Heterogeneous Computing using openCL lecture 2

F21DP Distributed and Parallel Technology

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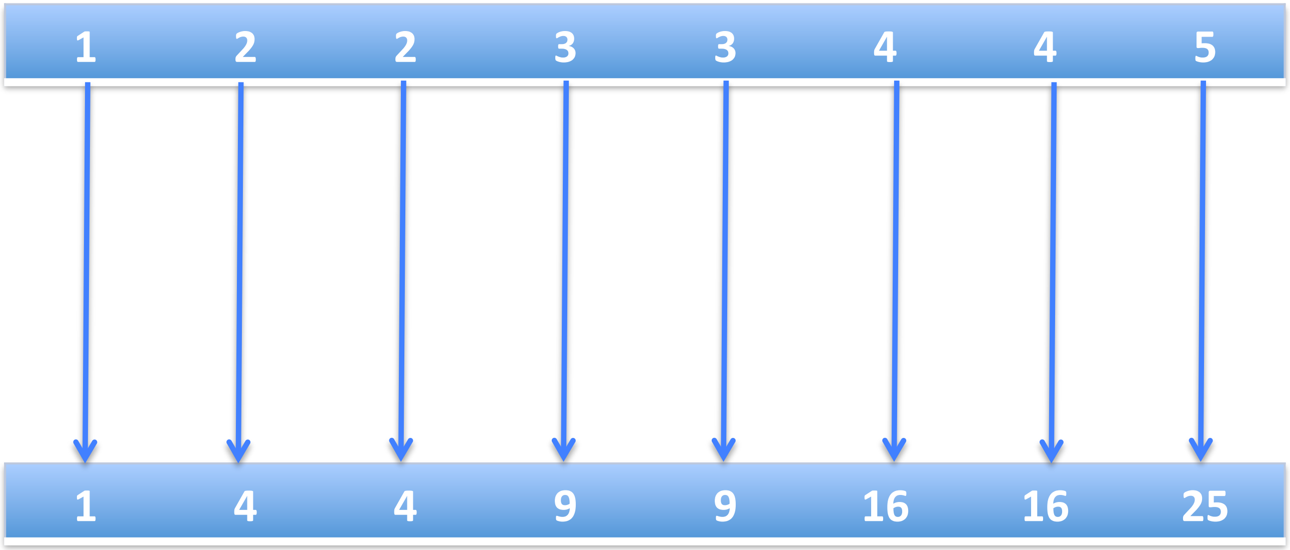
Example: Squares



result[i] = data[i] * data[i]

Selecting a Platform

```
cl_int  clGetPlatformIDs (cl_uint num_entries,
                          cl_platform_id *platforms,
                          cl_uint *num_platforms)
```

- Each OpenCL implementation (i.e. an OpenCL library from AMD, NVIDIA, etc.) defines *platforms* which enable the host system to interact with OpenCL-capable devices
  - Currently each vendor supplies only a single platform per implementation

Selecting Devices

- Once a platform is selected, we can then query for the devices that it knows how to interact with

```
clGetDeviceIDs⁴ (cl_platform_id platform,
                 cl_device_type device_type,
                 cl_uint num_entries,
                 cl_device_id *devices,
                 cl_uint *num_devices)
```

- We can specify which types of devices we are interested in (e.g. all devices, CPUs only, GPUs only)
- This call is performed twice as with clGetPlatformIDs
  - The first call is to determine the number of devices, the second retrieves the device objects

Contexts

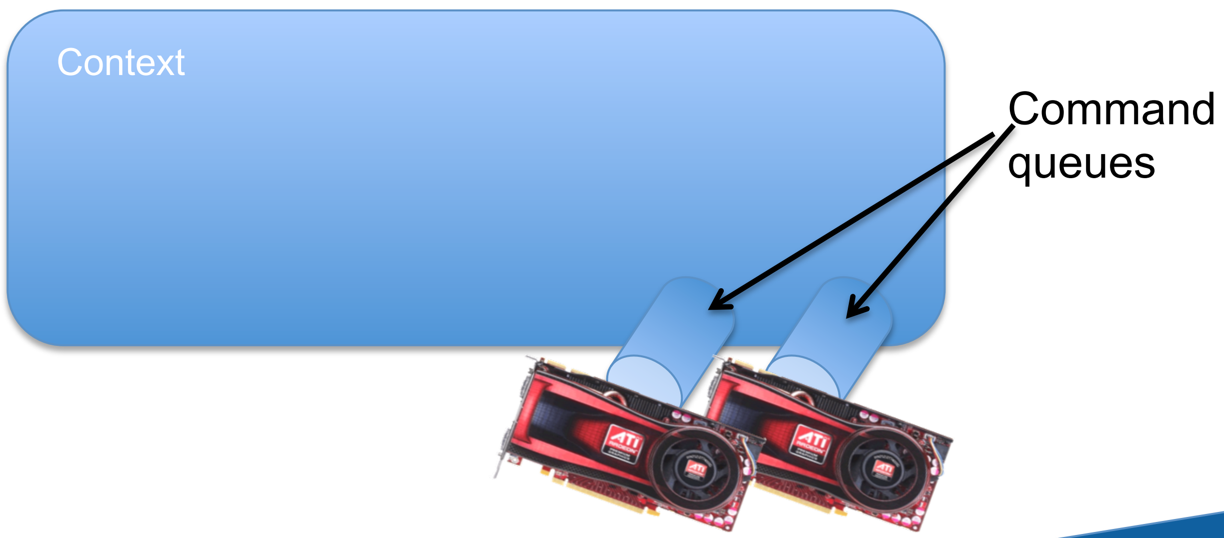
- Is an abstract execution environment

```
cl_context    clCreateContext (const cl_context_properties *properties,
                               cl_uint num_devices,
                               const cl_device_id *devices,
                               void (CL_CALLBACK *pfn_notify)(const char *errinfo,
                                        const void *private_info, size_t cb,
                                        void *user_data),
                               void *user_data,
                               cl_int *errcode_ret)
```

