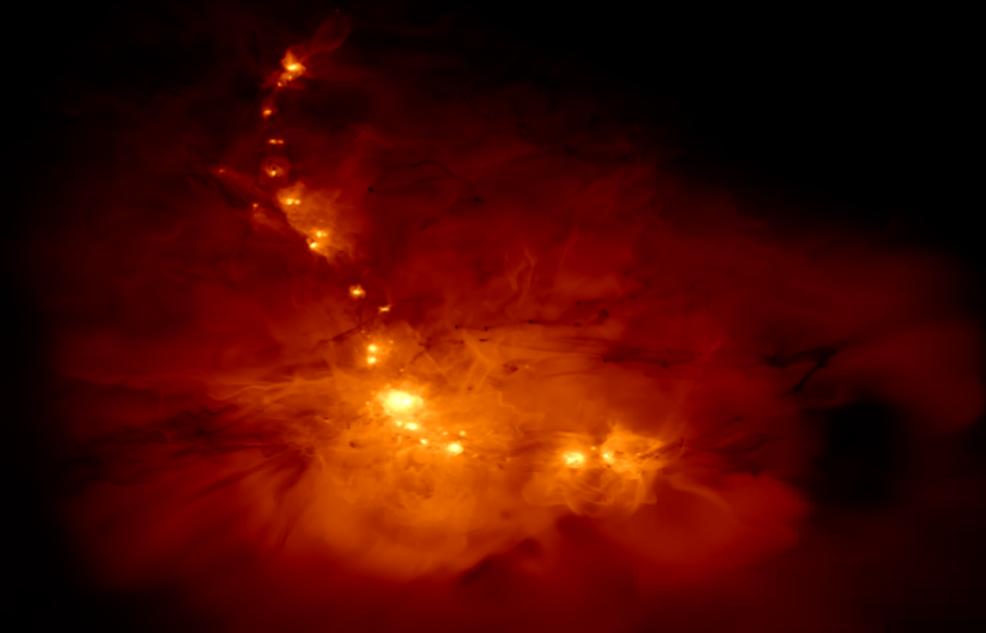


Radiation hydrodynamics of star formation

Infrared feedback in molecular clouds

Master thesis presentation



Structure

- Radiation hydrodynamics
- Numerical methods
- Molecular clouds
- Star formation theory
- Simulation results

Hydrodynamics

- Particles — Continuum
- Microscopic — Macroscopic

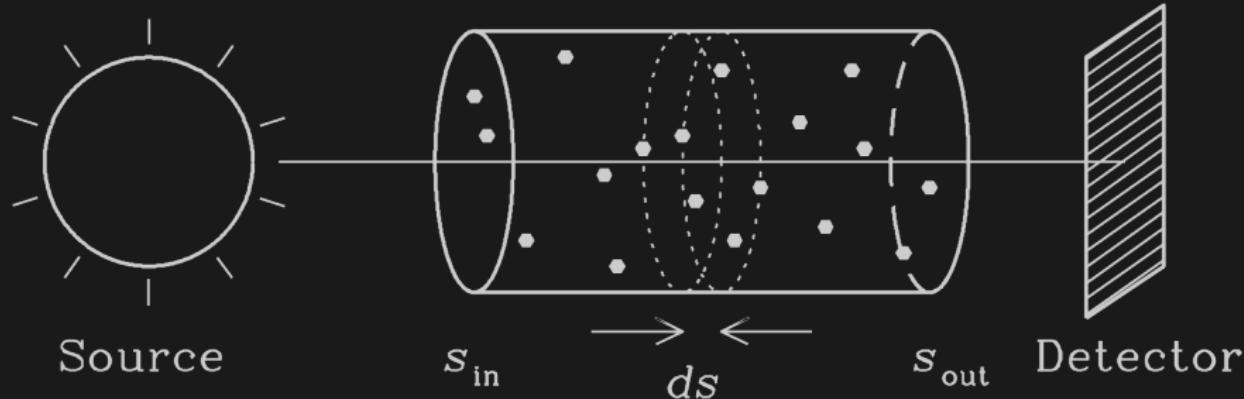
Euler equations

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

$$\frac{\partial(\rho \mathbf{u})}{\partial t} + \nabla \cdot (\rho(\mathbf{u} \otimes \mathbf{u}) + \mathbb{P}) = \rho \mathbf{a}$$

$$\frac{\partial E}{\partial t} + \nabla \cdot (E + \mathbb{P})\mathbf{u} = \rho \mathbf{a} \mathbf{u}$$

