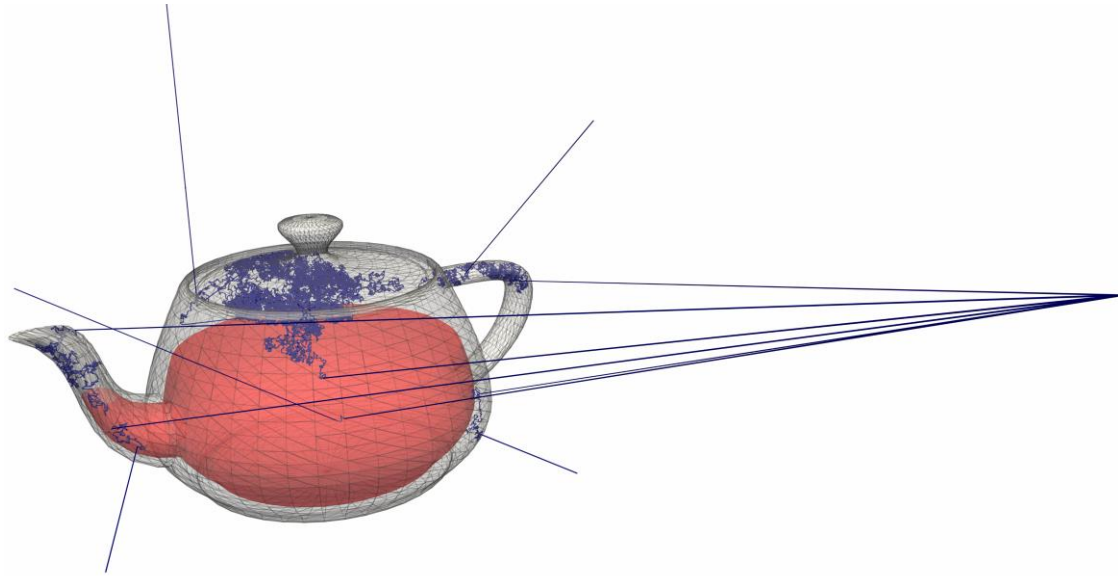
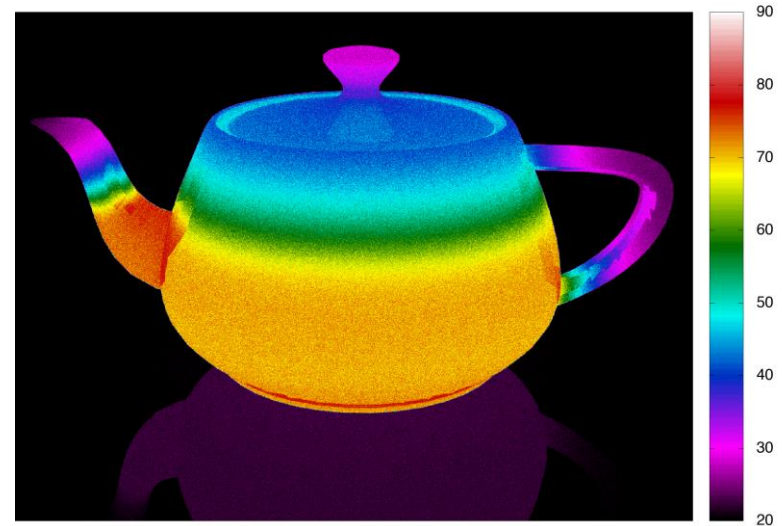


Stardis overview



(a) Example of thermal paths sampled to compute rendering image of the tea pot



(b) Computer generated image of the tea pot
[Eymet et al.,2019]

Léa Penazzi, Olivier Farges

Tuesday, November 16th, 2021



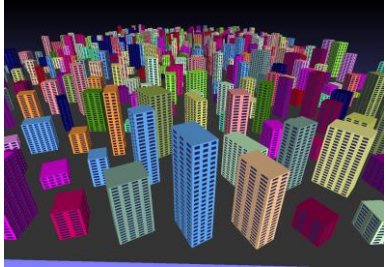
① Scientific context

- Méso-Star: Make know-how accessible
- Partnership between LAPLACE/UPS/Méso-Star
- EDStar group
- Objectives of EDStar platform

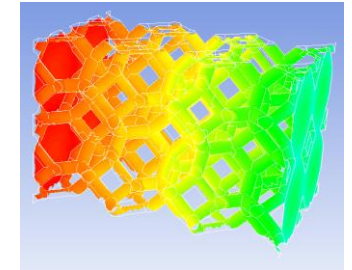
② Stardis overview

- What is Stardis ?
- Stardis, for who ?
- Why use Stardis ?
- Structure of Stardis framework
- Main functionalities of Stardis
- What may be the need ?