Command Queues

- Command queues associate a context with a device

```
cl_command_queue   clCreateCommandQueue (cl_context context,
                                         cl_device_id device,
                                         cl_command_queue_properties properties,
                                         cl_int *errcode_ret)
```



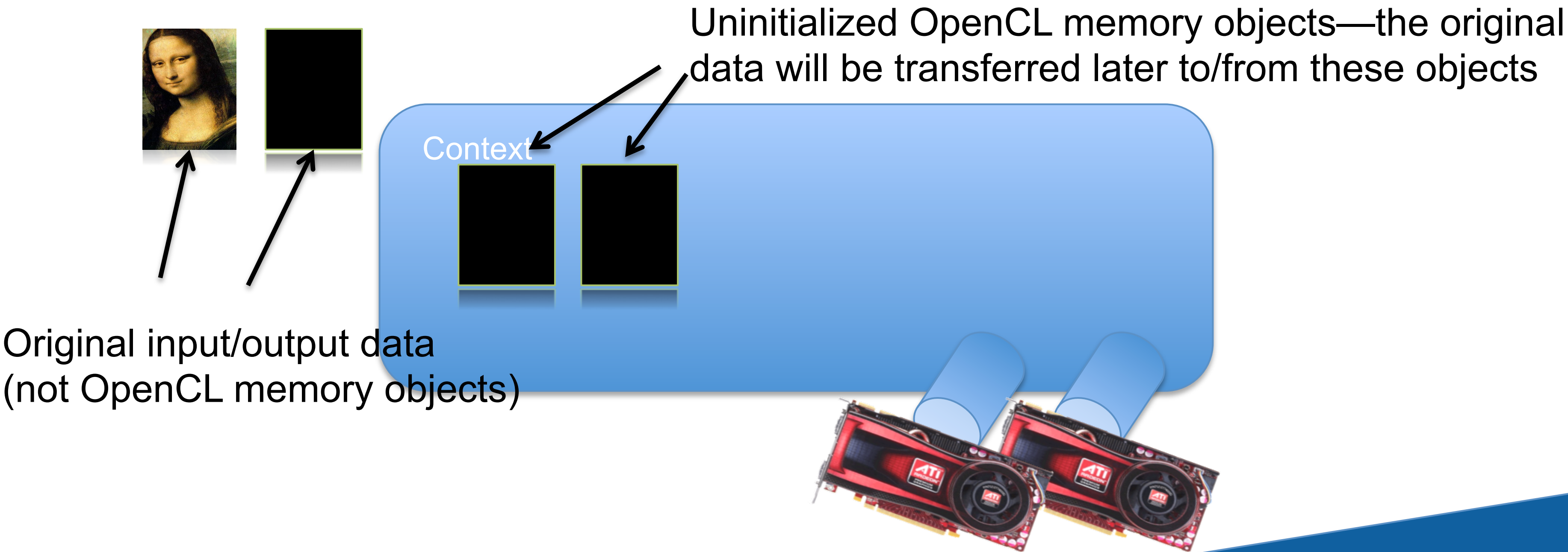
Lucky You !☺

```
/******************************************************************************
 * initGPU : sets up the openCL environment for using a GPU.
 *         Note that the system may have more than one GPU in which case
 *         the one that has been pre-configured will be chosen.
 *         If anything gows wrong in the course, error messages will be
 *         printed to stderr and the last error encountered will be returned.
 *
 ******************************************************************************/
extern cl_int initGPU ();
```

Choses **platform** and **device** and creates a **context** and a **command queue** for you ☺

