# The CEHINAV-SPH code.

L.M.González

# Lagrangian Compresible Navier-Stokes equations:

$$\frac{d\rho}{dt} = -\rho\nabla\cdot\mathbf{v}$$

$$\frac{d\,\mathbf{v}}{dt} = -\nabla P + \nu\nabla^2\mathbf{v}$$

$$\frac{d\mathbf{r}}{dt} = \mathbf{v}$$

$$P = \frac{\rho_0\, c_s^2}{\gamma}\left(\left(\frac{\rho}{\rho_0}\right)^{\gamma} - 1\right)$$

# Weakly compressible SPH equations WCSPH (spatial discretization).

$$
\begin{aligned}
\frac{d\rho_a}{dt} &= \sum_{b\in\mathcal{N}_a} m_b\,\mathbf{v}_{ab}\,\nabla_a W_{ab} \\
\frac{d\,\mathbf{v}_a}{dt} &= -\sum_{b\in\mathcal{N}_a}\left\{ m_b\left(\frac{P_a}{\rho_a^2}+\frac{P_b}{\rho_b^2}\right) - \frac{8\mu m_b}{\rho_a\rho_b}\frac{\mathbf{v}_{ab}\cdot\mathbf{r}_{ab}}{r_{ab}^2}\right\}\nabla_a W_{ab} \\
\frac{d\mathbf{r}_a}{dt} &= \mathbf{v}_a \\
P &= \frac{\rho_0\,c_s^2}{\gamma}\left(\left(\frac{\rho}{\rho_0}\right)^{\gamma}-1\right)
\end{aligned}
$$

# Predictor-corrector time discretization.

1- Predictor

$$\mathbf{r}^{n+1} = \mathbf{r}^n + dt\mathbf{v}^n + \frac{dt}{2}\mathbf{f}^n$$

$$\mathbf{v}^{n+1/2} = \mathbf{v}^n + dt\mathbf{f}^n$$

$$\rho^{n+1/2} = \rho^n + dt(\frac{d\rho}{dt})^n$$

2-Subroutine RATES calculates $\mathbf{f}^{n+1/2}$ and $(\frac{d\rho}{dt})^{n+1/2}$,

3-Pressure calculation.

$$P^{n+1} = \frac{\rho_0\, c_s^2}{\gamma}\left(\left(\frac{\rho^{n+1/2}}{\rho_0}\right)^{\gamma} - 1\right)$$

4-Corrector calculates:

$$\mathbf{v}^{n+1} = \mathbf{v}^{n+1/2} + \frac{dt}{2}(\mathbf{f}^{n+1/2} - \mathbf{f}^n)$$

$$\rho^{n+1} = \rho^{n+1/2} + \frac{dt}{2}((\frac{d\rho}{dt})^{n+1/2} - (\frac{d\rho}{dt})^n)$$

$$\mathbf{f}^{n+1/2} = \mathbf{f}^{n+1/2}_{press} + \mathbf{f}^{n+1/2}_{visc}$$

$$\mathbf{f}^{n+1/2}_{press} = -\sum_{b \in \mathcal{N}_a} m_b \left( \frac{P_a}{\rho_a^2} + \frac{P_b}{\rho_b^2} \right) \nabla_a W_{ab}$$

$$\mathbf{f}^{n+1/2}_{visc} = -\sum_{b \in \mathcal{N}_a} \frac{8 \mu m_b}{\rho_a \rho_b} \frac{\mathbf{v}_{ab} \cdot \mathbf{r}_{ab}}{r_{ab}^2} \nabla_a W_{ab}$$

$$\left(\frac{d\rho}{dt}\right)^{n+1/2} = \sum_{b \in \mathcal{N}_a} m_b \frac{\rho_a}{\rho_b} \mathbf{v}_{ab} \cdot \nabla_a W_{ab}$$

# Predictor-corrector time discretization in the ISPH version.

1- Predictor

$$\mathbf{r}^{n+1} = \mathbf{r}^n + dt\mathbf{v}^n + \frac{dt}{2}\mathbf{f}^n$$

$$\mathbf{v}^{n+1/2} = \mathbf{v}^n + dt\mathbf{f}^n$$

2-Subroutine RATES calculates $\mathbf{f}^{n+1/2}(\lambda^n)$

3-Corrector calculates:

