Class 17 – Apr 2nd, 2020

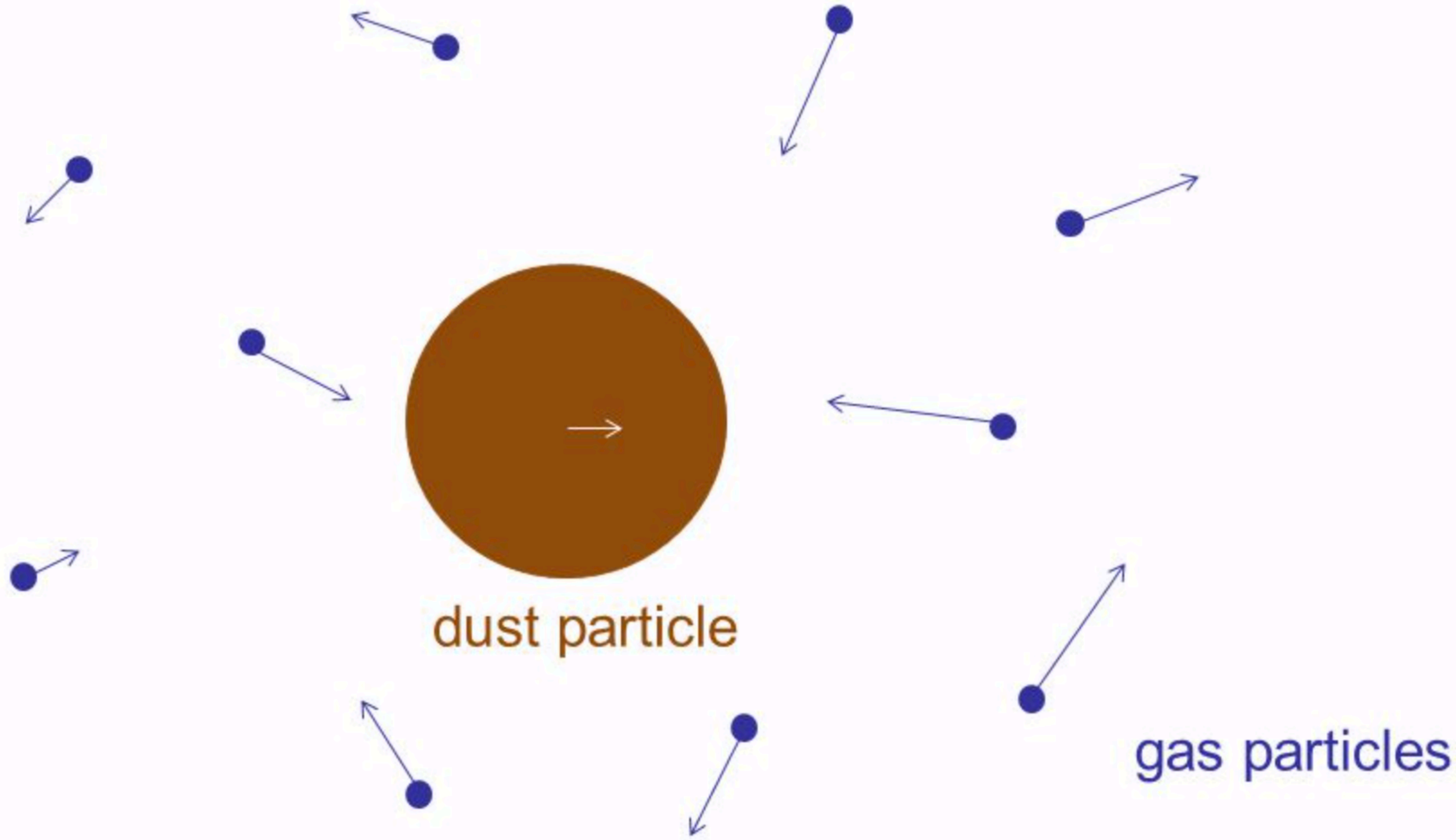
Dust Dynamics and Planetesimal Formation

- Drag force
- Fragmentation
- Friction time and Stokes number
- The meter-size barrier

Friction between a particle and the gas

Take a spherical dust particle with radius a and material density ρ_s

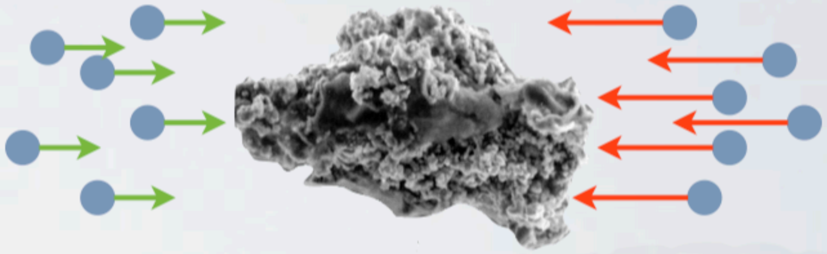
<u>*Epstein drag regime*</u> = $a \ll \lambda_{mfp}$ and $|v| \ll c_s$



