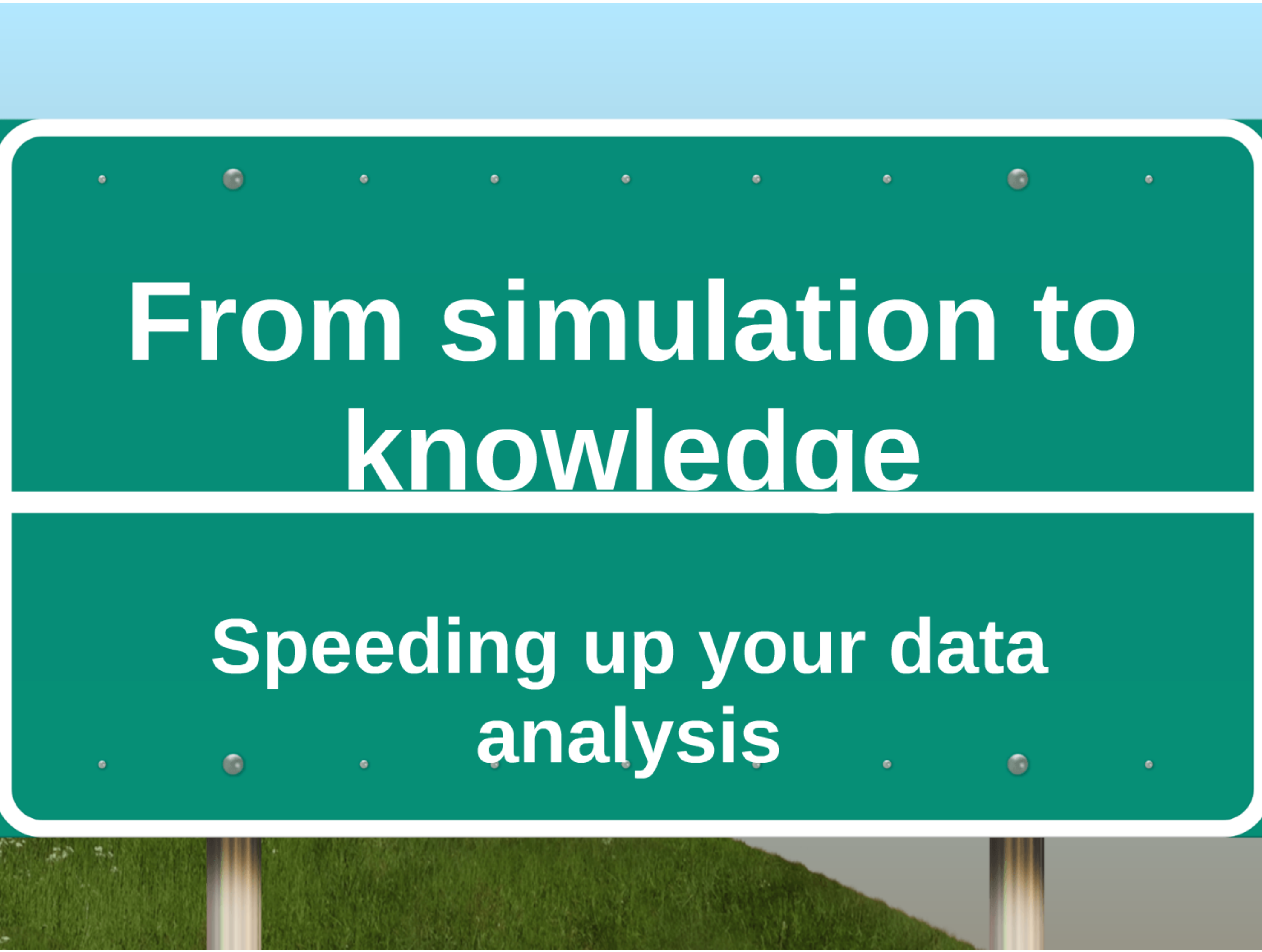
From simulation to knowledge

Speeding up your data analysis



From simulation to knowledge

Speeding up your data analysis

From simulation to knowledge

Speeding up your data analysis

Approaches to speed up analysis

1) Try to read data only once

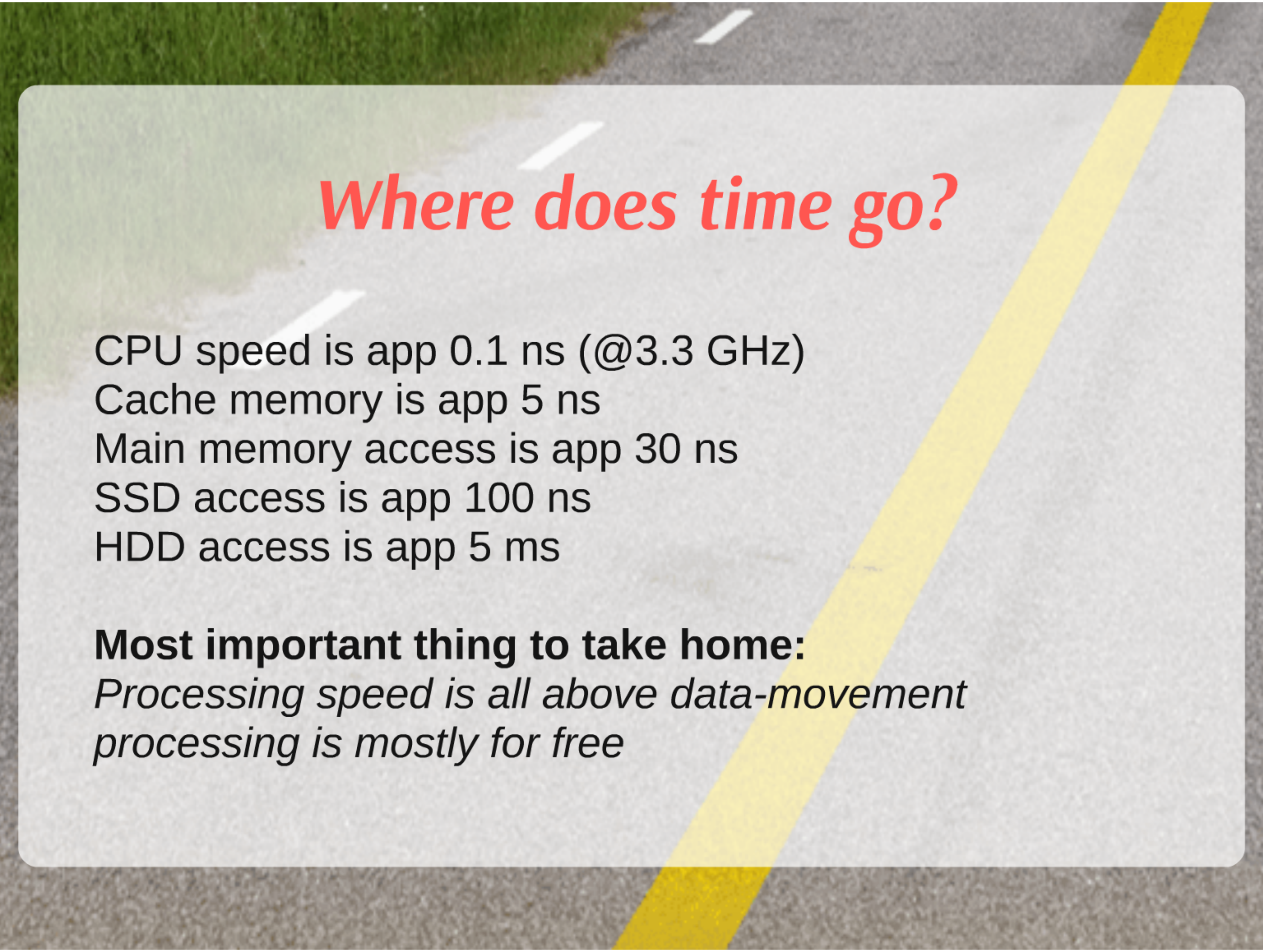
2) Read only the data you need

3) Parallelize your analysis

Where does time go?

CPU speed is app 0.1 ns (@3.3 GHz)
Cache memory is app 5 ns
Main memory access is app 30 ns
SSD access is app 100 ns
HDD access is app 5 ms

Most important thing to take home:
Processing speed is all above data-movement processing is mostly for free



Where does time go?

