Modular GRMHD: Con2Prim Routines

Samuel Cupp
in collaboration with Terrence Pierre Jacques,
Leo Werneck, Zach Etienne

University of Idaho

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  - routines to convert between conservative and primitive variables
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- separating different pieces of the code as much as is reasonable helps keep the intention of each piece of code clear, and makes the usage and dependencies of individual functions clearer
- IllinoisGRMHD already exists in two different infrastructures (Cactus, NRPy+), and a unified code structure across these different ecosystems will help streamline maintenance and future development of the code

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- Work has begun on conservative-to-primitive routines, equation of state code, and reconstruction code

Philosophy: Contributor Pipeline

- Students of NR must become experts in
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- Largest barrier for many physicists is often computational in nature
- Most common background for current physicists is Python and basic C++
- We aim to minimize barrier for entry by using
  - Python for codegen (NRPy+)
  - C with minimal data structures, minimal abstraction

Philosophy: Infrastructure Agnosticism

- IllinoisGRMHD, like many codes, is a monolithic code, meaning
  - it is difficult/messy to extend or improve
  - all code exists in the same directory–functions/routines not easily discoverable to developers
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- IllinoisGRMHD must also work in 2 different infrastructures:
  - Einstein Toolkit
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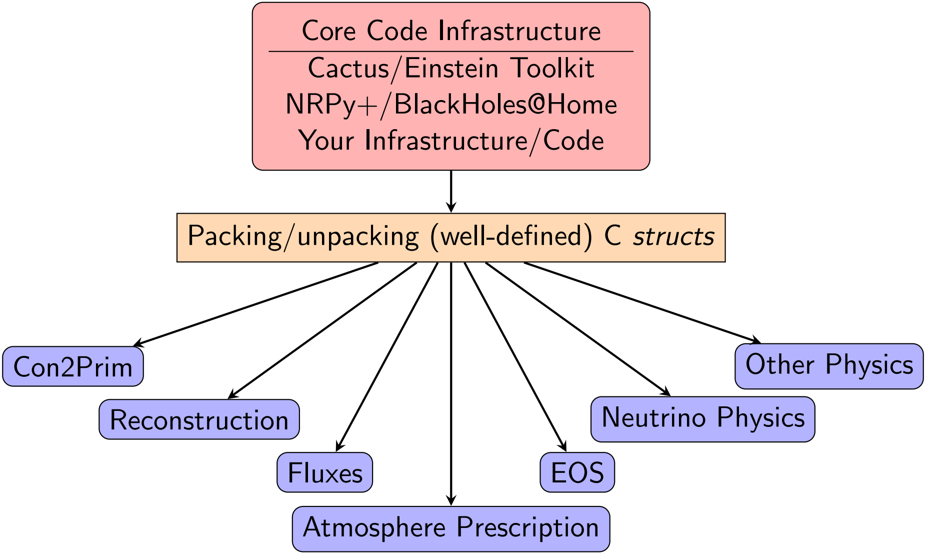
- Ultimate goals of modularization are to
  - "de-EinsteinToolkitify" IllinoisGRMHD
  - aim for zero dependencies on other codes

  while adopting best practices in code development, such as
  - Extensive documentation (via Jupyter notebooks)
  - Automatic codegen whenever useful (via NRPy+)
  - Self-contained unit tests for each module (with their own main() functions)
  - "Perfect" examples of how to implement the module

Project Vision



Core Code Infrastructure

Cactus/Einstein Toolkit

NRPy+/BlackHoles@Home

Your Infrastructure/Code

Packing/unpacking (well-defined) C *structs*

Con2Prim

Reconstruction

Fluxes

Atmosphere Prescription

EOS

Neutrino Physics

Other Physics

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- Creating a shared library of Con2Prim routines with a common interface would simplify the process of experimenting with new routines for all groups
- Implementation of a new routine can be immediately tested and used by others once it is made public.

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- Code has been condensed into a small number of functions, and some logic has been reduced or pulled into the associated functions
- Functions for packing/unpacking the structs are provided

Con2Prim Pseudocode

```
Declare/initialize GRMHD_parameters params;
Declare/initialize eos_parameters eos;
Declare/initialize con2prim_diagnostics diagnostics;
OMP for (loop over grid)
{
  Declare/initialize metric_quantities metric;
  Declare/initialize primitive_quantities prims, prims_guess;
  Declare/initialize conservative_quantities cons, cons_undens;

  apply_inequality_fixes( &params, &eos, &metric, &prims, &cons, &diagnostics);

  undensitize_conservatives( &eos, &metric, &prims, &cons, &cons_undens );

  guess_primitives( &eos, &metric, &prims, &cons, &prims_guess );

  con2prim_method( &eos, &metric, &cons_undens, &prims_guess, &diagnostics );

  if(con2prim fails)
    font_fix( &eos, &metric, &cons_undens, &prims, &prims_guess, &diagnostics);

  return_primitives(&prims, primitive variable pointers);

  return_conservatives(&cons, conservative variable pointers);
}

diagnostic_report(&diagnostics);
```

Current Status and Remaining Tasks

- significant progress towards condensing Con2Prim code into a small number of self-contained function calls
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- Current thorn implementation is tentative and will change significantly before release
- Code will move to a different location eventually, but my working version is available at `https://github.com/SamuelCupp/Con2Prim_beta`