Radiative transfer



s increases \rightarrow

$\leftarrow \tau$ increases

Radiative transfer

Radiative transfer equation

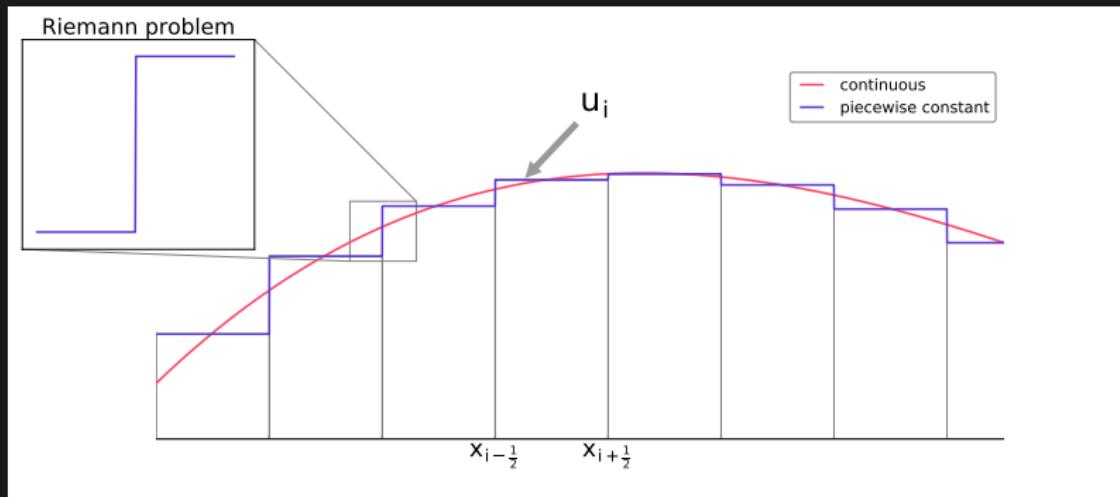
$$\frac{1}{c} \frac{\partial I_\nu}{\partial t} + \hat{\mathbf{n}} \cdot \nabla I_\nu = j_\nu - \alpha_\nu I_\nu$$

$$\frac{\partial E_\nu}{\partial t} + \nabla \cdot \mathbf{F}_\nu = 4\pi j_\nu - \alpha_\nu c E_\nu$$

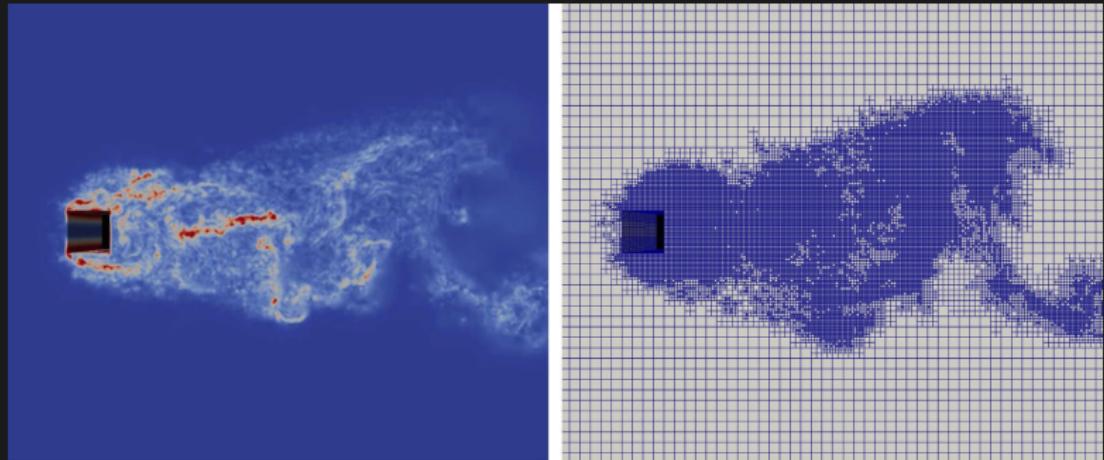
$$\frac{1}{c^2} \frac{\partial \mathbf{F}_\nu}{\partial t} + \nabla \cdot \mathbb{P}_\nu = -\frac{\alpha_\nu \mathbf{F}_\nu}{c}$$

