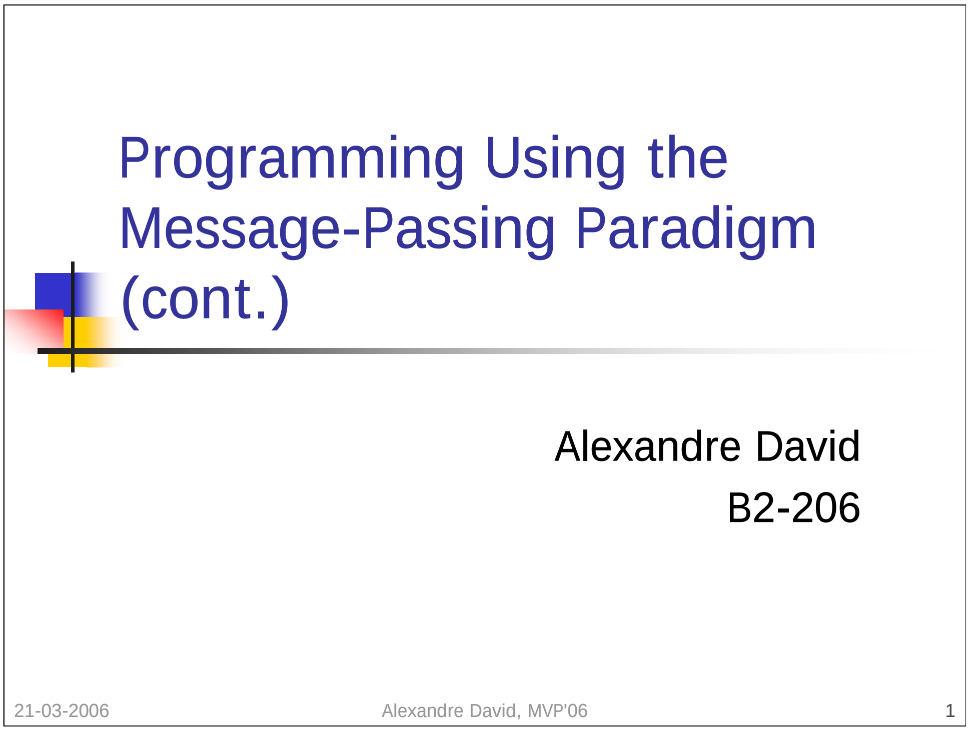
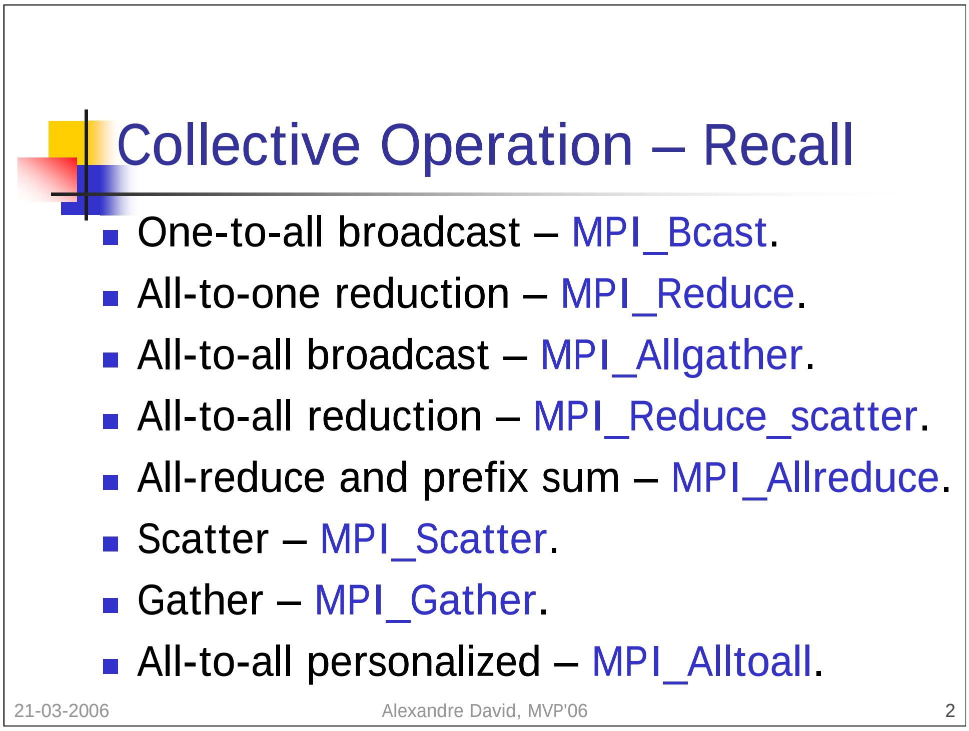


Programming Using the Message-Passing Paradigm (cont.)

