Parallel Processing and the Madrigal Database

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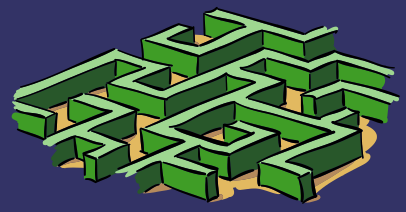
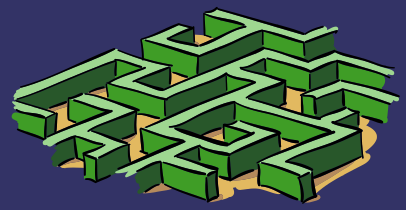


Parallel Processing and the Madrigal Database

- Madrigal Database
- Parallel Processing and a GPU
- CUDA

  Implementing CUDA into Madrigal
  - Data Structures
  - Transferring Data
  - Making functions CUDA capable
- Results
- Future Work



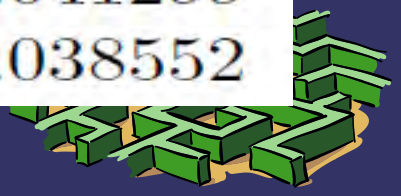
The Madrigal Database

Online database of upper atmospheric data, accessible online and through a variety of API's.

The Madrigal Database

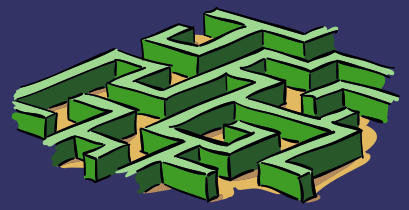
- Not only does Madrigal display data which is collected, it also has several parameters which are derived based upon the data.
- Computation of these parameters can slow down data access.

Differential Time for Madrigal Derived Parameters	
Mnemonic of Parameter	Differential Time (sec)
TSYG_EQ_XGSM	0.111329
TSYG_EQ_YGSM	0.111303
TSYG_EQ_XGSE	0.111035
TSYG_EQ_YGSE	0.110543
CGM_LAT	0.041299
CGM_LONG	0.038552