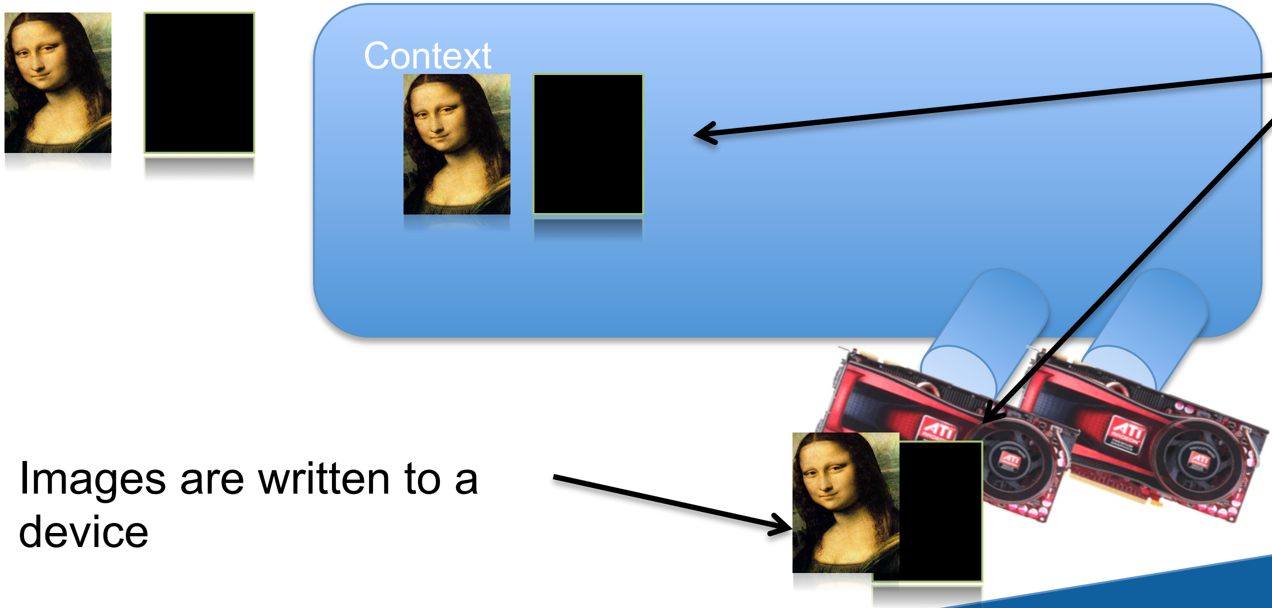
Memory Objects

```
cl_mem   clCreateBuffer (cl_context context,
                         cl_mem_flags flags,
                         size_t size,
                         void *host_ptr,
                         cl_int *errcode_ret)
```



Transferring Data

```
cl_int  clEnqueueWriteBuffer (cl_command_queue command_queue,
                              cl_mem buffer,
                              cl_bool blocking_write,
                              size_t offset,
                              size_t cb,
                              const void *ptr,
                              cl_uint num_events_in_wait_list,
                              const cl_event *event_wait_list,
                              cl_event *event)
```

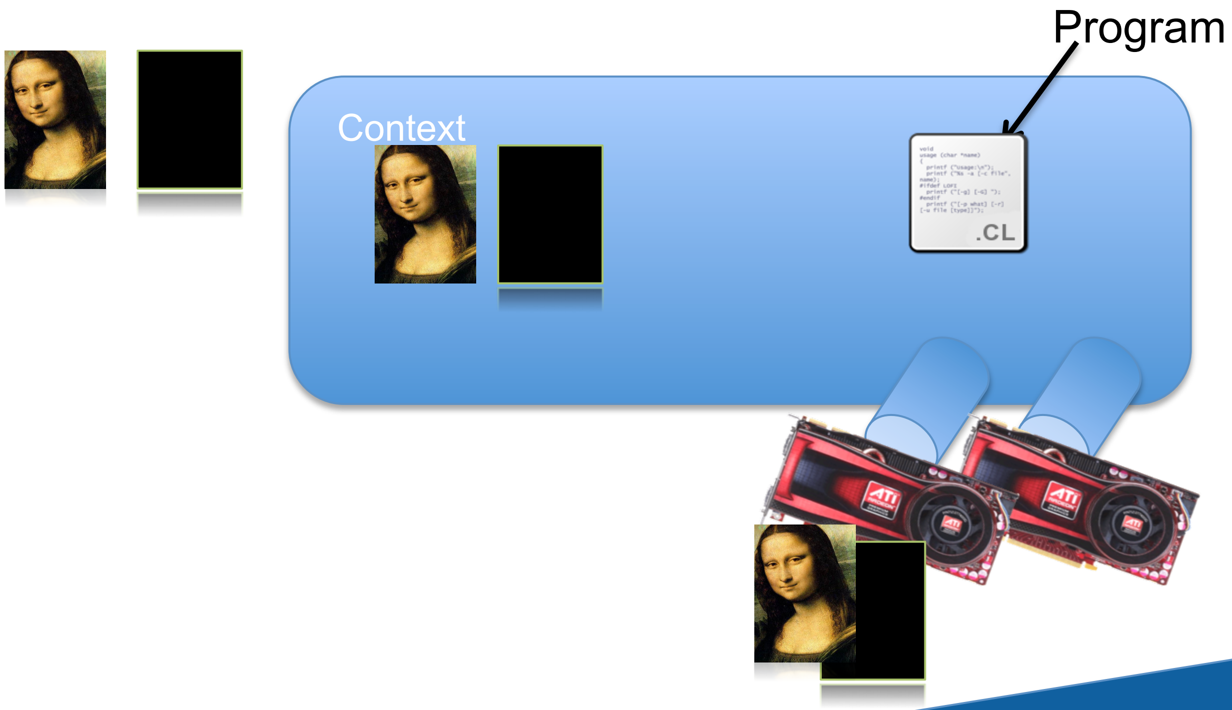


The images are redundant here to show that they are both part of the context (on the host) and physically on the device