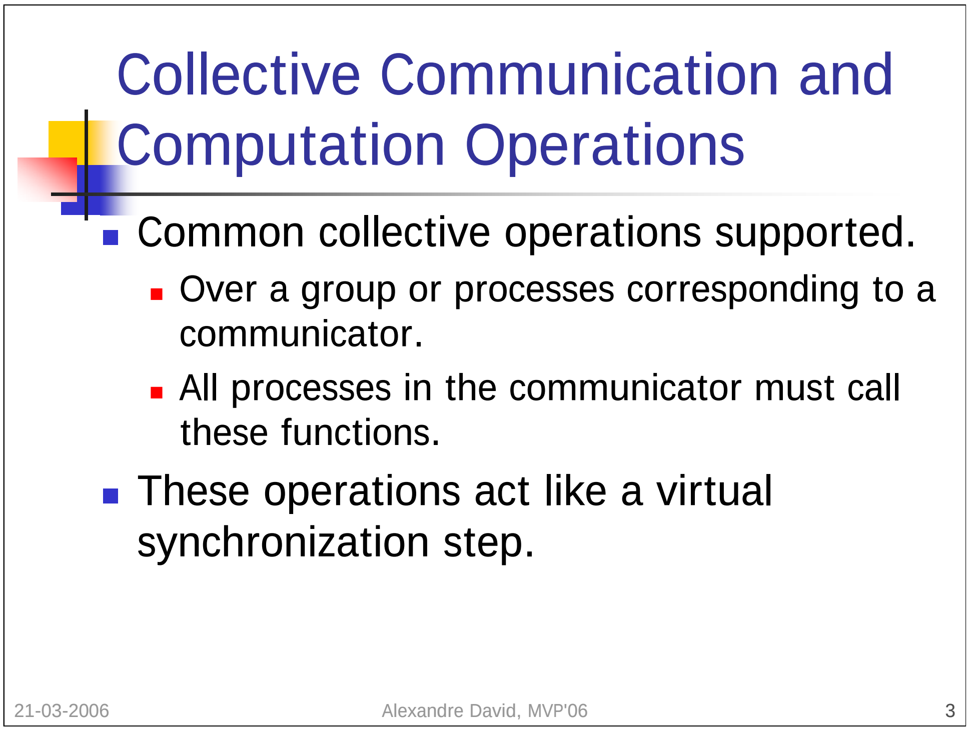
Alexandre David
B2-206



Collective Operation – Recall

- One-to-all broadcast – MPI_Bcast.
- All-to-one reduction – MPI_Reduce.
- All-to-all broadcast – MPI_Allgather.
- All-to-all reduction – MPI_Reduce_scatter.
- All-reduce and prefix sum – MPI_Allreduce.
- Scatter – MPI_Scatter.
- Gather – MPI_Gather.
- All-to-all personalized – MPI_Alltoall.

You should know what these operations do.



Collective Communication and Computation Operations

- Common collective operations supported.
  - Over a group or processes corresponding to a communicator.
  - All processes in the communicator must call these functions.
- These operations act like a virtual synchronization step.

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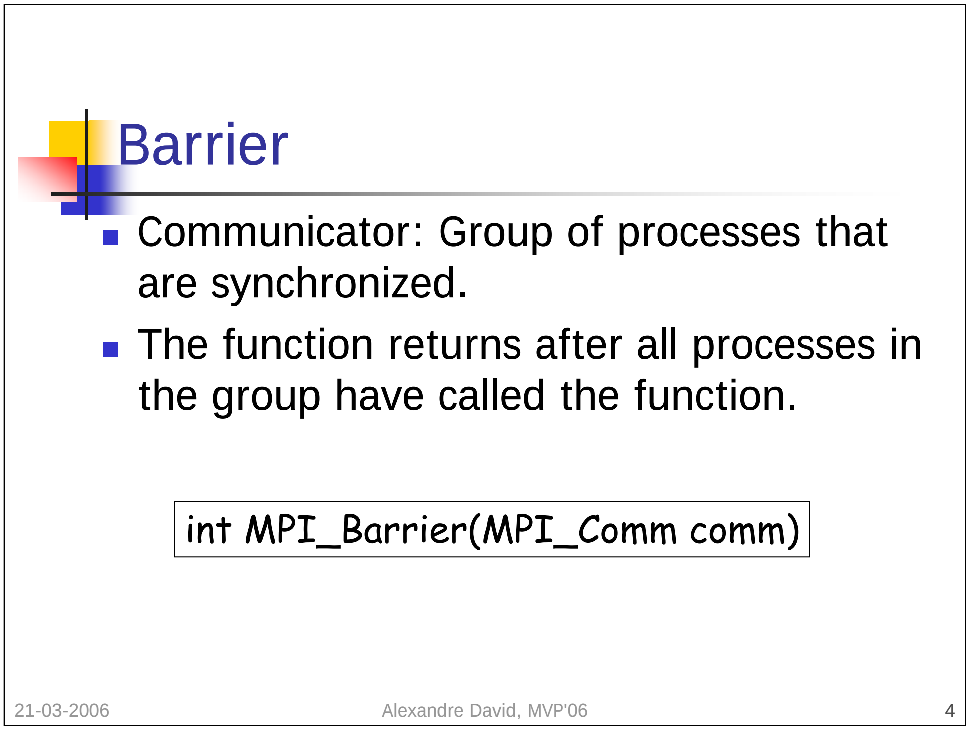
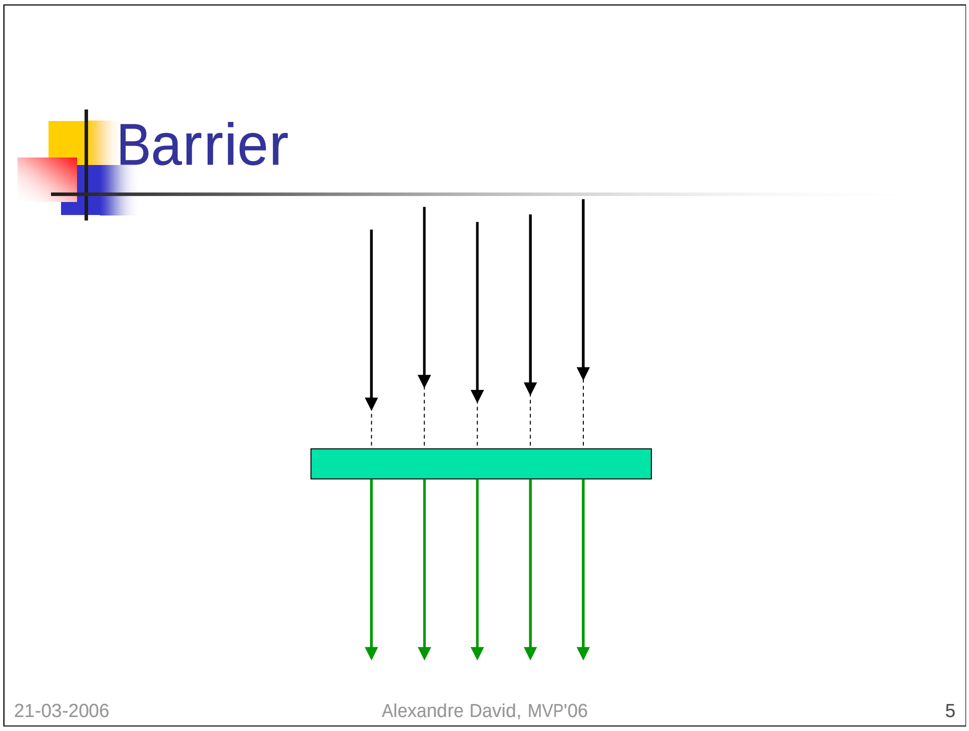
Parallel programs should be written such that they behave correctly even if a global synchronization is performed before and after the collective call.