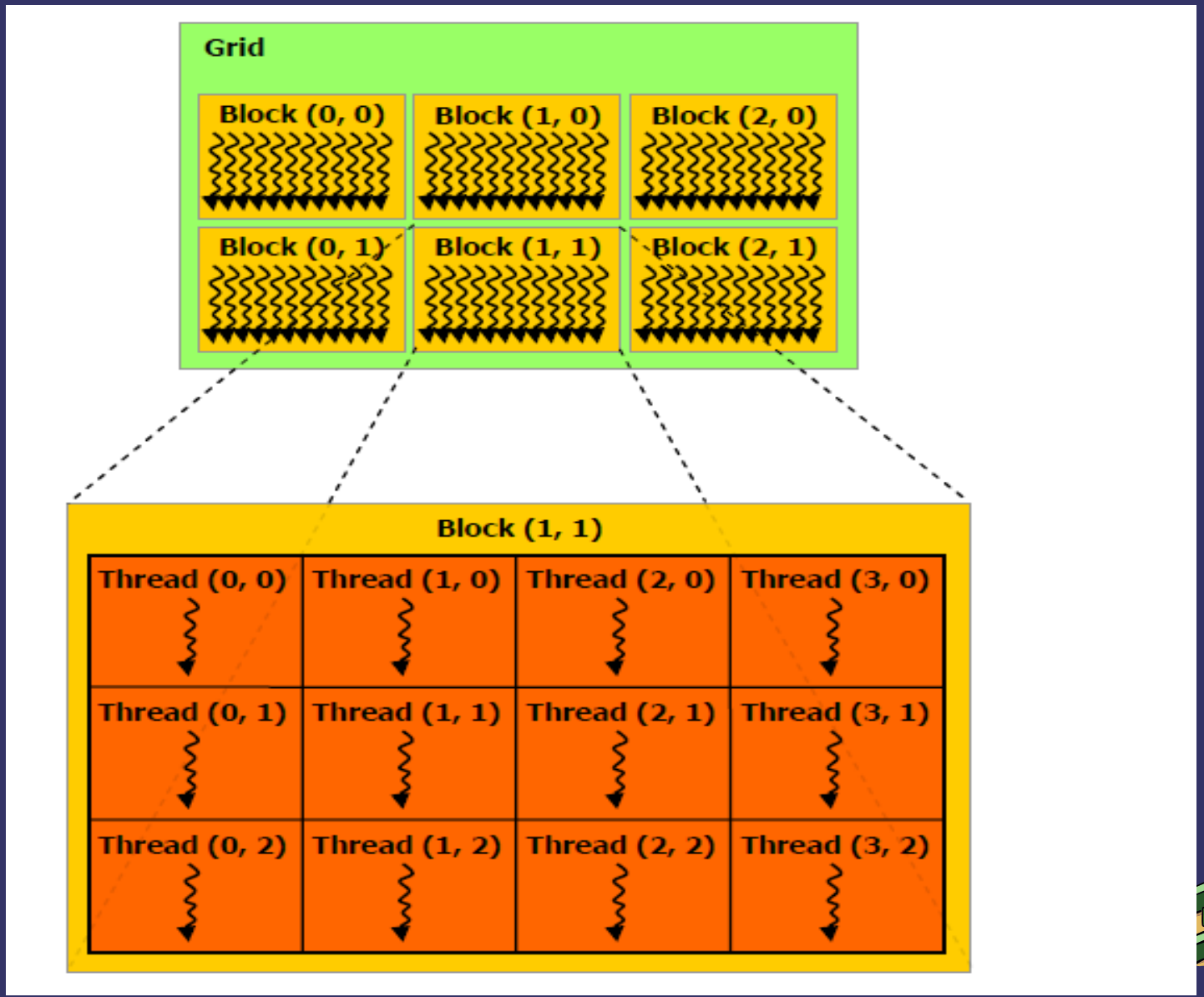


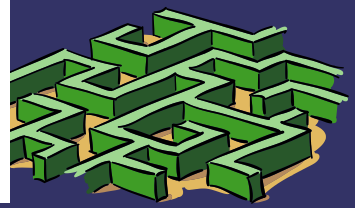
Parallel Processing and a GPU

- A GPU (Graphics Processing Unit) allows for several computations to occur at the same time.