CPU speed is app 0.1 ns (@3.3 GHz)
Cache memory is app 5 ns
Main memory access is app 30 ns
SSD access is app 100 ns
HDD access is app 5 ms

Most important thing to take home:
Processing speed is all above data-movement processing is mostly for free

Approaches to speed up analysis

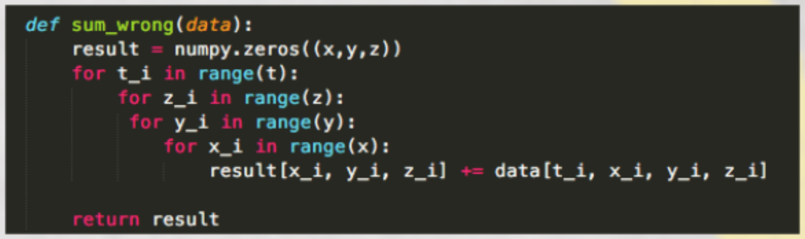
1) Try to read data only once

2) Read only the data you need

3) Parallelize your analysis

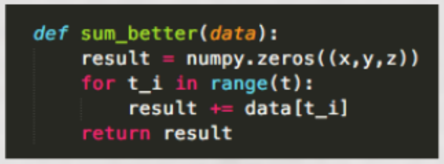
Parallelize I

Use vectorized code



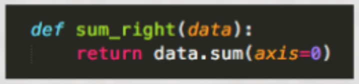
```python
def sum_wrong(data):
    result = numpy.zeros((x,y,z))
    for t_i in range(t):
        for z_i in range(z):
            for y_i in range(y):
                for x_i in range(x):
                    result[x_i, y_i, z_i] += data[t_i, x_i, y_i, z_i]

    return result
```

134.12 sec



```python
def sum_better(data):
    result = numpy.zeros((x,y,z))
    for t_i in range(t):
        result += data[t_i]
    return result
```

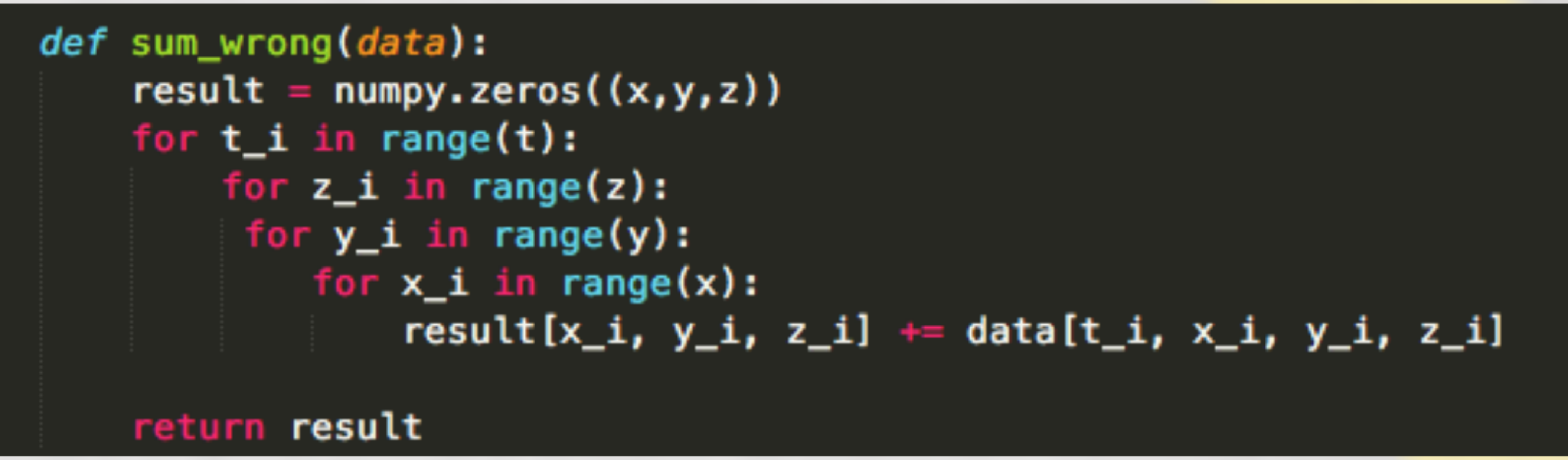
0.16 sec



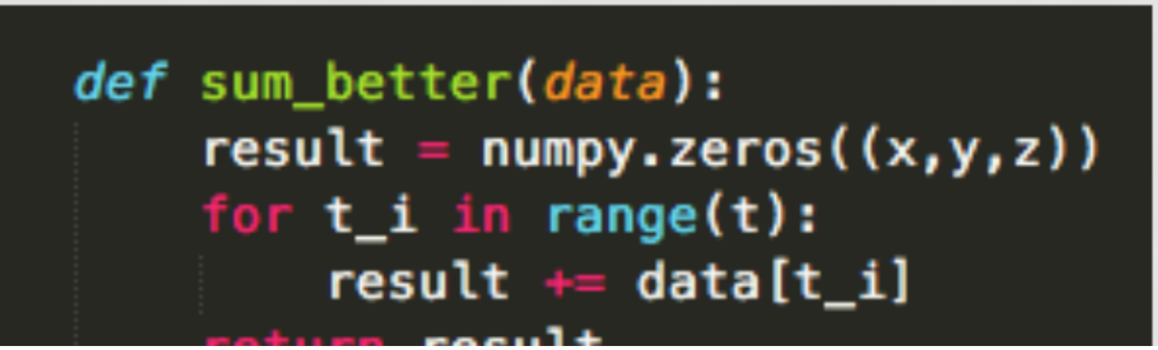
```python
def sum_right(data):
    return data.sum(axis=0)
```

0.15 sec

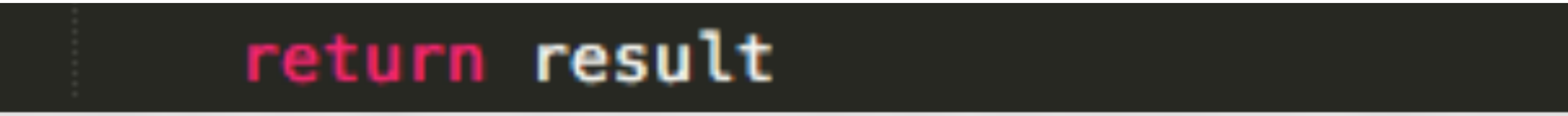
Use vectorized code



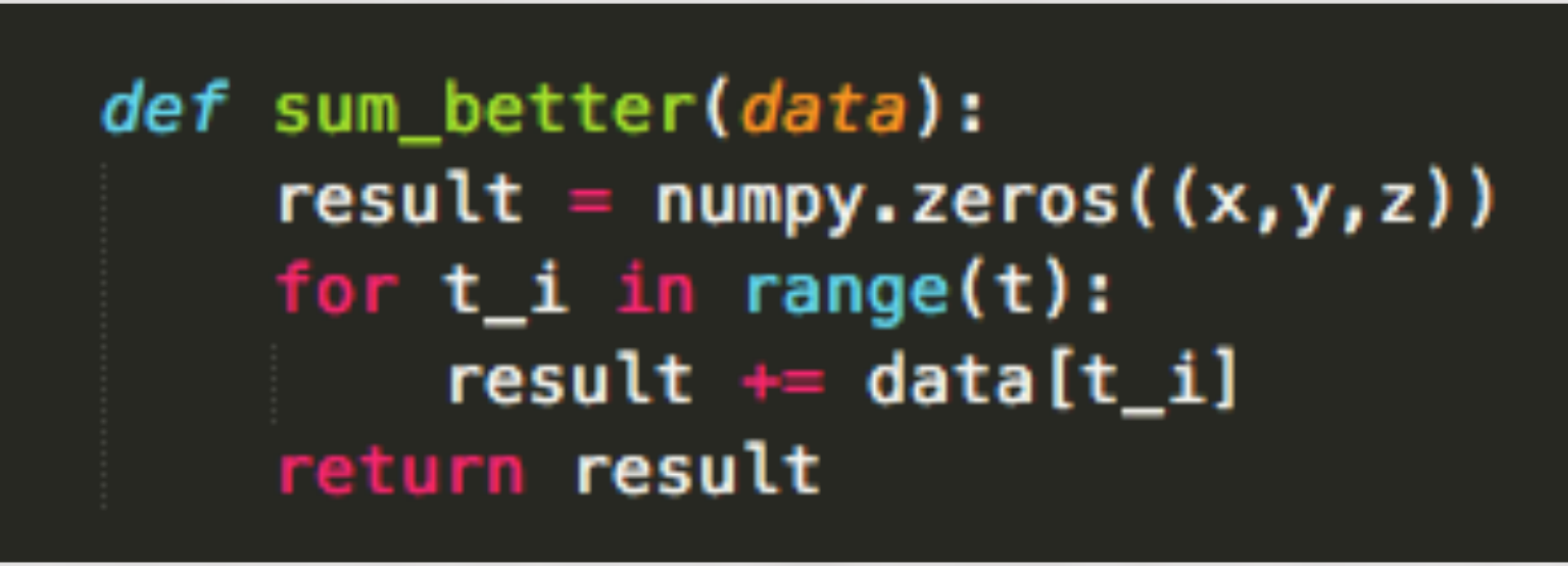
```python
def sum_wrong(data):
    result = numpy.zeros((x,y,z))
    for t_i in range(t):
        for z_i in range(z):
         for y_i in range(y):
            for x_i in range(x):
                result[x_i, y_i, z_i] += data[t_i, x_i, y_i, z_i]

    return result
```



```python
def sum_better(data):
    result = numpy.zeros((x,y,z))
    for t_i in range(t):
        result += data[t_i]
    return result
```



```
    return result
```



```
def sum_better(data):
    result = numpy.zeros((x,y,z))
    for t_i in range(t):
        result += data[t_i]
    return result
```

```
def sum_right(data):
```

```python
        return result
```

```python
def sum_right(data):
    return data.sum(axis=0)
```

```
z_i]
```

