APE: providing physical conditions for chemical models and synthetic observations

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irap astrophysique & planétologie

hemtrip — The CHEMical TRail In Protostars: From the deeply embedded phase to the planet-forming disk

European Research Council — Established by the European Commission

ABSTRACT

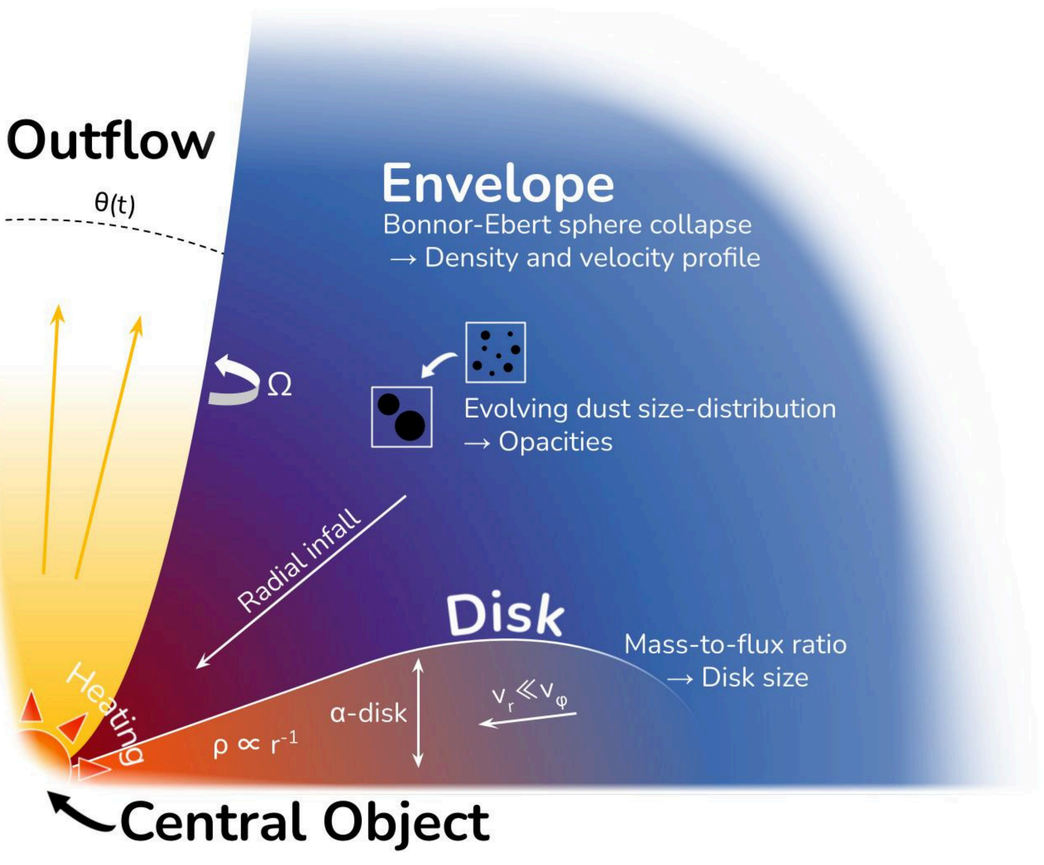
Chemical models and synthetic observations are of paramount importance to interpret and predict observations. Coupled together they offer a great opportunity to increase our understanding of the processes involved in star formation.

The new publicly available Analytical Protostellar Environment (APE) code (Marchand et al. 2025) has been designed for this purpose. It allows simulations and synthetic observations to be perfomed at low computational cost, providing a powerful approach to interpret and predict observations. APE use a semi-analytical model describing dynamically the formation and the evolution of the protostar and its environment from the onset of the prestellar collapse to the end of the Class I stage. It includes the central object, the envelope, the protoplanetary disk and the outflow. The APE code itself directly allows to work with different modes to either produce density and temperature maps at a given time, or to follow the physical history of individual particles. The code is provided with interfaces to other publicly available codes to perform chemical simulations (Nautilus), radiative transfer calculations (RADMC-3D) and synthetic interferometry imaging (Imager).

