mathbf{v}_i}{Dt} = -\sum m_j\left(\frac{P_i}{\rho_i^2} + \frac{P_j}{\rho_j^2} + \Pi_{ij}\right)\nabla_i W(\mathbf{r}_i - \mathbf{r}_j; h) - (\nabla\Phi)_i$$

$$\frac{Du_i}{Dt} = -\sum m_j\left(\frac{P_i}{\rho_i^2} + \frac{1}{2}\Pi_{ij}\right)(\mathbf{v}_i - \mathbf{v}_j)\nabla_i W(\mathbf{r}_i - \mathbf{r}_j; h) + \frac{\Gamma-\Lambda}{\rho}$$

3. Physical process

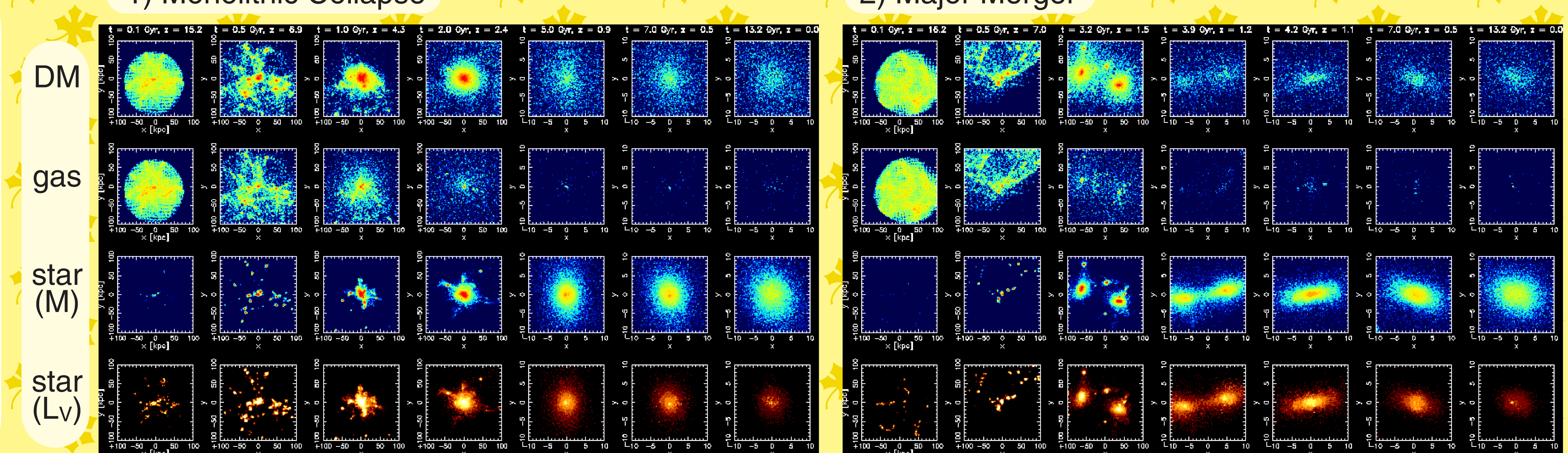


4. Initial Condition

- cosmological initial condition GRAFIC (Bertschinger 1995)
- $H_0=50$, $\Omega_0=1.0$, $\lambda_0=0.0$, $\sigma_8=1$, $z_c\sim23$
- 1-3σ over-dense region: a sphere with 55 kpc radius
- $N_{tot}\sim10000,40000,60000$ (the half for gas, the rest for dark matter)
- $M_{tot}\sim10^{12}$ M⊙, baryon fraction=0.1
- $M_{gas}\sim10^{6-7}$ M⊙, $M_{DM}\sim10^{7-8}$ M⊙
- small rotation: spin parameter $\lambda\sim0.02$