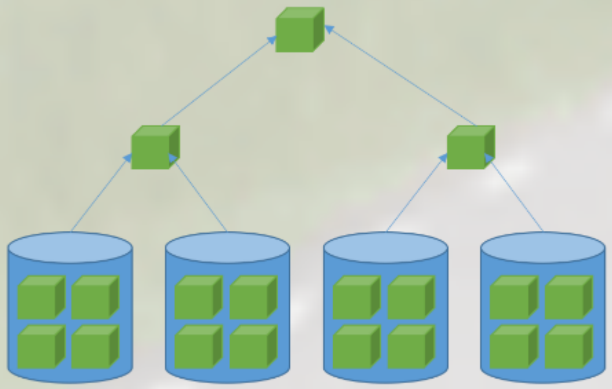
134.12 sec

0.16 sec

0.15 sec

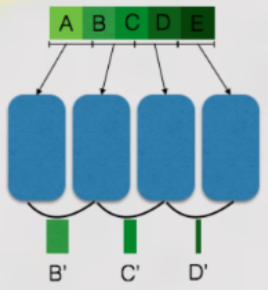
Parallelize II

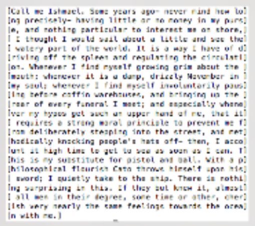
Make your IO parallel



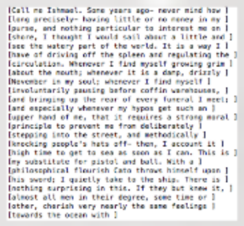
Map - Reduce

hadoop DISCO



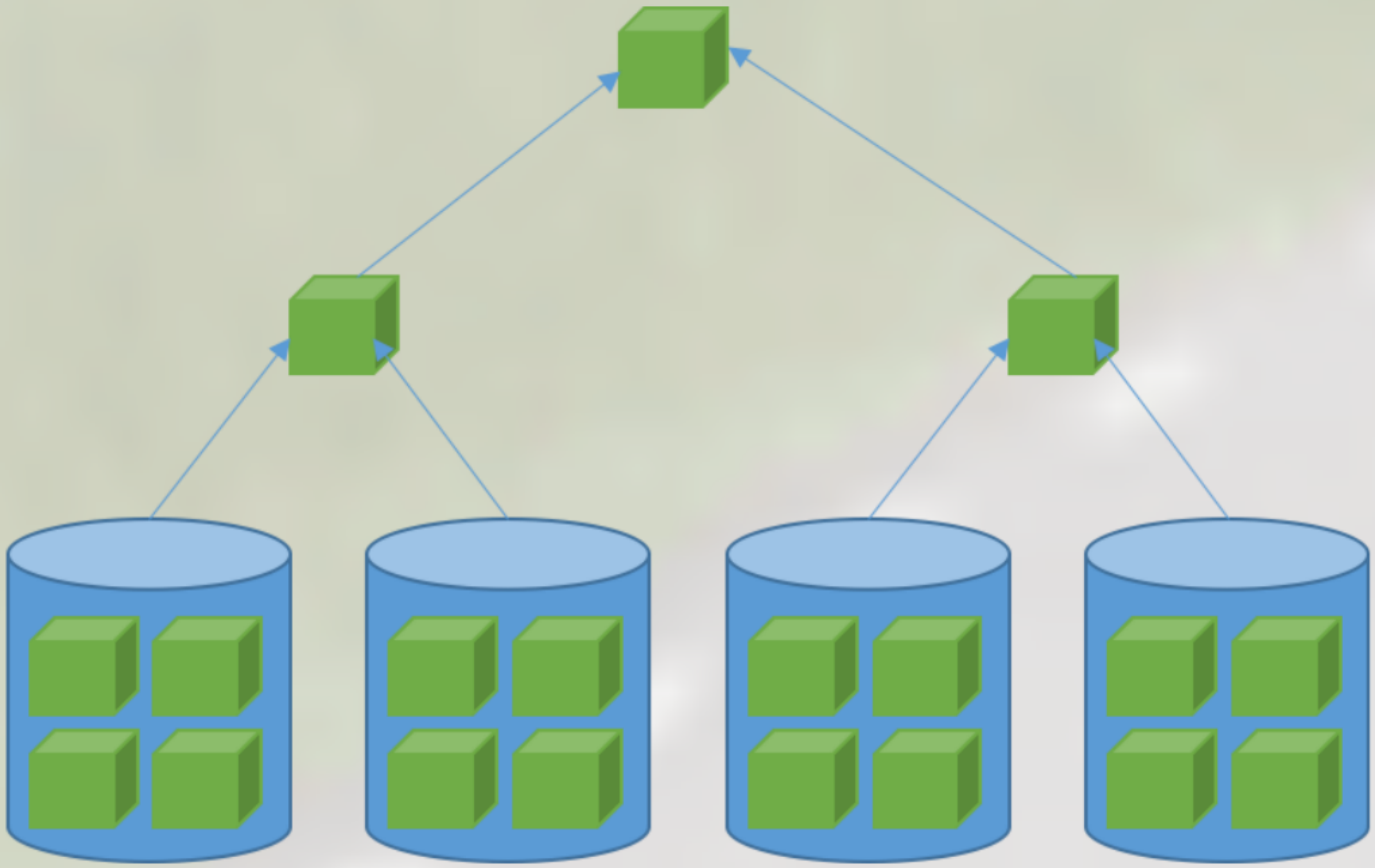


```
[Call me Ishmael. Some years ago- never mind how lo]
[ng precisely- having little or no money in my purs]
[e, and nothing particular to interest me on shore,]
[ I thought I would sail about a little and see the]
[ watery part of the world. It is a way I have of d]
[riving off the spleen and regulating the circulati]
[on. Whenever I find myself growing grim about the ]
[mouth; whenever it is a damp, drizzly November in ]
[my soul; whenever I find myself involuntarily paus]
[ing before coffin warehouses, and bringing up the ]
[rear of every funeral I meet; and especially whene]
[ver my hypos get such an upper hand of me, that it]
[ requires a strong moral principle to prevent me f]
[rom deliberately stepping into the street, and met]
[hodically knocking people's hats off- then, I acco]
[unt it high time to get to sea as soon as I can. T]
[his is my substitute for pistol and ball. With a p]
[hilosophical flourish Cato throws himself upon his]
[ sword; I quietly take to the ship. There is nothi]
[ng surprising in this. If they but knew it, almost]
[ all men in their degree, some time or other, cher]
[ish very nearly the same feelings towards the ocea]
[n with me.]
```



```
[Call me Ishmael. Some years ago- never mind how ]
[long precisely- having little or no money in my ]
[purse, and nothing particular to interest me on ]
[shore, I thought I would sail about a little and ]
[see the watery part of the world. It is a way I ]
[have of driving off the spleen and regulating the ]
[circulation. Whenever I find myself growing grim ]
[about the mouth; whenever it is a damp, drizzly ]
[November in my soul; whenever I find myself ]
[involuntarily pausing before coffin warehouses, ]
[and bringing up the rear of every funeral I meet; ]
[and especially whenever my hypos get such an ]
[upper hand of me, that it requires a strong moral ]
[principle to prevent me from deliberately ]
[stepping into the street, and methodically ]
[knocking people's hats off- then, I account it ]
[high time to get to sea as soon as I can. This is ]
[my substitute for pistol and ball. With a ]
[philosophical flourish Cato throws himself upon ]
[his sword; I quietly take to the ship. There is ]
[nothing surprising in this. If they but knew it, ]
[almost all men in their degree, some time or ]
[other, cherish very nearly the same feelings ]
[towards the ocean with ]
```

