Charm4Py

Productive Parallel Programming

- Recent interest in productivity in parallel programming

- Especially as compute nodes become more heterogeneous
    - Kokkos, Raja, DPC++, …

Python

- Massive success in data science, ML
- Recent attention by HPC community

- Productive language to glue together hot code paths
    - Written in C/C++, JIT-compiled to heterogeneous devices

Charm4Py

- Productivity + performance:
    - Distributed execution of Charm++ with rich software ecosystem of Python

pandas

Numba

SciPy

NumPy

TensorFlow

Charm4Py Basics

- Define chare classes in Python

- Create a main driver that creates chares, begins execution.
- That’s it!

- No opaque compile errors, no additional files required

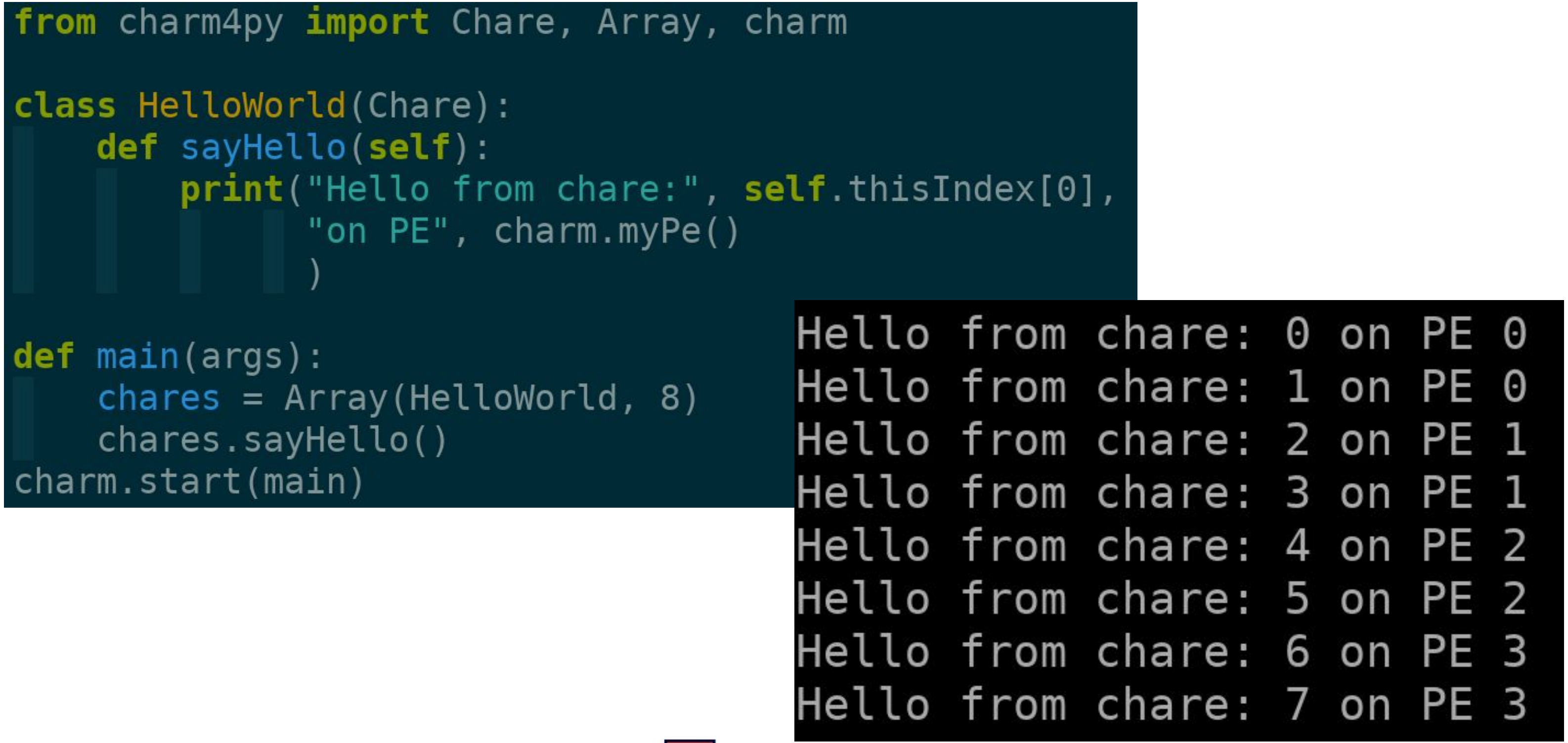
Charm4Py Basics

```
from charm4py import Chare, Array, charm

class HelloWorld(Chare):
    def sayHello(self):
        print("Hello from chare:", self.thisIndex[0],
              "on PE", charm.myPe()
              )

def main(args):
    chares = Array(HelloWorld, 8)
    chares.sayHello()
charm.start(main)
```