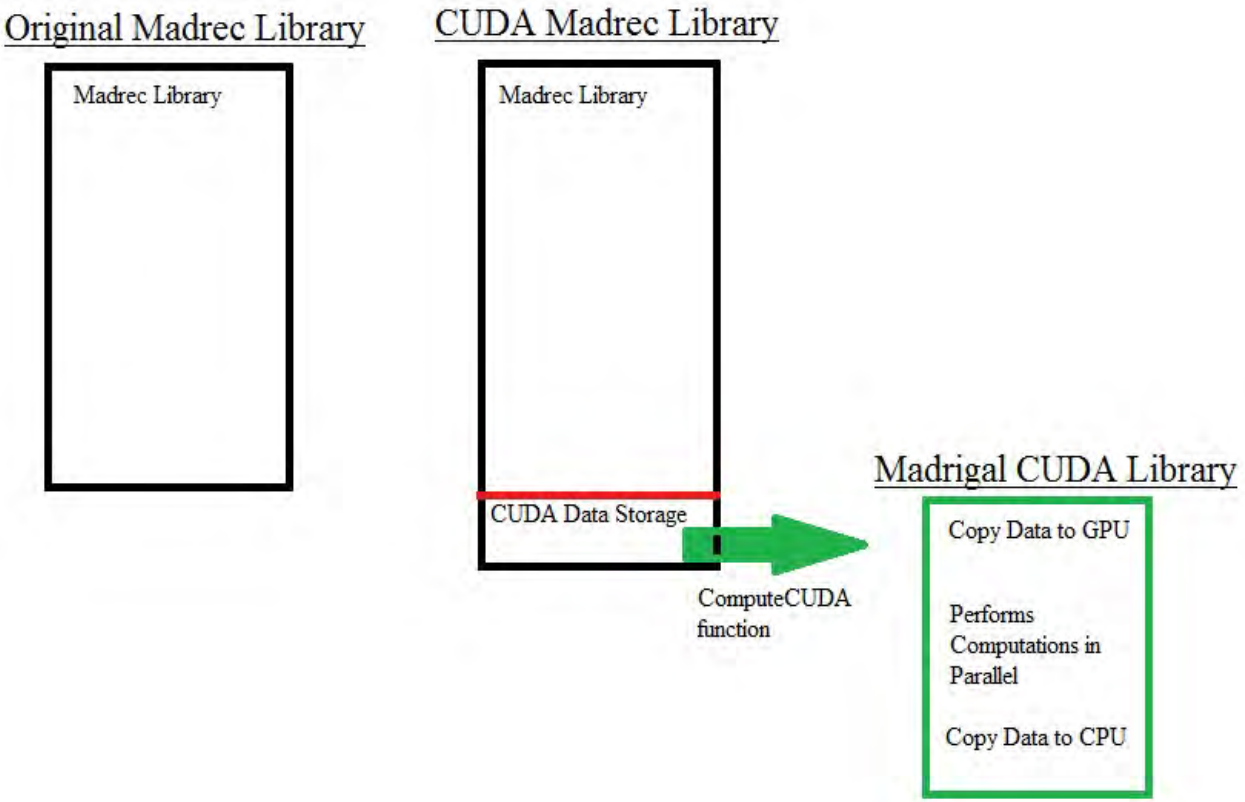


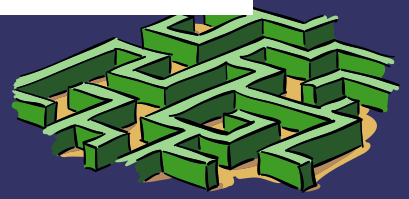
CUDA


Grid
Block (0, 0)
Block (1, 0)
Block (2, 0)
Block (0, 1)
Block (1, 1)
Block (2, 1)
Block (1, 1)
Thread (0, 0)
Thread (1, 0)
Thread (2, 0)
Thread (3, 0)
Thread (0, 1)
Thread (1, 1)
Thread (2, 1)
Thread (3, 1)
Thread (0, 2)
Thread (1, 2)
Thread (2, 2)
Thread (3, 2)