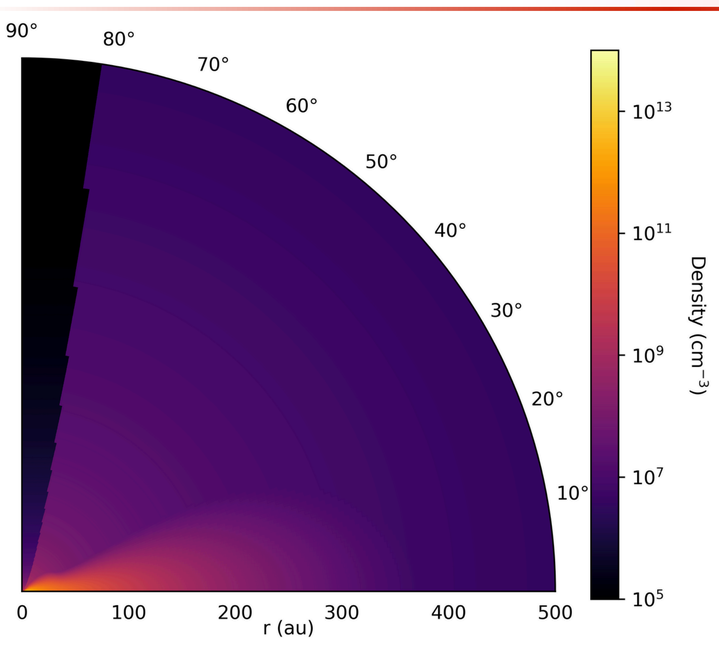
General description

APE is a **semi-analytical model** describing **dynamically** the **formation** and the **evolution** of:

- the **central object** (protostar)
- the **envelope**
- the **protoplanetary disk**
- the **outflow**



2 modes of APE

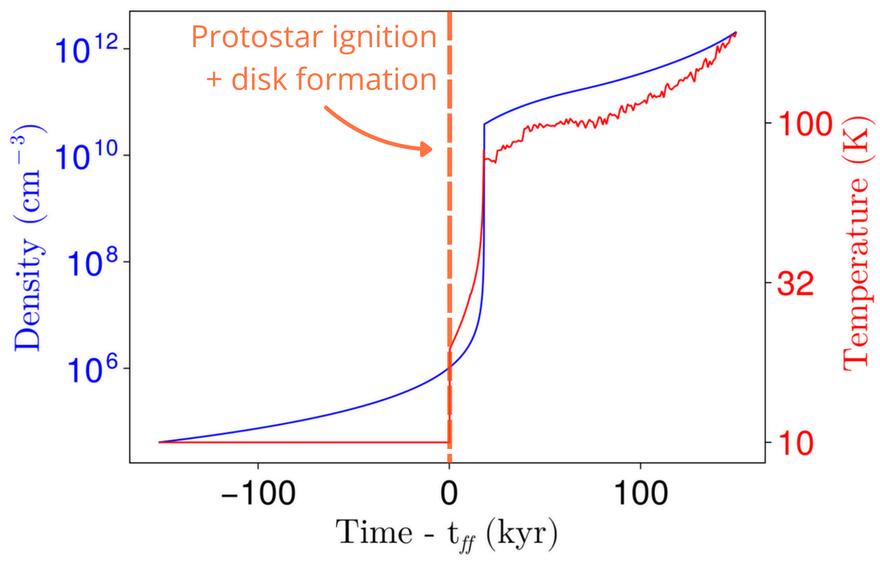


Snapshot mode

The **snapshot mode** provides **temperature**, **density** and **grain size-distribution maps** at a **chosen time**

Particle mode

The **particle mode** provides the **time history** of the **physical properties** of a **particle** (temperature, density, visual extinction, position, velocity, ...)

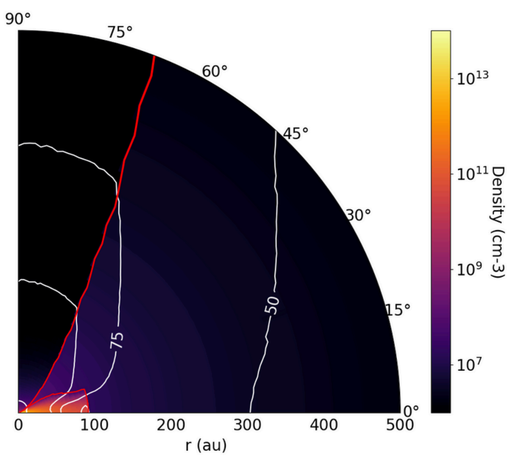


What can you do with APE?