Numerical methods

$$\frac{\partial \mathbf{U}}{\partial t} + \nabla \cdot \mathbf{F} = \mathbf{S} \quad \Rightarrow \quad \mathbf{U}_i^{n+1} = \mathbf{U}_i^n - \frac{\Delta t}{\Delta x} (\mathbf{F}_{i+1/2}^{n+1/2} - \mathbf{F}_{i-1/2}^{n+1/2})$$



Adaptive Mesh Refinement





<http://apod.nasa.gov/apod/image/1510/M16HubbleV4-X3walker.jpg>

Philipp Denzel

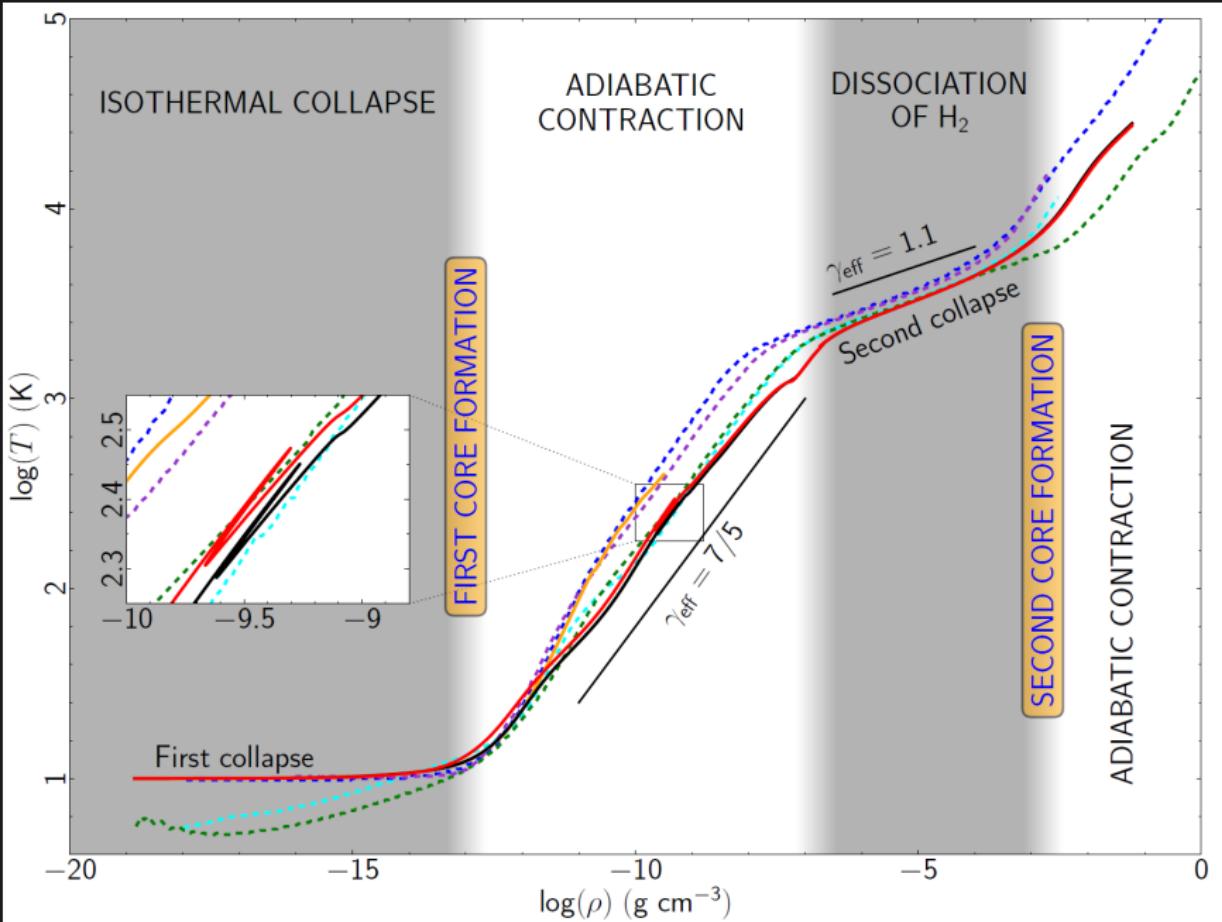
Radiation hydrodynamics of star formation