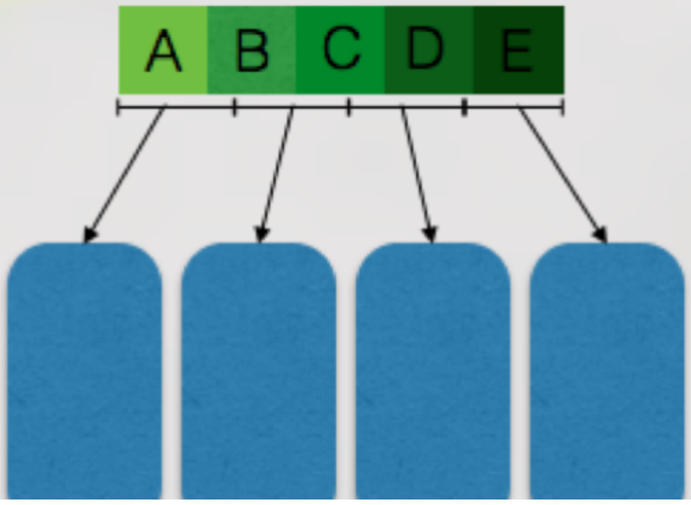
Make your IO parallel

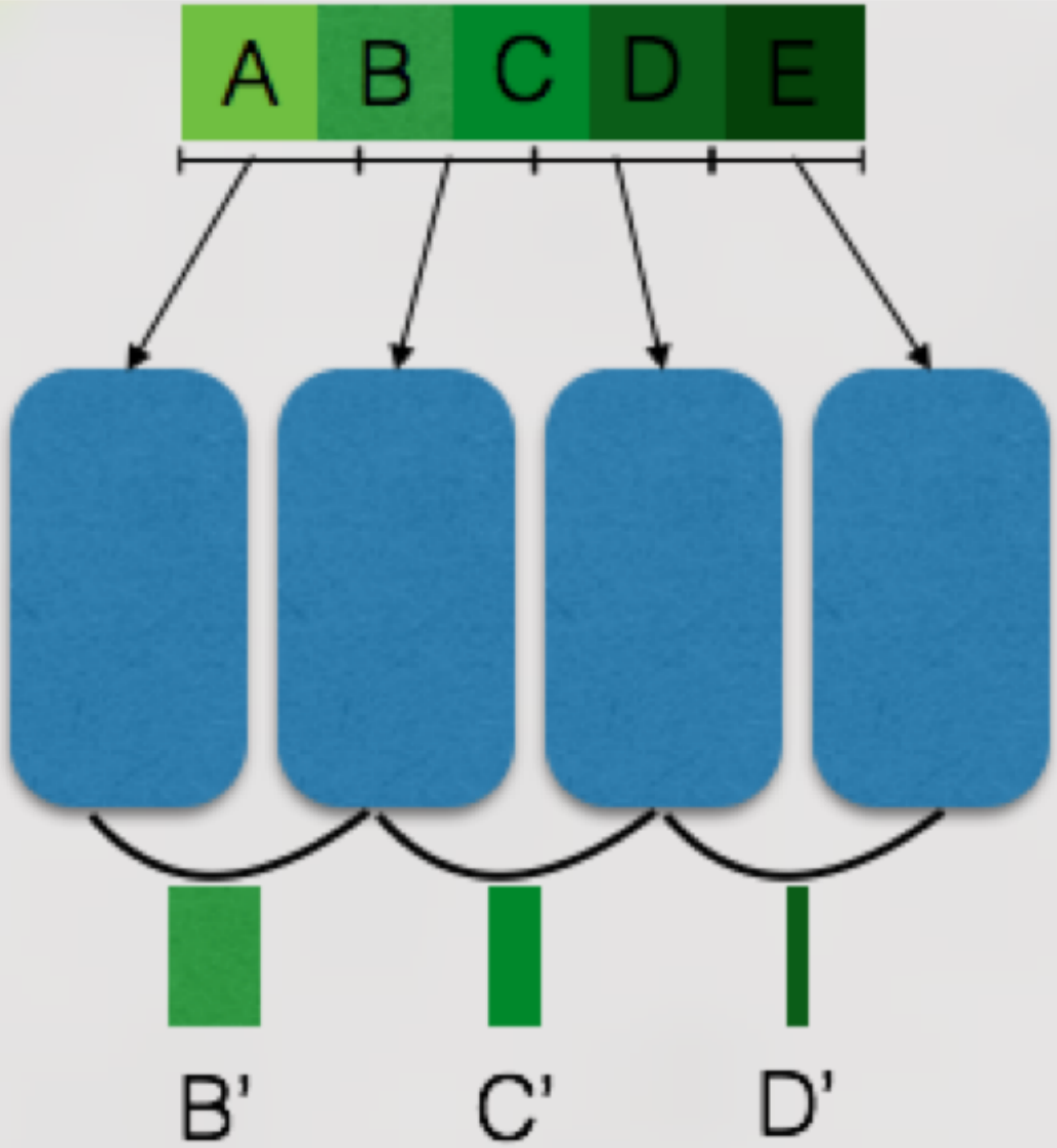


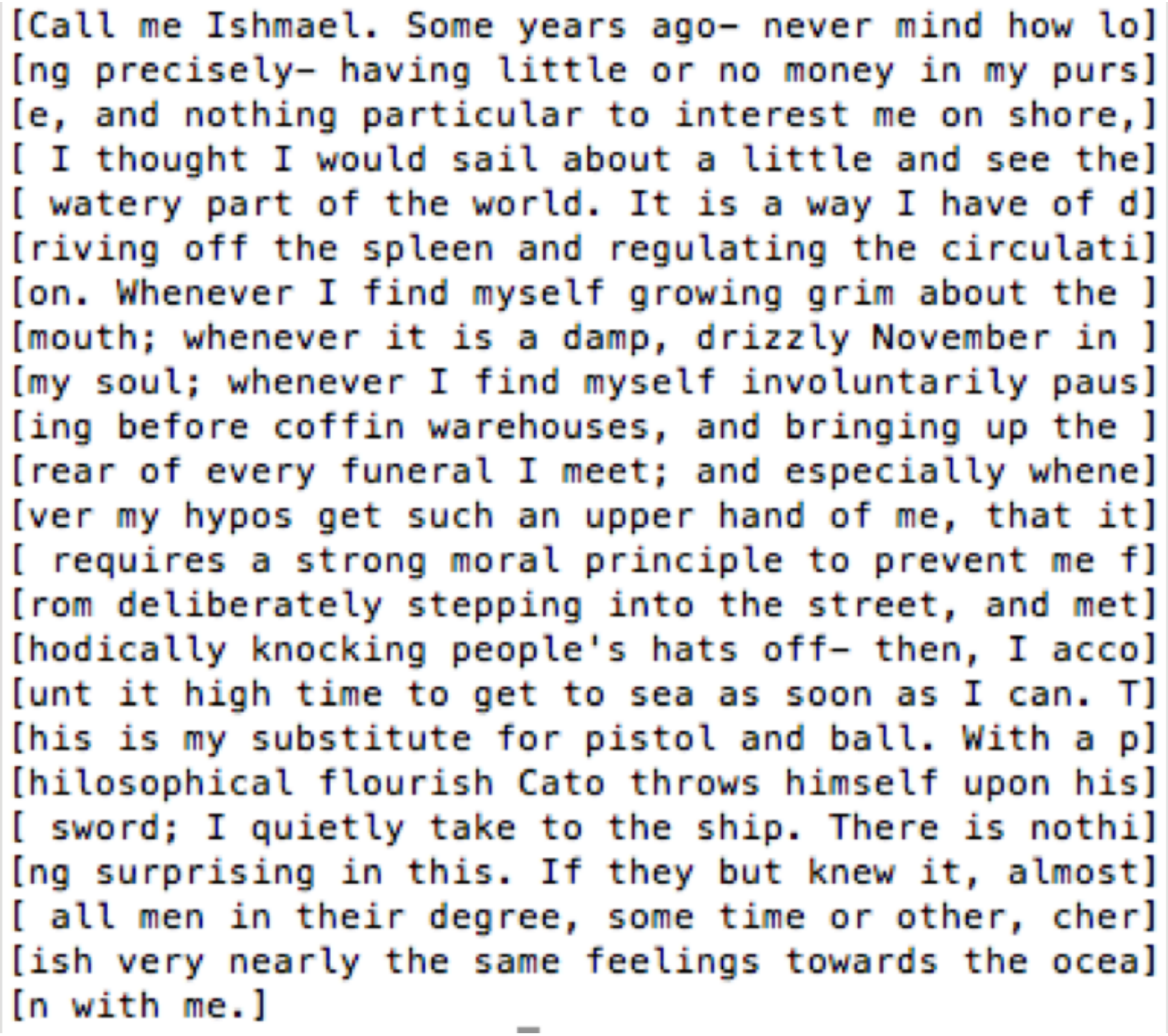
Map - Reduce

hadoop

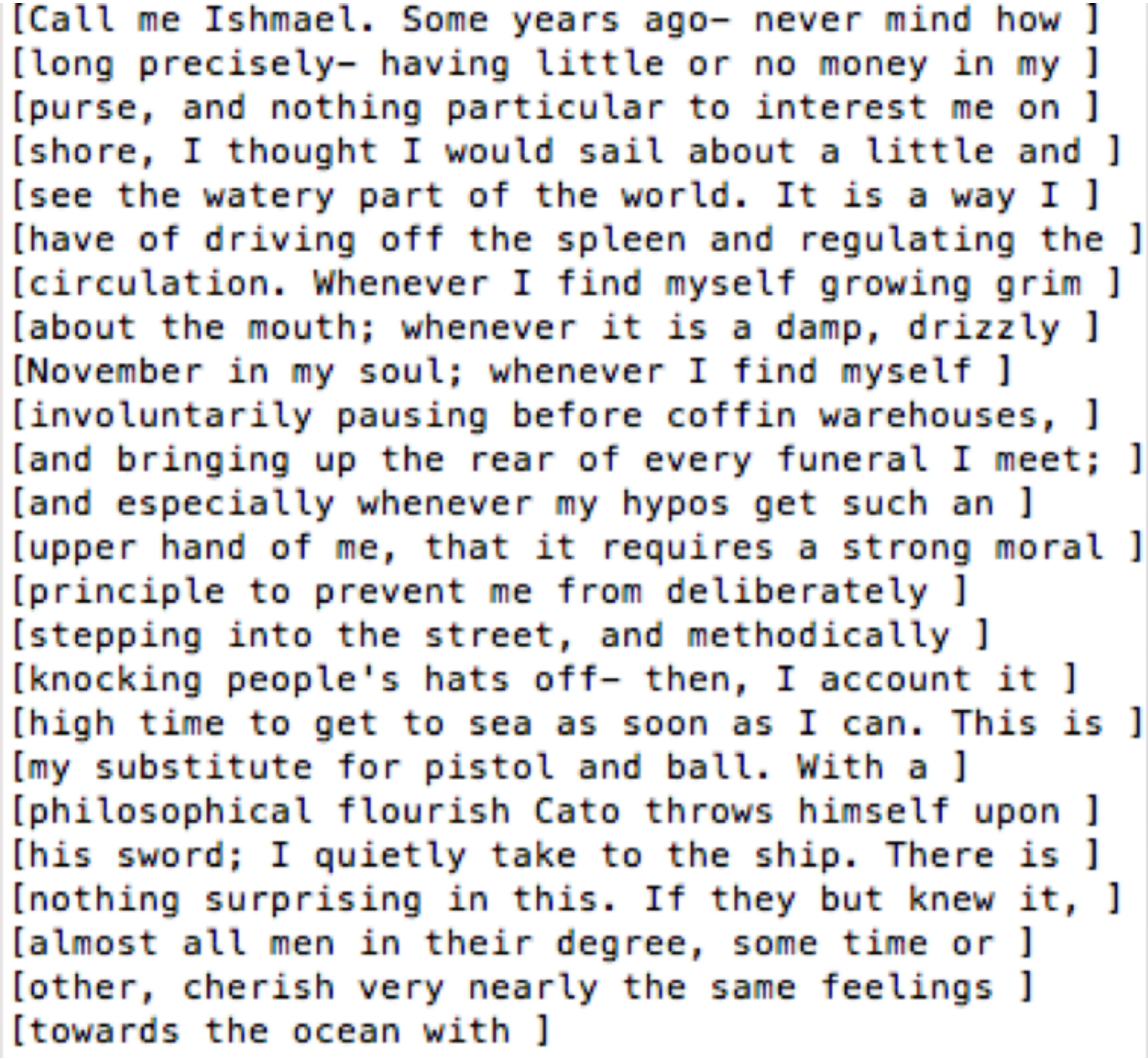
DISCO




A
B
C
D
E
B'
C'
D'

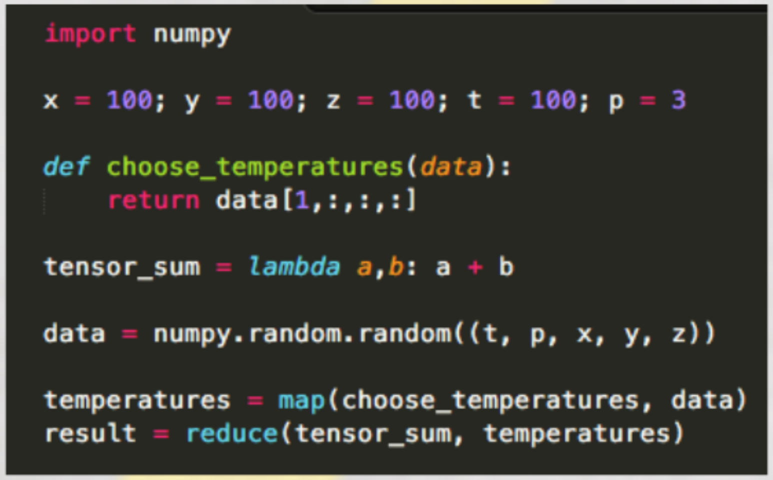


```
[Call me Ishmael. Some years ago- never mind how lo]
[ng precisely- having little or no money in my purs]
[e, and nothing particular to interest me on shore,]
[ I thought I would sail about a little and see the]
[ watery part of the world. It is a way I have of d]
[riving off the spleen and regulating the circulati]
[on. Whenever I find myself growing grim about the ]
[mouth; whenever it is a damp, drizzly November in ]
[my soul; whenever I find myself involuntarily paus]
[ing before coffin warehouses, and bringing up the ]
[rear of every funeral I meet; and especially whene]
[ver my hypos get such an upper hand of me, that it]
[ requires a strong moral principle to prevent me f]
[rom deliberately stepping into the street, and met]
[hodically knocking people's hats off- then, I acco]
[unt it high time to get to sea as soon as I can. T]
[his is my substitute for pistol and ball. With a p]
[hilosophical flourish Cato throws himself upon his]
[ sword; I quietly take to the ship. There is nothi]
[ng surprising in this. If they but knew it, almost]