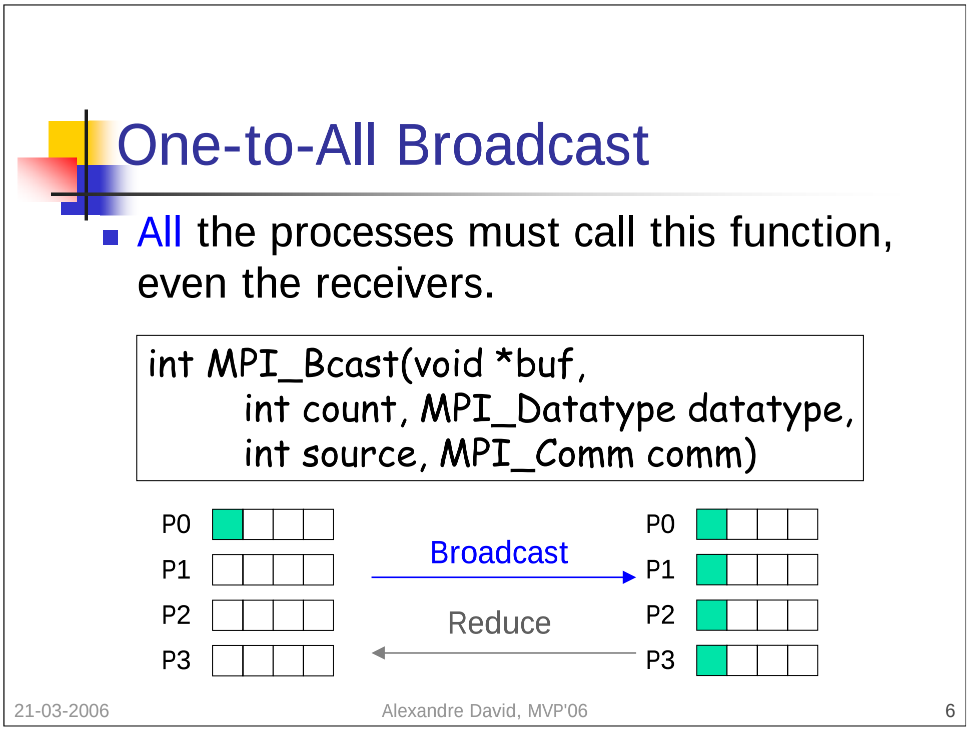
Barrier

- Communicator: Group of processes that are synchronized.
- The function returns after all processes in the group have called the function.

```
int MPI_Barrier(MPI_Comm comm)
```



Barrier

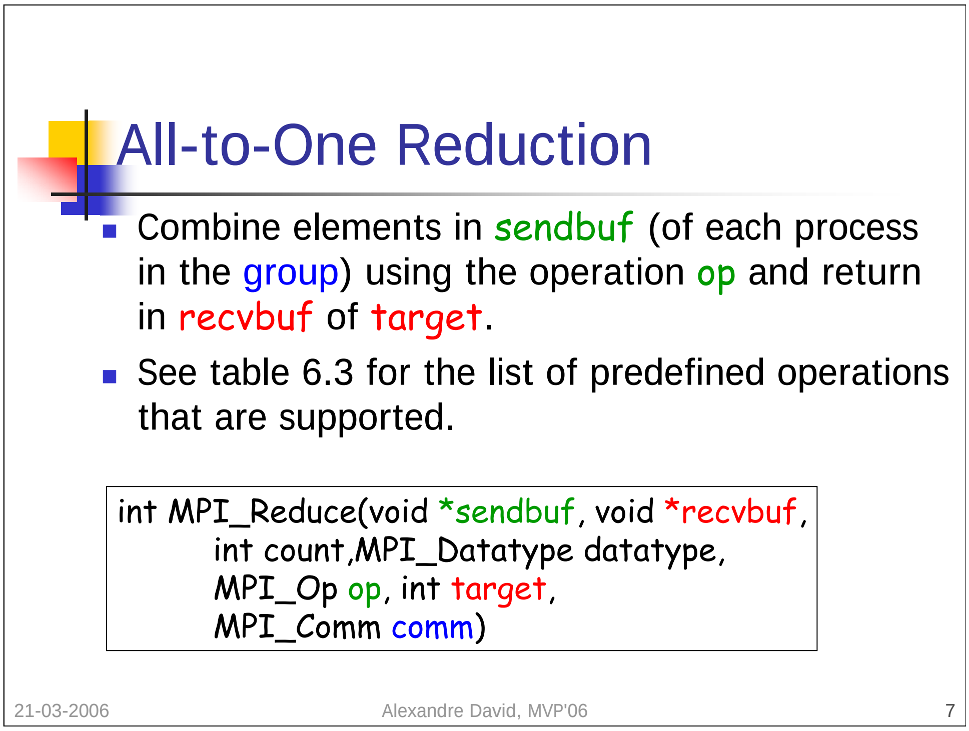


One-to-All Broadcast

- All the processes must call this function, even the receivers.

```
int MPI_Bcast(void *buf,
          int count, MPI_Datatype datatype,
          int source, MPI_Comm comm)
```