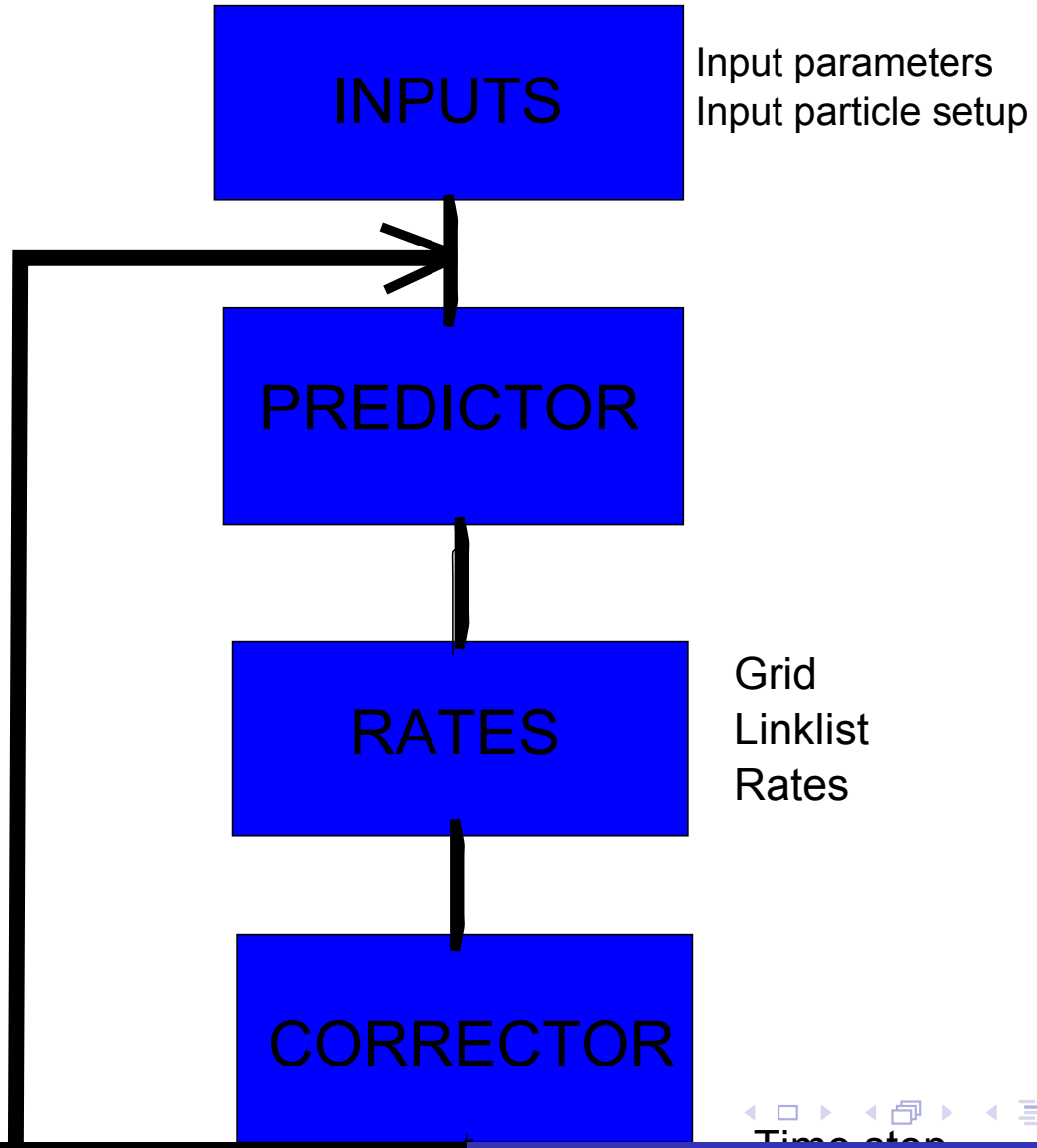
$$\mathbf{v}^{n+1} = \mathbf{v}^{n+1/2} + \frac{dt}{2}(\mathbf{f}^{n+1/2} - \mathbf{f}^n)$$

4-Calculation of the Lagrange multipliers($\lambda^{n+1}$).