Thermal performance of buildings



Heat transfer in porous media



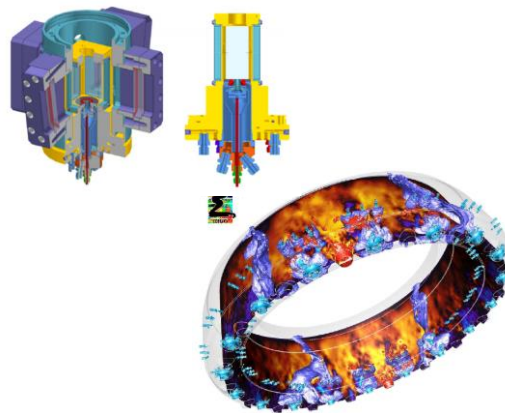
Solving **complex thermal and energy** problems

- High spatial and time scale ratios
- Coupling of phenomena

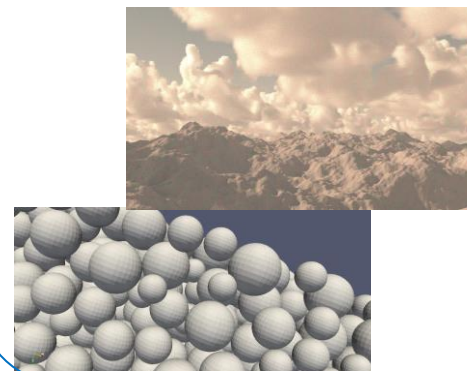
Solar processes



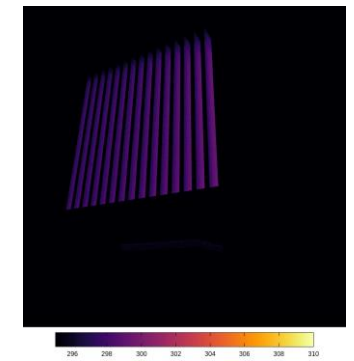
Combustion

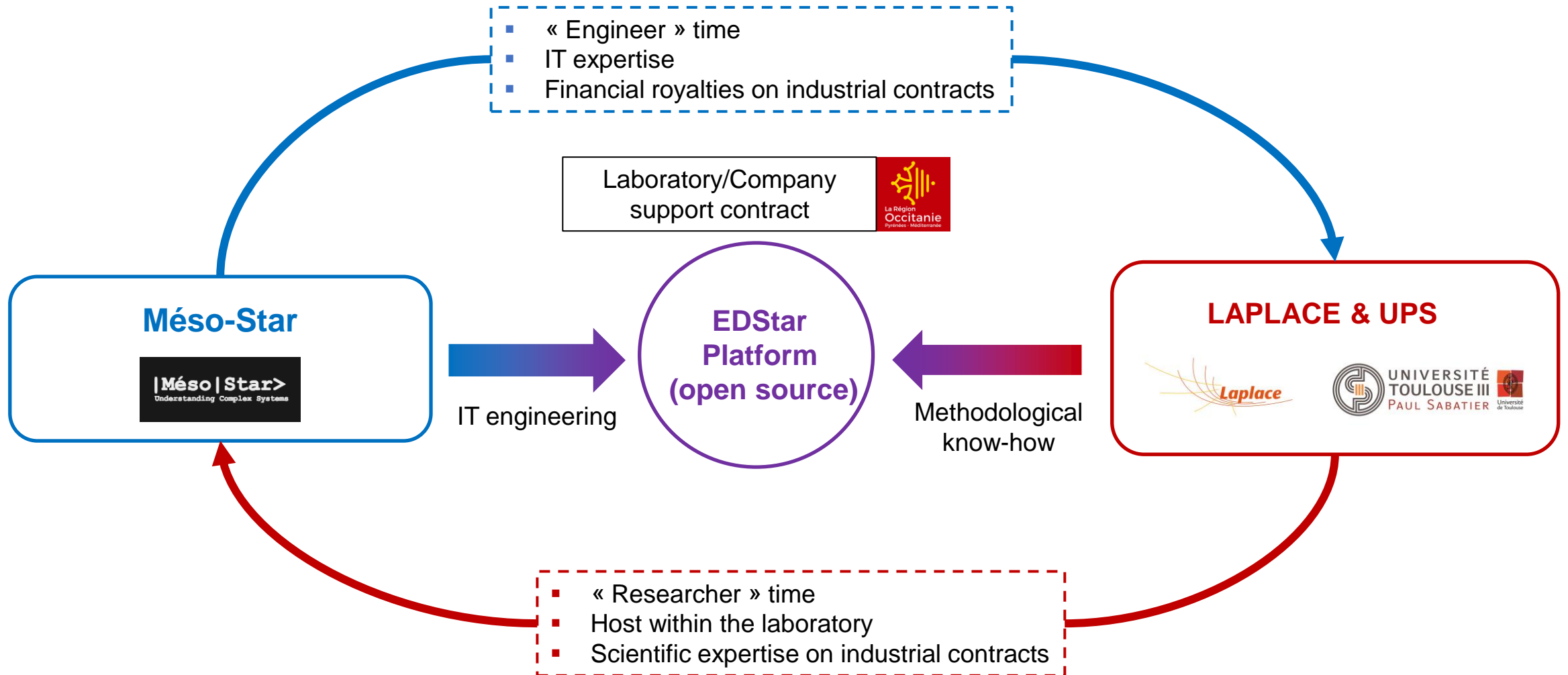


Atmospheric/planetary physics



Electronic devices thermal transfer