P0
P1
P2
P3
Broadcast
Reduce
P0
P1
P2
P3

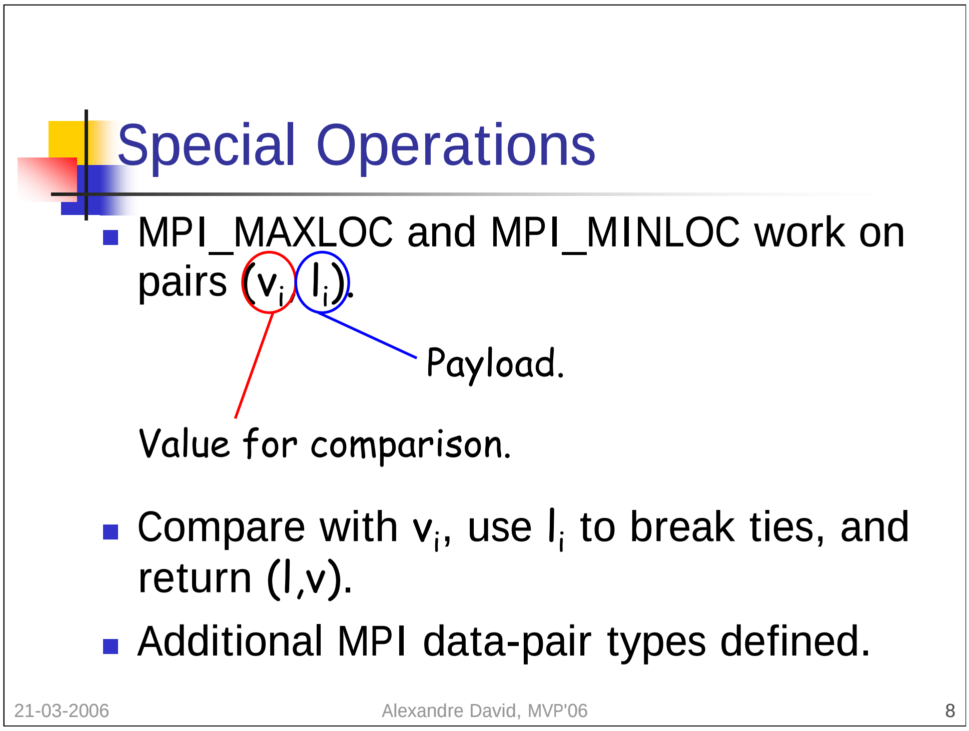


All-to-One Reduction

- Combine elements in sendbuf (of each process in the group) using the operation op and return in recvbuf of target.
- See table 6.3 for the list of predefined operations that are supported.

```
int MPI_Reduce(void *sendbuf, void *recvbuf,
        int count,MPI_Datatype datatype,
        MPI_Op op, int target,
        MPI_Comm comm)
```

Constraint on the count of items of type datatype. All the processes call this function even those that are not the target and they all provide a recvbuf. When count > 1, the operation is applied element-wise. **Why do they all need a recvbuf?**



Special Operations

- MPI_MAXLOC and MPI_MINLOC work on pairs (v_i, l_i).

Payload.

Value for comparison.

- Compare with v_i, use l_i to break ties, and return (l,v).
- Additional MPI data-pair types defined.

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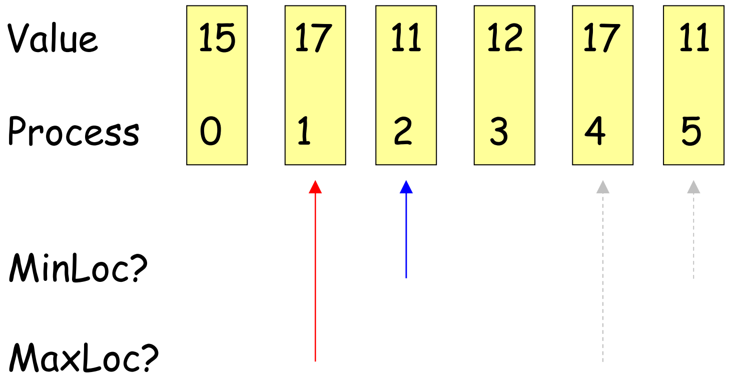
See table 6.4 for the different pair data types.

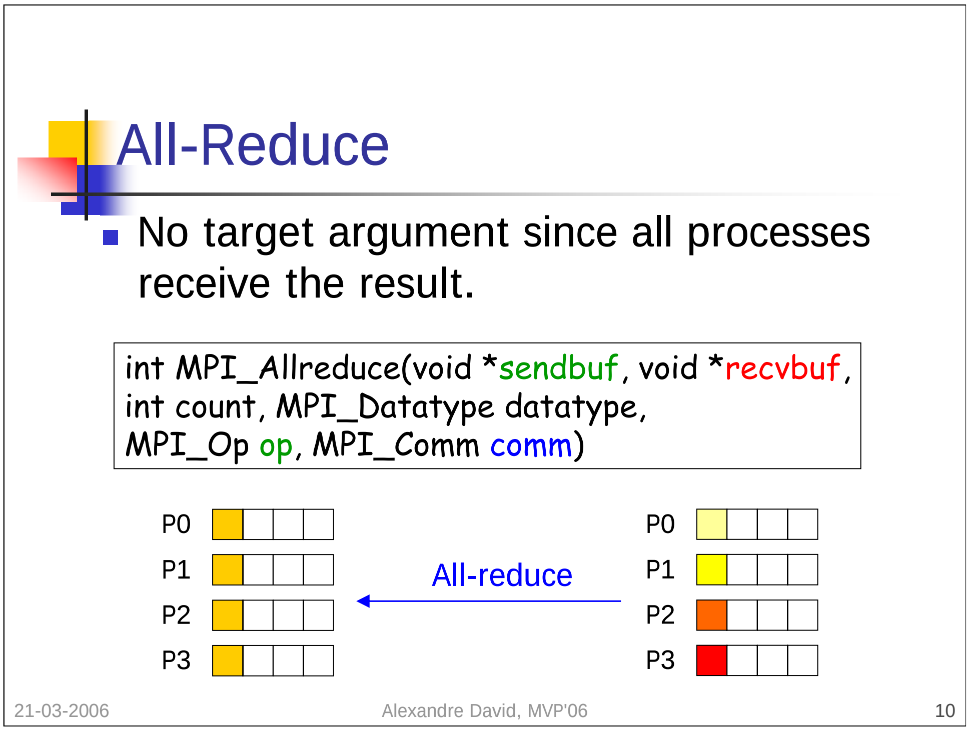
Example



Value	15	17	11	12	17	11
Process	0	1	2	3	4	5

MinLoc?

MaxLoc?