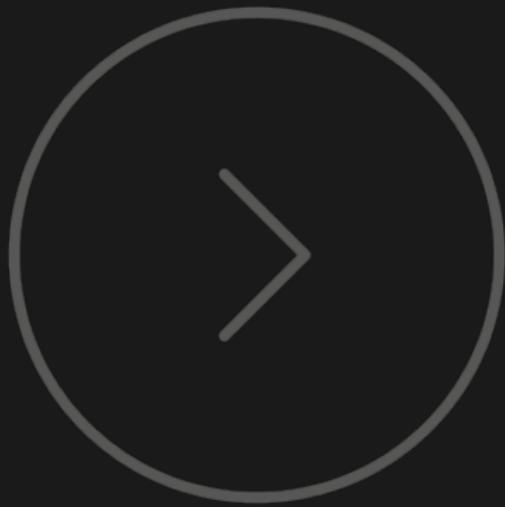
Credit: NASA, ESA/Hubble and the Hubble Heritage Team
<http://cdn.spacetelescope.org/archives/images/screen/heic1501a.jpg>

Philipp Denzel

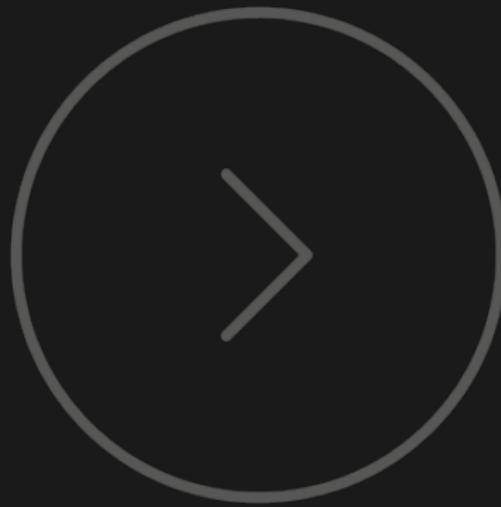
Radiation hydrodynamics of star formation



