pynucastro: Code Generation and Visualization for Nuclear Reaction Networks

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Abstract

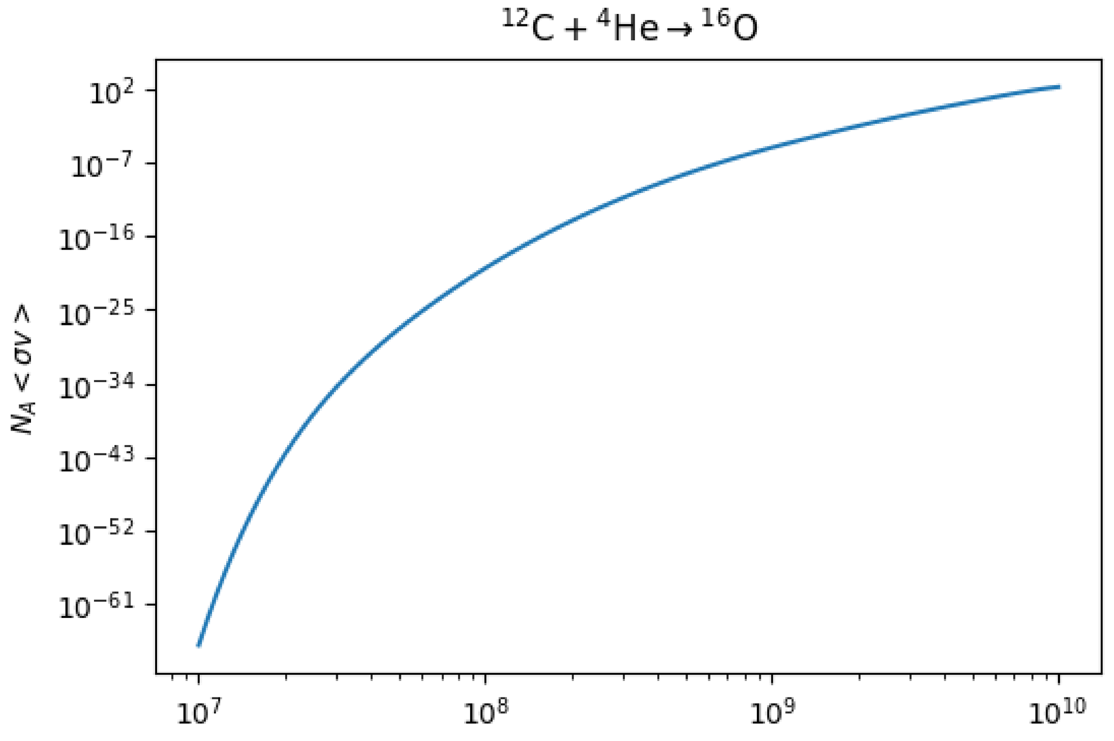
pynucastro is developed to meet both pedagogical and research needs in the field of nuclear astrophysics by providing a Python interface to nuclear reaction rate databases (including the JINA Reaclib nuclear reaction rate database). It is meant for both **interactive exploration** of reaction rates (through Jupyter notebooks) and for creating **reaction networks for simulation codes**.

Capabilities

- Supports Reaclib library snapshots [1]
- Supports weak rates [2] tabulated in $(\mathrm{T}, \rho \mathrm{Y_e})$
- Visualizes connections between nuclei as a network graph
- Evaluates rates as a function of temperature
- Symbolically constructs the ODE right hand side and Jacobian
- Generates Python or Fortran code implementing the network