Charm4Py Basics



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def main(args):
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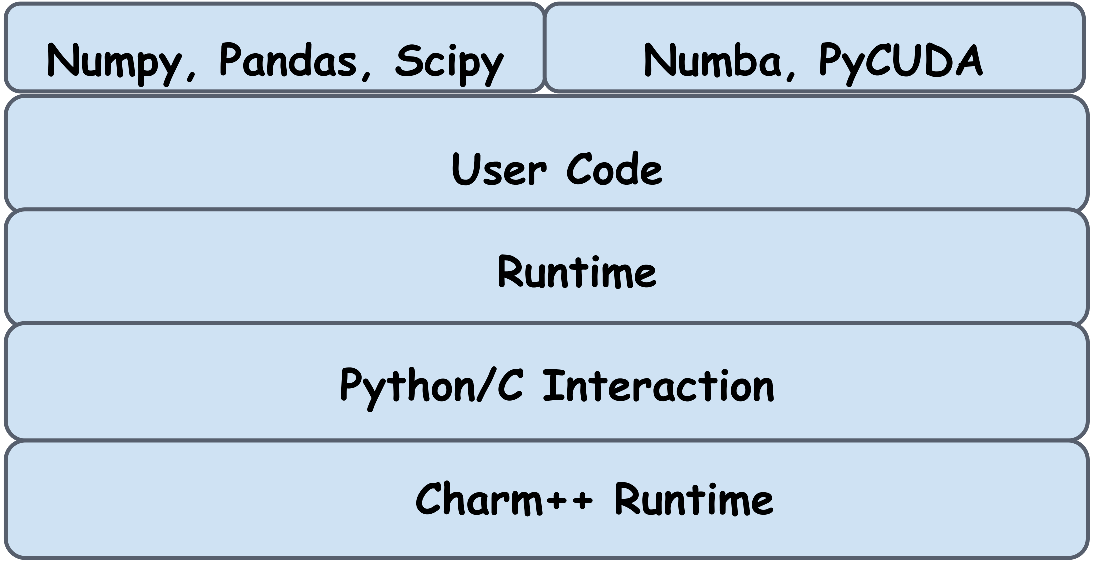
```