[ all men in their degree, some time or other, cher]
[ish very nearly the same feelings towards the ocea]
[n with me.]
```



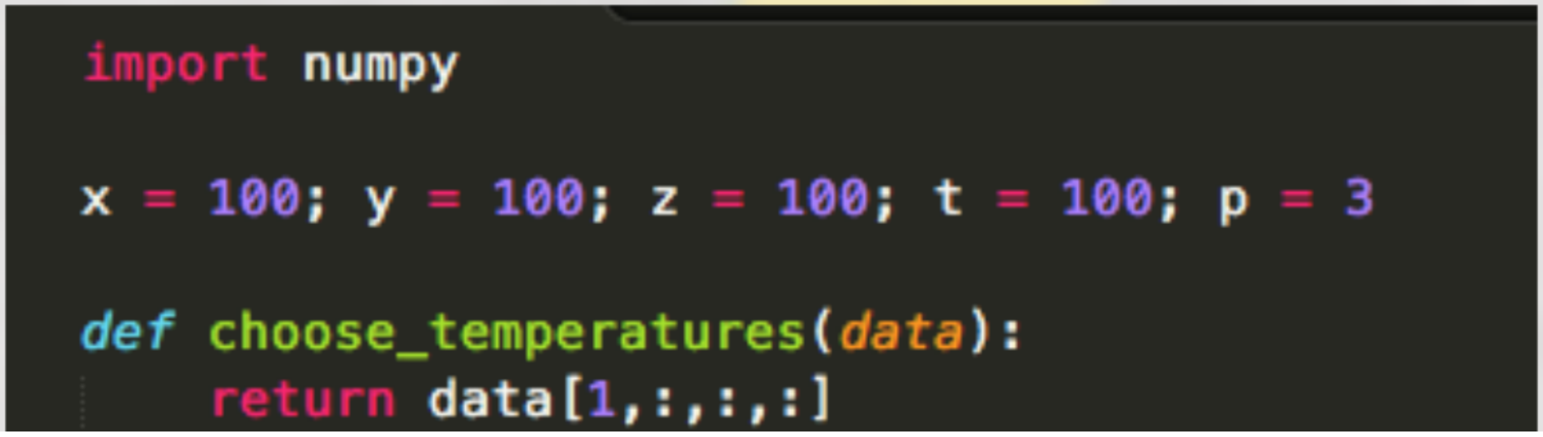
```
[Call me Ishmael. Some years ago- never mind how ]
[long precisely- having little or no money in my ]
[purse, and nothing particular to interest me on ]
[shore, I thought I would sail about a little and ]
[see the watery part of the world. It is a way I ]
[have of driving off the spleen and regulating the ]
[circulation. Whenever I find myself growing grim ]
[about the mouth; whenever it is a damp, drizzly ]
[November in my soul; whenever I find myself ]
[involuntarily pausing before coffin warehouses, ]
[and bringing up the rear of every funeral I meet; ]
[and especially whenever my hypos get such an ]
[upper hand of me, that it requires a strong moral ]
[principle to prevent me from deliberately ]
[stepping into the street, and methodically ]
[knocking people's hats off- then, I account it ]
[high time to get to sea as soon as I can. This is ]
[my substitute for pistol and ball. With a ]
[philosophical flourish Cato throws himself upon ]
[his sword; I quietly take to the ship. There is ]
[nothing surprising in this. If they but knew it, ]
[almost all men in their degree, some time or ]
[other, cherish very nearly the same feelings ]
[towards the ocean with ]
```