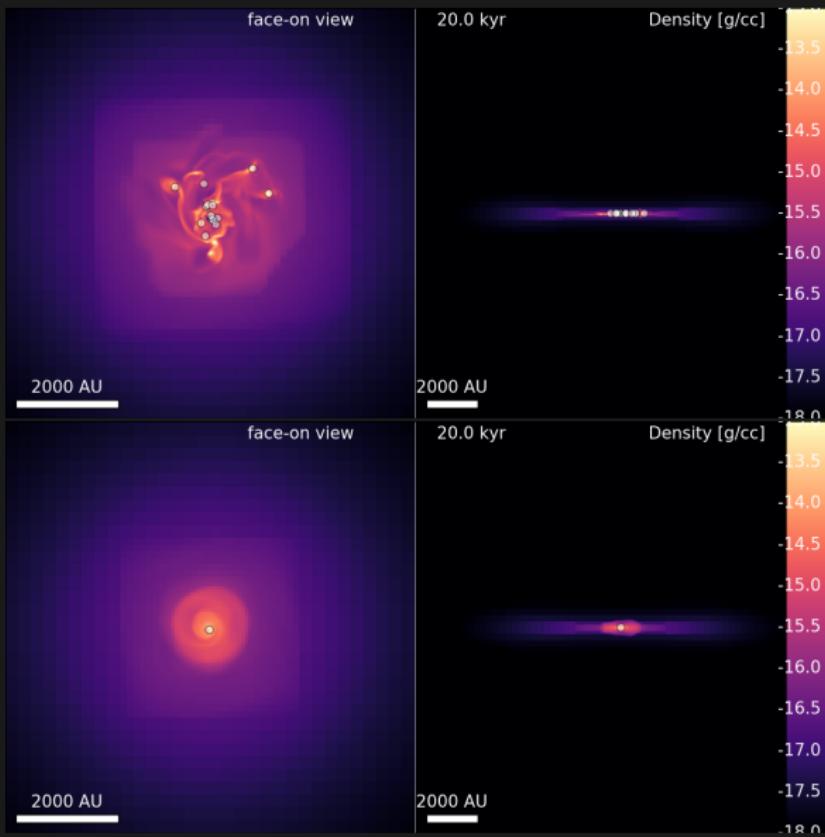
Core collapse – pure HD



Core collapse – RHD

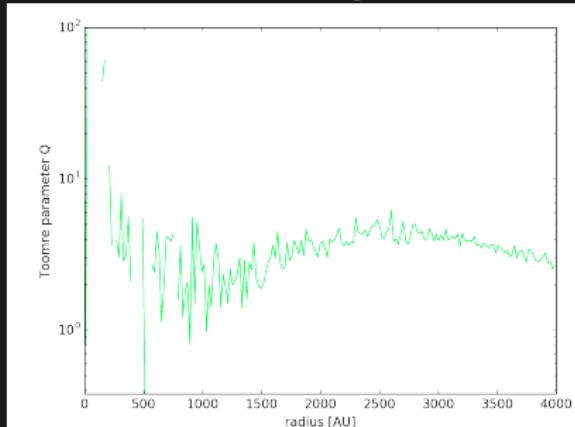


Comparison at 20 kyr

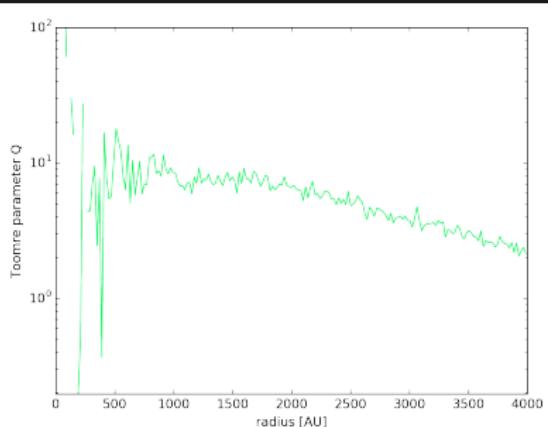


Toomre analysis

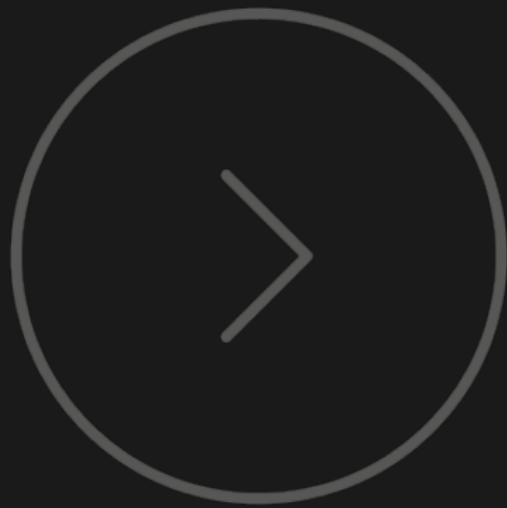
HYDO



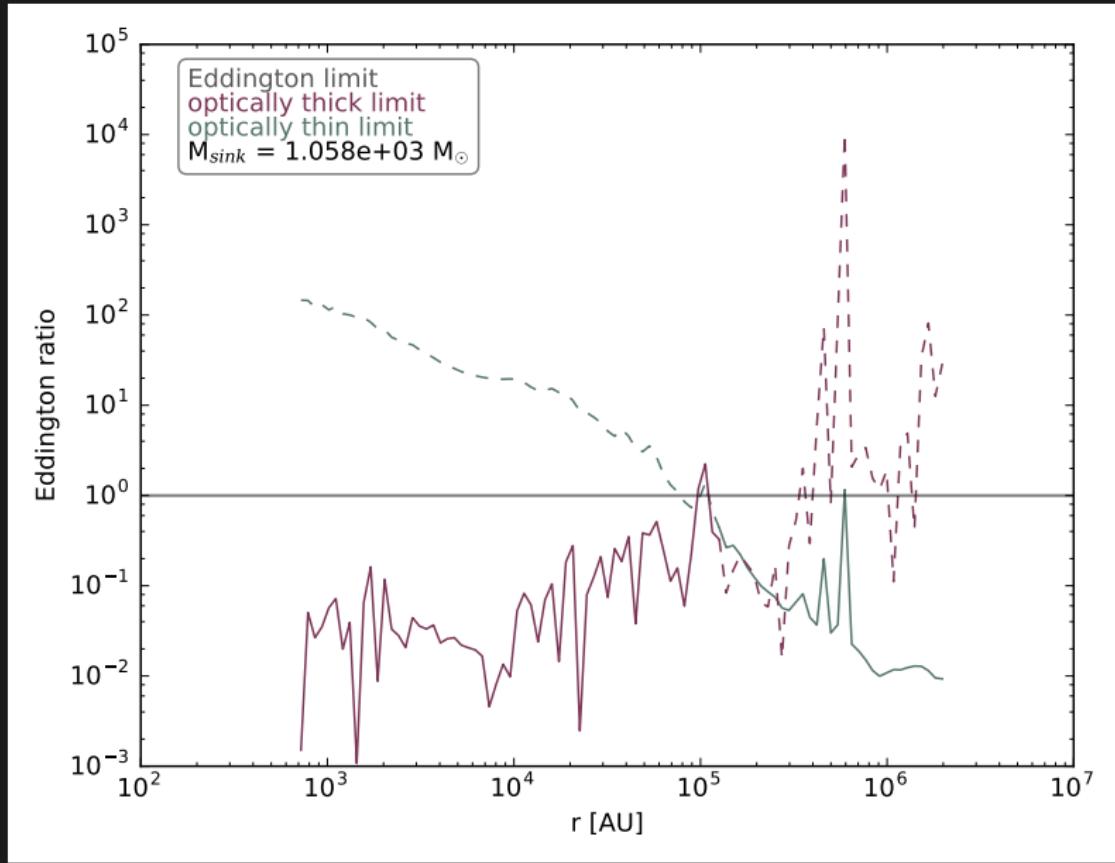
RHD



Simulated molecular cloud