```
Hello from chare: 0 on PE 0
Hello from chare: 1 on PE 0
Hello from chare: 2 on PE 1
Hello from chare: 3 on PE 1
Hello from chare: 4 on PE 2
Hello from chare: 5 on PE 2
Hello from chare: 6 on PE 3
Hello from chare: 7 on PE 3
```

Overview



Numpy, Pandas, Scipy

Numba, PyCUDA

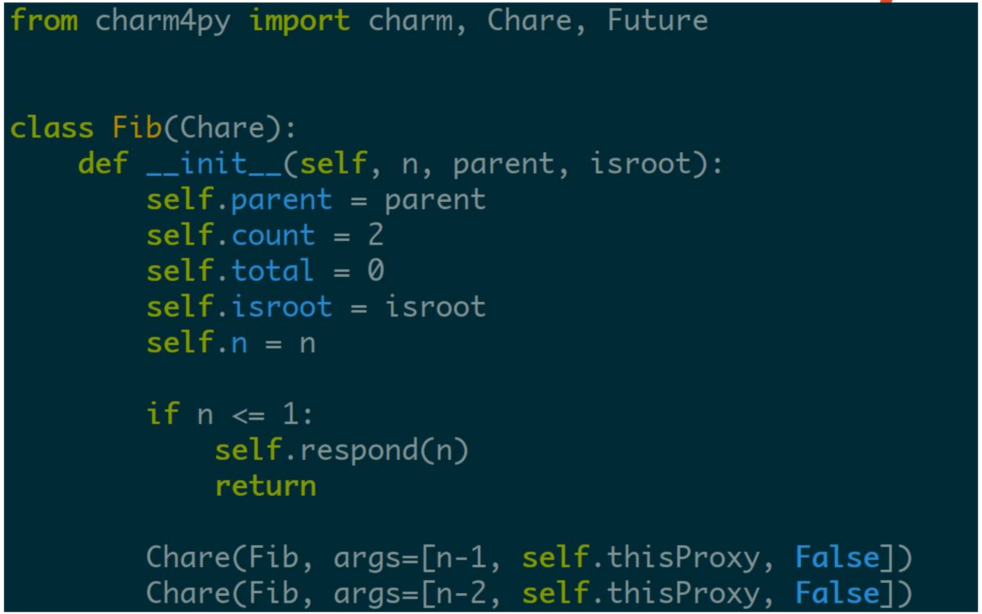
User Code

Runtime

Python/C Interaction

Charm++ Runtime

Charm4Py: Fibonacci



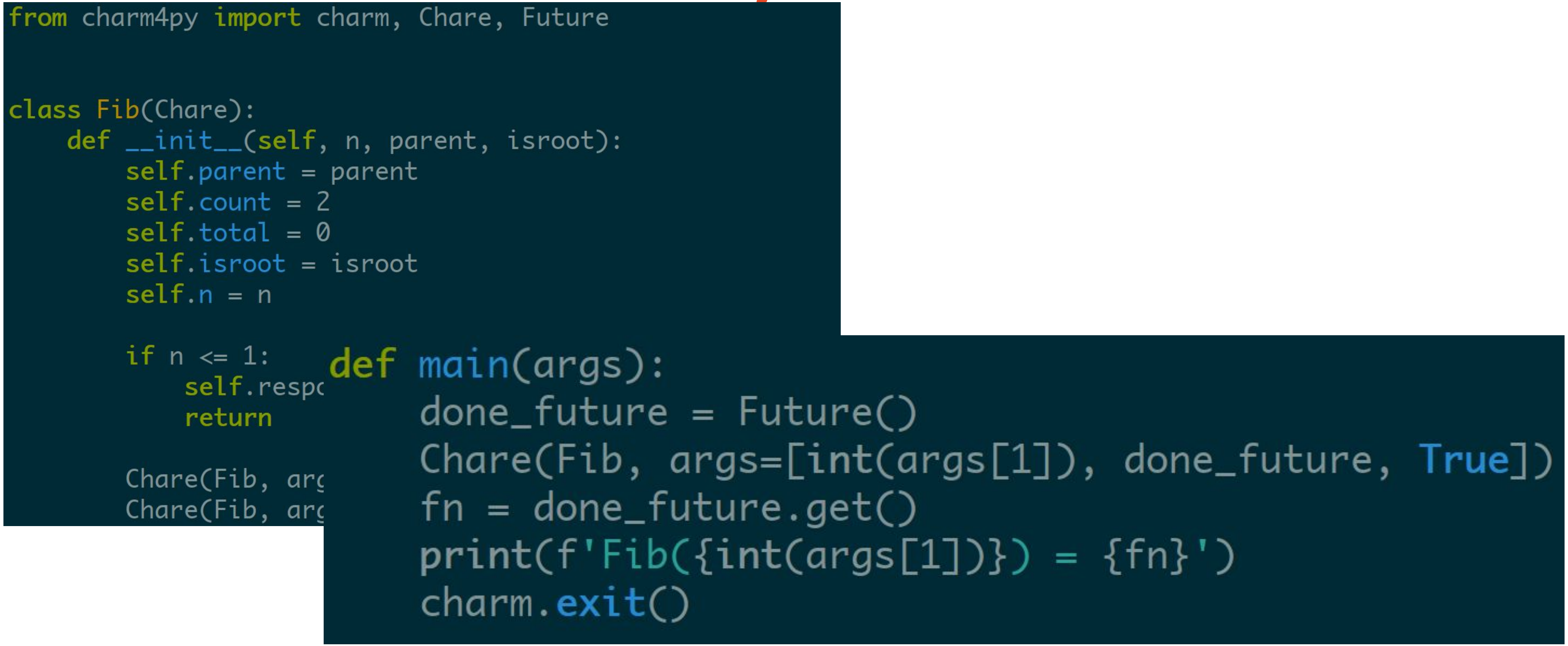
```
from charm4py import charm, Chare, Future


class Fib(Chare):
    def __init__(self, n, parent, isroot):
        self.parent = parent
        self.count = 2
        self.total = 0
        self.isroot = isroot
        self.n = n