Images are written to a device

Programs

```
cl_program    clCreateProgramWithSource (cl_context context,
                                          cl_uint count,
                                          const char **strings,
                                          const size_t *lengths,
                                          cl_int *errcode_ret)
```



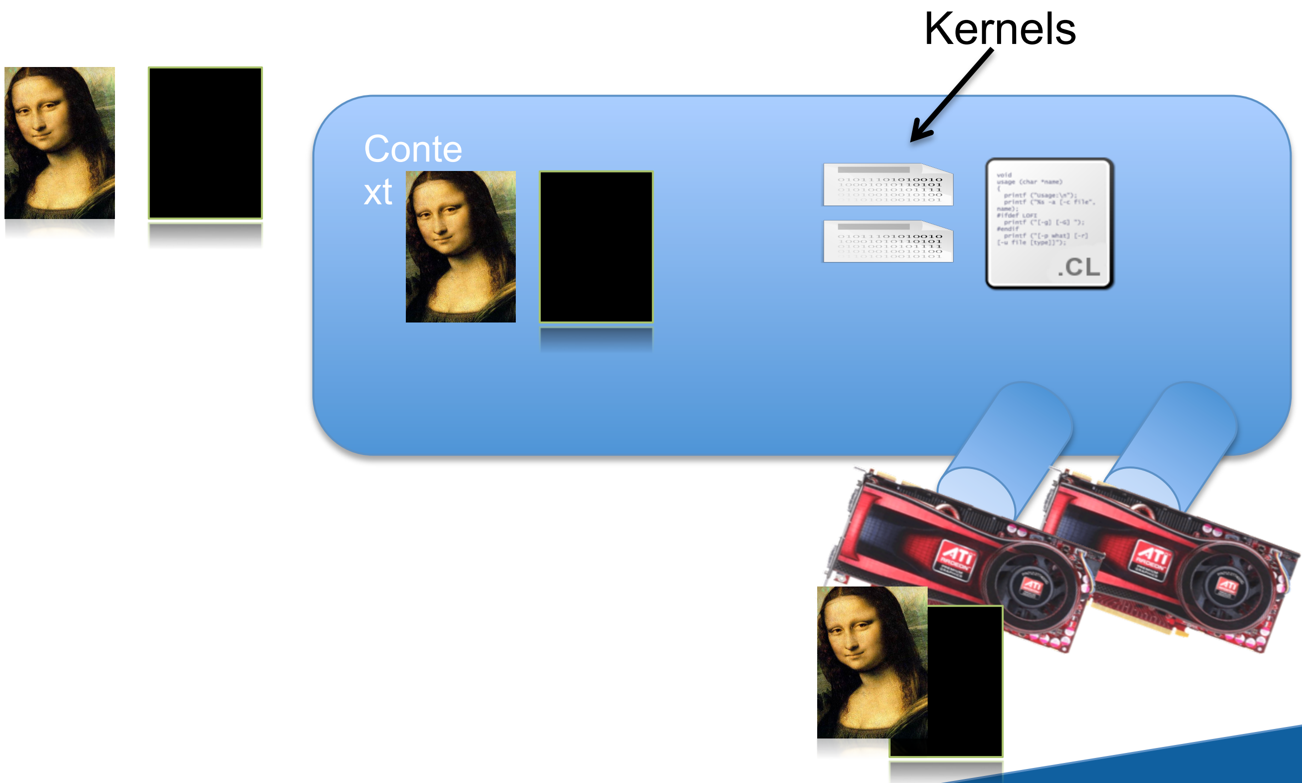
Compiling Programs

```
cl_int    clBuildProgram (cl_program program,
                          cl_uint num_devices,
                          const cl_device_id *device_list,
                          const char *options,
                          void (CL_CALLBACK *pfn_notify)(cl_program program,
                                                         void *user_data),
                          void *user_data)
```

- This function compiles and links an executable from the program object for each device in the context
  - If *device_list* is supplied, then only those devices are targeted
- Optional preprocessor, optimization, and other options can be supplied by the *options* argument