Working with Reaclib

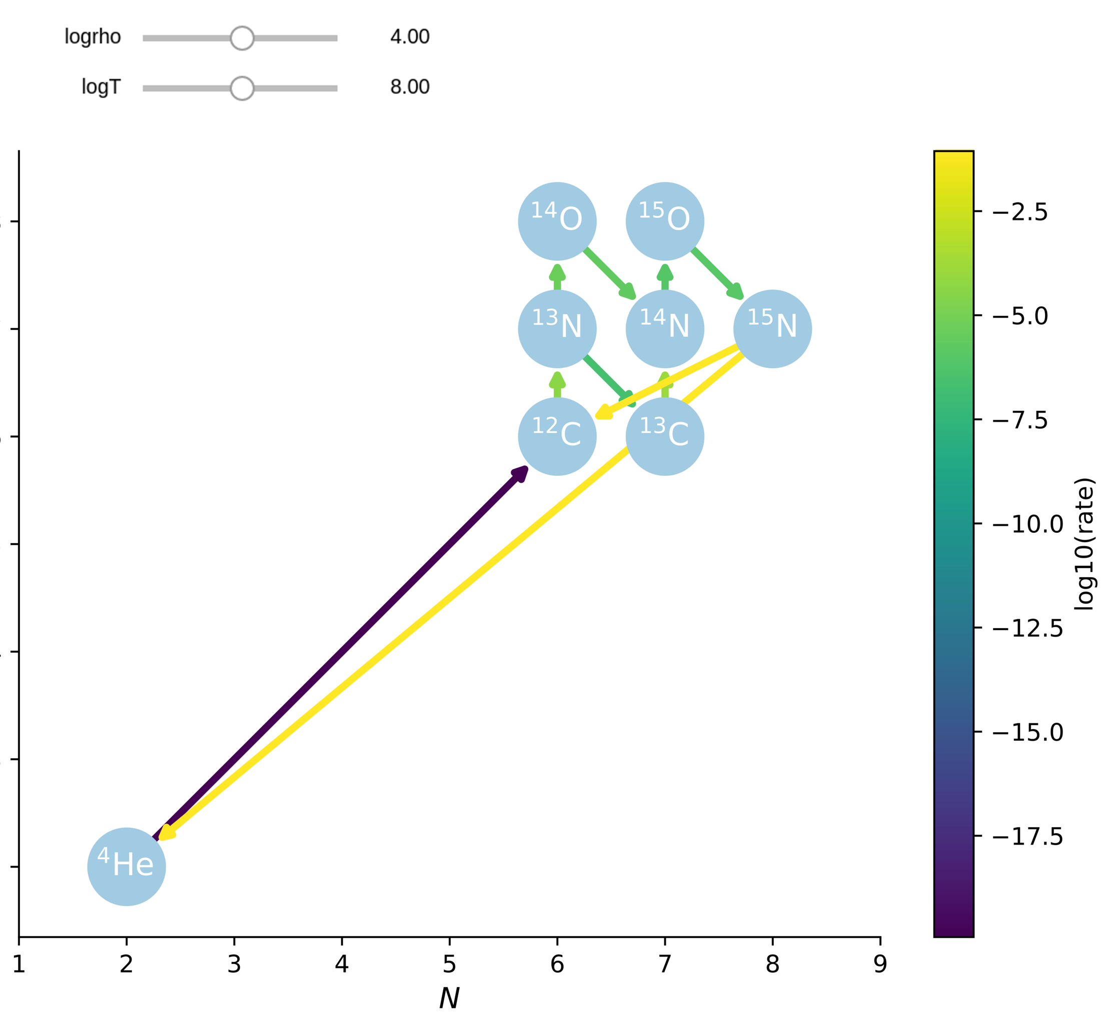
pynucastro can interpret reaction rates parameterized in the standard Reaclib formats, storing each rate internally using the **Rate** class. **Rate** interprets the Reaclib format and knows how to evaluate the rate as a function of temperature.



Creating a Network

The **Library** class allows pynucastro to work easily with files containing multiple rates, including Reaclib snapshots. We use **Library** to obtain the CNO rates linking our desired nuclei in just a few lines of Python in the following Jupyter notebook:

```
%matplotlib inline
import pynucastro as pyna

mylibrary = pyna.rates.Library('20180201ReaclibV2.22')

all_nuclei = ["p", "he4", "c12", "n13", "c13", "o14", "n14", "o15", "n15"]

cno_library = mylibrary.linking_nuclei(all_nuclei, with_reverse=False)

cno_network = pyna.networks.PythonNetwork(libraries=cno_library)

cno_network.write_network('network_module.py')

comp = pyna.Composition(cno_network.get_nuclei())
comp.set_solar_like()

re = pyna.Explorer(cno_network, comp)
re.explore()
```



Using the **Composition** and **Explorer** classes, we also construct an interactive graph of the network with the value of each rate indicated by its arrow color with variable density and temperature.

Python Code Generation

The **PythonNetwork** class generates Python code to calculate each rate as a function of temperature and the ODE right hand side. pynucastro includes a sample Python integrator using SciPy.