        if n <= 1:
            self.respond(n)
            return

        Chare(Fib, args=[n-1, self.thisProxy, False])
        Chare(Fib, args=[n-2, self.thisProxy, False])
```

Charm4Py: Fibonacci



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        Chare(Fib, arg
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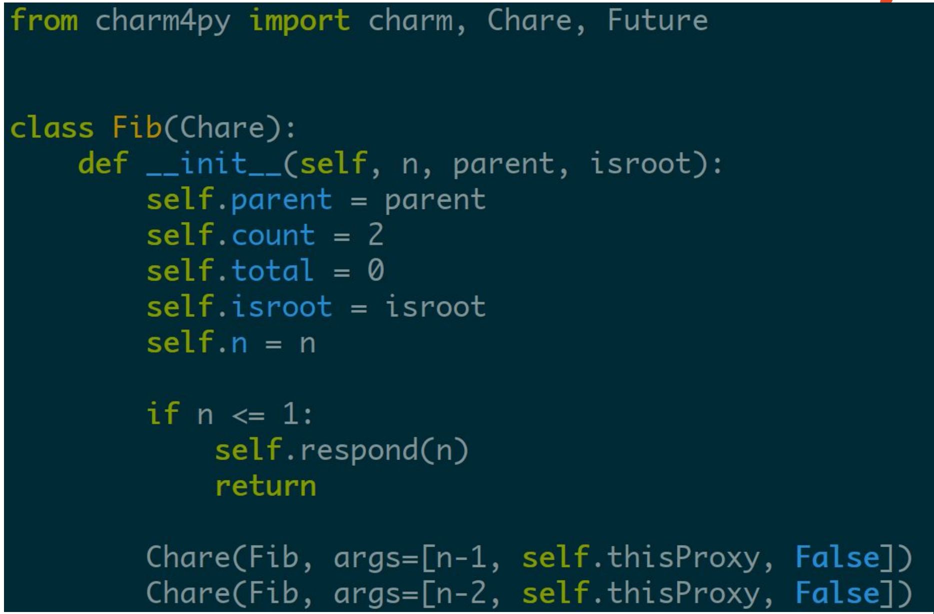
```

```
def main(args):
    done_future = Future()
    Chare(Fib, args=[int(args[1]), done_future, True])
    fn = done_future.get()
    print(f'Fib({int(args[1])}) = {fn}')
    charm.exit()
```

Charm4Py: Fibonacci



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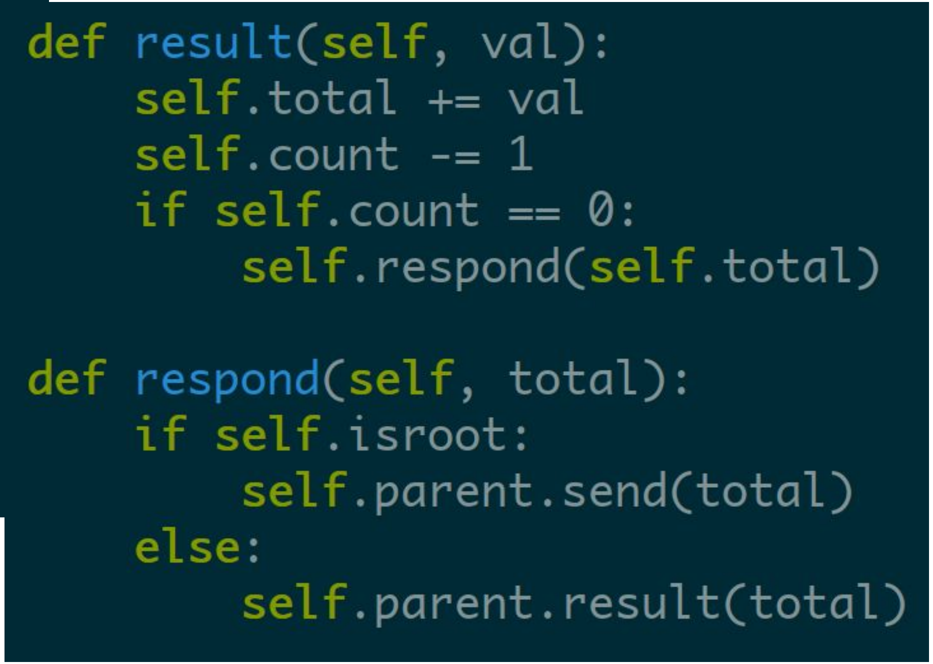
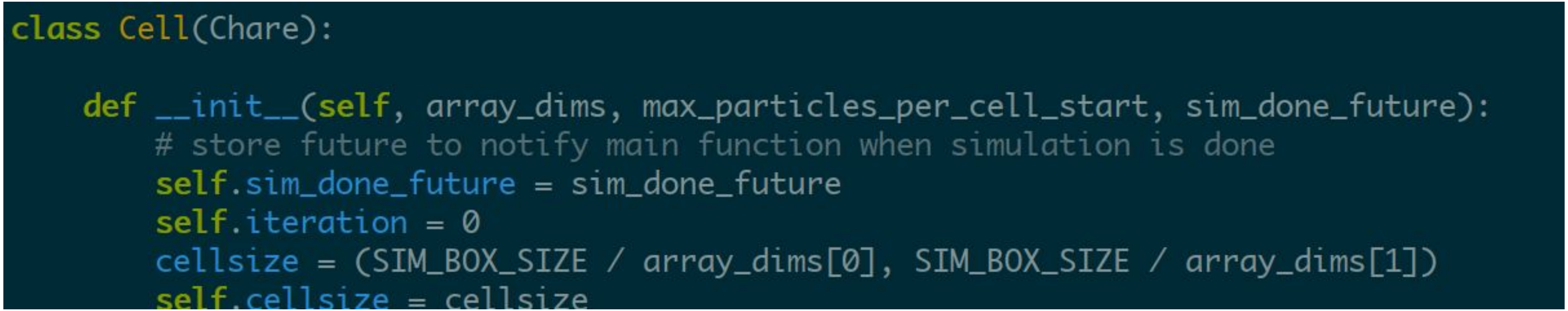


```
def result(self, val):
    self.total += val
    self.count -= 1
    if self.count == 0:
        self.respond(self.total)

def respond(self, total):
    if self.isroot:
        self.parent.send(total)
    else:
        self.parent.result(total)
```