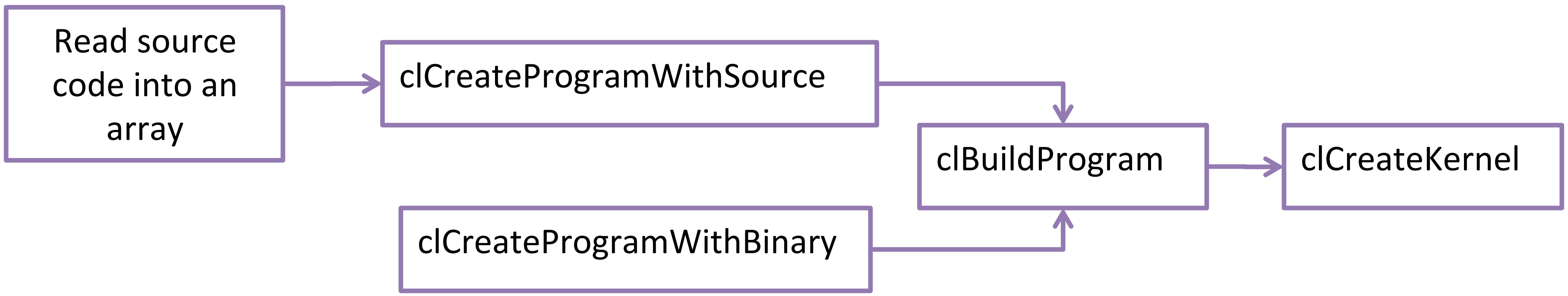
Kernels

```
cl_kernel    clCreateKernel (cl_program program,
                             const char *kernel_name,
                             cl_int *errcode_ret)
```



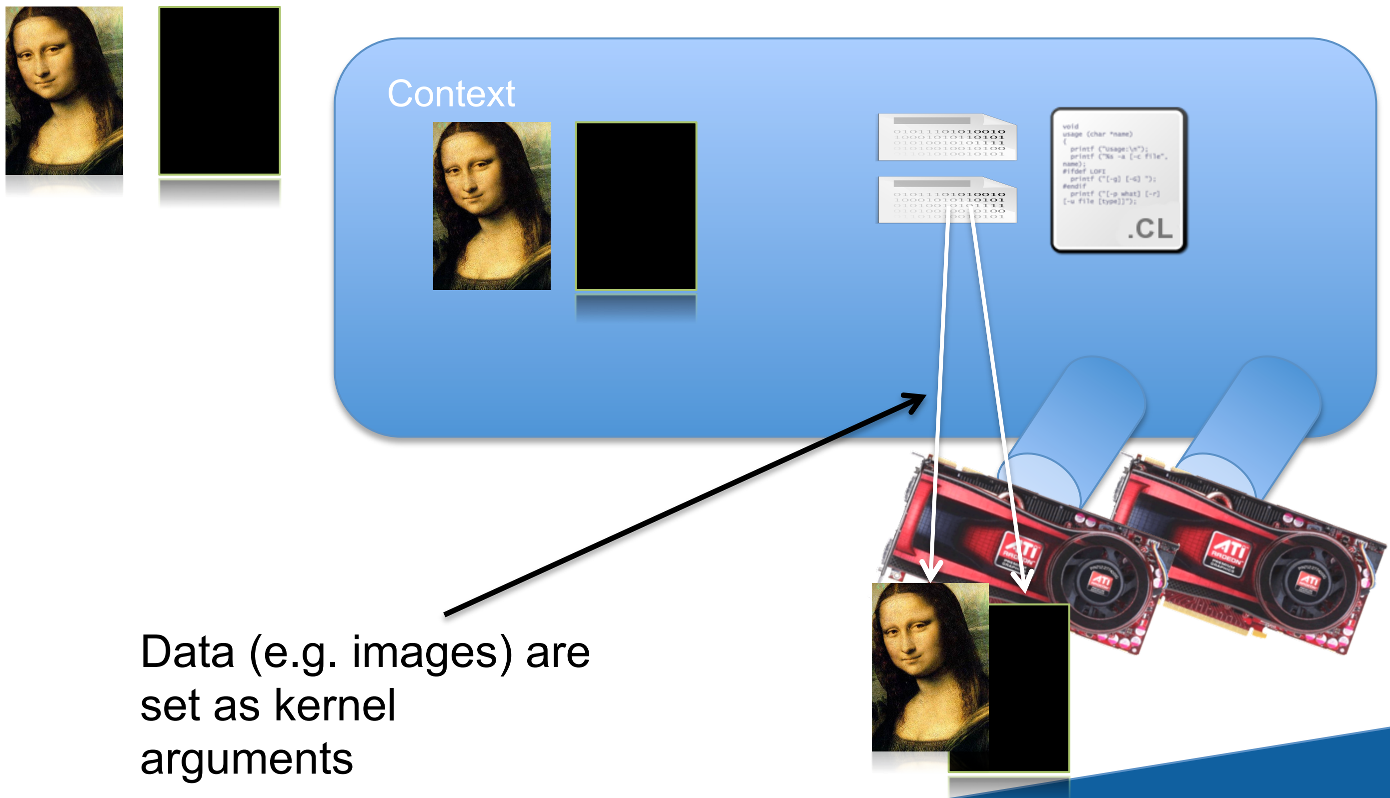
Runtime Compilation

- There is a high overhead for compiling programs and creating kernels
  - Each operation only has to be performed once (at the beginning of the program)
    - The kernel objects can be reused any number of times by setting different arguments