All-Reduce

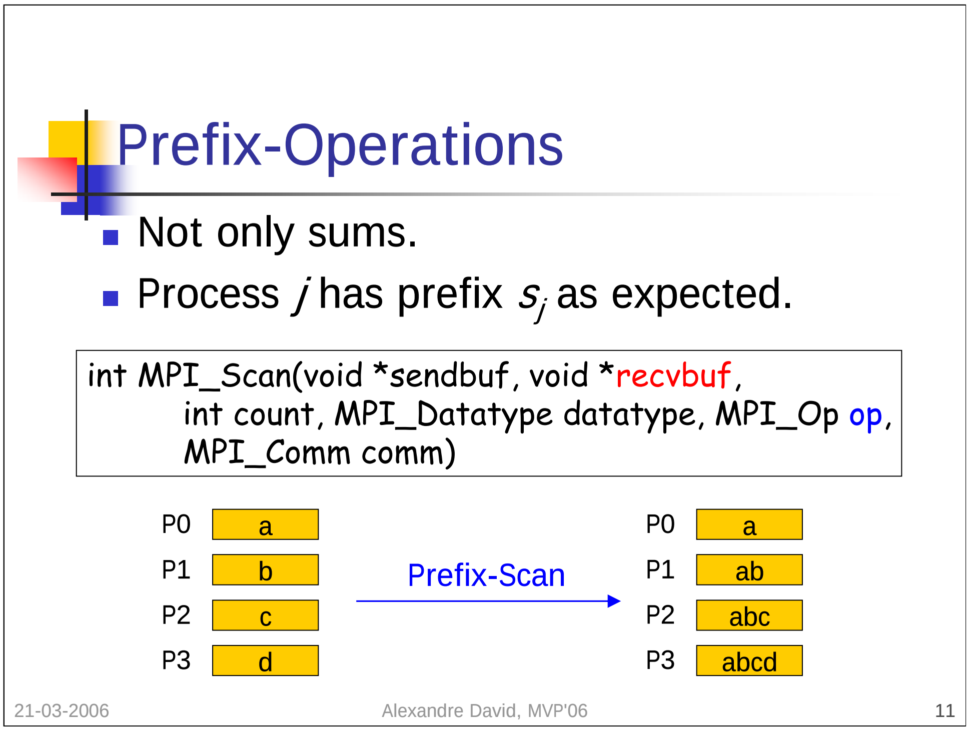
- No target argument since all processes receive the result.

```
int MPI_Allreduce(void *sendbuf, void *recvbuf,
int count, MPI_Datatype datatype,
MPI_Op op, MPI_Comm comm)
```

P0 🟨□□□
P1 🟨□□□
P2 🟨□□□
P3 🟨□□□

All-reduce

P0 🟨□□□
P1 🟨□□□
P2 🟧□□□
P3 🟥□□□



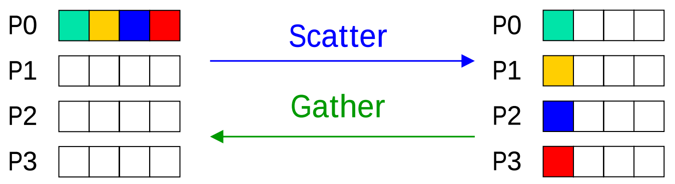
Prefix-Operations

- Not only sums.
- Process *j* has prefix s_j as expected.

```
int MPI_Scan(void *sendbuf, void *recvbuf,
        int count, MPI_Datatype datatype, MPI_Op op,
        MPI_Comm comm)
```

		Prefix-Scan		
P0	a		P0	a
P1	b	→	P1	ab
P2	c		P2	abc
P3	d		P3	abcd

Scatter and Gather



P0
P1
P2
P3

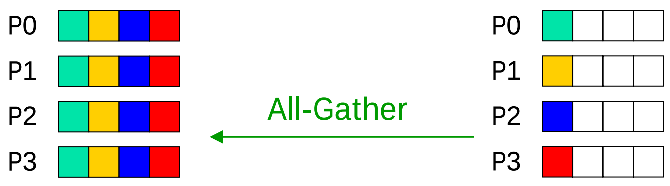
Scatter

Gather

P0
P1
P2
P3

All-Gather

- Variant of gather.