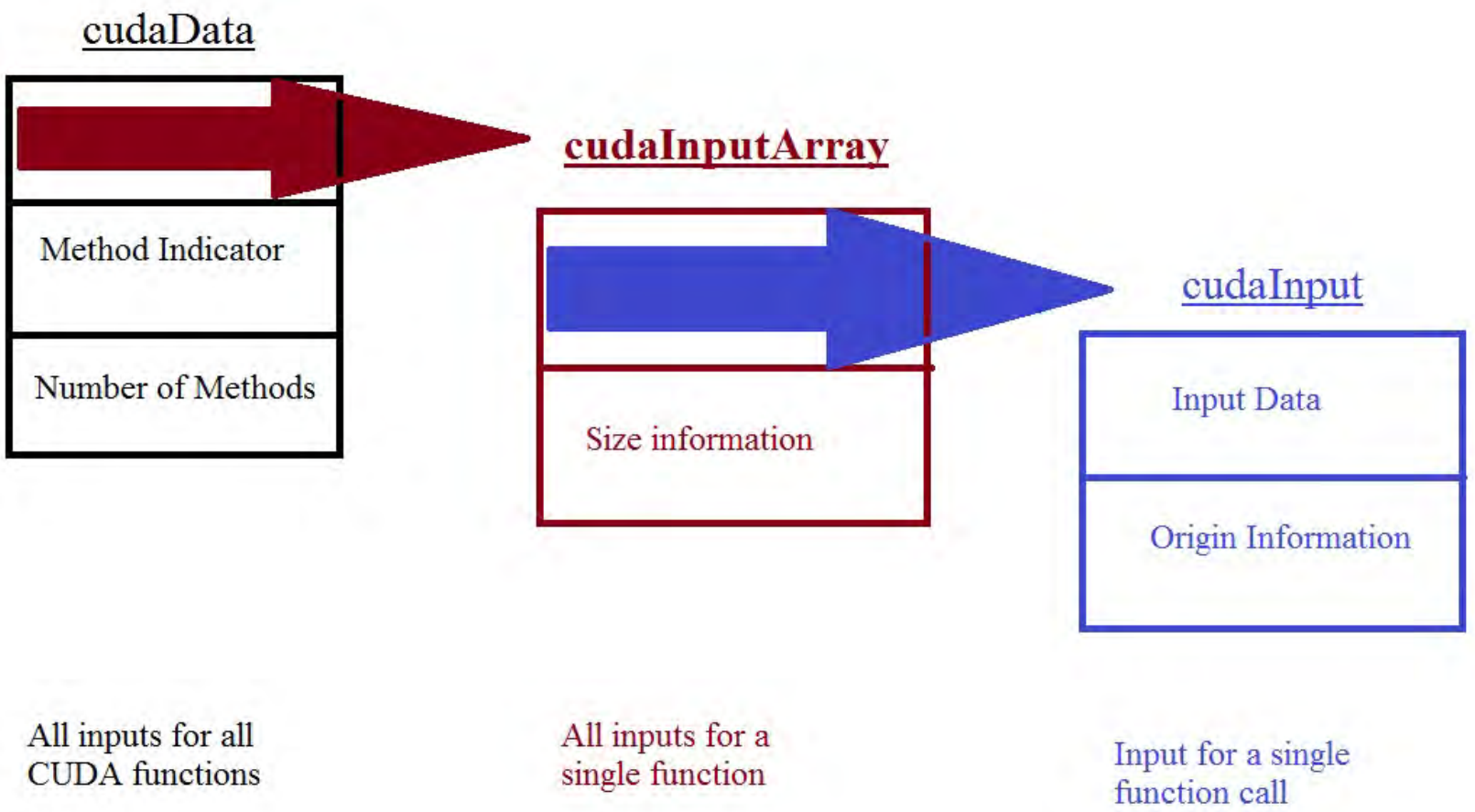


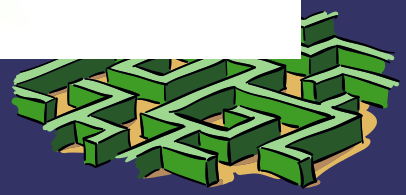
Implementation





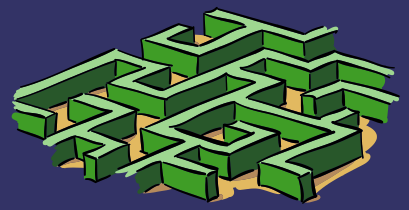
Data Storage



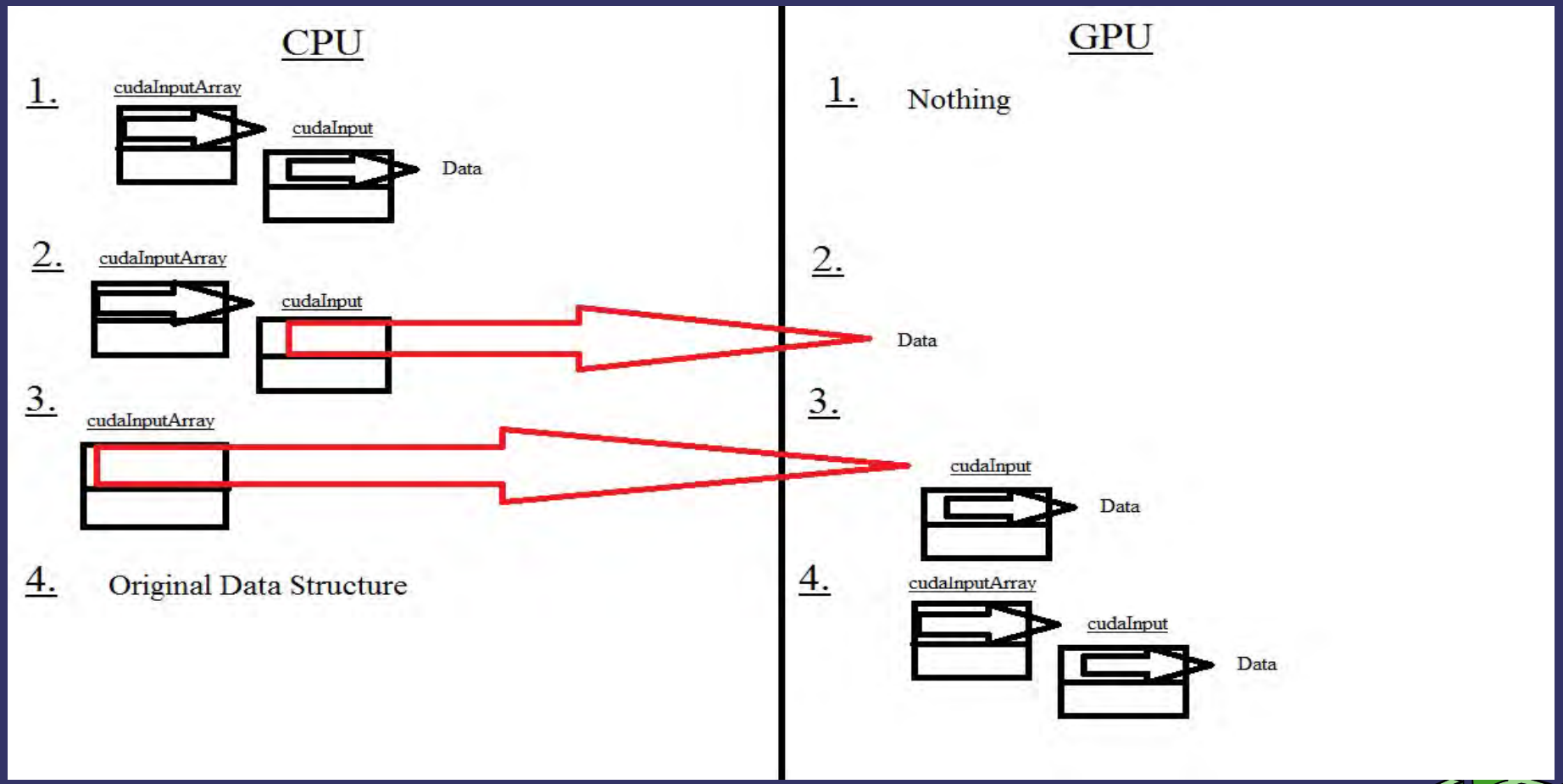


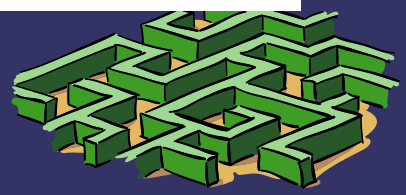
Data Storage

```
17
18/*This holds all necessary information for one single computation to be done in cuda.  The first five elements a
19 * to every cuda function, the last three are information stored for writing data back into the Madrigal structu
20typedef struct {
21    int inputCount;      /*Number of inputs passed to function.*/
22    double * inputs;     /*Array of doubles of length inputCount which contains input values for function.*/
23    int outputCount;     /*Number of outputs expected from function.*/
24    double * outputs;    /*Array of doubles of length outputCount which contains output values from function.*/
25    FILE * errFile;      /*Pointer to an error file.*/
26    int CycId;           /*The Cycle Id of the file the Madrigal data was taken from*/
27    int RecId;           /*The Record Id of the Madrigal file data comes from*/
28    int TypeId;          /*The type index of the Madrigal file*/
29} cudaInput;
```



