Hybrid simulations of dusty plasma

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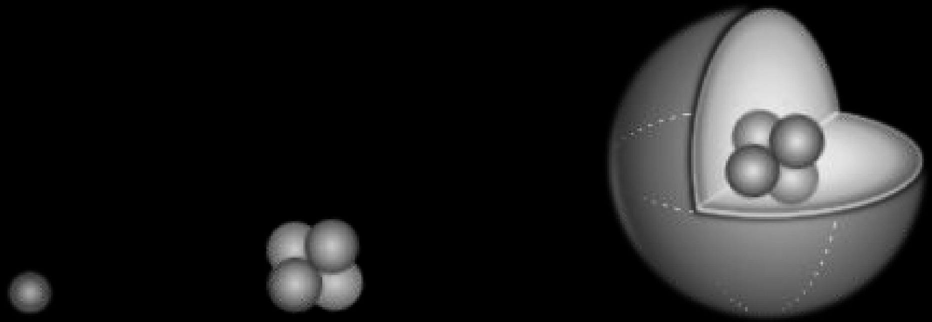
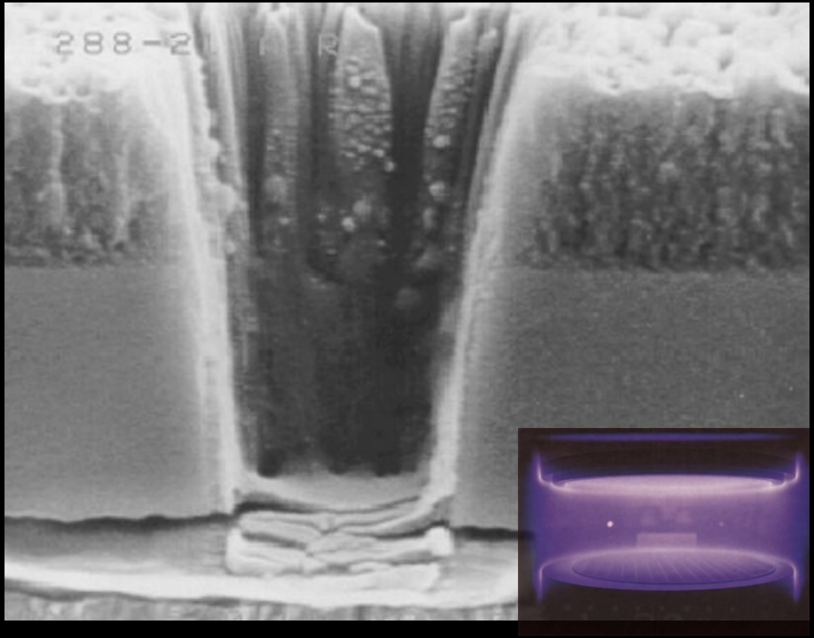
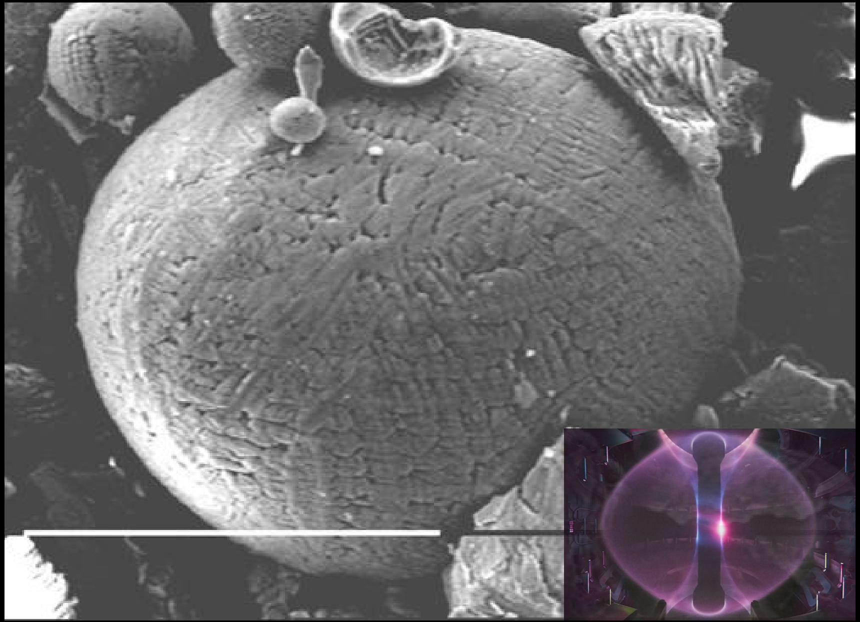
electrons + ions + neutrals = plasma

