Dynamical friction in a turbulent gaseous medium

Sandrine Lescaudron

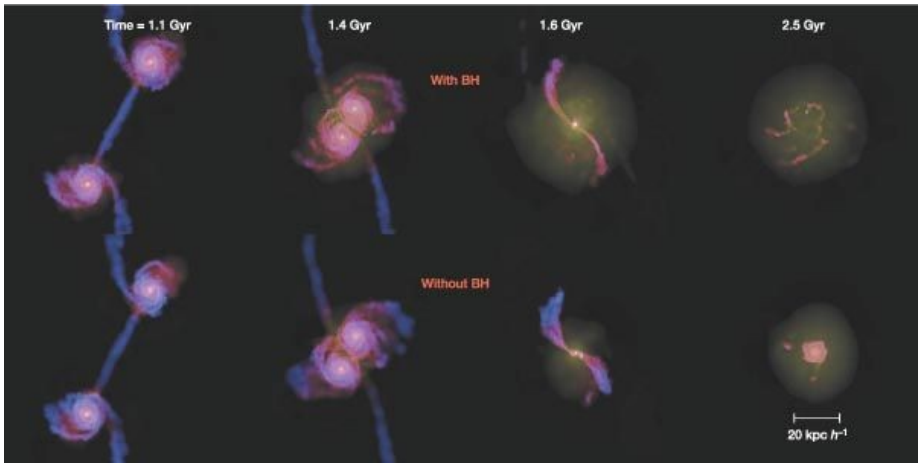
Supervisors : Marta VOLONTERI et Yohan DUBOIS

Institut d'Astrophysique de Paris

Cosmic Explosions - 3 June 2019

Context

- Co-evolution galaxy / central BH
- BH accretes matter / releases a fraction of energy
- Galaxy mergers enhance gas accretion