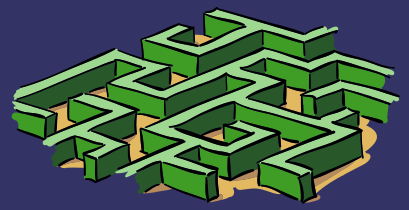
Memory Transfer





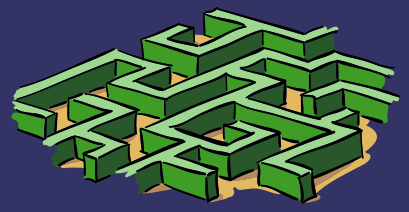
CUDA Function Restrictions

- No Time Library
- No File Access
- No Double Precision
- Derivation Chain
- FORTRAN
- If a method survives these restrictions, 6 steps to making CUDA capable



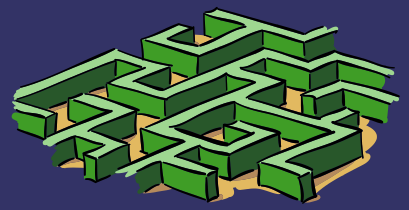
Example Device Function

```
__device__ int getNeNel(int inCount,
                double * inputArr,
                int outCount,
                double * outputArr,
                FILE * errFile)
{
    double Nel = 0.0;

    Nel = getElecDensity(inputArr[0],
                         inputArr[1],
                         inputArr[2],
                inputArr[3]);


    if (Nel == missing)
    {
        outputArr[0] = missing;
        outputArr[1] = missing;

    }
    else
    {   outputArr[0] = pow(10.0, Nel);
        outputArr[1] = Nel;
    }
    return(0);
}
```



More about FORTRAN

- barf [ba:rf] 2. "He suggested using FORTRAN, and everybody barfed."- From The Shogakukan DICTIONARY OF NEW ENGLISH (Second edition)
- CUDA FORTRAN compiler . . . barfs
- f2c - generates unreadable code



Results

- Successfully built architecture for implementing CUDA into Madrigal.
- 2 working parallelized functions.

Theoretical Computation Time for 100,000 Computations for Madrigal Derived Parameters		
Mnemonic of Parameter	Time with CUDA (min)	Time without CUDA (min)
TSYG_EQ_XGSM	11	185
TSYG_EQ_YGSM	11	185
TSYG_EQ_XGSE	11	185
TSYG_EQ_YGSE	11	184
CGM_LAT	11	69
CGM_LONG	11	64

withCuda.txt (/home/dpackard/madroot/source/madc/madcuda) - gedit (on fermi)