Map Reduce on netCDF

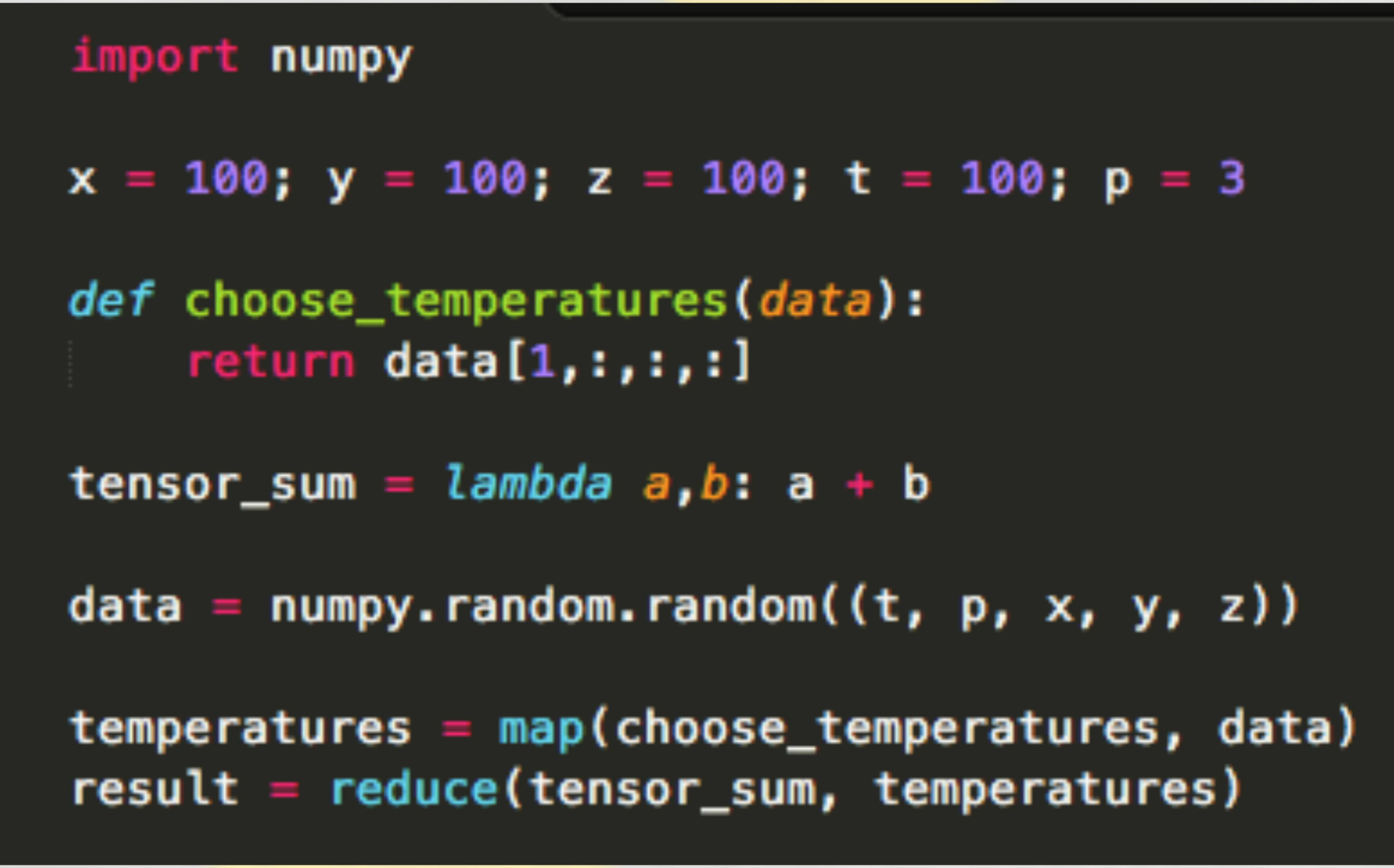


```
import numpy

x = 100; y = 100; z = 100; t = 100; p = 3

def choose_temperatures(data):
    return data[1,:,:,:]

tensor_sum = lambda a,b: a + b

data = numpy.random.random((t, p, x, y, z))

temperatures = map(choose_temperatures, data)
result = reduce(tensor_sum, temperatures)
```

lap Reduce on netCD

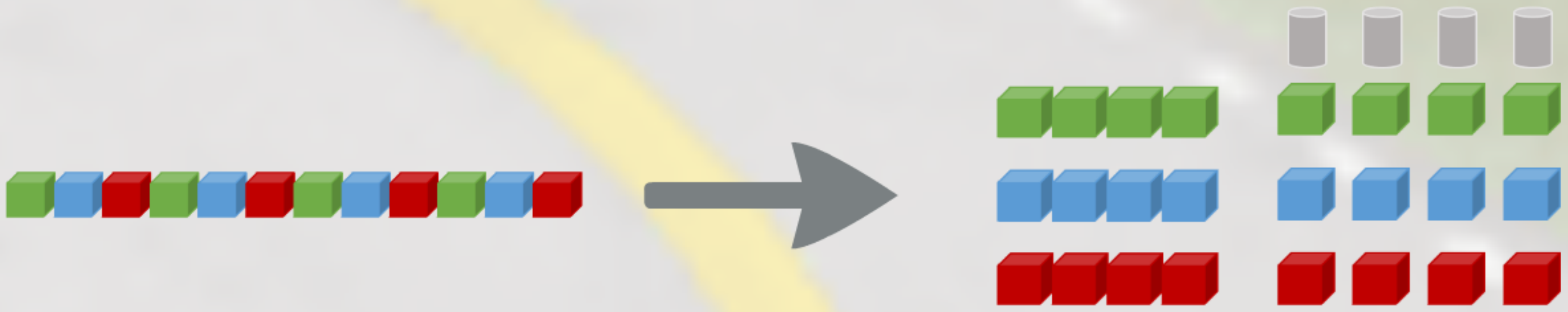


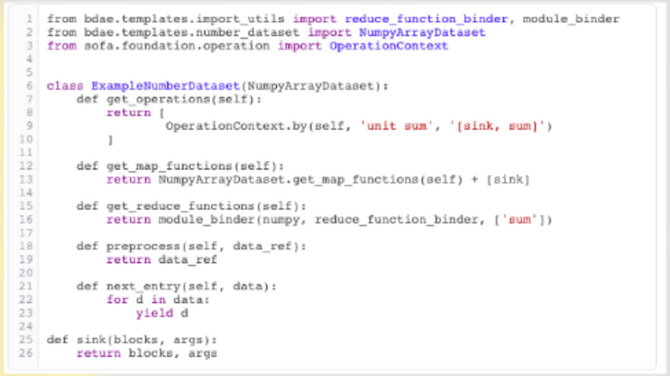
```
import numpy

x = 100; y = 100; z = 100; t = 100; p = 3

def choose_temperatures(data):
    return data[1,:,:,:]
```



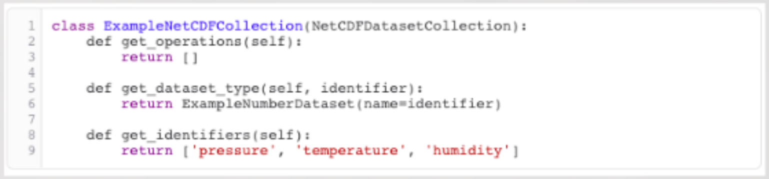
```python
import numpy

x = 100; y = 100; z = 100; t = 100; p = 3

def choose_temperatures(data):
    return data[1,:,:,:]

tensor_sum = lambda a,b: a + b

data = numpy.random.random((t, p, x, y, z))

temperatures = map(choose_temperatures, data)
result = reduce(tensor_sum, temperatures)
```

SOFA and BDAE

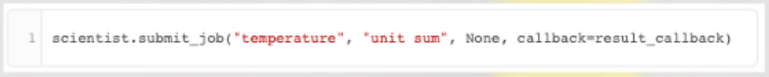




```python
from bdae.templates.import_utils import reduce_function_binder, module_binder
from bdae.templates.number_dataset import NumpyArrayDataset
from sofa.foundation.operation import OperationContext


class ExampleNumberDataset(NumpyArrayDataset):
    def get_operations(self):
        return [
                OperationContext.by(self, 'unit sum', '[sink, sum]')
        ]

    def get_map_functions(self):
        return NumpyArrayDataset.get_map_functions(self) + [sink]

    def get_reduce_functions(self):
        return module_binder(numpy, reduce_function_binder, ['sum'])

    def preprocess(self, data_ref):
        return data_ref

    def next_entry(self, data):
        for d in data:
            yield d

def sink(blocks, args):
    return blocks, args
```

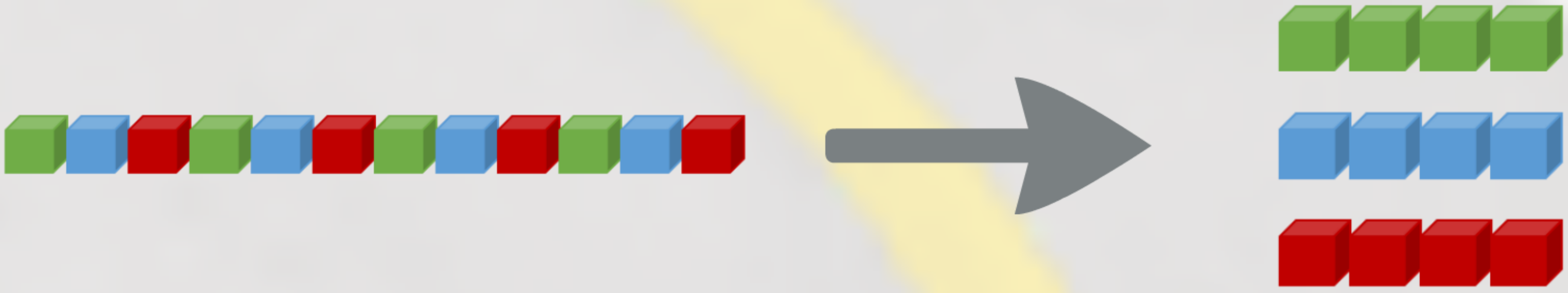


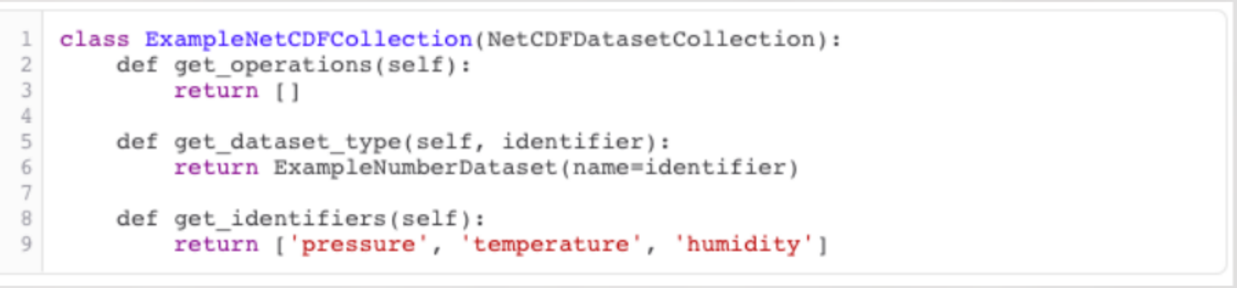
```python
class ExampleNetCDFCollection(NetCDFDatasetCollection):
    def get_operations(self):
        return []

    def get_dataset_type(self, identifier):
        return ExampleNumberDataset(name=identifier)

    def get_identifiers(self):
        return ['pressure', 'temperature', 'humidity']
```