Computer Science

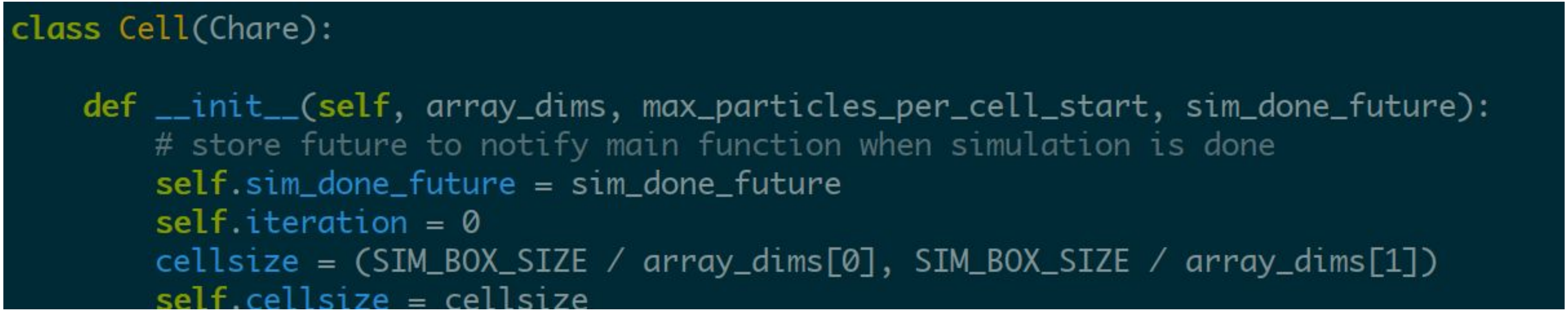
Array Creation



```
class Cell(Chare):

    def __init__(self, array_dims, max_particles_per_cell_start, sim_done_future):
        # store future to notify main function when simulation is done
        self.sim_done_future = sim_done_future
        self.iteration = 0
        cellsize = (SIM_BOX_SIZE / array_dims[0], SIM_BOX_SIZE / array_dims[1])
        self.cellsize = cellsize
```