electrons + ions + neutrals + dust = *dusty plasma*



Naturally-forming dust can act as a contaminant.





Theoretical

$$\vec{\nabla} \cdot \vec{B} = 0$$

$$\vec{\nabla} \times \vec{E} + \frac{1}{c}\frac{\partial B}{\partial t} = 0$$

$$\vec{\nabla} \cdot \vec{E} = 4\pi\rho$$

$$\vec{\nabla} \times \vec{B} - \frac{1}{c}\frac{\partial E}{\partial t} = \frac{4\pi}{c}\vec{J}$$

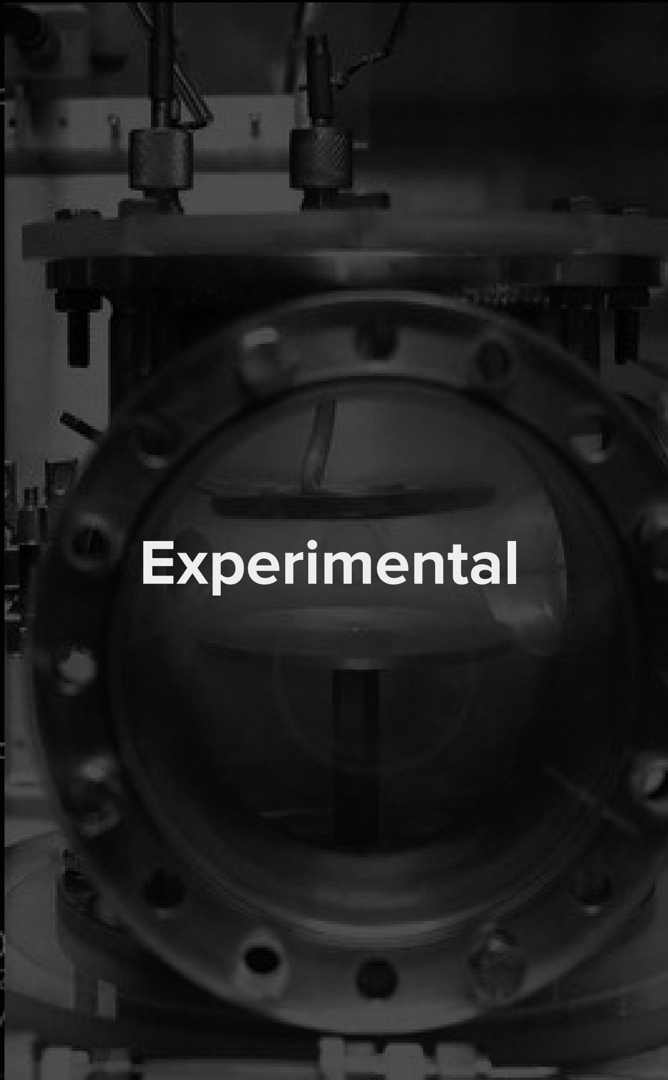
$$\vec{B} = \vec{\nabla} \times \vec{A}$$