APE provides **interfaces** to work with the following codes

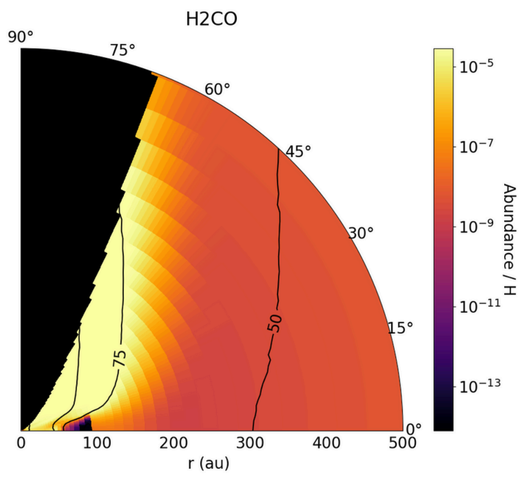
APE — Physical model — Marchand et al. 2025

Density, temperature maps



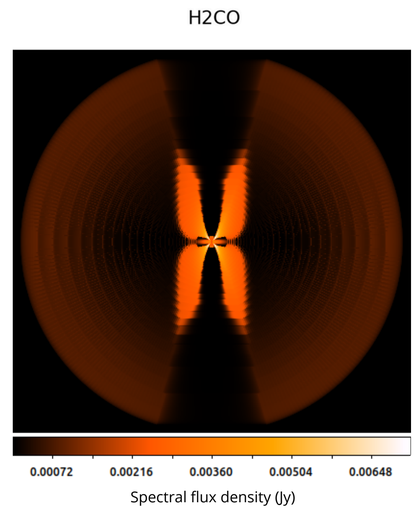
→ **Nautilus** — Chemical model — Ruaud et al. 2016

Abundance maps



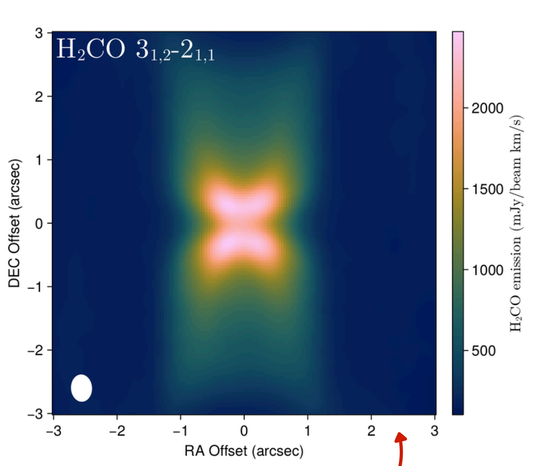
→ **RADMC-3D** — Radiative transfer — Dullemond et al. 2012

Emission maps



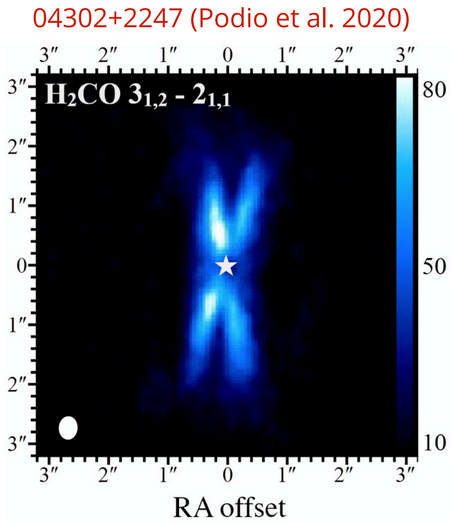
→ **Imager*** — Telescope simulation ↔ Observations

Synthetic observations hyperspectral cube



Example with moment 0 map from Marchand et al. 2025

Real observations of IRAS 04302+2247 (Podio et al. 2020)



* https://imager.oasu.u-bordeaux.fr

Other studies with APE

- Marchand et al. (submitted) — *The evolution of complex organic molecules during star formation*
- Marchand et al. (in preparation) — *Biases in the observation of protostars: insights from synthetic observations*
- Espagnet et al. (in preparation) — *Modeling the Chemical Impacts of Luminosity Outbursts in Protostellar Envelopes*

Download APE

https://bitbucket.org/pmarchan/ape_code

This study is part of a project that has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant agreement No. 949278, Chemtrip)