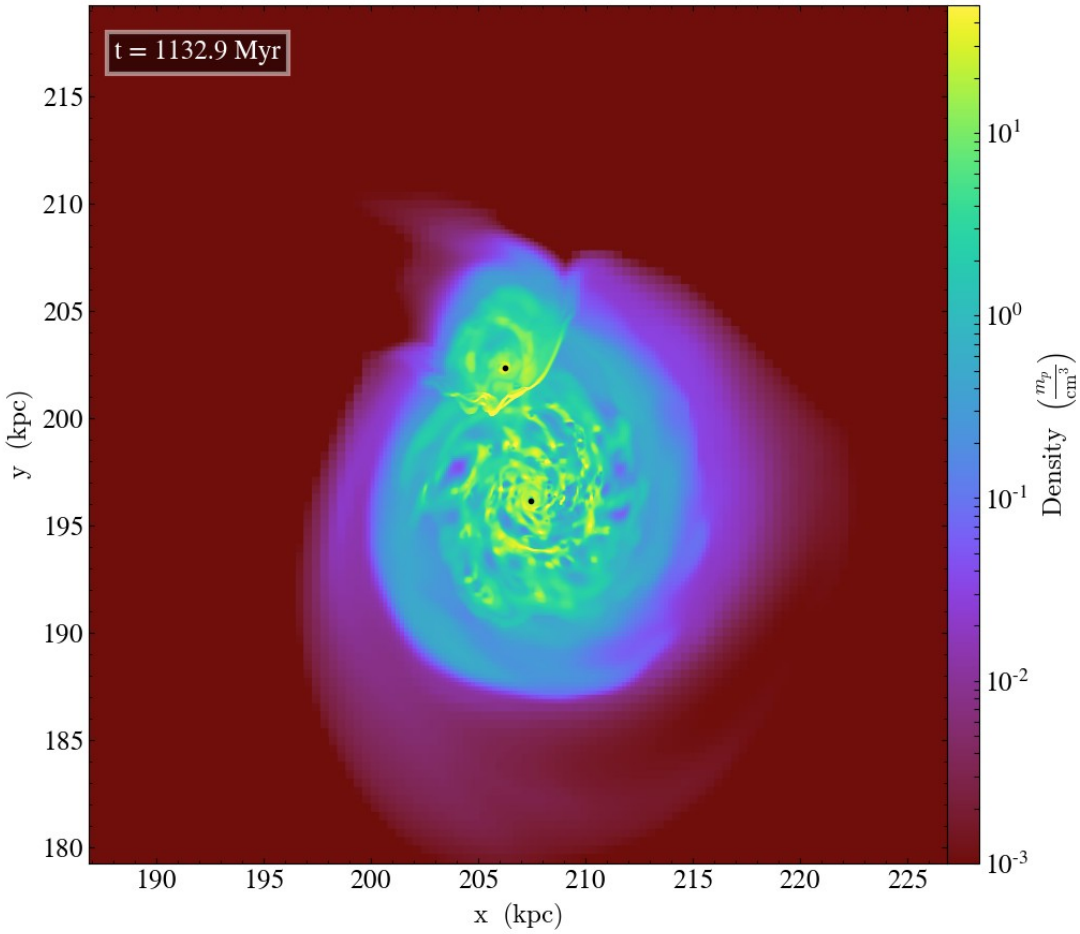


Di Matteo, Springel 2005

- Hydrodynamical simulations of galaxy mergers with the code Ramses (Teyssier 2002)
- Subgrid models for BHs : Bondi accretion, spin parameter evolution, BH mergers

Motivation

- BH ejected from its surrounding gas
- Sinking time not consistent
- Numerical problem
- Focus on dynamical friction in a turbulent gas medium



Theoretical background

Dynamical friction : loss of momentum and kinetic energy of a massive moving body through gravitational interaction with its own gravitationally induced wake

- **Chandrasekhar (1943) :**

Analytical theory for collisionless systems

$$\frac{\mathrm{d}\mathbf{v}_M}{\mathrm{d}t} = -16\pi^2 G^2 M m_a \ln\Lambda \left[\int_0^{v_M} \mathrm{d}v_a \, v_a^2 f(v_a)\right] \frac{\mathbf{v}_M}{v_M^3}$$