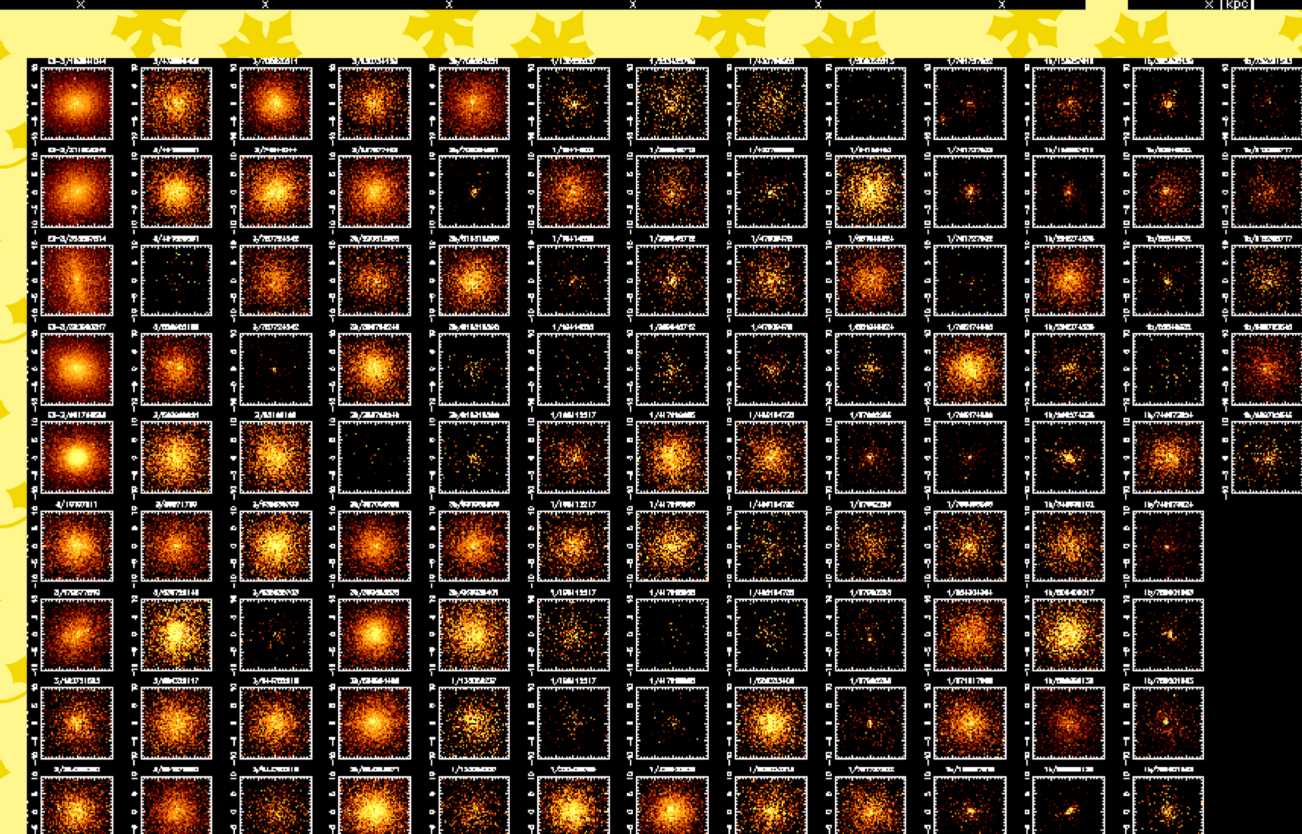
We calculate 65 regions and obtain 113 ellipticals that are formed by the star burst and have the de Vaucouleurs SB profile.

1) Monolithic Collapse → time　　2) Major Merger → time



5. Elliptical galaxies

- How elliptical galaxies form and evolve?
  Two distinct scenarios have been debated;
  monolithic collapse vs. disk-disk merger.
  We adopt the CDM fluctuation as the initial condition.
  → successive merging of sub-galaxies with $\sim10^{9-10}$ M⊙,
  → some ellipticals: no merger, some: major merger
  This scenario is the midway of the above two scenarios.
  The merging history is determined from the initial fluctuation.
- Observations of elliptical galaxies show
  - Tight relations among global properties, e.g., FJ, CMR, Mg2-s, FP....
  - A variety of the internal structures e.g., metallicity radial gradients
- We simulate many ellipticals and do the statistical study.