Array Creation



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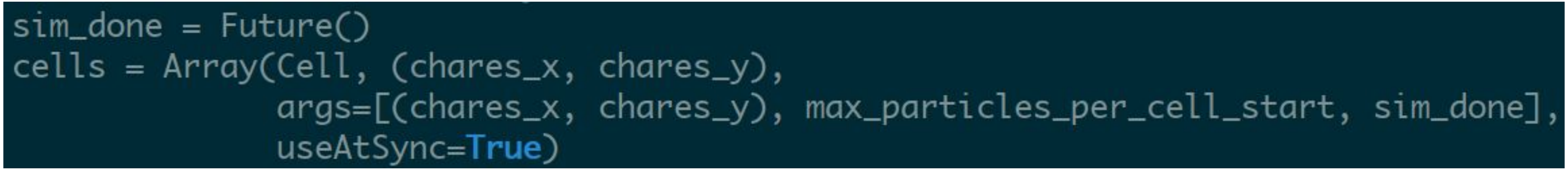
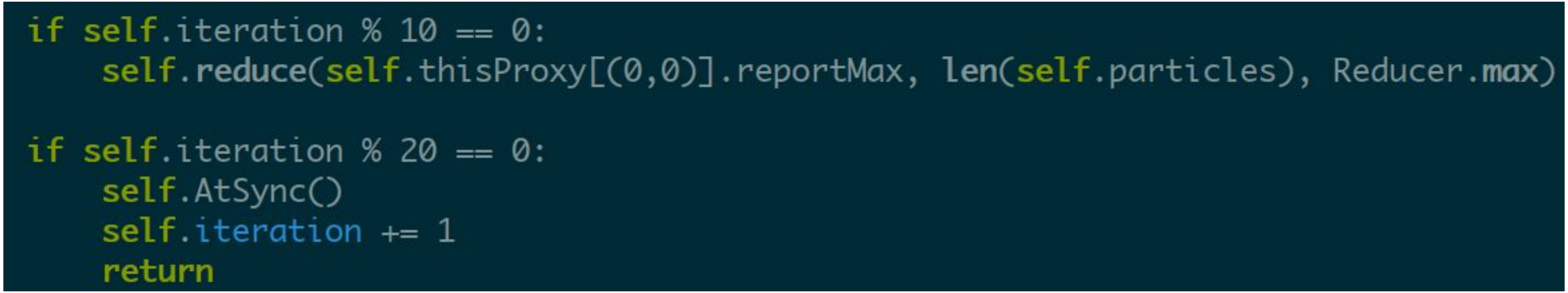


```
sim_done = Future()
cells = Array(Cell, (chares_x, chares_y),
              args=[(chares_x, chares_y), max_particles_per_cell_start, sim_done],
              useAtSync=True)
```

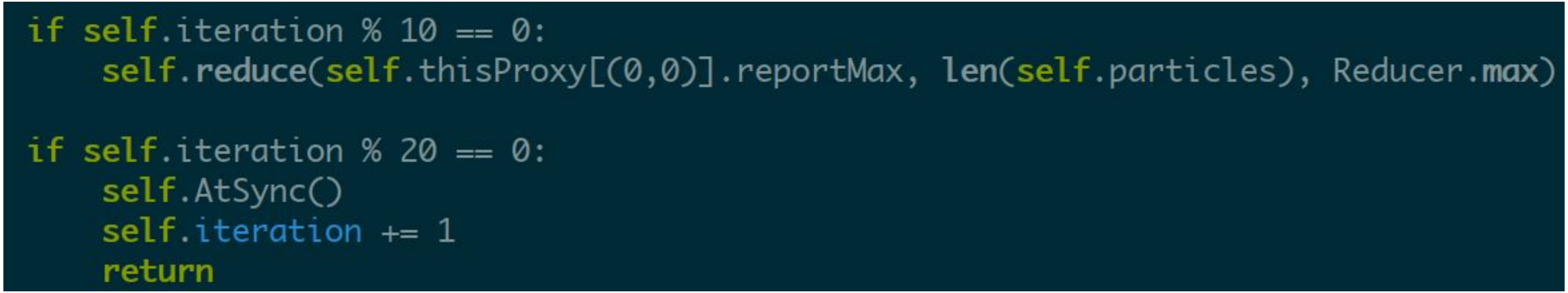
Arrays: Reductions, Load Balancing



```
if self.iteration % 10 == 0:
    self.reduce(self.thisProxy[(0,0)].reportMax, len(self.particles), Reducer.max)

if self.iteration % 20 == 0:
    self.AtSync()
    self.iteration += 1
    return
```