► More than **30 participants** at each **annual seminar**

EDStar Platform
(open source)

Researchers

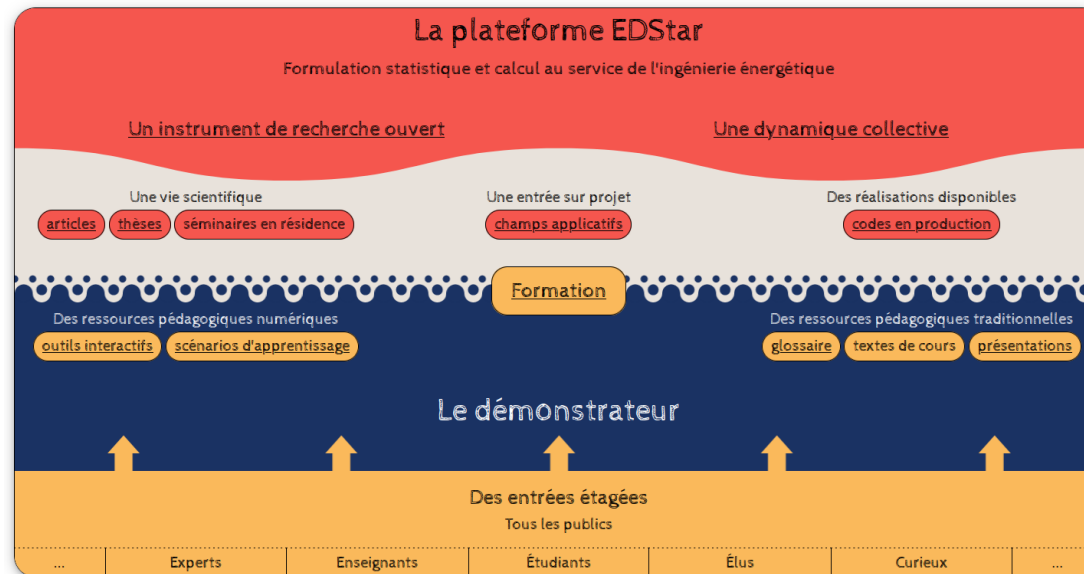


Research engineers




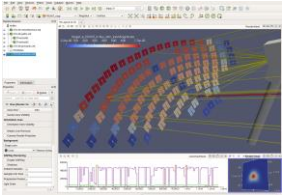
- PhotoLyx
- LAPLACE
- LTZ

- ▶ **EDStar**: Scientific computing platform for the **analysis** and **dimensioning** of energy systems
- ▶ Welcomes teams :
 - that **have reached the limits** of the usual **deterministic calculation strategies**
 - Wishing to **explore statistical alternatives**


