Dr. Tess Jaffe
NASA Goddard Space Flight Center
Mail Code 660

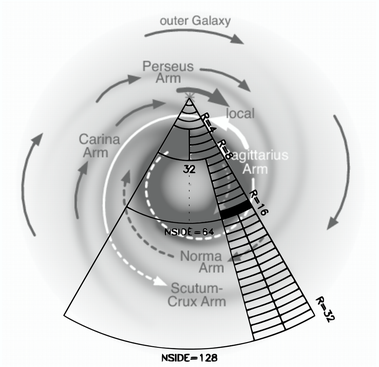
Modeling the Magnetic Field of the Milky Way

Science Division

Joe Taylor
University of Maryland: College Park
Department of Physics

Introduction

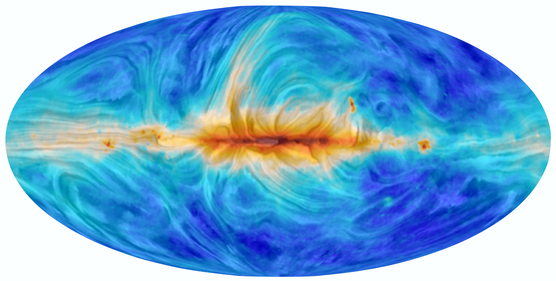
The collaborators of the IMAGINE project have developed HAMMURABI, an open-source code for creating simulated maps of galactic observables given inputs of the thermal electron distribution, cosmic ray distribution, and the structure of the GMF. A new version of the code, HAMMURABIX, is under development with more advanced integration techniques and a new parameter format. This project aims to make the new parameter interface more user-friendly and to quantify the difference in results of the two code versions.



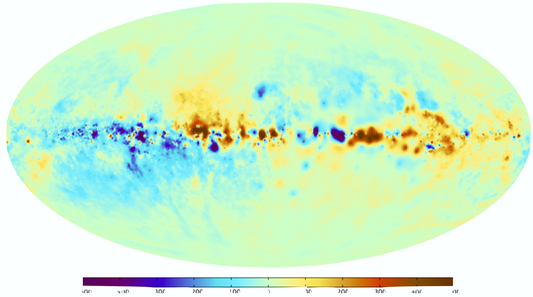
HAMMURABI integration grid on top of NE2001 thermal electron density model (greyscale) and van Eck et al. (2011) schematic for field directions.

Methodology

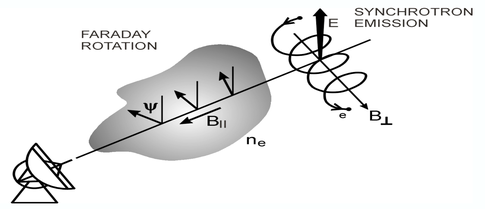
Main focus on comparing maps of synchrotron emission and Faraday rotation (RM).
Both codes were run with:
— Constant thermal electron field
— Exponential disk cosmic ray field
— Simple magnetic field model
  — Known features (shells of charge)
  — Low complexity
Any observed differences should be due to differences in the code, and not the inputs. Small differences are expected from the new integration techniques.



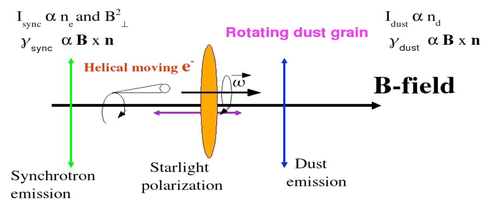
30 GHz polarized synchrotron (ESA, Planck Collaboration)



Faraday depth (rad/m²) (Oppermann et al. 2012)



Faraday rotation measure (RM)



Cartoon illustrating synchrotron emission from relativistic e⁻ as well as dust emission and absorption

Parameter Interface

```
hamx = hampyx.Hampy(custom_parameters = 'comp_params.xml',working_directory = 'test.out')
hamx.mod_par([['CRE','Verify','r0'],'1000.0'])
hamx.call(keychain=[
                  [['Grid','SunPosition','x'],'-8.5'],
                  [['FreeElectron','Regular','Verify','n0'],'0.'],
                  [['MagneticField','Regular'],'type','WMAP'],
                  [['FreeElectron','Regular'],'type','Verify']])
hamx_maps = hamx.get_obs()
```