P0 🟩🟨🟦🟥

P1 🟩🟨🟦🟥

P2 🟩🟨🟦🟥

P3 🟩🟨🟦🟥

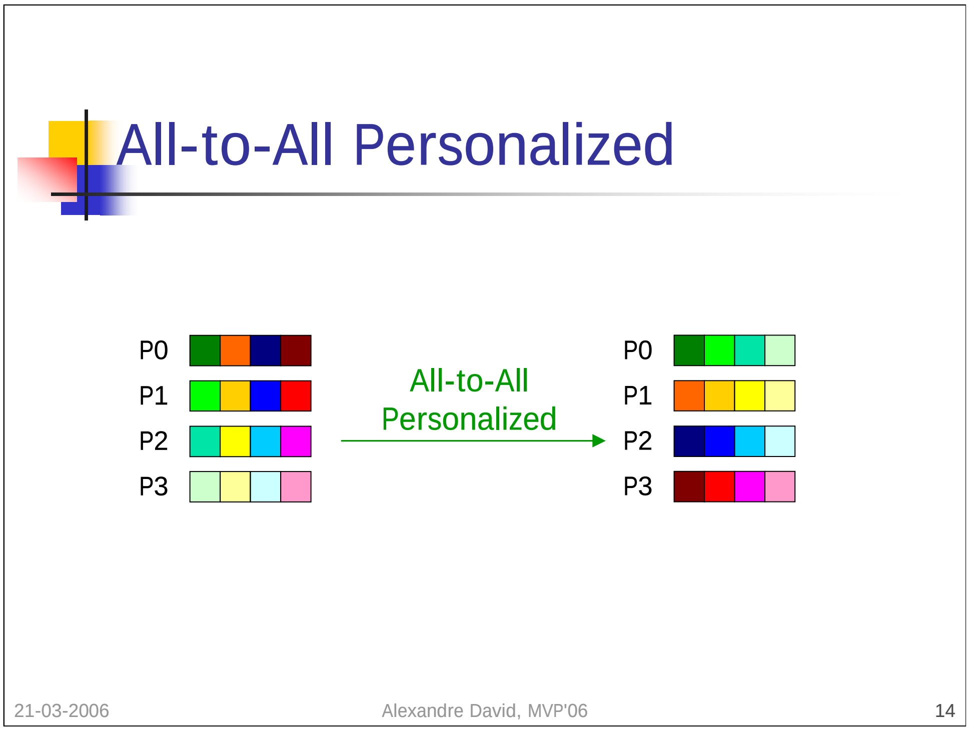
All-Gather

P0 🟩□□□

P1 🟨□□□

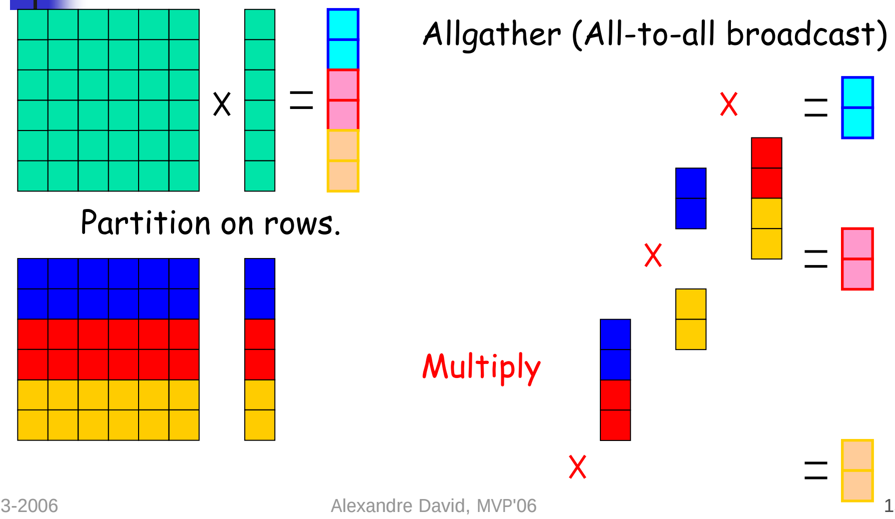
P2 🟦□□□

P3 🟥□□□

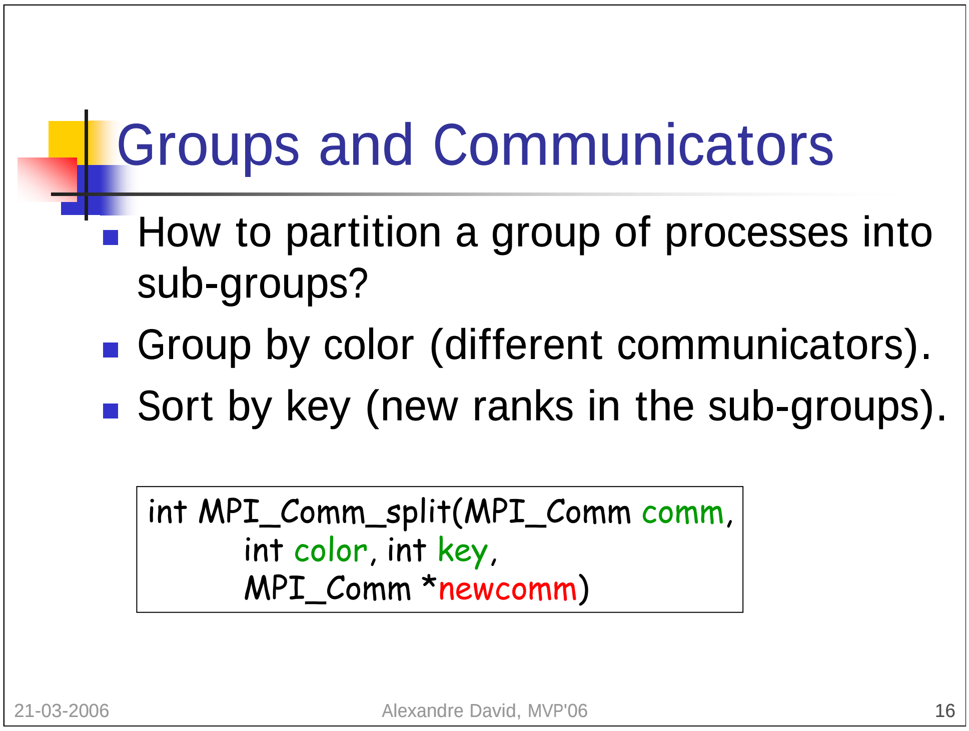


All-to-All Personalized

Example Matrix*Vector (Program 6.4)



Partition on rows.