$$\vec{E} = -\vec{\nabla}\phi - \frac{1}{c}\frac{\partial A}{\partial t}$$

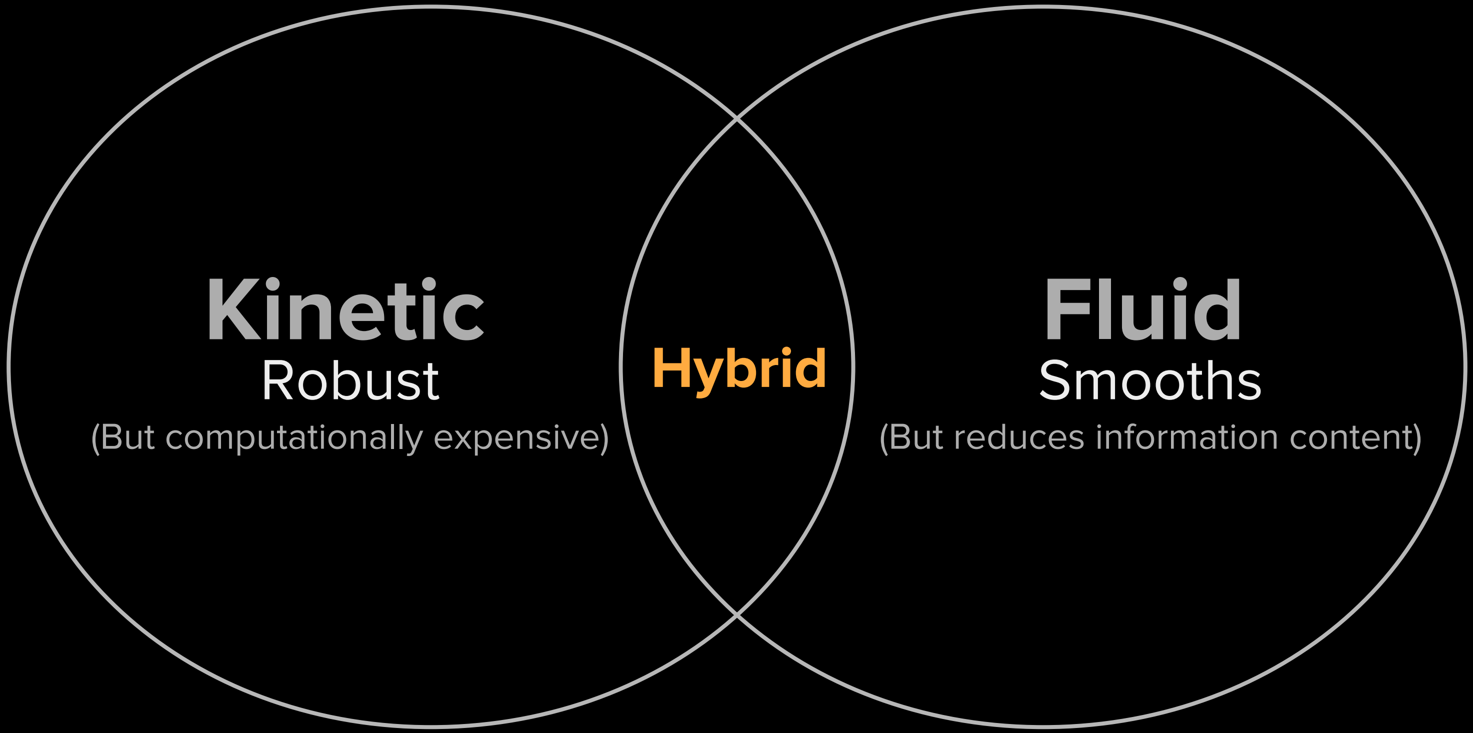
Computational

```
E_from_V(rho, J, dx):
"""Uses the finite differenc

source = rho[0:J-1]*dx**2
M = np.zeros((J-1,J-1))

for i in range(0, J-1):
    for j in range(0, J-1):
        if i == j:
            M[i,j] = 2.
        if i == j-1:
            M[i,j] = -1.
        if i == j+1:

M[0, J-2] = -1.
M[J-2, 0] = -1.

V = np.linalg.solve(M, sourc

E = np.zeros((J,1))

for i in range (1,J-2):
    E[i] = (V[i+1] - V[i-1])
E[J-2] = (V[0] - V[J-3]) / 2
E[0] = (V[1] - V[J-2]) / 2./
E[J-1] = E[0]
```