Epstein Regime:

if particle size ≲ gas mean free path

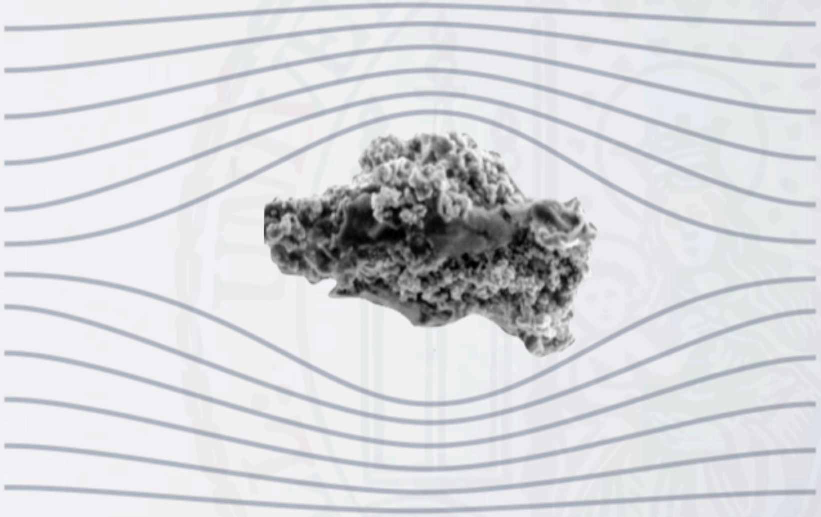
$$\vec{F}_{drag} = -\frac{4\pi}{3}\rho_g a^2 v_{th}\vec{v}$$



Stokes Regime:

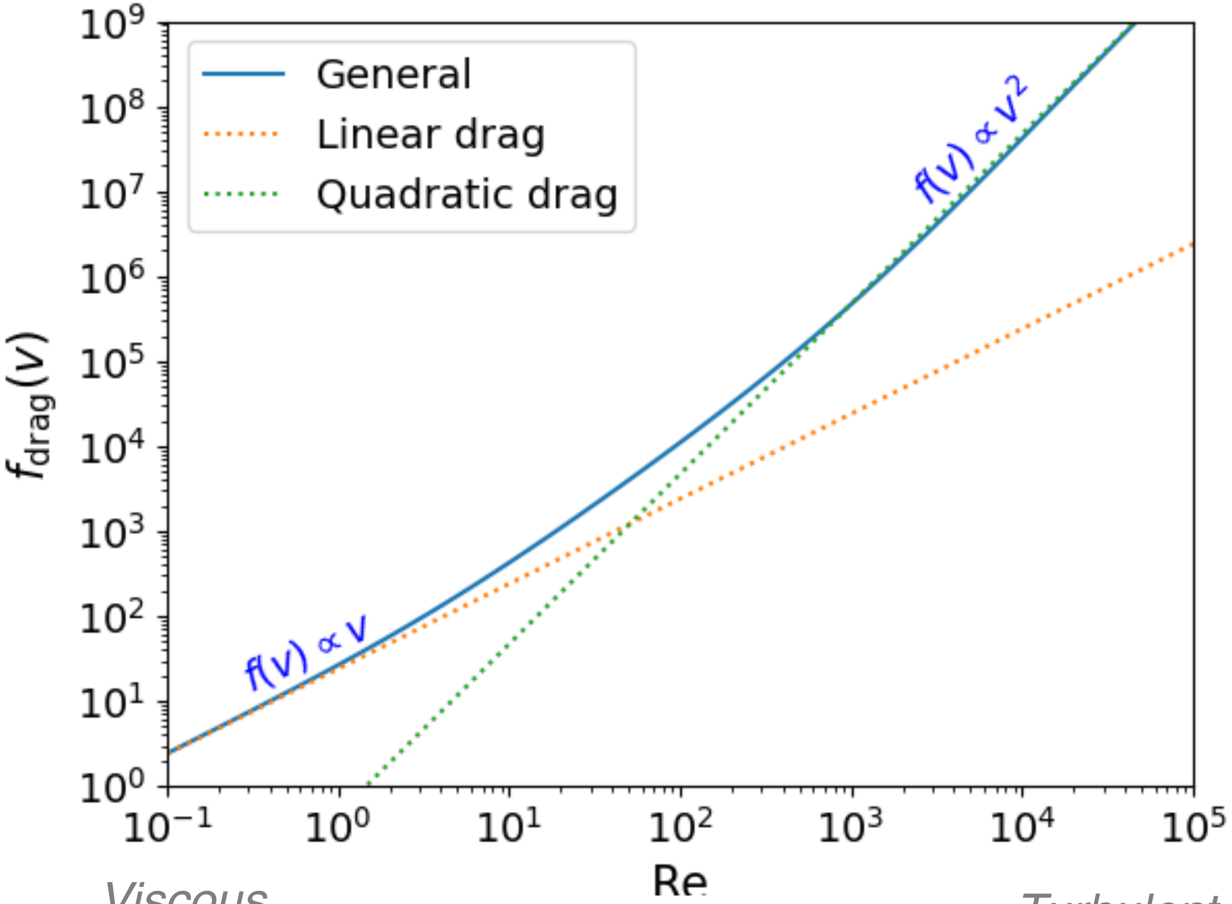
else

$$\vec{F}_{drag} = -\frac{C_D}{2}\pi a^2 \rho_g v \vec{v}$$

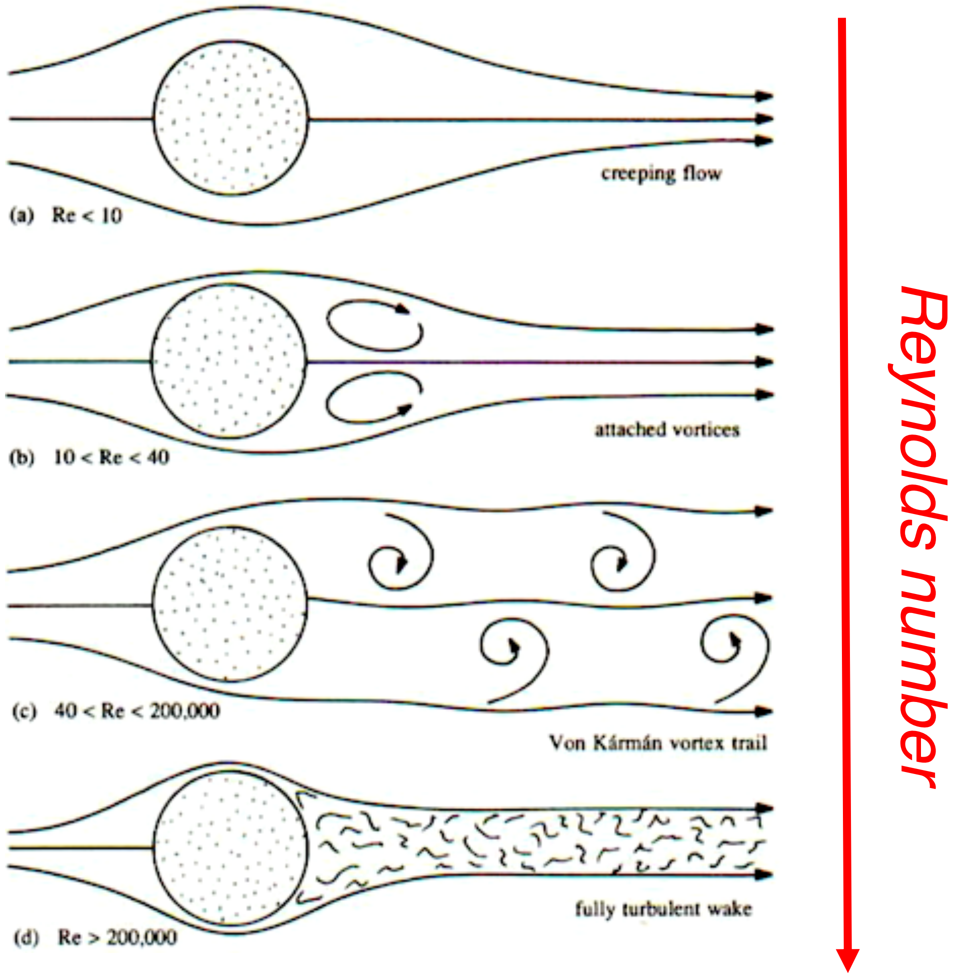


C_D depends on the particle Reynolds number

Linear vs quadratic drag

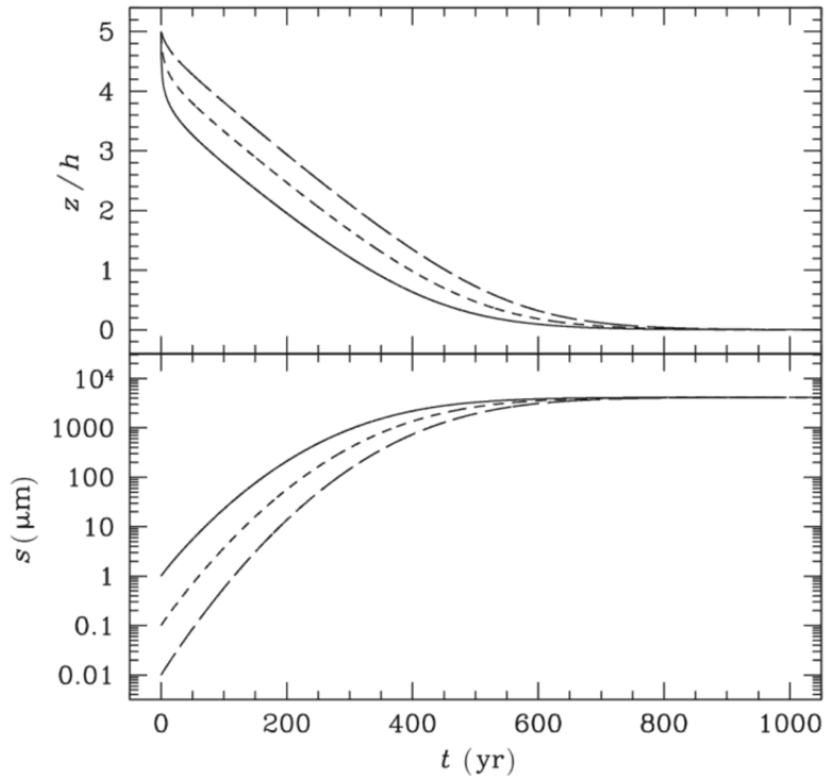