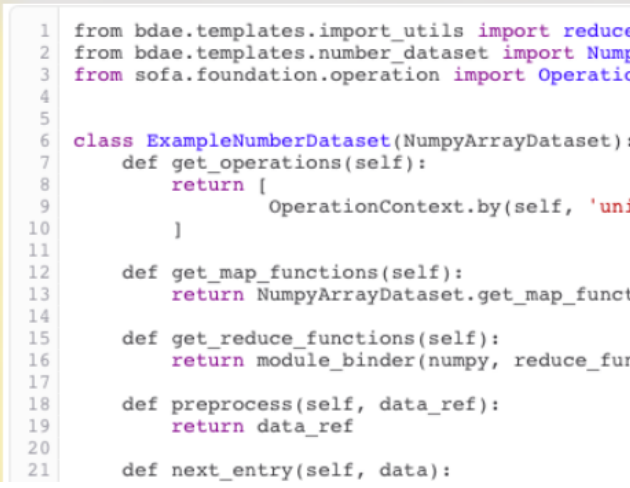
```python
scientist.submit_job("temperature", "unit sum", None, callback=result_callback)
```

SOFA and BDAE

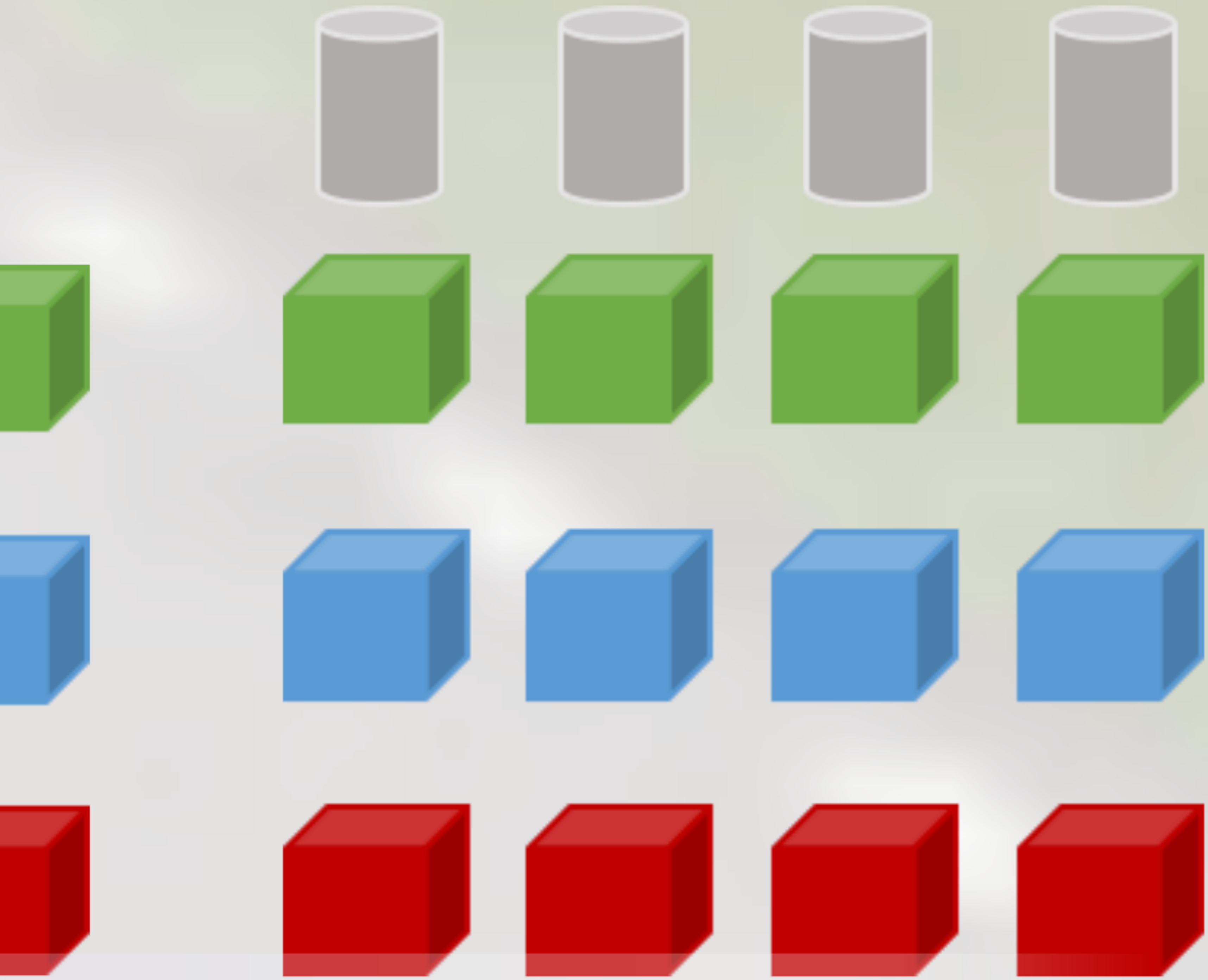




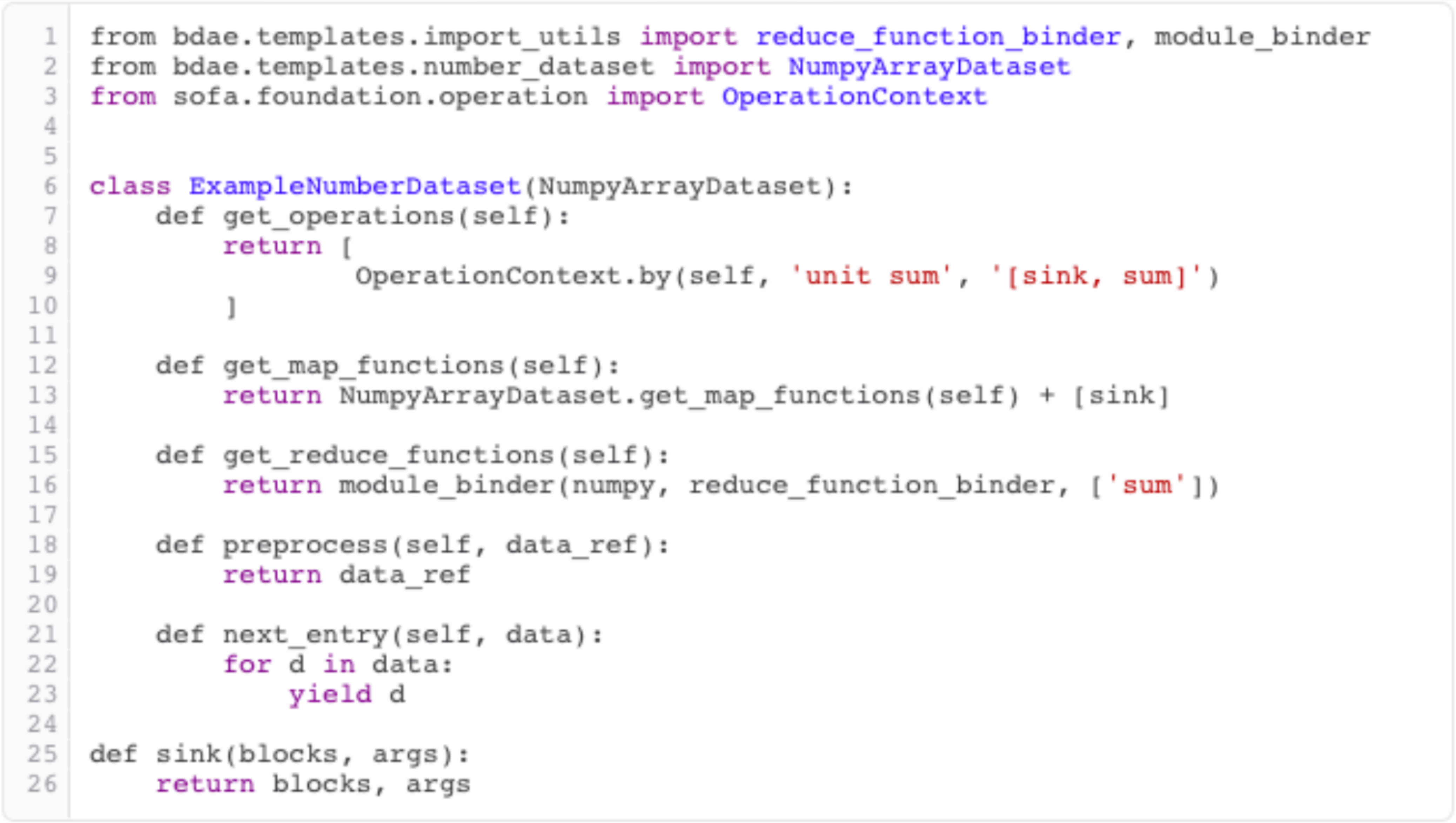
```python
class ExampleNetCDFCollection(NetCDFDatasetCollection):
    def get_operations(self):
        return []

    def get_dataset_type(self, identifier):
        return ExampleNumberDataset(name=identifier)

    def get_identifiers(self):
        return ['pressure', 'temperature', 'humidity']
```



```python
from bdae.templates.import_utils import reduc
from bdae.templates.number_dataset import Num
from sofa.foundation.operation import Operatio


class ExampleNumberDataset(NumpyArrayDataset):
    def get_operations(self):
        return [
                OperationContext.by(self, 'un
        ]

    def get_map_functions(self):
        return NumpyArrayDataset.get_map_funct

    def get_reduce_functions(self):
        return module_binder(numpy, reduce_fu

    def preprocess(self, data_ref):
        return data_ref

    def next_entry(self, data):
```



```python
class ExampleNetCDFCollection(NetCDFDatasetCollection):
    def get_operations(self):
        return []

    def get_dataset_type(self, identifier):
        return ExampleNumberDataset(name=identifier)

    def get_identifiers(self):
        return ['pressure', 'temperature', 'humidity']
```