Kernel Arguments

```
cl_int   clSetKernelArg (cl_kernel kernel,
                         cl_uint arg_index,
                         size_t arg_size,
                         const void *arg_value)
```



Lucky you II ☺

```
/****************************************************************************
 *
 * setupKernel : this routine prepares a kernel for execution. It takes the
 *            following arguments:
 *            - the kernel source as a string
 *            - the name of the kernel function as string
 *            - the number of arguments (must match those specified in the
 *              kernel source!)
 *            - followed by the actual arguments. Each argument to the kernel
 *              results in two or three arguments to this function, depending
 *              on whether these are pointers to float-arrays or integer values:
 *
 * legal argument sets are:
 *   FloatArr::clarg_type, num_elems::int, pointer::float *,    and
 *   IntConst::clarg_type, number::int
 *

typedef enum {
  FloatArr,
  IntConst
} clarg_type;
```

Lucky you II cont.

```
*           If anything goes wrong in the course, error messages will be
 *           printed to stderr. The pointer to the fully prepared kernel
 *           will be returned.
 *
 *           Note that this function actually performs quite a few openCL
 *           tasks. It compiles the source, it allocates memory on the
 *           device and it copies over all float arrays. If a more
 *           sophisticated behaviour is needed you may have to fall back to
 *           using openCL directly.
 *
 *******************************************************************************/

extern cl_kernel setupKernel( const char *kernel_source, char *kernel_name, int num_args, ...);
```

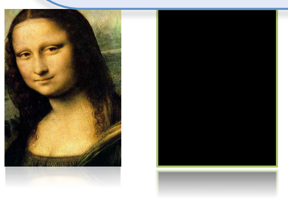
```
count = 1024;
kernel = setupKernel( KernelSource, "square", 3, FloatArr, count, data,
                                    FloatArr, count, results,
                                    IntConst, count);
```

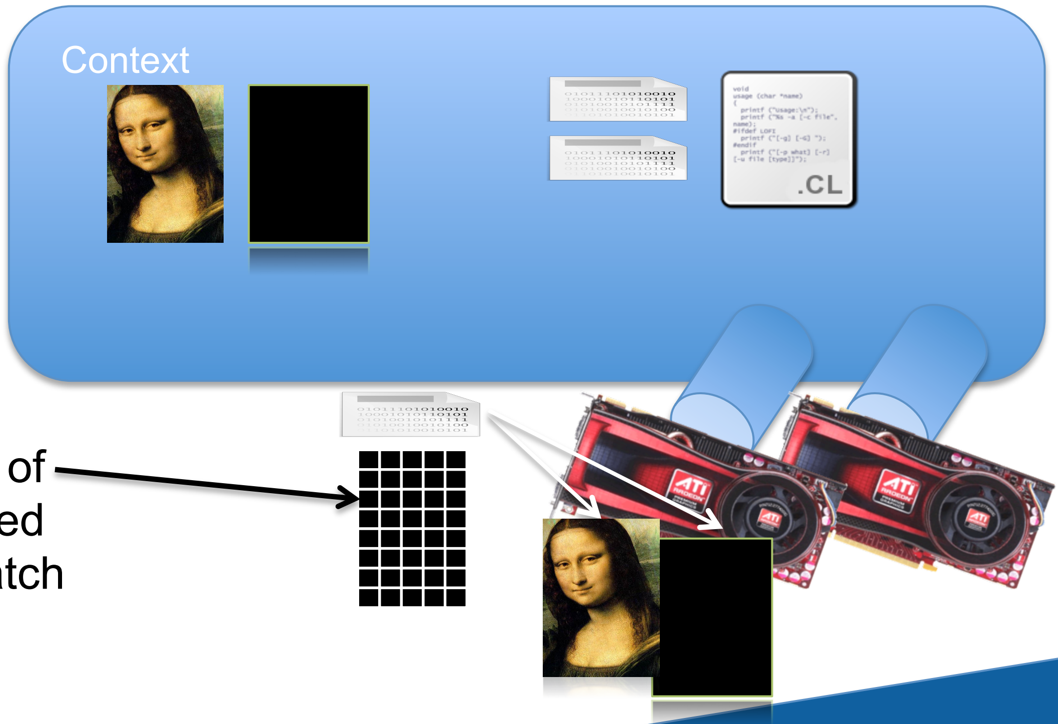
Lucky you II cont.

```
const char *KernelSource =              "\n"
  "__kernel void square(                 \n"
  "    __global float* input,            \n"
  "    __global float* output,           \n"
  "    const unsigned int count)         \n"
  "{                                     \n"
  "    int i = get_global_id(0);         \n"
  "      output[i] = input[i] * input[i];  \n"
  "}                                     \n”;

data = (float *) malloc (count * sizeof (float));
results = (float *) malloc (count * sizeof (float));

for (int i = 0; i < count; i++)
   data[i] = rand () / (float) RAND_MAX;

kernel = setupKernel( KernelSource, "square", 3, FloatArr, count, data,
                                          FloatArr, count, results,
                                          IntConst, count);
```