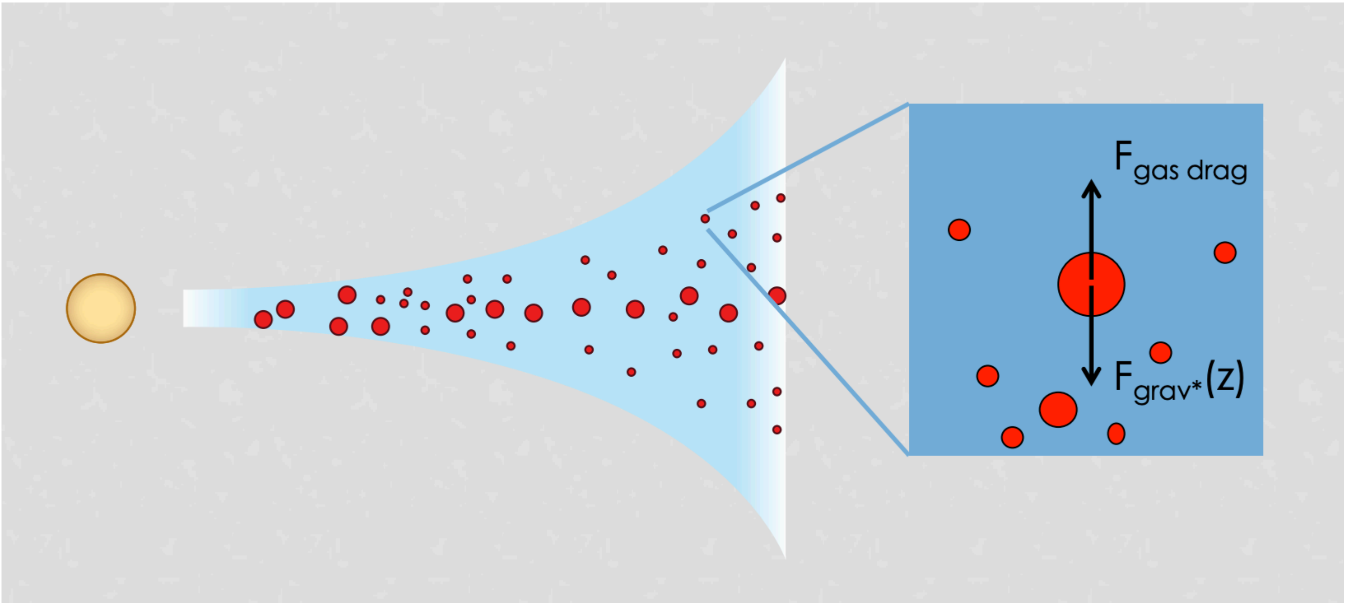
Viscous *Turbulent*



Lyra, Youdin, & Johansen 2020 (submitted)

Dust settling





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Astronomy & Astrophysics

Closed-form expressions for particle relative velocities induced by turbulence
(Research Note)