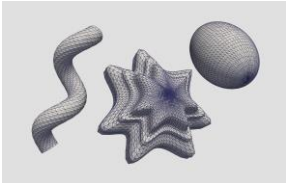


► **Completed** projects :


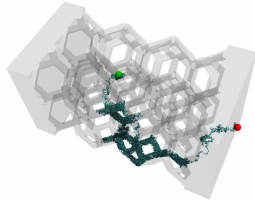
Solstice
The solar plant simulation




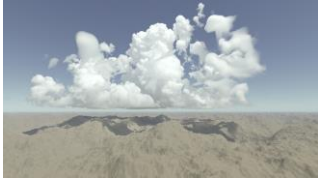
Schiff
Radiative properties of soft particles



Stardis
The Monte-Carlo framework for coupled thermal problems



Htrdr
The Monte-Carlo radiative transfer simulator



► **Teams external** to the platform carrying out projects currently hosted by the platform or in the process of being set up:



LMD/IPSL



CNRM/Météo-France



EDF



CSTB



AIRBUS

Airbus

...



What is Stardis ?

- ▶ Thermal simulation framework for **complex 2D** and **3D environments**
- ▶ Developed and based on **Monte-Carlo algorithms** :

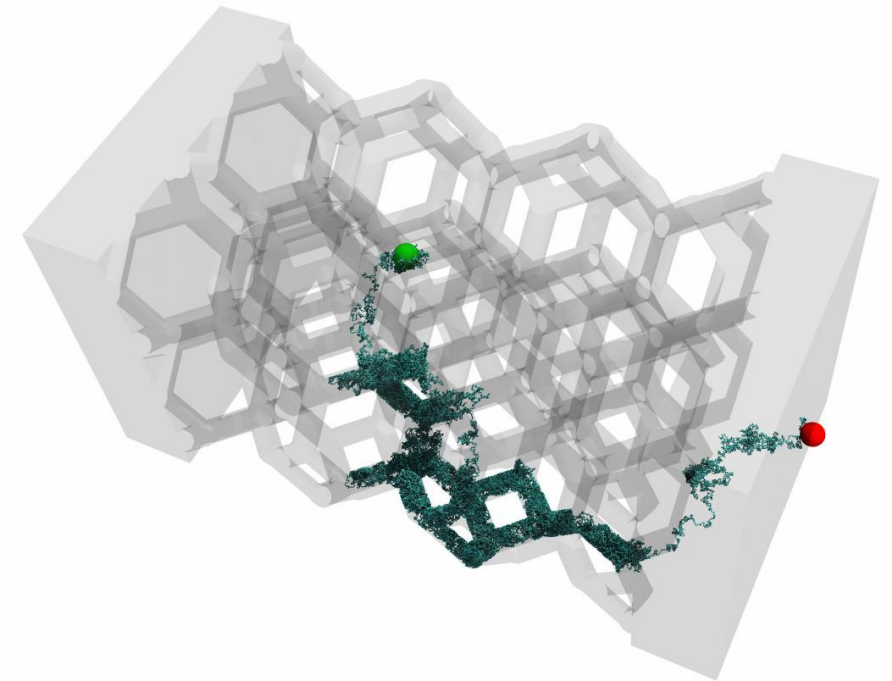
Reformulation of the main heat transfer phenomena :
conduction, convection and **radiation**



Cross-recursive algorithms : Simulation of « **thermal paths** »
exploring space and time until a boundary condition or initial
condition is found



Heat transfer phenomena are **naturally considered coupled**
(not separately)



*Example of conductive path sampled by Stardis in a foam geometry: it starts from the probe position (**green point**) and after several diffusive steps reaches a boundary condition (**red point**)*



Stardis, for who ?