Executing the Kernel

```
cl_int    clEnqueueNDRangeKernel (cl_command_queue command_queue,
                                  cl_kernel kernel,
                                  cl_uint  work_dim,
                                  const size_t *global_work_offset,
                                  const size_t *global_work_size,
                                  const size_t *local_work_size,
                                  cl_uint num_events_in_wait_list,
                                  const cl_event *event_wait_list,
                                  cl_event *event)
```

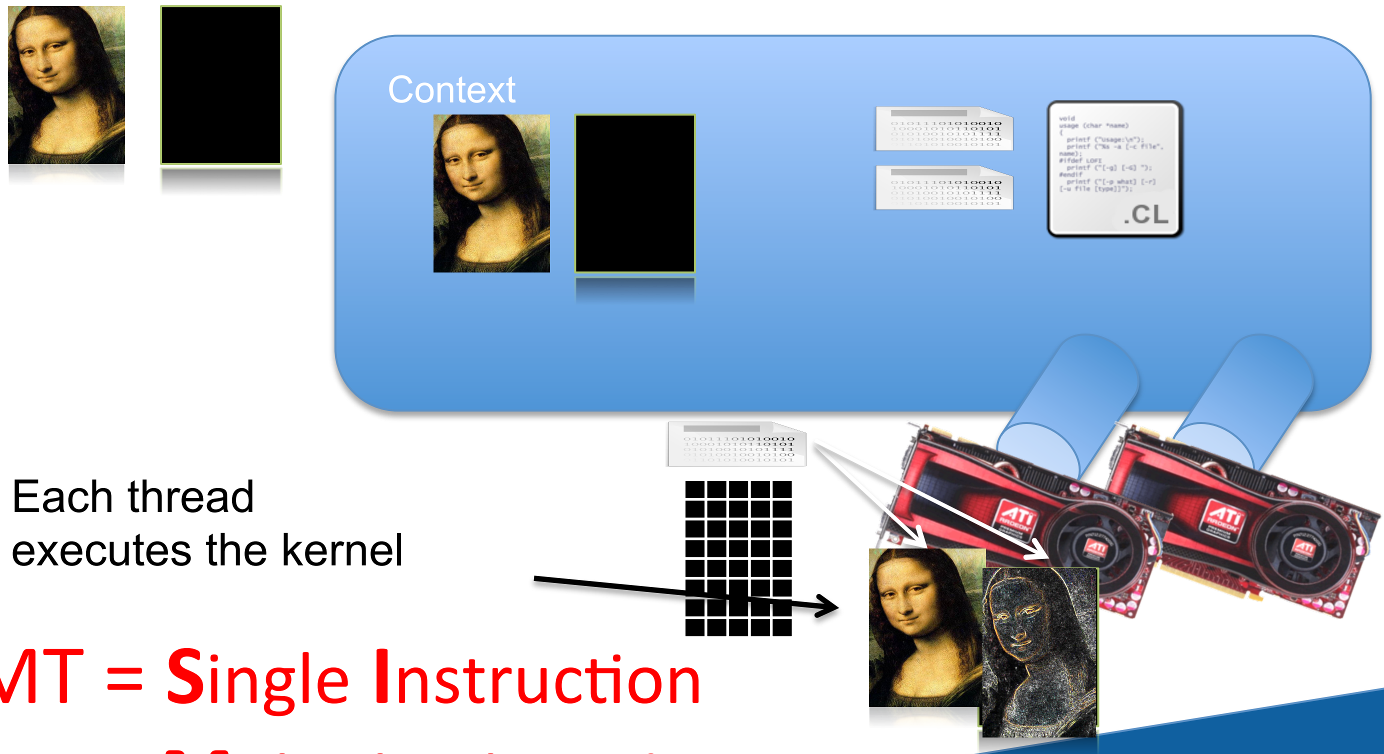




An index space of threads is created (dimensions match the data)