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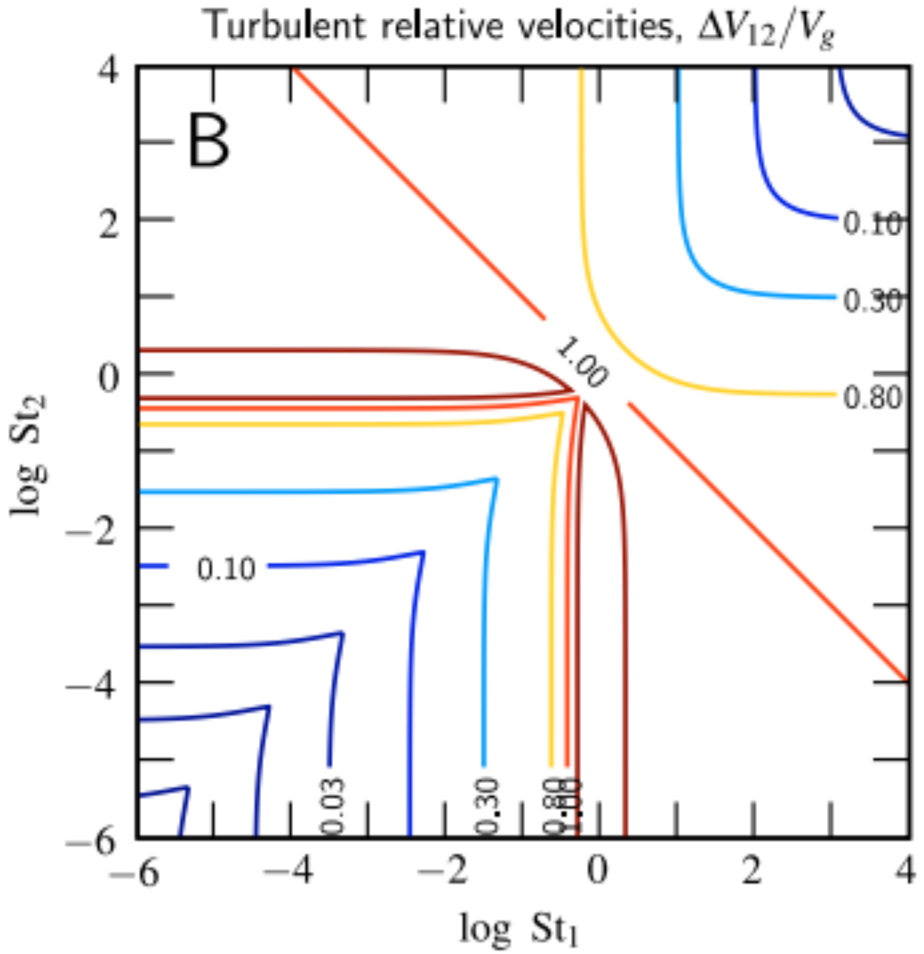
ABSTRACT

In this note we present complete, closed-form expressions for random relative velocities between colliding particles of arbitrary size in nebula turbulence. These results are exact for very small particles (those with stopping times much shorter than the large eddy overturn time) and are also surprisingly accurate in complete generality (that is, also apply for particles with stopping times comparable to, or much longer than, the large eddy overturn time). We note that some previous studies may have adopted previous simple expressions, which we find to be in error regarding the size dependence in the large particle regime.

Key words. turbulence – dust, extinction – planetary systems: protoplanetary disks



