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Documentation - Computational Approximation of the Gravitational Potential Due to Caustic Ring Dark Matter on NEMO

Introduction:

      One of the great unsolved mysteries of modern physics is the story behind dark matter. Thus far, dark matter has only been observed through its large-scale gravitational interactions with light matter. At first this seems to pose a huge problem for determining dark matter's identity since two leading candidates, axions and WIMPs, though fundamentally different particles, behave very similarly at large scales. However, as pointed out by Pierre Sikivie's theory, it may be possible to break this behavioral symmetry though dark matter infall into galaxies thanks to the rotation of their velocity fields. In the case of axions, dark matter falls in with a net overall rotation and is predicted to form caustic ring density patterns, while the case of WIMP dark matter is predicted to produce tent-like density structures. The provided mpc potential program makes the assumption that dark matter is composed of axions, and estimates the caustic rings' gravitational influence for NEMO simulations. For a far more in-depth explanation of Sikivie's caustic ring theory, the following papers may be very useful:

Caustic rings of dark matter: http://arxiv.org/abs/astro-ph/9705038
Axion BEC Dark Matter: http://arxiv.org/abs/1111.3976
An argument that the dark matter is axions : http://arxiv.org/abs/1210.0040

Installation:
The following instructions have been found to work for Linux Mint 14.

First, dependencies must be taken care of. Below are the names of the dependencies as written on the NEMO site on the left (http://bima.astro.umd.edu/nemo/#installation), and the libraries I used (apt-get'd) on the right:

- pgplot or plplot   pgplot5 and libplplot11
- hdf4   libhdf4-0
- cfitsio   libcfitsio3
- pvm   libpvm3
- png   libpng12-0
- gsl   libgsl0-dev
- fftw   fftw2
- rdl (readline)   libreadline5 (not 6!)

In addition, we need Miriad installed. But it's not a nice apt-get library. We've got to manually build this stuff. Do the following somewhere good:

- curl ftp://ftp.astro.umd.edu/progs/bima/miriad.tar.gz | tar zxf -
- wget -O - ftp://ftp.astro.umd.edu/progs/bima/miriad.tar.gz | tar zxf -
- cd miriad/
- ./autogen
- ./configure
- ./make
- Watch lots and lots of text scrolls. It may take a few minutes.
- ./make install

Now let's make sure that NEMO can find Miriad. While in the Miriad directory, do this:

- MIR=$PWD; export MIR

And add something like that (replace the $PWD with the proper directory name, which you can get with echo $MIR) to your .bashrc so your computer will remember where to find Miriad.

Also check the value of $VENDOR. I didn't even have it set, which made NEMO fail when it wanted to try some vendor-specific stuff that didn't apply to me. I just set VENDOR="DUMMY". Make sure to export it and shove it into your .bashrc like you did with MIR.

Now we're finally ready to tackle NEMO:

- wget ftp://ftp.astro.umd.edu/pub/nemo/nemo_cvs.tar.gz
- tar zxf nemo_cvs.tar.gz
- curl ftp://ftp.astro.umd.edu/pub/nemo/nemo_cvs.tar.gz | tar zxf -
- cd nemo_cvs
- cvs login ; cvs update -d (I just hit enter on the login. Login probably does nothing.)

But wait! There's a typo in one of the files that may not be solved by the time you read this. Check to make sure unless this is really dang old documentation:

- gedit ./src/orbit/misc/orbintv.c
- Scroll all the way to the bottom, and replace the f[3] with an f[6]
- Exit gedit

And now we can build everything (hopefully). The first time we build stuff, some won't get built correctly. Do it again, and the issue is resolved. It seems to be an issue with linking stuff. Below is the command you run twice:

- src/scripts/test_a_new_nemo_cvs reuse=1 nemo=.

If all went well, you should see a bunch of "OK"s after the second one completes. If there are any "Problems"s, then you have a problem. Otherwise, you're ready to move on to the dark matter caustics module. The module needs to know where to throw its files, so let's set up environmental variables to make the job simple. Like with that MIR variable earlier, we need to go into the root directory of a program, this time the top of the NEMO folder (which should be called nemo_cvs... unless this documentation is really old). Once in there, do this:

- NEMO=$PWD; export NEMO
- NEMOINC=$NEMO/inc; export NEMOINC
- NEMOOBJ=$NEMO/obj; export NEMOOBJ
- NEMOLIB=$NEMO/lib; export NEMOLIB
- NEMOHOST=`$NEMO/src/scripts/hosttype`; export NEMOHOST
- POTPATH=$NEMO/obj/potential; export POTPATH

These are also used by NEMO and should be included in your .bashrc like MIR. Next, go into the nemo_caustics folder, and compile sharable objects for NEMO to read:

- cp ./mpc.c $NEMO/src/orbit/potential/data/
- cd $NEMO/src/orbit/potential/data/
- gcc -fPIC -c -W -I$NEMO -I$NEMOINC -I$NEMOINC/max -o mpc.o mpc.c
- gcc --shared -o mpc.so mpc.o
- cp mpc.so $NEMOOBJ/potential/

At this point it would be a good idea to make sure the installation was successful. A makefile, Testfile, should be provided in nemo_caustics. Run the following command in nemo_caustics, which will run NEMO with the mpc potential and compare the results with known "correct" values:

- make -f Testfile all

If all tests pass, then you should be all set. Otherwise, have fun figuring out any issues that pop up!

How it works:

This program makes use of two estimates for the gravitational influence of a caustic ring. The first, "close" estimate was derived in the limit of approaching the ring. Originally derived and written in C++ by Heywood Tam, this approximation has been adapted to the mpc potential. The full derivation of the "close" estimate can be found here: http://arxiv.org/abs/1205.1260. A second, "far" estimate was later derived by Pierre Sikivie, as discussed in Dumas et al., in preparation 2014. This is calculated independently for all caustic rings.