Theoretical background

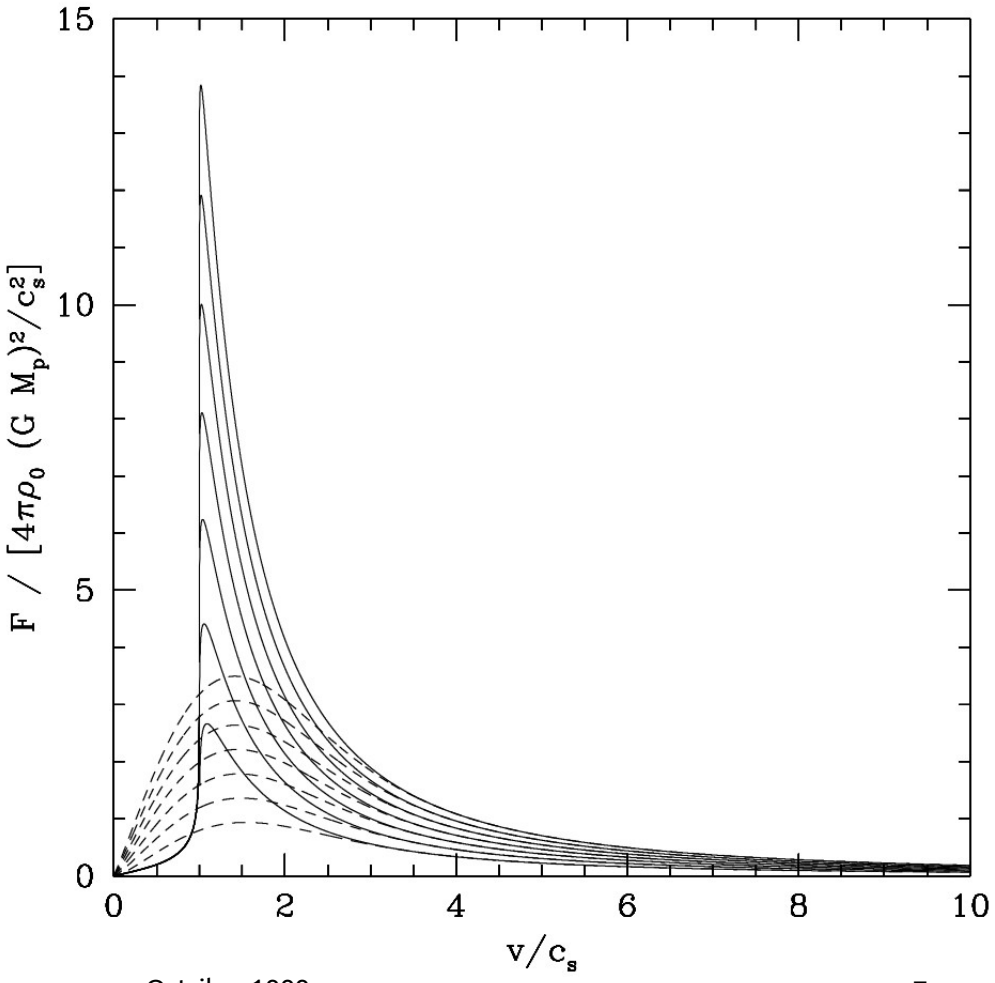
- **Ostriker E. (1999) :**

Corresponding theory in a uniform gaseous medium

$$F_{DF} = -\frac{4\pi(GM_p)^2\rho_0}{V^2} I$$

$$I_{subsonic} = \frac{1}{2}\ln\left(\frac{1+M}{1-M}\right) - M$$

$$I_{supersonic} = \frac{1}{2}\ln\left(1-\frac{1}{M^2}\right) + \ln\left(\frac{Vt}{r_{min}}\right)$$

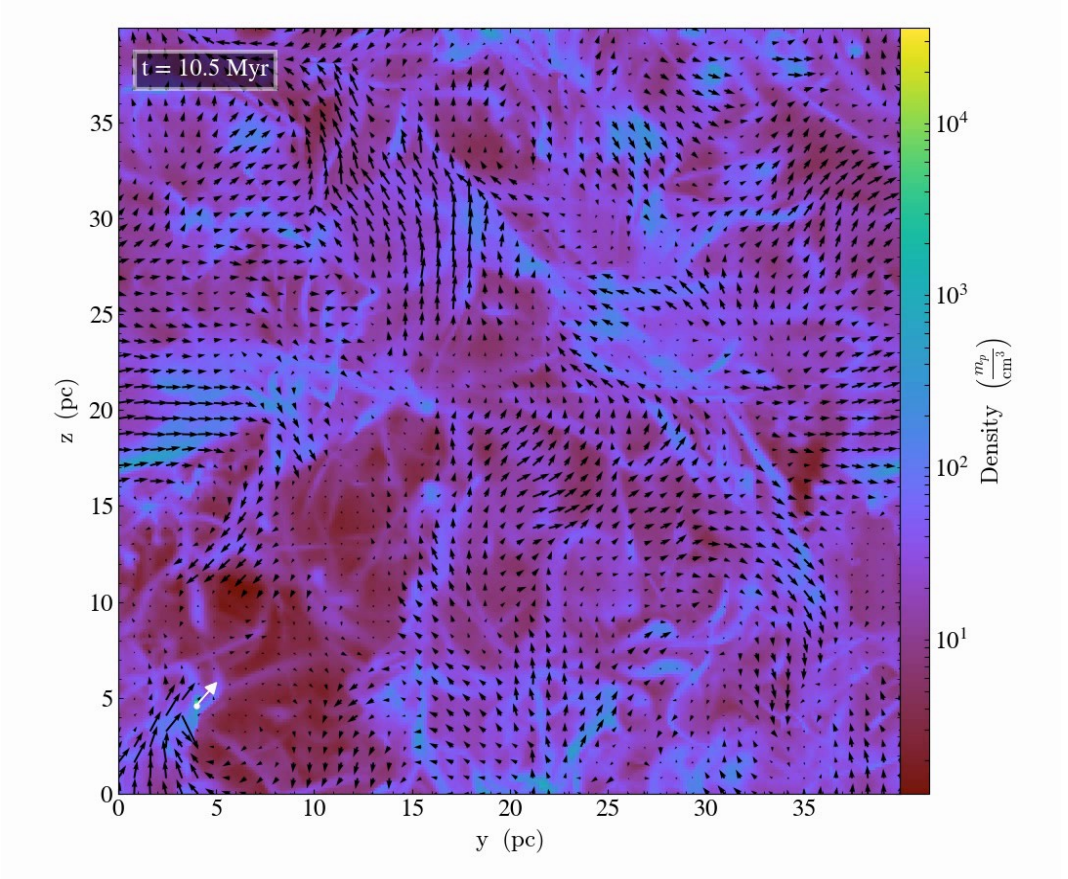


Ostriker 1999

Hydrodynamical simulations

Turbulent box :