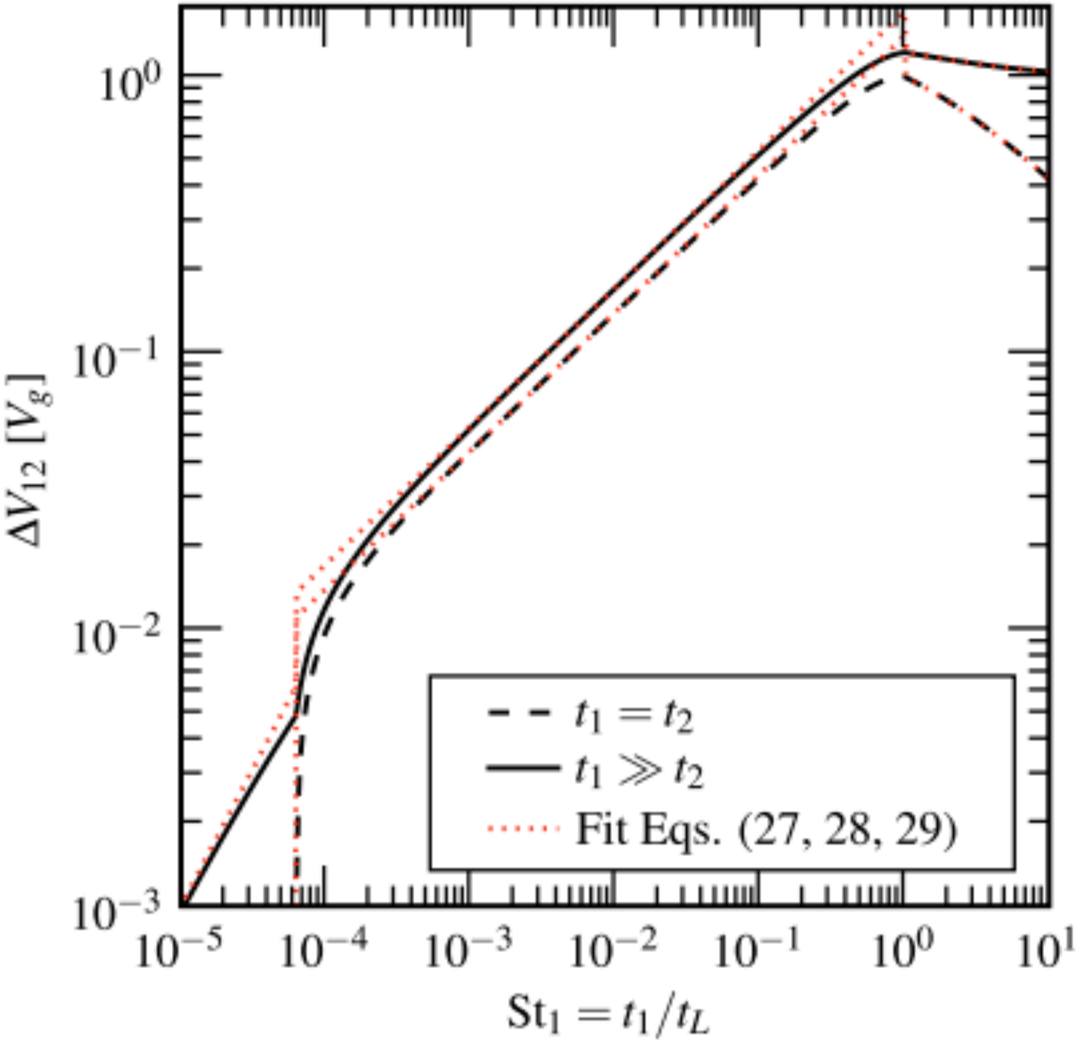
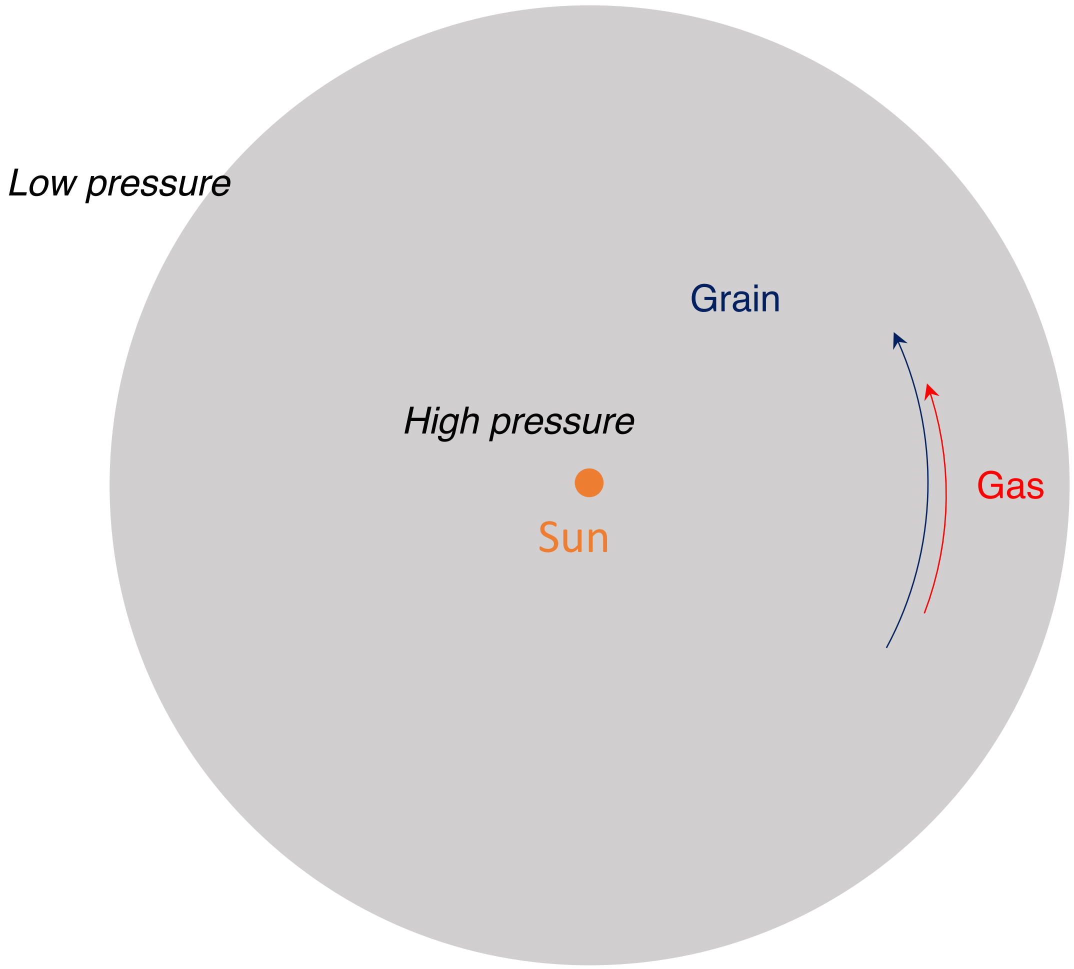