▶ Stardis framework :

- Regular **thermal simulation tool**
- Engineers, researchers, students **willing to appropriate the statistical formulation of heat transfer**

from **theoretical concepts**



to **practical implementation**



Released under **free licences**

Garanty users the ability to **freely use, study, modify or extend** the complete source code **according to their needs**



Why use Stardis ?

- ▶ **Not meant to fully replace** already established and highly validated thermal simulation tools
- ▶ **Additional tool** useful for various purposes:

Probe computation

- Will **not** compute the **full temperature field** of a system
- Used to **focus** on a **specific spatial/temporal zone**

Reference method

- Estimation of a **quantity** and its **numerical uncertainty**
- Useful to **validate result** obtained by **any thermal solver** (when no analytical solution available, physical intuition impossible etc.)

Educational purposes

- **Thermal paths** naturally **explore** spatial and temporal zones of interest in the system
- **Direct visualization** of **what contributes** to a given result (ex: main sources of heat, what transfer modes are dominant etc.)

Sensitivity analysis

- **Green functions** (transfer functions) : can be reused for **very fast** post-processing computations
- Enable **exploring the sensitivity** of any result to variations of a boundary or initial condition or internal power source.



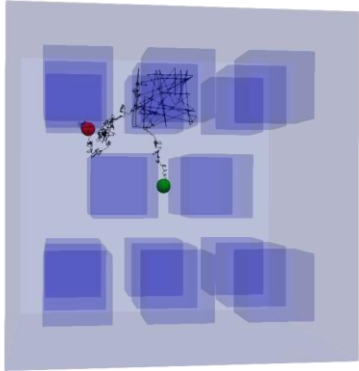
Structure of Stardis framework

► **Two** main components :

- **Input** data : geometry, thermal properties, boundary conditions etc.
- **Heat transfer simulation**
- **Results** post-processing

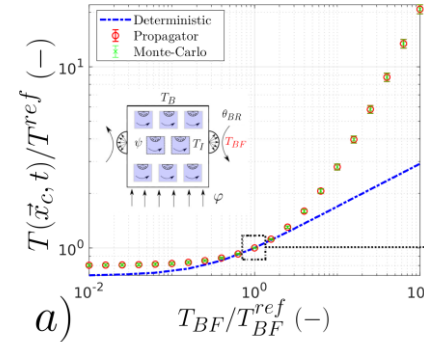


Probe computation



- Computes **temperature at a given position** (spatial and temporal)
- Computes the quantity and its **numerical uncertainty**

Green function

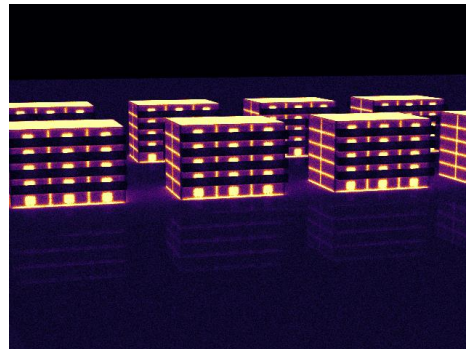


- Computes **temperature** at a given position (spatial and temporal) as a **function of heat sources**
- **Transfer function** depending on heat sources (fast post-processing computation)



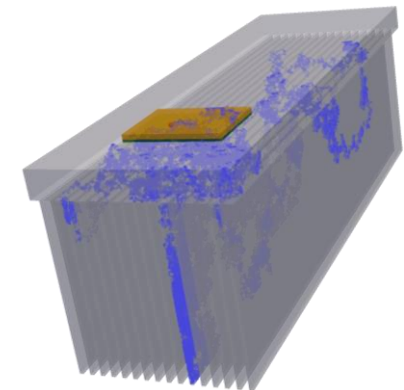
Infrared rendering

- **Rendering of a scene** without prior knowledge of the temperature field
- **Solving** the **coupled heat transfer problem**



Thermal path visualization

- **Outputs** the **complete history** of a set of **thermal path**
- **Physics data** stored along thermal paths



What may be the need?