New parameter interface, shown above and below to the right in a python Jupyter

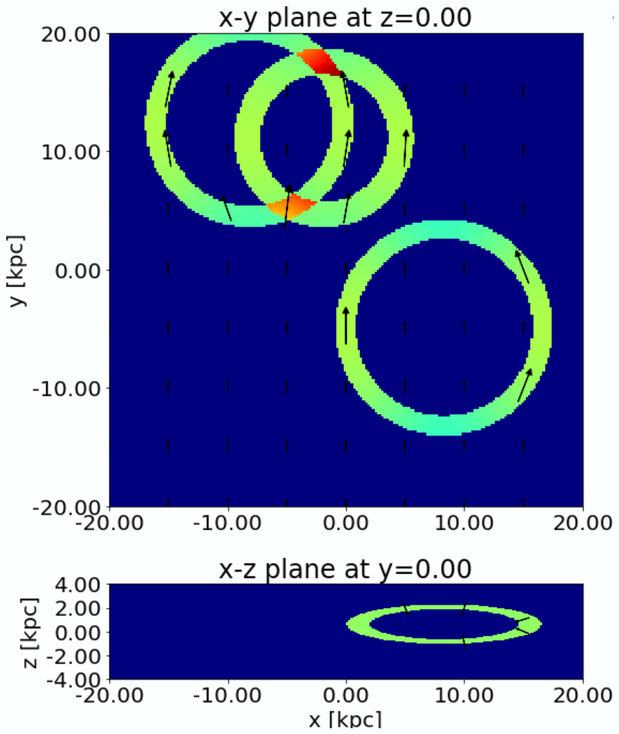
```
<!-- analytic/numeric CRE -->
<CRE type="Verify">
    <Analytic>
        <alpha value="3.0"/>
        <beta value="0.0"/>
        <theta value="0.0"/>
        <r0 value="5.0"/>
        <z0 value="1.0"/>
        <E0 value="20.6"/>
        <j0 value="0.0217"/>
    </Analytic>
    <!-- verification -->
    <Verify>
        <alpha value="3.0"/>
        <r0 value="1000.0"/>
        <E0 value="20.6"/>
        <j0 value="0.0217"/>
    </Verify>
</CRE>
```

An example of the XML parameter hierarchical formatting

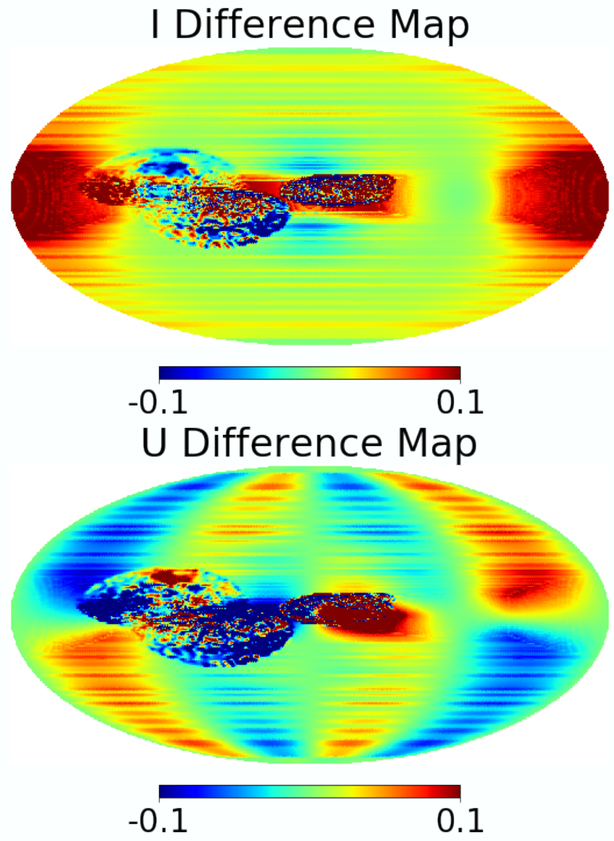
```
hamx.get_ele(['MagneticField','Regular','Verify'],'All')

MagneticField
|--> Regular {'cue': '1', 'type': 'WMAP'}
|--> Random {'cue': '0', 'seed': '0', 'type': 'Local'}
Regular
|--> WMAP {}
|--> Jaffe {}
|--> Verify {}
Verify
|--> b0 {'value': '2.0'}
|--> l0 {'value': '0'}
|--> r {'value': '10'}
```

XML parameter format:
— Useful hierarchal parameter system
— Allows for storage of multiple models
  — Easy switching and choosing
— Not user friendly
New parameter interface:
— Allows for easy interaction with XML
  — Read in .xml files / write parameters
  — Fetch observable arrays
  — Flexible parameter passing

Version Comparisons



Mock magnetic field comprised of shells of charge sitting in a box with no other external field.



Normalized difference maps between HAMMURABI and HAMMURABIX I and U Stokes' parameters

Discussion

Variance of each normalized difference map ~6-8%
— Roughly expected amount of difference
— New integration technique has smoother interpolation, leading to lines across simple areas of the sky and noisy differences near features
Some features still not explained:
— Strong disagreement about the anti-pole
— Stronger differences in certain quadrants (U map)

Comparison tests are ongoing:
— Small differences appear to be as expected
— Larger differences believed to be from slightly different input models
Future work needed to fully characterize the systemic differences
— Careful consideration of differences near major features
— More advanced CRE, TE, and GMF tests
— Comprehensive unit tests

References & Acknowledgments

Thanks to IMAGINE Collaborators Tess Jaffe and Jiaxin Wang

[1] Waelkens A., Jaffe T., Reinecke M., Kitaura F. S., Enßlin T. A., 2009, AAP, 495, 697
[2] C. L. Van Eck, J. C. Brown, J. M. Stil, K. Rae, S. A. Mao, B. M. Gaensler et al., ApJ 728 (2011) 97
[3] N. Oppermann, H. Junklewitz, G. Robbers, M. R. Bell, T. A. Enßlin, A. Bonafede et al., A&A 542 (2012) A93