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withCuda.txt

```
Data derived from file /home/dpackard/madroot/experiments/1998/
mlh/20jan98/mil980120g.001:
Filters used:

Millstone Hill UHF Zenith Antenna: 01/20/1998 1352:43-1353:52
           NE           DNE
 3.34023e+11   7.62703e+10
 3.63206e+11   8.82463e+09
 6.50342e+11   1.04483e+10
 1.18580e+12   1.06456e+10
 1.55876e+12   8.19204e+09
 1.51597e+12   1.75411e+10
 1.18532e+12   9.88795e+09
 9.35479e+11   8.19946e+09
 7.38549e+11   4.63850e+09
 5.93402e+11   4.37644e+09
 4.86785e+11   3.37599e+09
 3.93984e+11   3.09683e+09
 3.37749e+11   2.73483e+09
 2.96093e+11   3.98895e+09
 2.60151e+11   3.60277e+09
 2.18505e+11   5.58886e+09
 1.85723e+11   5.50978e+09
 1.53606e+11   5.65642e+09
 1.47586e+11   9.74002e+09
 1.37247e+11   1.05974e+10
 1.13981e+11   9.24752e+09
 9.17815e+10   9.45959e+09
 7.68738e+10   1.11404e+10
 6.52810e+10   1.15178e+10
 6.03754e+10   1.61648e+10
 6.13636e+10   1.34049e+10
 8.23298e+10   1.34862e+10

Millstone Hill UHF Steerable Antenna: 01/20/1998 1354:15-1355:24
           NE           DNE
 9.30999e+10   6.58555e+07
 1.23244e+11   4.16243e+09
 2.13676e+11   2.85282e+09
 2.40414e+11   3.99968e+09
 2.22025e+11   4.92430e+09
 1.77295e+11   5.36776e+09
 1.31678e+11   2.29279e+09
 1.05297e+11   1.76415e+09
 8.29879e+10   7.79771e+08
 7.01339e+10   1.58440e+09
 5.94290e+10   2.01509e+09
 4.83677e+10   2.90560e+09
 4.68181e+10   4.27112e+09
 4.17361e+10   4.89150e+09
 3.91470e+10   5.18748e+09
 3.45430e+10   5.50158e+09
```

Ln 1, Col 1 INS

withoutCuda.txt (/home/dpackard/madroot/source/madc/madcuda) - gedit

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withoutCuda.txt

```
Data derived from file /home/dpackard/madroot/experiments/1998/mlh/20jan98/
mil980120g.001:
Filters used:

Millstone Hill UHF Zenith Antenna: 01/20/1998 1352:43-1353:52
           NE           DNE
 3.34024e+11   7.62694e+10
 3.63206e+11   8.82503e+09
 6.50342e+11   1.04476e+10
 1.18580e+12   1.06469e+10
 1.55876e+12   8.18942e+09
 1.51597e+12   1.75396e+10
 1.18532e+12   9.88779e+09
 9.35478e+11   8.19870e+09
 7.38549e+11   4.63814e+09
 5.93402e+11   4.37513e+09
 4.86784e+11   3.37503e+09
 3.93984e+11   3.09607e+09
 3.37749e+11   2.73452e+09
 2.96093e+11   3.98883e+09
 2.60151e+11   3.60280e+09
 2.18504e+11   5.58903e+09
 1.85723e+11   5.50974e+09
 1.53606e+11   5.65677e+09
 1.47586e+11   9.73973e+09
 1.37247e+11   1.05979e+10
 1.13981e+11   9.24717e+09
 9.17813e+10   9.45980e+09
 7.68737e+10   1.11404e+10
 6.52809e+10   1.15179e+10
 6.03754e+10   1.61648e+10
 6.13636e+10   1.34049e+10
 8.23298e+10   1.34861e+10

Millstone Hill UHF Steerable Antenna: 01/20/1998 1354:15-1355:24
           NE           DNE
 9.30999e+10   6.58819e+07
 1.23244e+11   4.16227e+09
 2.13676e+11   2.85239e+09
 2.40414e+11   3.99932e+09
 2.22025e+11   4.92353e+09
 1.77295e+11   5.36835e+09
 1.31678e+11   2.29270e+09
 1.05297e+11   1.76428e+09
 8.29878e+10   7.79840e+08
 7.01337e+10   1.58466e+09
 5.94291e+10   2.01499e+09
 4.83676e+10   2.90561e+09
 4.68181e+10   4.27106e+09
```

Ln 1, Col 1 INS

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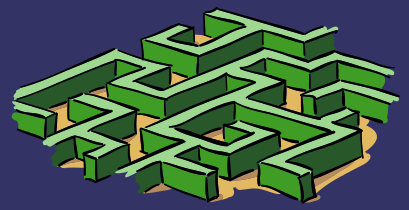
Future Work

- Filtering Logic implemented into CUDA framework
- Handle Calls to FORTRAN Libraries
- More Methods
- Less time for data storage



Acknowledgments

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- Haystack community
- REU's