- ▶ **Short-term** or punctual need → **Precise question** or issue regarding a thermal system
- ▶ **Mid-term or long-term** objective → **Research issues** that needs to be fully studied

Stardis Consortium

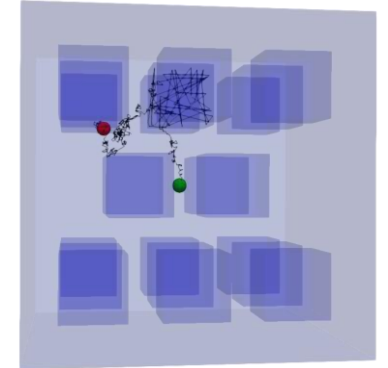
Intended for engineers and researchers who wish to acquire full control of Stardis:

- Ability to **integrate** Stardis **in their practice** as a thermal engineer
- Ability to **modify the code** for specific needs
- A **detail understanding** of the algorithms
- **Involvement** in development choices

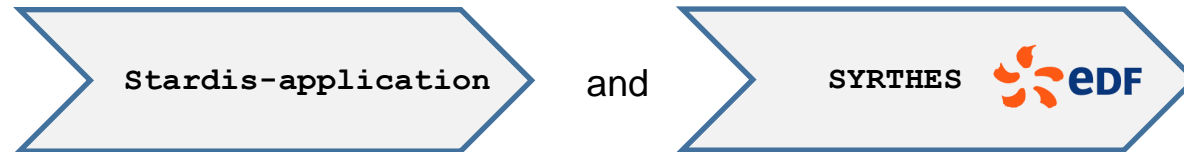


▶ **Stardis-Solver** :

- Simulates coupled **conductive-convective-radiative heat transfer** by sampling **thermal path**
- A thermal path explores **space and time** until a **boundary condition or an initial condition** is met
- Does **not** require **any volumetric mesh**
- Requires definitions of **thermal properties**, **limit/boundary conditions** and **geometry** defining contours of the objects



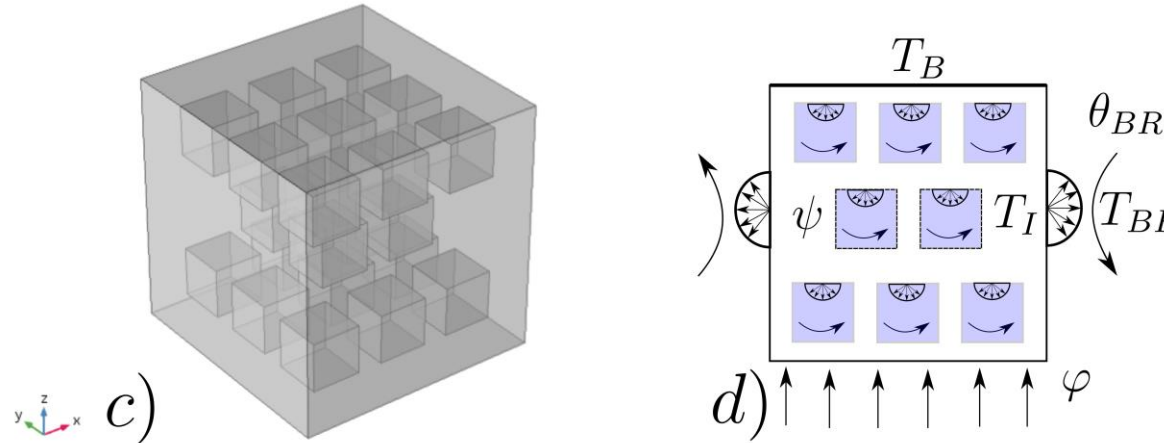
▶ Currently used in **two projects** :



▶ Based on following **assumptions**:

- **Conduction** : **Discretization** of thermal heat transfer in solids → conductive path length
- **Convection** : Fluid media supposed to be **isothermal** (perfectly agitated fluids)
- **Radiation** : Local radiative transfer is **linearized** (around a reference known temperature)