Arrays: Reductions, Load Balancing



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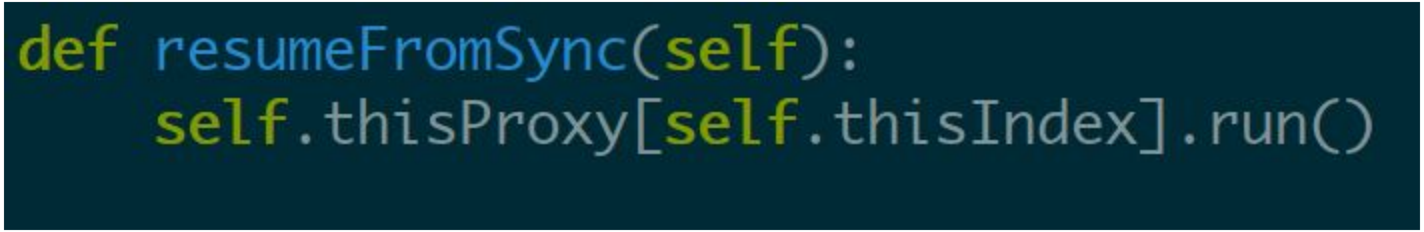
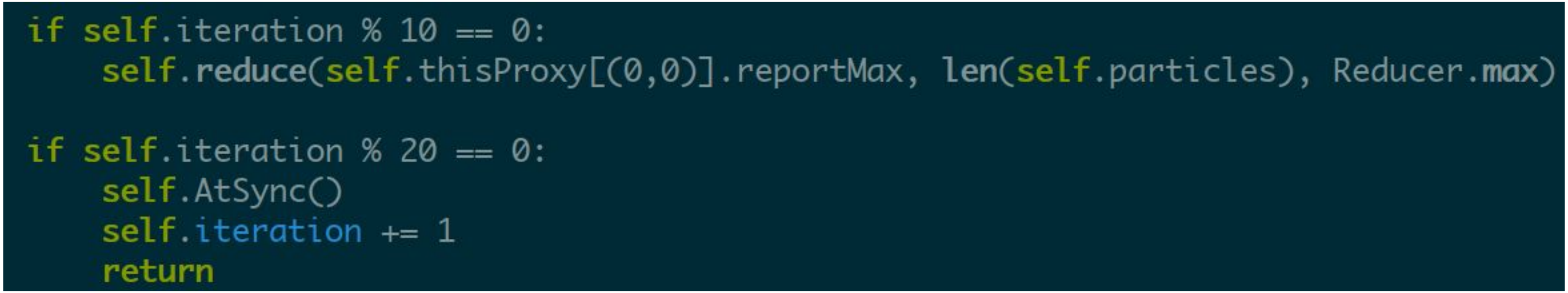


```
def resumeFromSync(self):
    self.thisProxy[self.thisIndex].run()
```

Arrays: Reductions, Load Balancing



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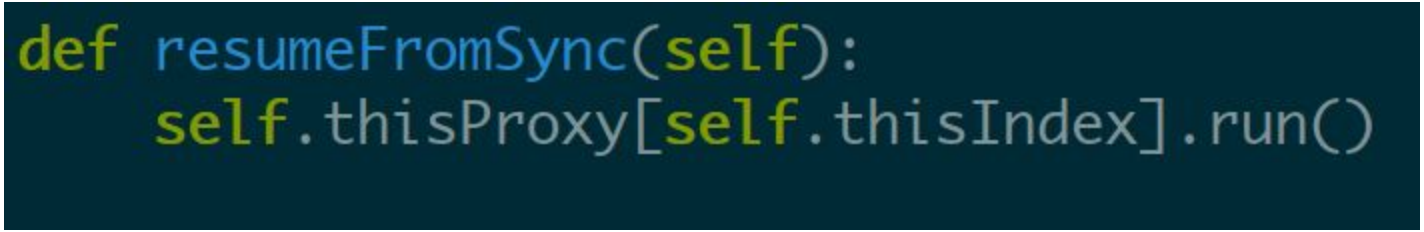

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No need to define a PUP! Pickle is used

Channels

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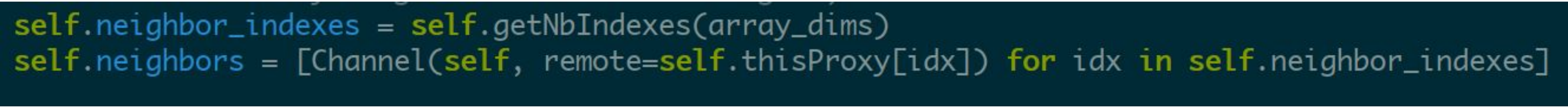
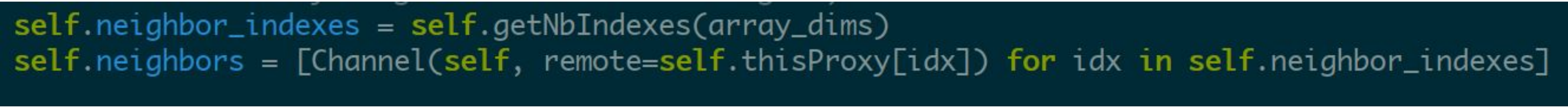


```
self.neighbor_indexes = self.getNbIndexes(array_dims)
self.neighbors = [Channel(self, remote=self.thisProxy[idx]) for idx in self.neighbor_indexes]
```