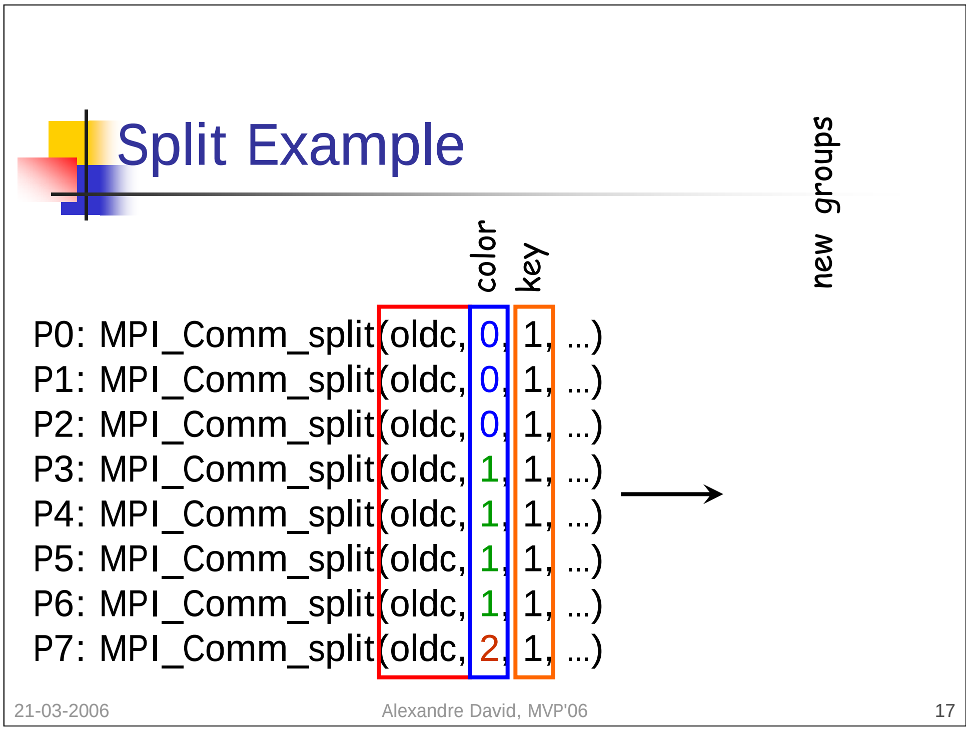


Groups and Communicators

- How to partition a group of processes into sub-groups?
- Group by color (different communicators).
- Sort by key (new ranks in the sub-groups).

```
int MPI_Comm_split(MPI_Comm comm,
         int color, int key,
         MPI_Comm *newcomm)
```

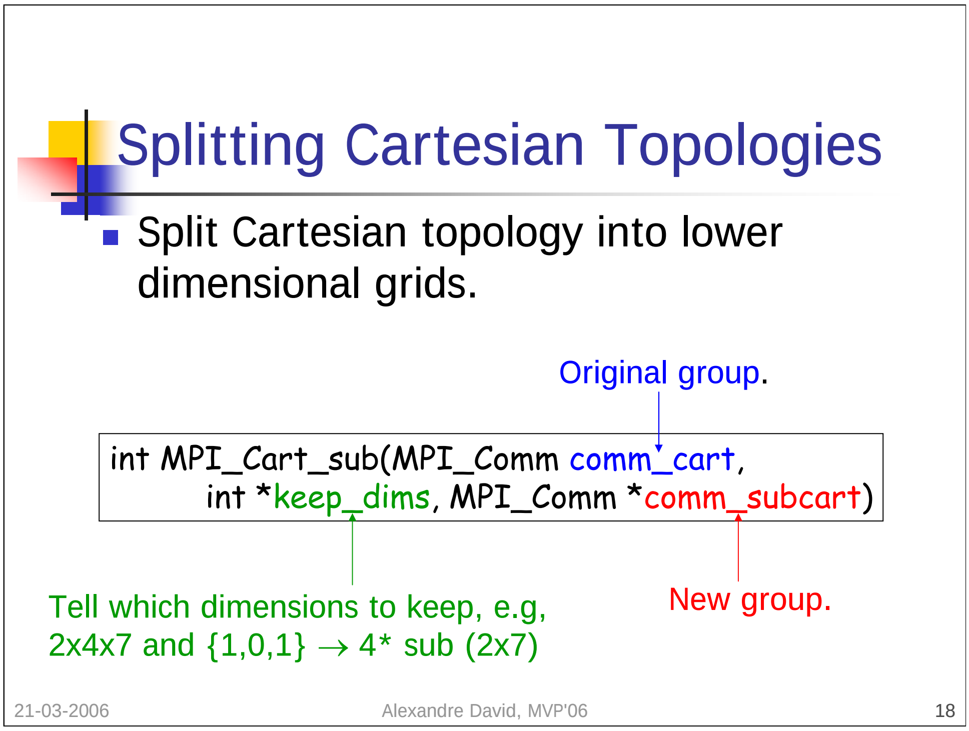
Sometimes, parallel algorithms need a restricted communication to certain subsets of processes.



Split Example

color
key
new groups

```
P0: MPI_Comm_split(oldc, 0, 1, ...)
P1: MPI_Comm_split(oldc, 0, 1, ...)
P2: MPI_Comm_split(oldc, 0, 1, ...)
P3: MPI_Comm_split(oldc, 1, 1, ...)
P4: MPI_Comm_split(oldc, 1, 1, ...)
P5: MPI_Comm_split(oldc, 1, 1, ...)
P6: MPI_Comm_split(oldc, 1, 1, ...)
P7: MPI_Comm_split(oldc, 2, 1, ...)
```



Splitting Cartesian Topologies

- Split Cartesian topology into lower dimensional grids.

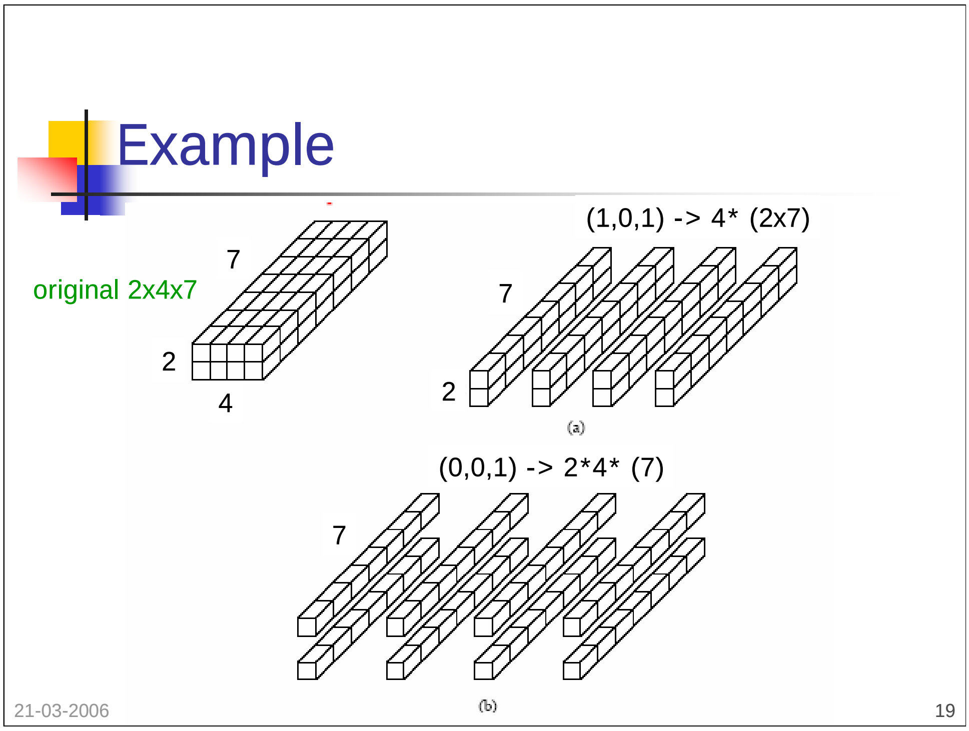
Original group.

```
int MPI_Cart_sub(MPI_Comm comm_cart,
        int *keep_dims, MPI_Comm *comm_subcart)
```

Tell which dimensions to keep, e.g,
2x4x7 and {1,0,1} → 4* sub (2x7)

New group.