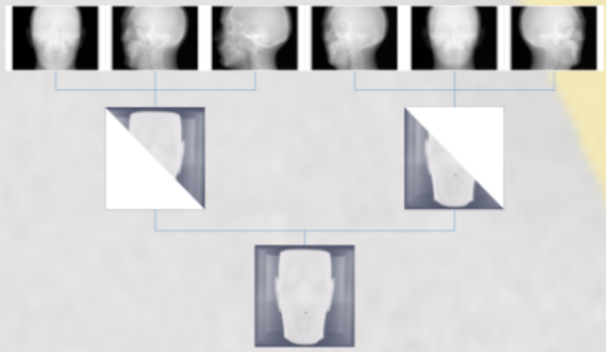
```python
from bdae.templates.import_utils import reduce_function_binder, module_binder
from bdae.templates.number_dataset import NumpyArrayDataset
from sofa.foundation.operation import OperationContext


class ExampleNumberDataset(NumpyArrayDataset):
    def get_operations(self):
        return [
                OperationContext.by(self, 'unit sum', '[sink, sum]')
        ]

    def get_map_functions(self):
        return NumpyArrayDataset.get_map_functions(self) + [sink]

    def get_reduce_functions(self):
        return module_binder(numpy, reduce_function_binder, ['sum'])

    def preprocess(self, data_ref):
        return data_ref

    def next_entry(self, data):
        for d in data:
            yield d

def sink(blocks, args):
    return blocks, args
```

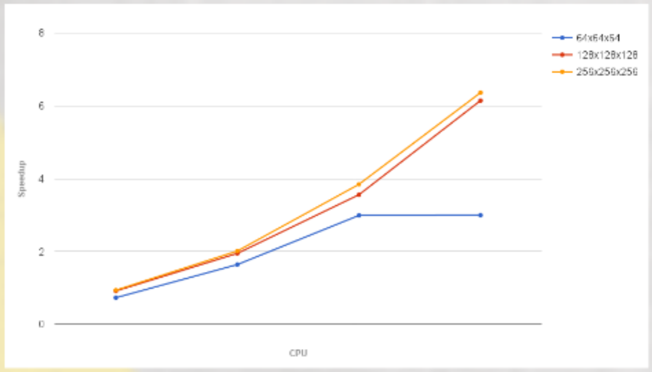
```
ature', 'humidity']
```

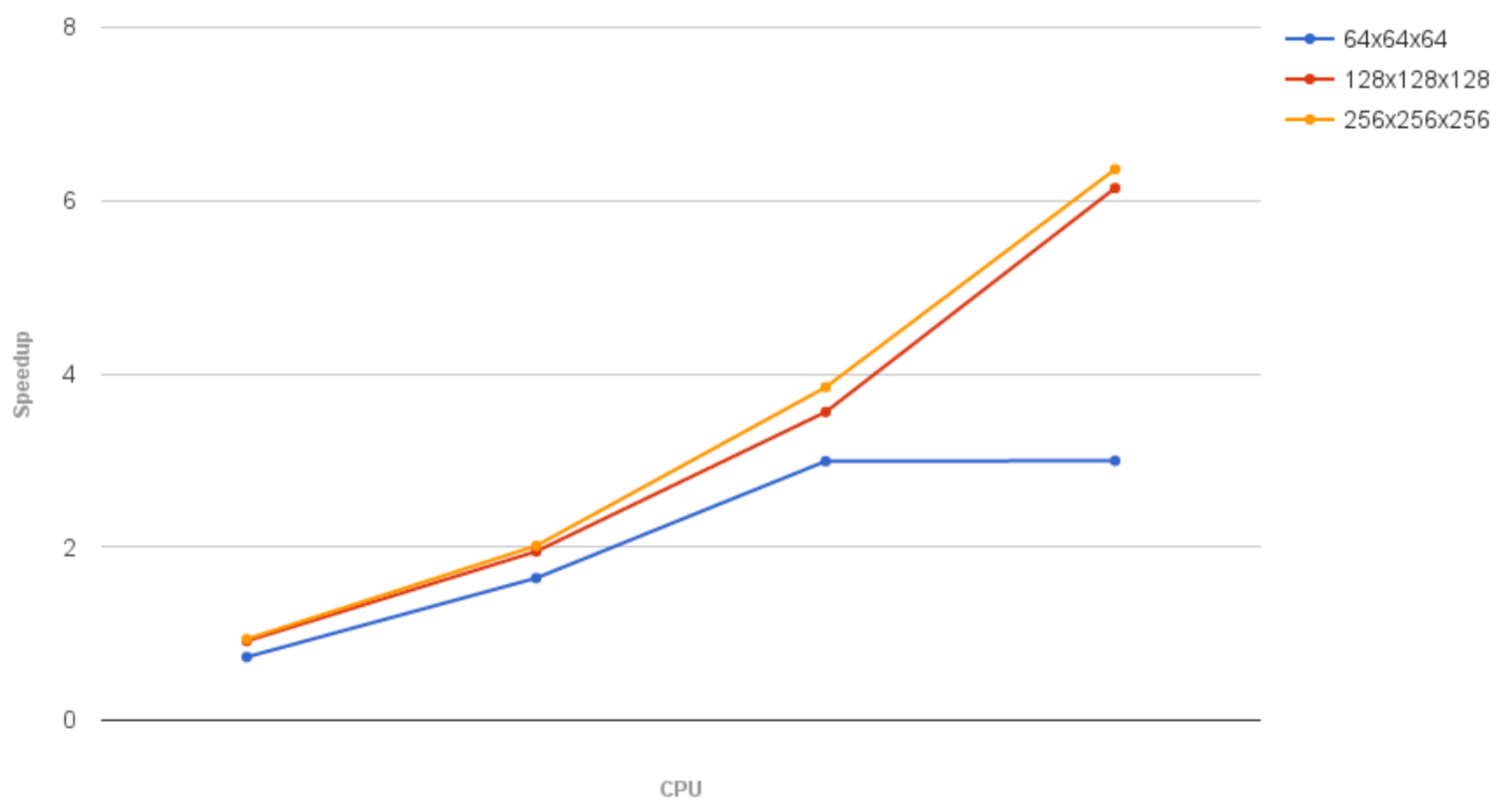
```
            return module_bin

    def preprocess(self, 
        return data_ref

    def next_entry(self, 
        for d in data:
            yield d

def sink(blocks, args):
    return blocks, args
```

```
scientist.submit_job("temperature", "unit sum", None, callback=result_callback)
```

CT Reconstruction in BDAE






8
6
4
2
0
Speedup
CPU
64x64x64
128x128x128
256x256x256

Summary

Reading data is the most expensive operation you there is

Much analysis is trivially parallelized - but use tools - do not write your own parallel programs

Big data tools are well suited for data analysis - but traditional tools like Hadoop suffer from the residual problem

GC-503
MONTAÑA
LA DATA

From simulation to knowledge

Speeding up your data analysis

Where does time go?

CPU speed is app 0.1 ns (@3.3 GHz)
Cache memory is app 5 ns
Main memory access is app 30 ns
SSD access is app 100 ns
HDD access is app 5 ms

Most important thing to take home:
Processing speed is all above data-movement processing is mostly for free

Approaches to speed up analysis

1) Try to read data only once

2) Read only the data you need

3) Parallelize your analysis