Channels

Point-to-point communication channel between chares



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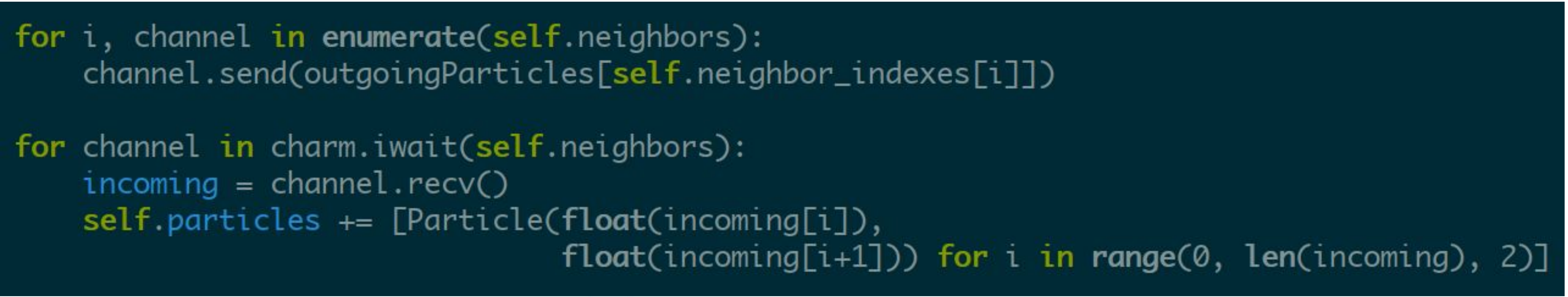

```
for i, channel in enumerate(self.neighbors):
    channel.send(outgoingParticles[self.neighbor_indexes[i]])

for channel in charm.iwait(self.neighbors):
    incoming = channel.recv()
    self.particles += [Particle(float(incoming[i]),
                                float(incoming[i+1])) for i in range(0, len(incoming), 2)]
```

Reductions: Targeting Futures

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```
self.reduce(self.sim_done_future)
```

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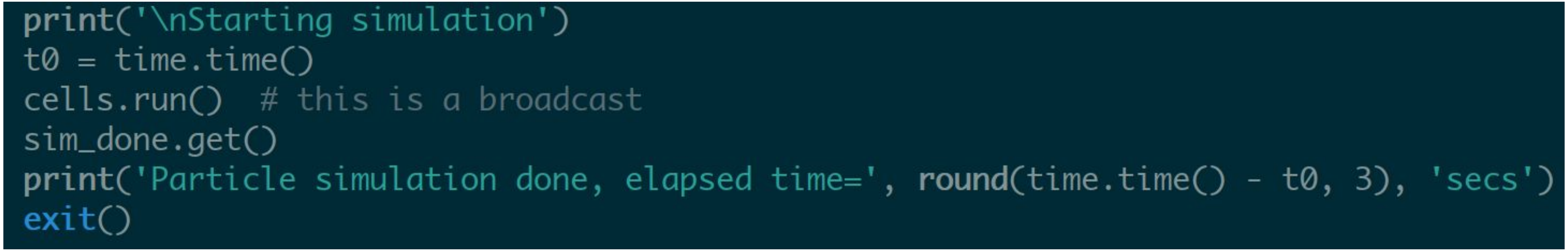
Main chare:



```
print('\nStarting simulation')
t0 = time.time()
cells.run()  # this is a broadcast
sim_done.get()
print('Particle simulation done, elapsed time=', round(time.time() - t0, 3), 'secs')
exit()
```

Running Programs

On your local machine

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On your local machine

```
python3 -m charmrun.start +p2 ./fib.py 10
```

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On a cluster

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```

```
mpirun -np 2 python3 ./fib.py 10
```

More Information

Source: https://github.com/UIUC-PPL/charm4py

Docs: https://charm4py.readthedocs.io/en/latest/