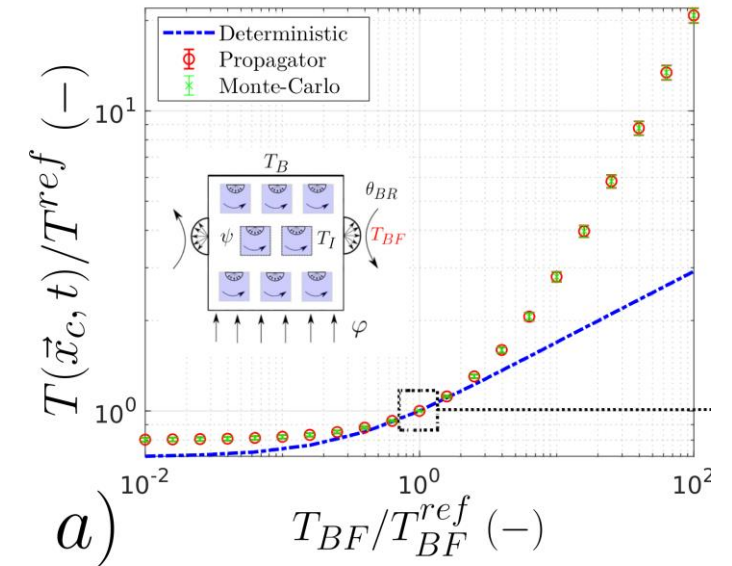




$$T(\vec{x}_{\text{obs}}, t_{\text{obs}}) \approx \underbrace{\frac{N_F}{N}}_{m_F} T_F + \underbrace{\frac{N_B}{N}}_{m_B} T_B + \underbrace{\frac{N_I}{N}}_{m_I} T_I + \underbrace{\frac{N_{BR}}{N}}_{m_{BR}} T_{BR} + \underbrace{\frac{1}{N} \sum_{i=1}^N \beta_{\psi}(\vec{x}_{\gamma_i, \psi})}_{m_{\psi}} \psi + \underbrace{\frac{1}{N} \sum_{i=1}^N \beta_{\varphi}(\vec{x}_{\gamma_i, \varphi})}_{m_{\varphi}} \varphi$$

► **Computation time** to output the **transfer function** :

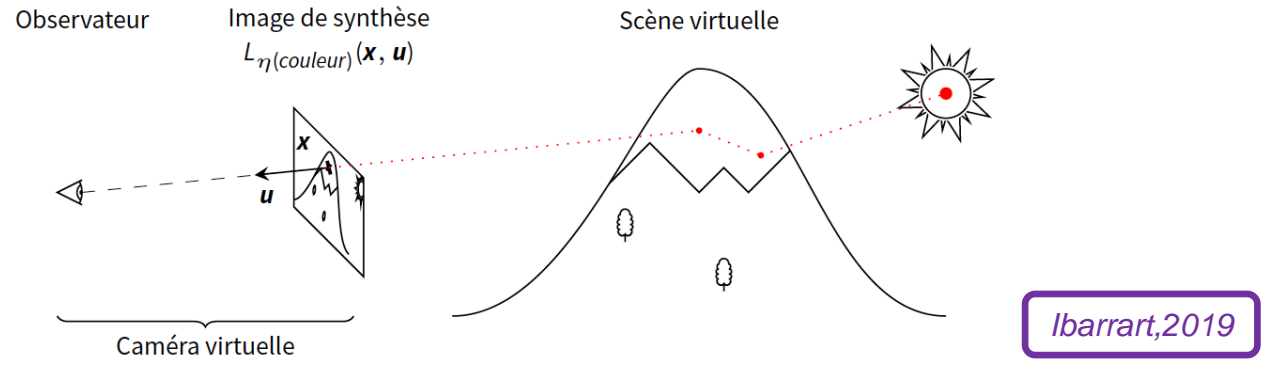
- Conduction + convection : ~ 50s *
- Conduction + convection + radiation : ~ 1min *