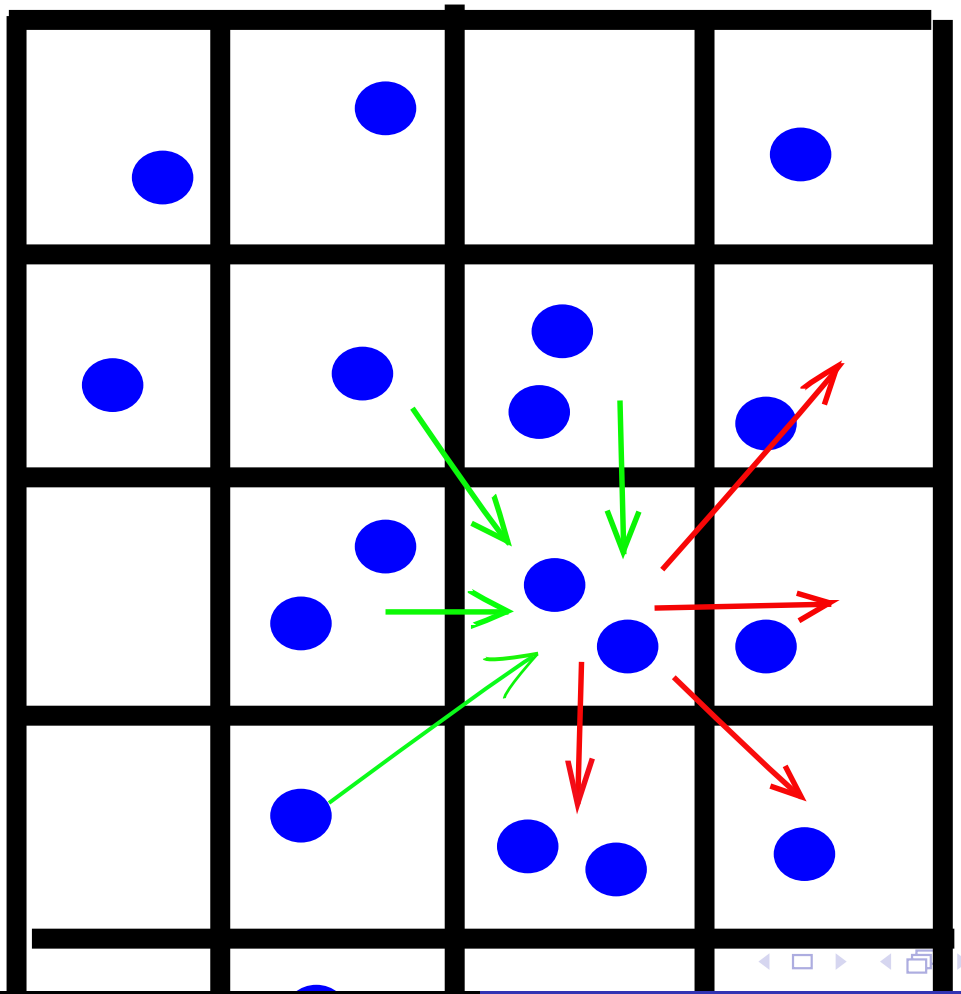
$$\mathbf{r}'^{n+1} = \mathbf{r}^{n+1} + \sum_j \Omega_{ij}\lambda_j$$

$$\mathbf{v}'^{n+1} = \mathbf{v}^{n+1} + \frac{2}{dt}\sum_j \Omega_{ij}\lambda_j$$