Executing the Kernel

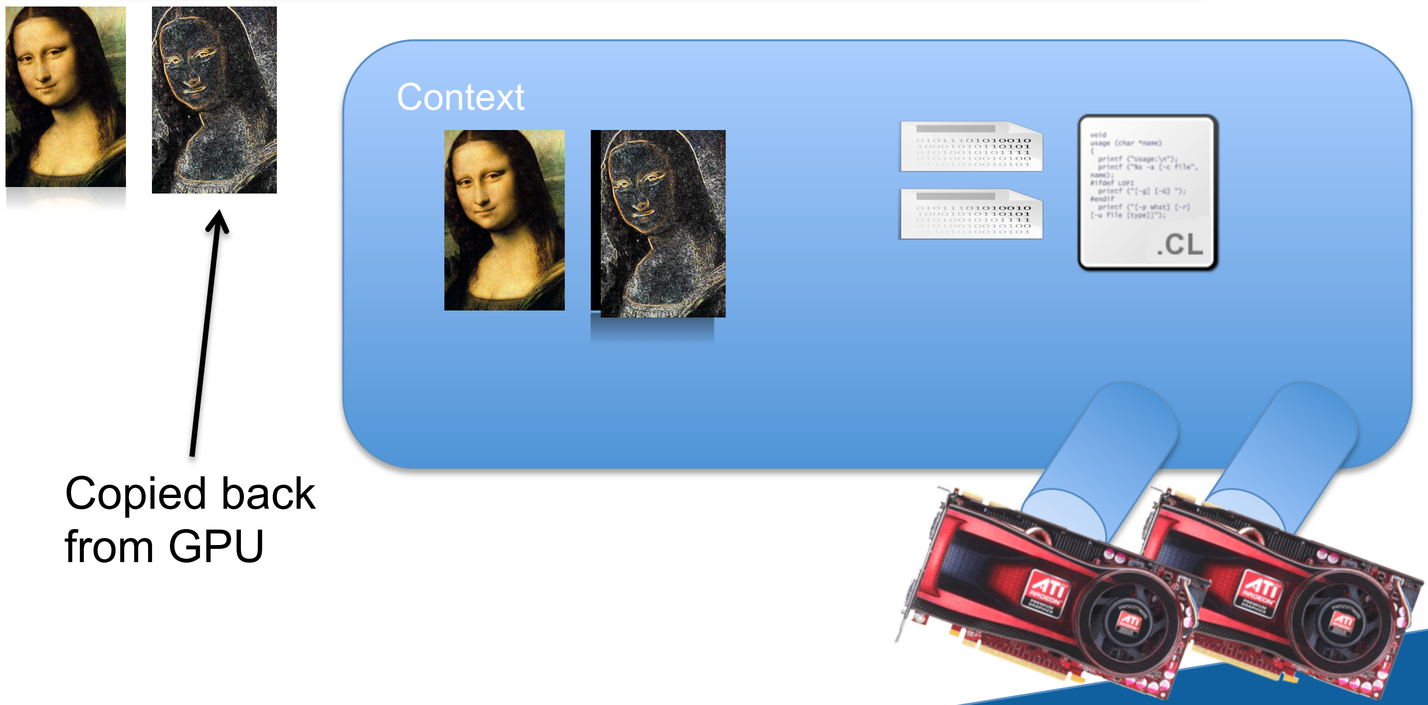
- A thread structure defined by the index-space that is created
  - Each thread executes the same kernel on different data



SIMT = **S**ingle **I**nstruction
Multiple **T**hreads

Copying Data Back

```
cl_int  clEnqueueReadBuffer (cl_command_queue command_queue,
                             cl_mem buffer,
                             cl_bool blocking_read,
                             size_t offset,
                             size_t cb,
                             void *ptr,
                             cl_uint num_events_in_wait_list,
                             const cl_event *event_wait_list,
                             cl_event *event)
```



Lucky you III ☺

```
/**************************************************************************
 *
 * runKernel : this routine executes the kernel given as first argument.
 *            The thread-space is defined through the next two arguments:
 *            <dim> identifies the dimensionality of the thread-space and
 *            <globals> is a vector of length <dim> that gives the upper
 *            bounds for all axes. The argument <local> specifies the size
 *            of the individual warps which need to have the same dimensionality
 *            as the overall range.
 *            If anything gows wrong in the course, error messages will be
 *            printed to stderr and the last error encountered will be returned.
 *
 *            Note that this function not only executes the kernel with the given
 *            range and warp-size, it also copies back *all* arguments from the
 *            kernel after the kernel's completion. If a more sophisticated
 *            behaviour is needed you may have to fall back to using openCL directly.
 *
 **************************************************************************/

extern cl_int runKernel( cl_kernel kernel, int dim, size_t *global, size_t *local);
```

```
size_t global[1] = {1024};
size_t local[1] = {32};
runKernel( kernel, 1, global, local);
```

Finally: Release the Resources

```
/*****************************************************************************
 *
 * freeDevice : this routine releases all acquired ressources.
 *           If anything gows wrong in the course, error messages will be
 *           printed to stderr and the last error encountered will be returned.
 *
 *****************************************************************************/

extern cl_int freeDevice();
```

OpenCL Timing

- OpenCL provides "events" which can be used for timing kernels
  - Events will be discussed in detail in Lecture 11
- We pass an event to the OpenCL enqueue kernel function to capture timestamps
- Code snippet provided can be used to time a kernel
  - Add profiling enable flag to create command queue
  - By taking differences of the start and end timestamps we discount overheads like time spent in the command queue

```
cl_event event_timer;
clEnqueueNDRangeKernel(
        myqueue , myKernel,
        2, 0, globalws, localws,
        0, NULL, &event_timer);
```

```
unsigned long starttime, endtime;
```

```
clGetEventProfilingInfo( event_time,
    CL_PROFILING_COMMAND_START,
    sizeof(cl_ulong), &starttime, NULL);
```

```
clGetEventProfilingInfo(event_time,
    CL_PROFILING_COMMAND_END,
    sizeof(cl_ulong), &endtime, NULL);
```

```
unsigned long elapsed =
(unsigned long)(endtime - starttime);
```