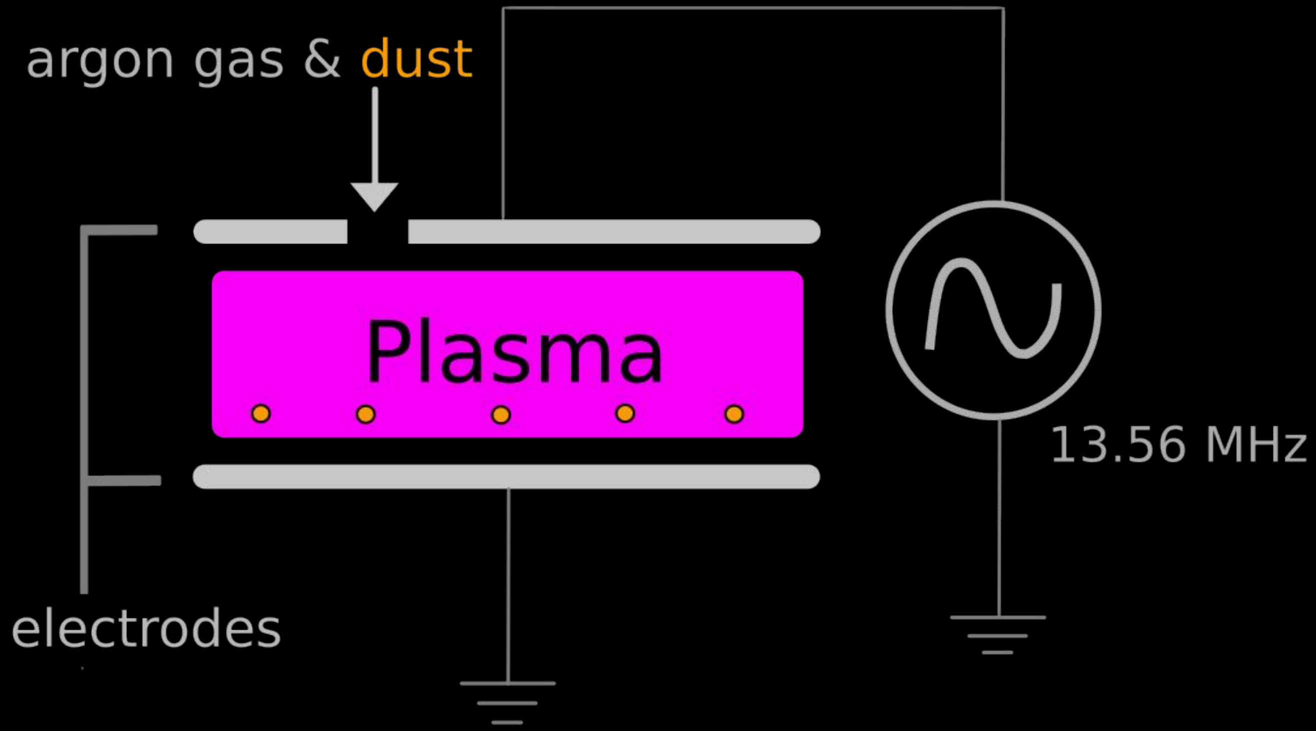
Experimental



Plasma simulations can be divided into two main categories.



CCRF Discharge Plasma



Goal: Hack together a hybrid fluid-kinetic simulation using Python.

Kinetic

- Electrons
  - *Particle-in-cell (PIC)*

Fluid

- Dust
- Ions

```
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M[0, J-2] = -1.
M[J-2, 0] = -1.

V = np.linalg.solve(M, sou

E = np.zeros((J,1))

for i in range (1,J-2):
    E[i] = (V[i+1] - V[i-1
E[J-2] = (V[0] - V[J-3]) /
E[0] = (V[1] - V[J-2]) / 2
E[J-1] = E[0]
```

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Test problem: instability of opposing electron streams in a uniform background

Goal: Create free and open source content

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Cool! This is in Python right? I'd be interested in seeing the source :)

github.com/space-isa