StarKiller Microphysics

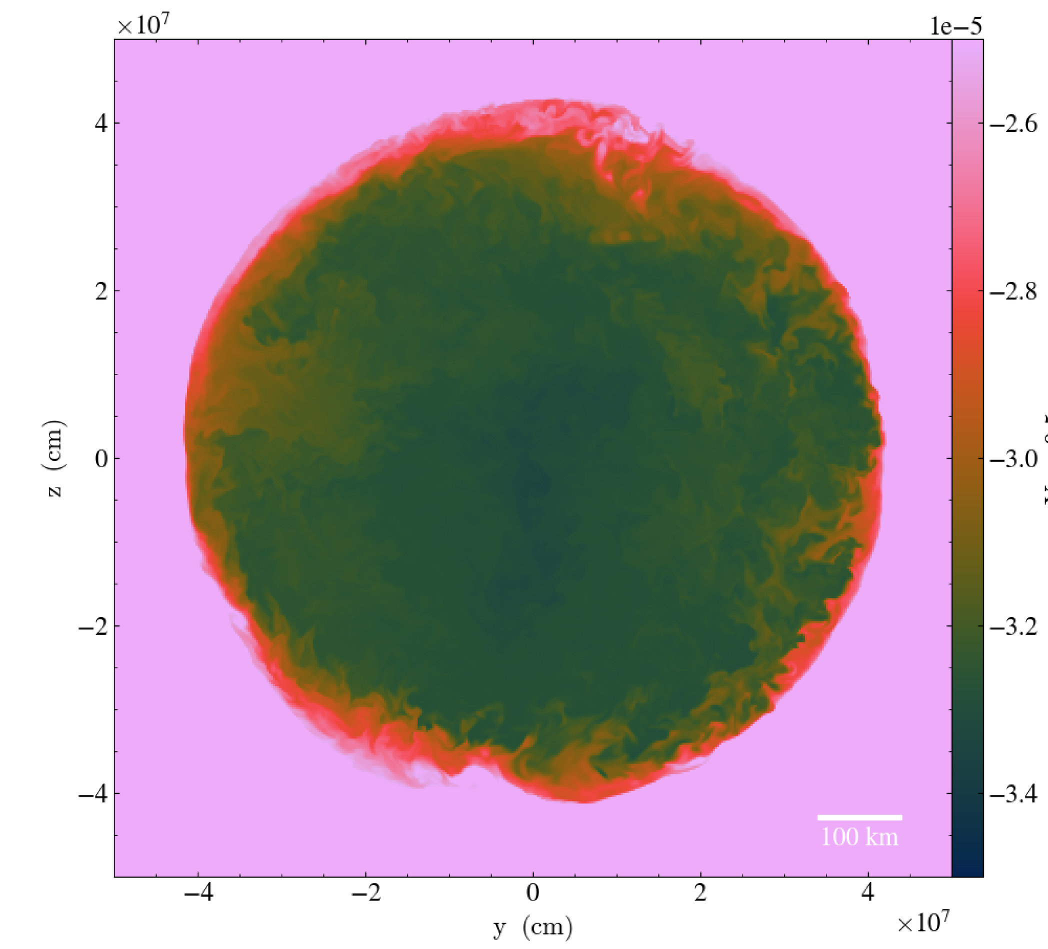
The **StarKillerNetwork** class generates Fortran reaction network code for astrophysical simulations that use the StarKiller Microphysics repository [3].

- Right hand side and Jacobian with SymPy [4]
- Couples to a stellar equation of state
- Incorporates screening and thermal neutrinos
- Supports CUDA Fortran

This short Python script builds a ^{12}C burning network with tabulated weak $A = 23$ rates:

```
# C-burning with A=23 URCA rate module generator

from pynucastro.networks import StarKillerNetwork

files = ["c12-c12a-ne20-cf88",
         "c12-c12n-mg23-cf88",
         "c12-c12p-na23-cf88",
         "c12-ag-o16-nac2",
         "na23--ne23-toki",
         "ne23--na23-toki",
         "n--p-wc12"]

urca_net = StarKillerNetwork(files)
urca_net.write_network()
```

Electron fraction in a Maestro low-Mach hydrodynamics simulation of a 3-D convecting white dwarf core using the $A = 23$ Urca network:



Ongoing Development

- Implementing nuclear partition functions
- Expanding support for weak rate tabulations

Getting pynucastro

- pynucastro is freely available under the **BSD 3-Clause open source** license.
- For the companion **software paper**, see [5].
- Visit us on GitHub to **download** pynucastro or report **issues** and **request features**:

`https://github.com/pynucastro/pynucastro`

- For pynucastro **documentation** and examples, visit the pynucastro website:

`https://pynucastro.github.io/pynucastro`

Acknowledgements

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