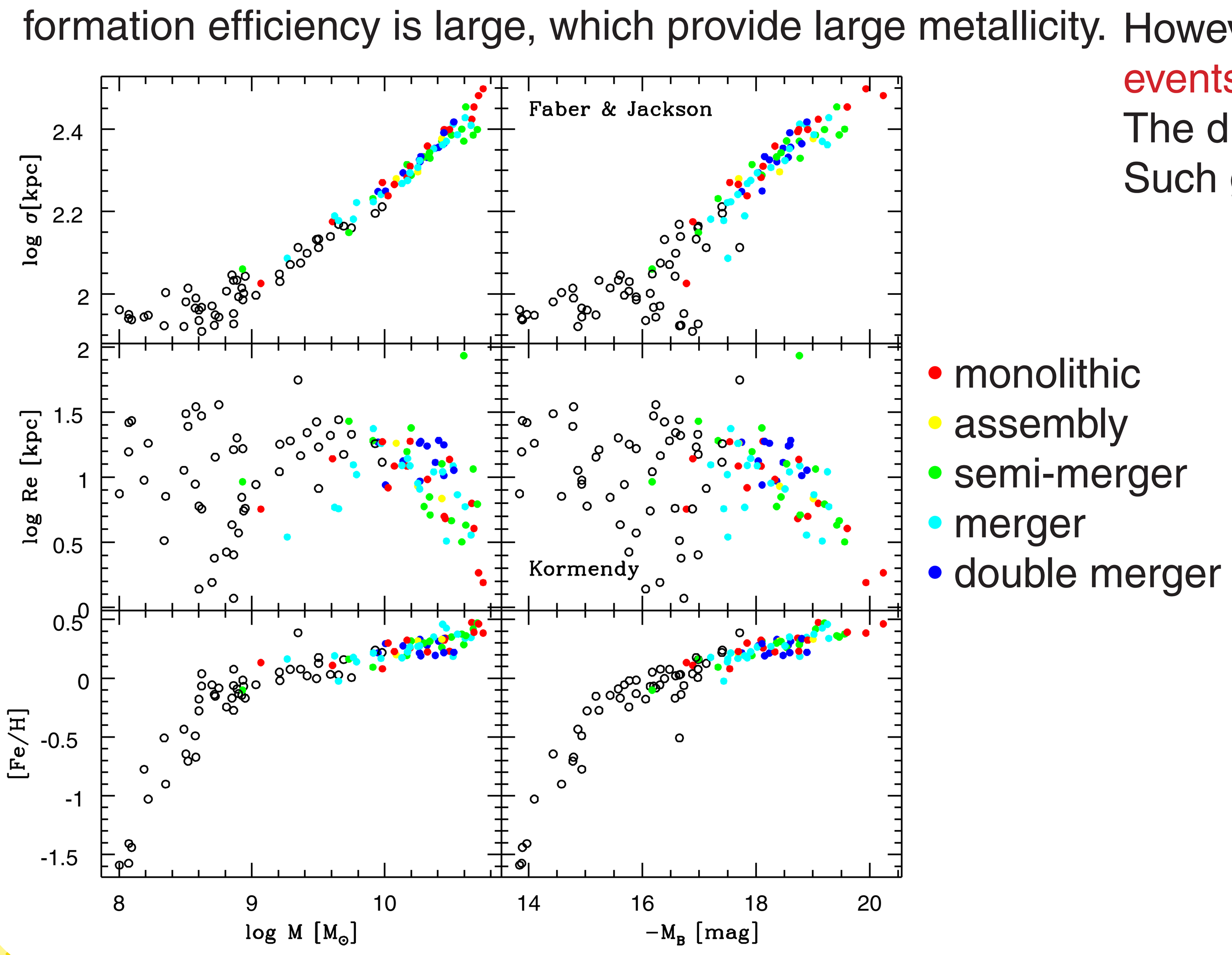


V-luminosity Map (z=0)