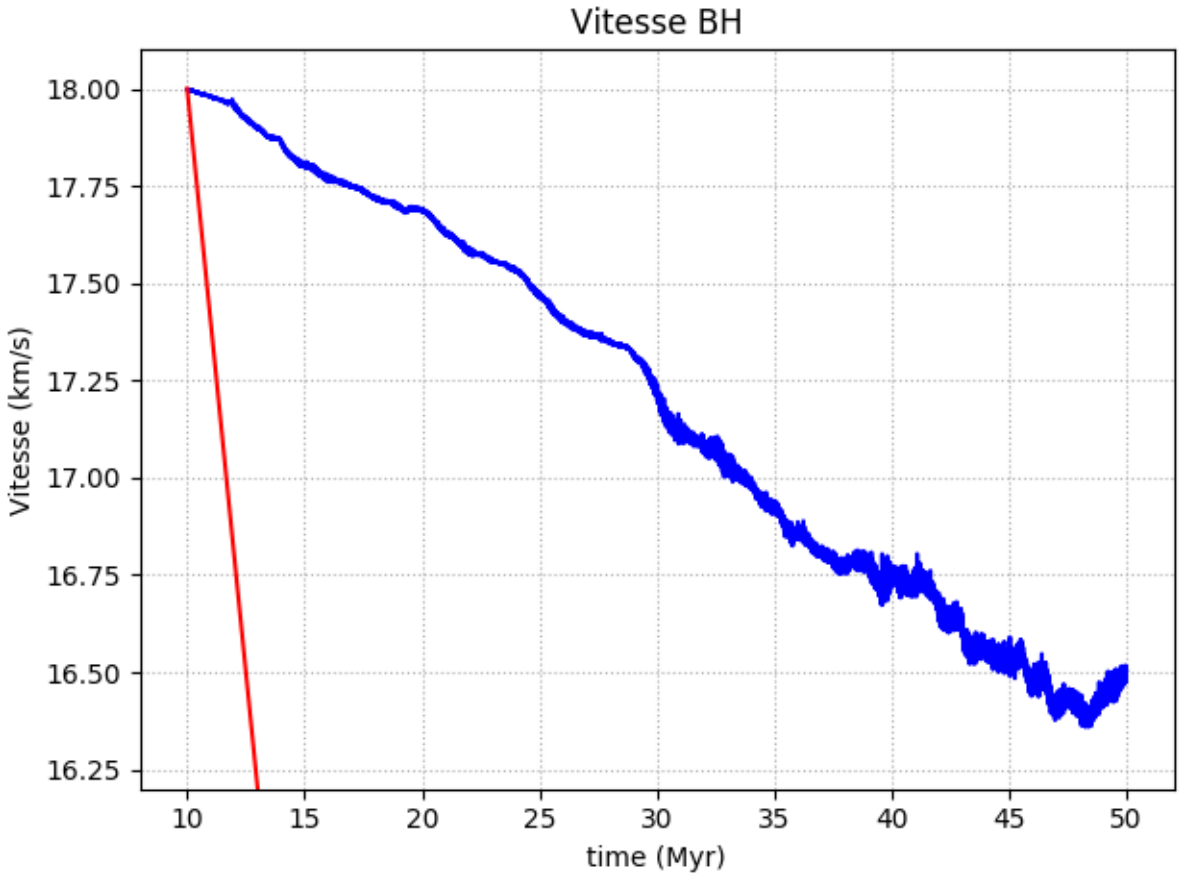
- **Small scale simulations (40pc) at very high resolution (0.16 pc)**
- **Periodic box**
- **MHD solver with a turbulent forcing model**
- **Dynamics of a supermassive BH, varying BH mass and velocity and gas initial density**



Results

- **BH mass : 10^5 Msun**
- **BH velocity : 18 km/s**
- **Gas density : 5 part/cm^3**

BH velocity decreases more slowly than expected



Conclusion

Work in progress… ongoing developments :

- **Refine the analytical study and the comparison with simulations**
- **Run simulations without turbulence to ensure they properly match with analytical formula**
- **Extend the range of BH mass, BH velocity and gas density initial conditions**
- **Propose a model for the dynamical friction in a turbulent gaseous medium**