The keep_dims (boolean) array tells which dimensions to keep for the new sub-group partitioning. The coordinate will match, e.g., (1,2,3) in the original will give (1,3) and will be in the 2nd sub-group.

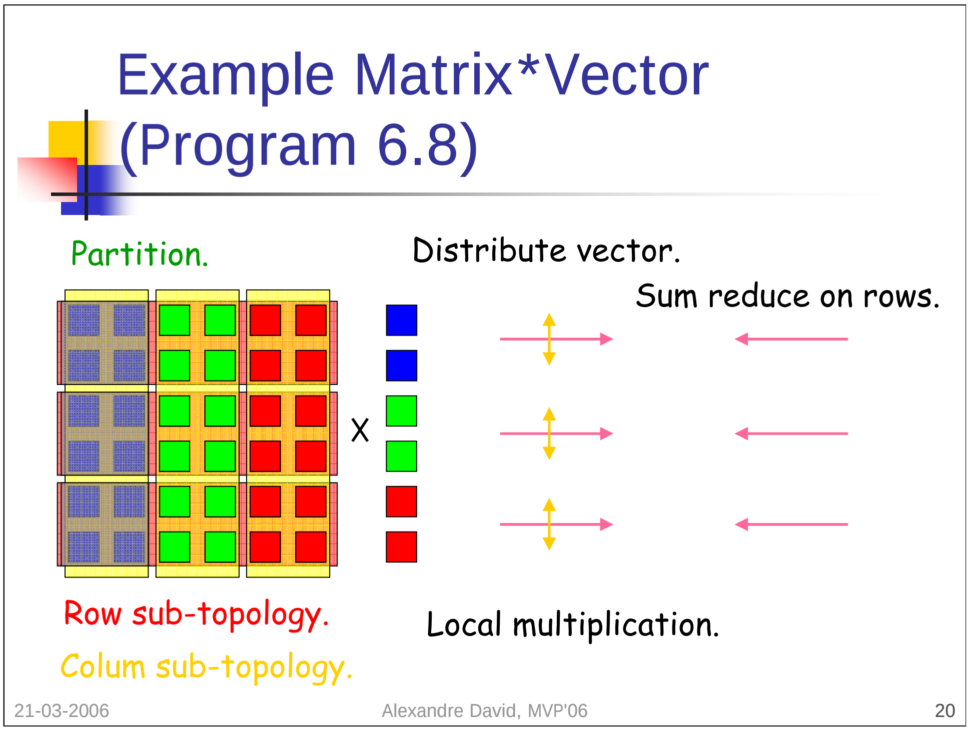


Example

original 2x4x7

(1,0,1) -> 4* (2x7)

(0,0,1) -> 2*4* (7)



Example Matrix*Vector (Program 6.8)

Partition.

Distribute vector.

Sum reduce on rows.

X

Row sub-topology.

Colum sub-topology.

Local multiplication.

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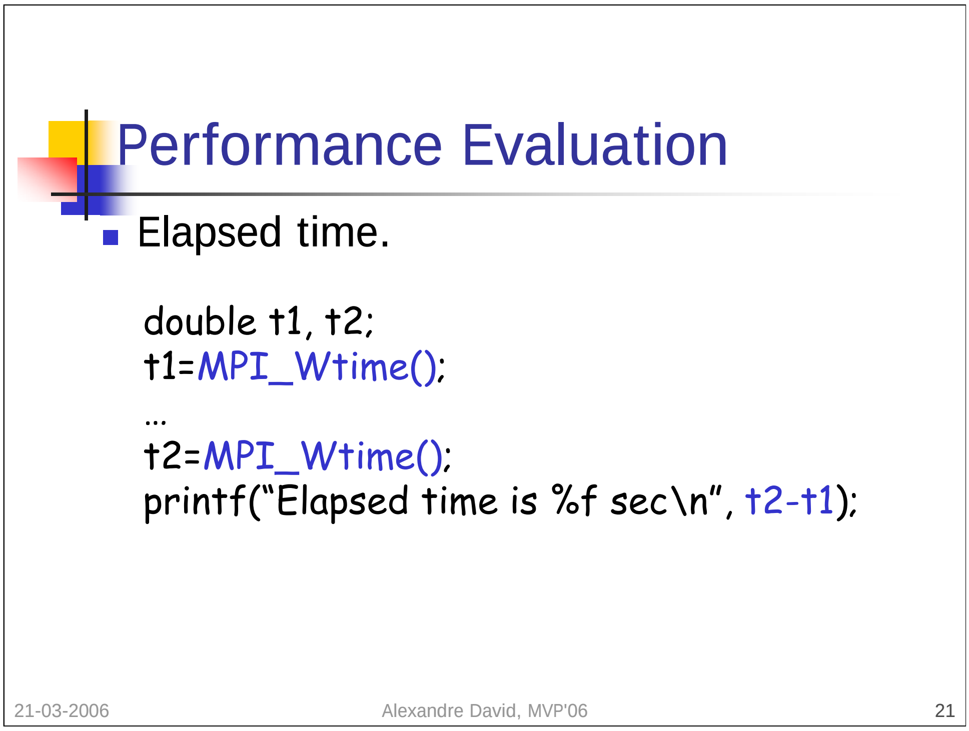

Performance Evaluation

- Elapsed time.

```
double t1, t2;
t1=MPI_Wtime();
…
t2=MPI_Wtime();
printf("Elapsed time is %f sec\n", t2-t1);
```