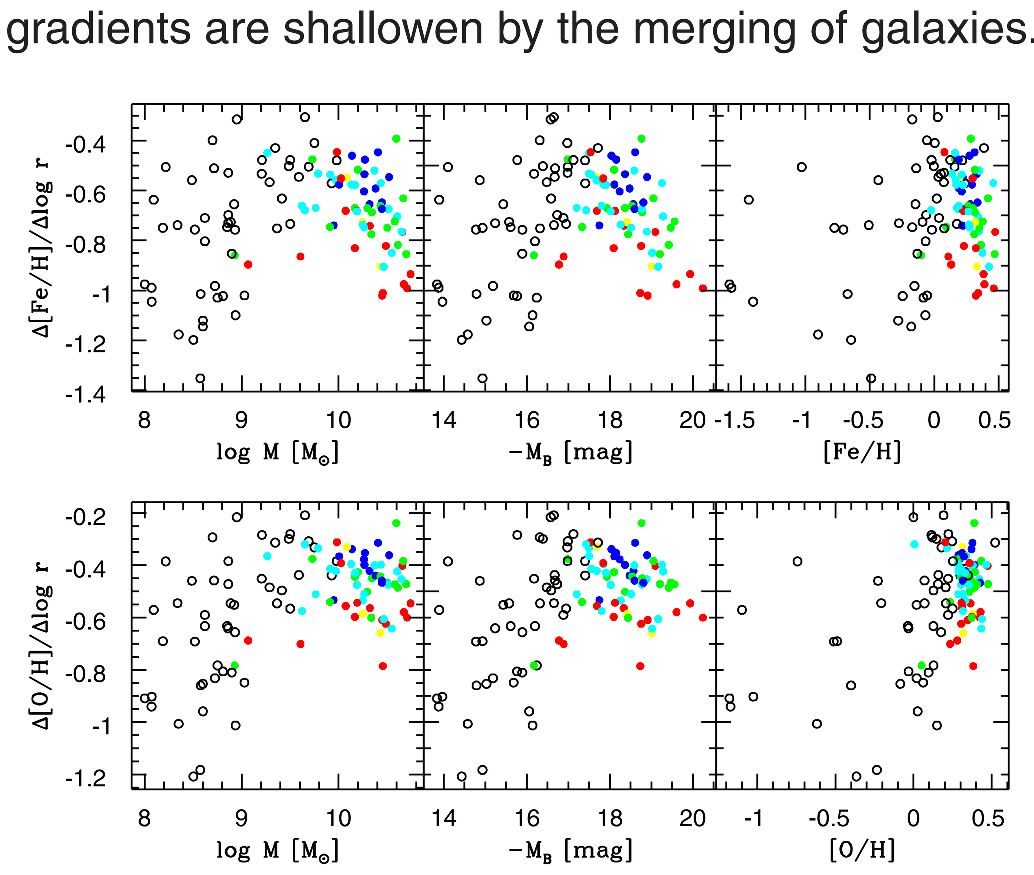
Star Formation History

6. Results

We reproduce the tight relations: Faber-Jackson relation, Kormendy relation, and the mass-metallicity relation.
In the massive elliptical, the density is large, and the star formation efficiency is large, which provide large metallicity.



We reproduce the observed average (-0.3) and dispersion (-0.8 to 0) of the metallicity gradients (Kobayashi & Arimoto 1999); Most elliptical galaxies have the metallicity radial gradients, and the gradients do not correlate with masses or metallicities. However, we find that the number and scale of the merging events correlate with the metallicity gradients (see color dots). The dissipative collapse produces the steep gradients as -0.1. Such gradients are shallowen by the merging of galaxies.



7. Conclusion

We simulate the formation and chemodynamical evolution of more than 100 elliptical galaxies by using our GRAPE-SPH code. The simulated galaxies are formed by the star burst and have de Vaucouleurs surface brightness profile.
We reproduce the tight relations among global properties; Faber-Jackson relation, Kormendy relation, and the mass-metallicity relation.
We also reproduce the variety of the internal structures: the lack of relations between metallicity gradients and masses / metallicities.
This is because the steep metallicity gradients are formed by the dissipative collapse and are destroyed by the merging of galaxies.
Therefore, the metallicity gradient inform the merging history of the galaxy, and it is a key to investigate the origin of elliptical galaxies.