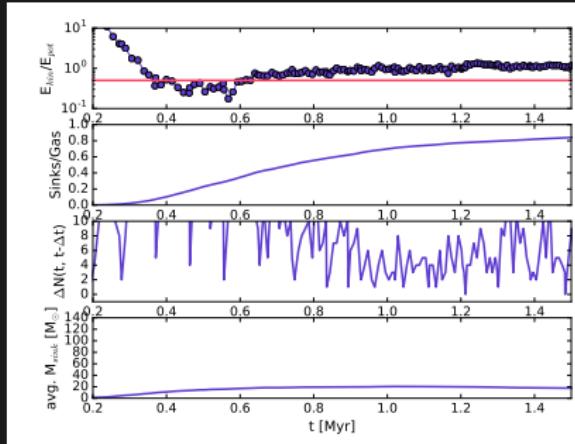


Eddington analysis

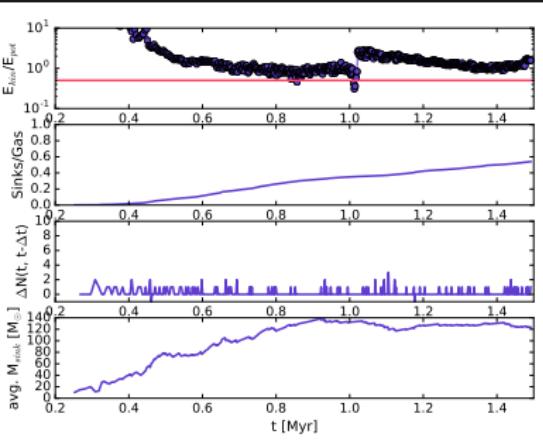


Star cluster

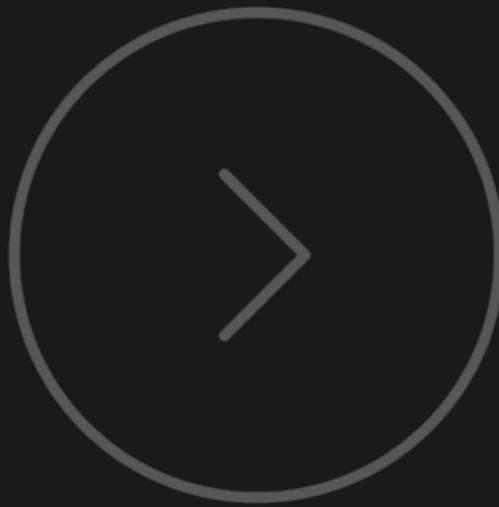
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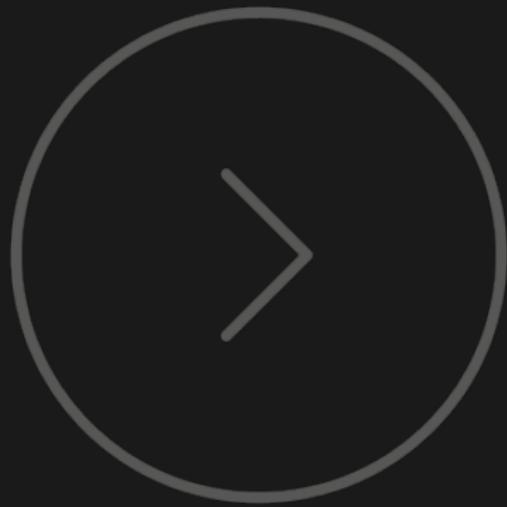
RHD



Thank you for listening!



Escapers



Cloud temperature