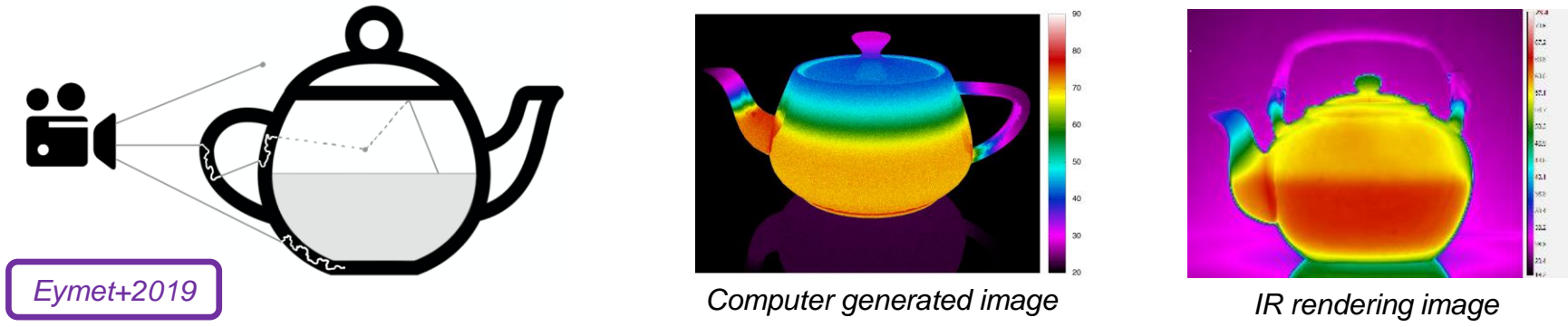


Infrared rendering

- **Rendering image** : Computation of an **intensity** → Computation of an **equivalent black body temperature** in each image pixel

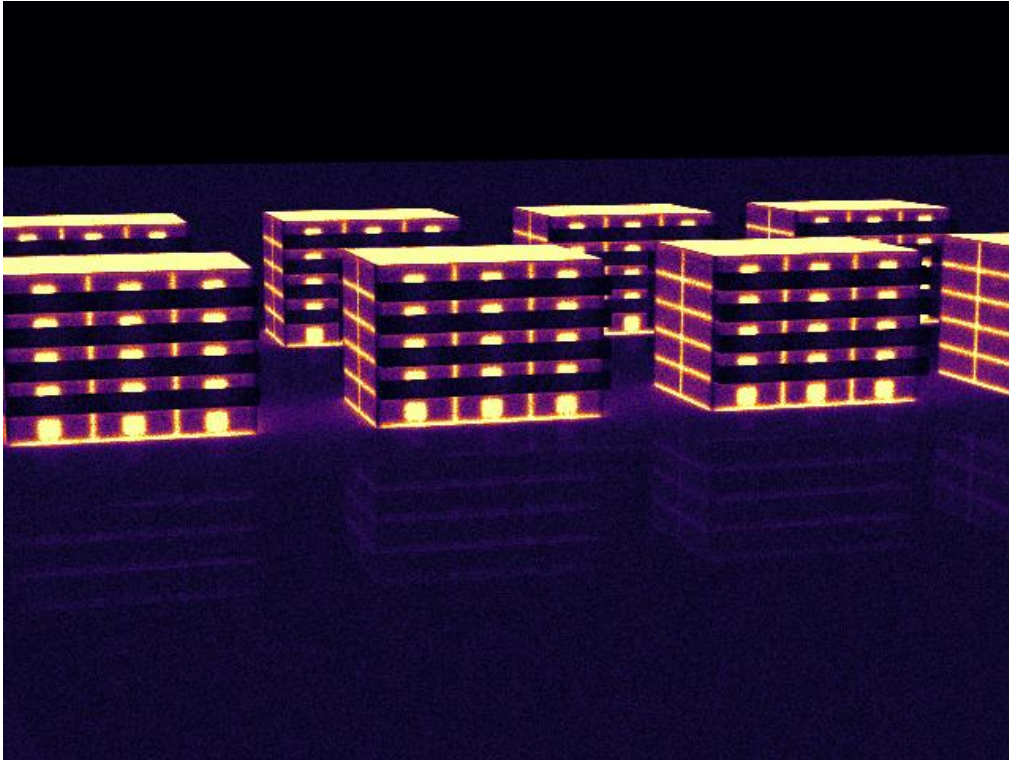


- **Typical example** of such algorithms : Computation of a **teapot IR rendering image**





Infrared rendering



Computer generated image of a neighbourhood [B. Piaud, 2021]

- ▶ External air temperature : 0°C
- ▶ Internal air cavities temperature : 20°C
- ▶ Ground temperature (-2 or -3m) : 13°C
- ▶ 640 x 480 pixels
- ▶ 1024 realizations / pixel
 - = 314 M of Monte-Carlo realizations
- ▶ **Computation time : ~ 5h** (AMD Ryzen 9 5950X)