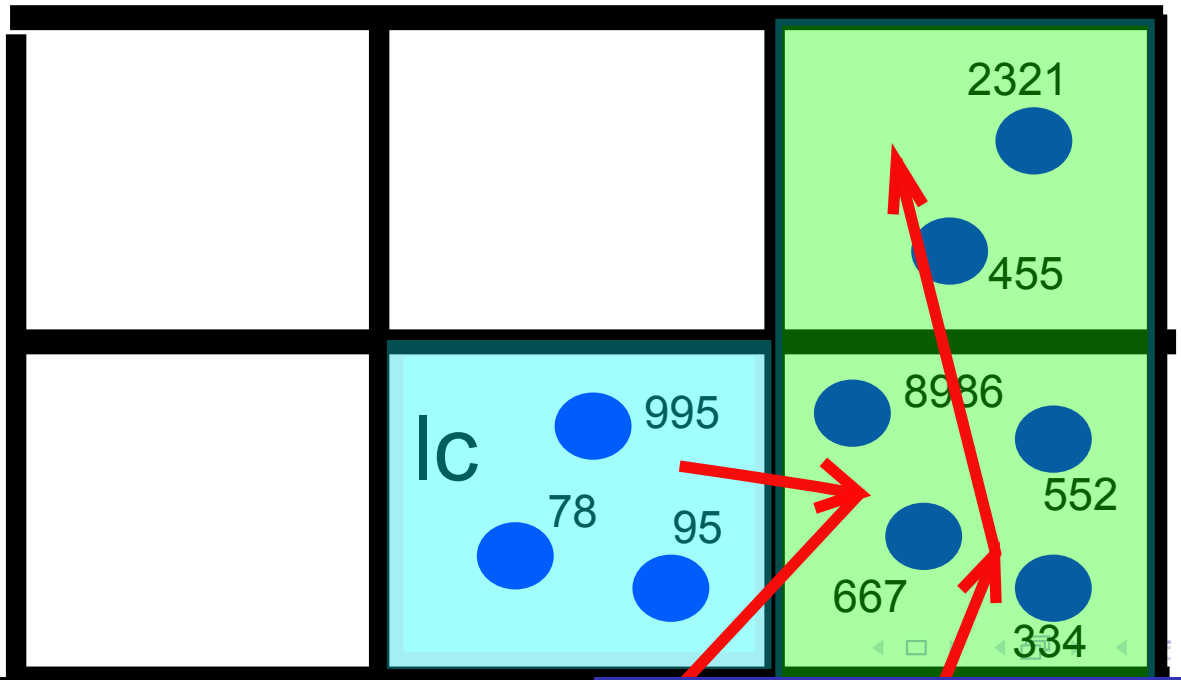
# General structure of the code.



# How to detect neighbours.



# Particle connection.



# GRID subroutine.

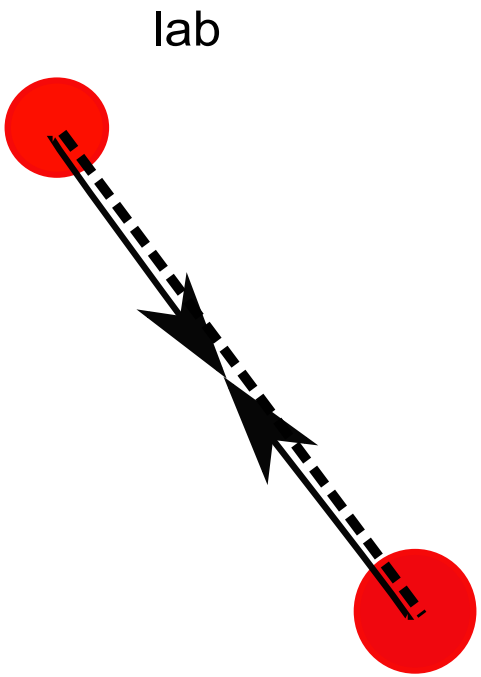
See subroutine wbg.f90

# LINKLIST subroutine.

See subroutine wbl.f90

- Linklist(i)= links the particle **i** with the following particle with lower label in one cell.
- Max-particle(lcell)= Label of the highest particle in the cell **lcell**
- Num-particle(lcell)= number of particles in the cell **lcell**

# RATES pseudocode.




```
DO lc=1,...,ncells
        Calculation(lnc,nnc)
            DO i=1,....,num_particles(lc)
             labp
                DO j=1,....,nnc
                 lab=lnc(j)
                Forces calculation(labp,lab)
                ENDDO
            ENDDO
ENDDO
```