Fig. 3. Exact solution to Eq. (16) for ΔV_{12} in the case of identical particles (dashed line) and $t_1 \gg t_2$ (solid line) for a Reynold number of 10^8. The dotted curves are approximations to Eq. (16) given by Eqs. (27)–(29).

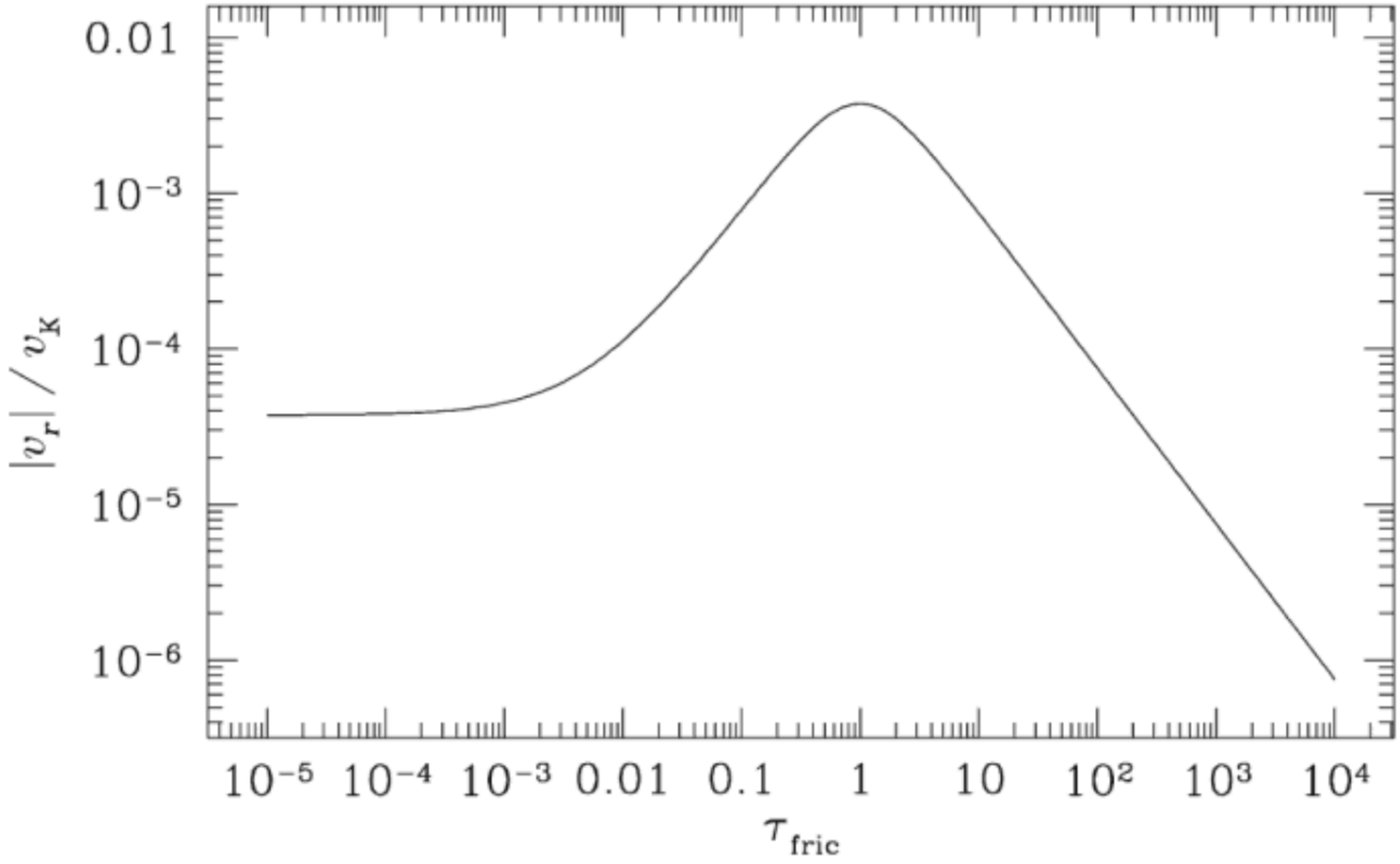
Sub-Keplerian wind



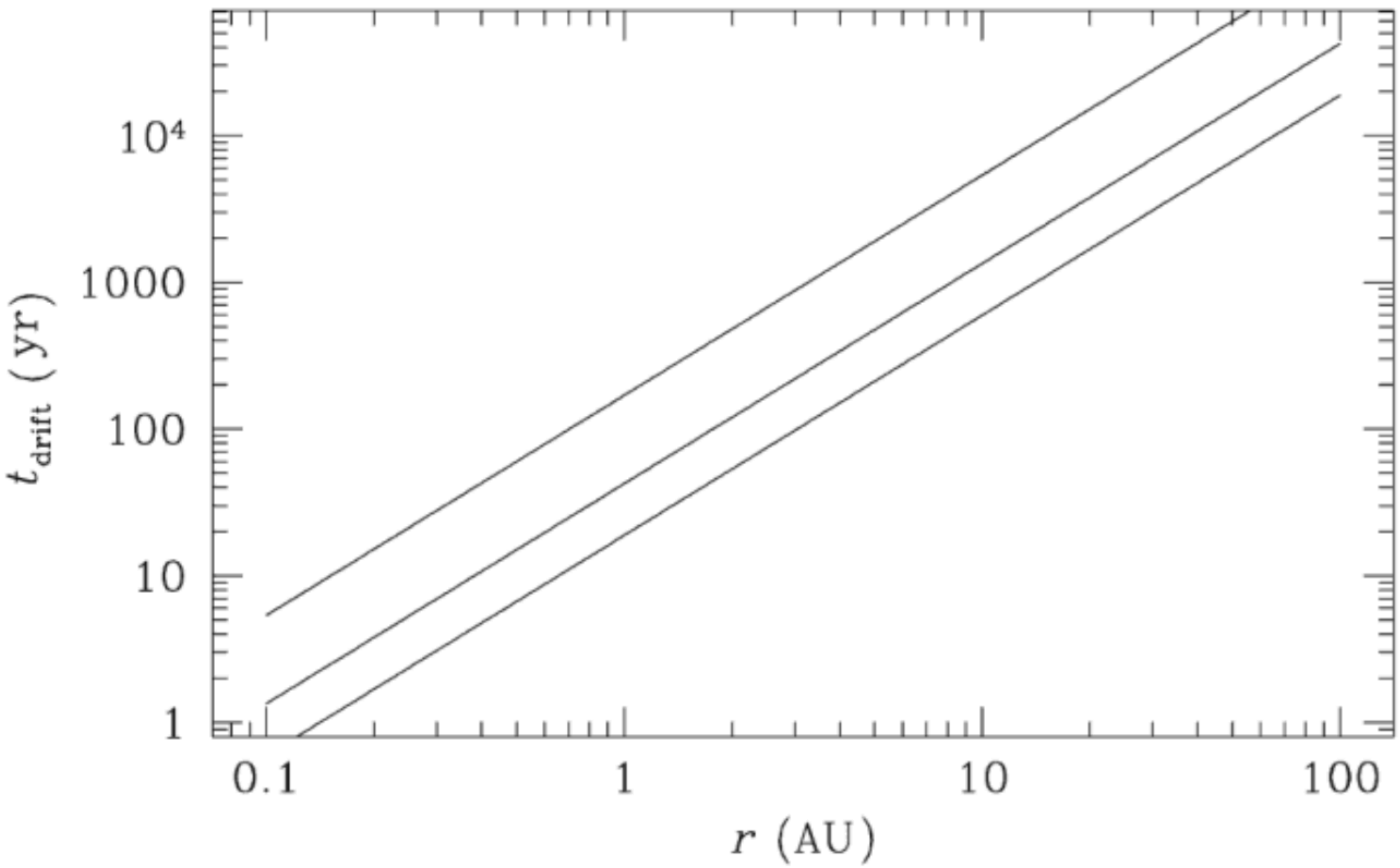
The gas has some pressure support.

The grains have none.

Radial Drift



Radial drift in VERY fast !!



Pebbles lost in ~ 100 yr

Coagulation + Fragmentation + Drift