HPC methods for high resolution Radon transform and deblending

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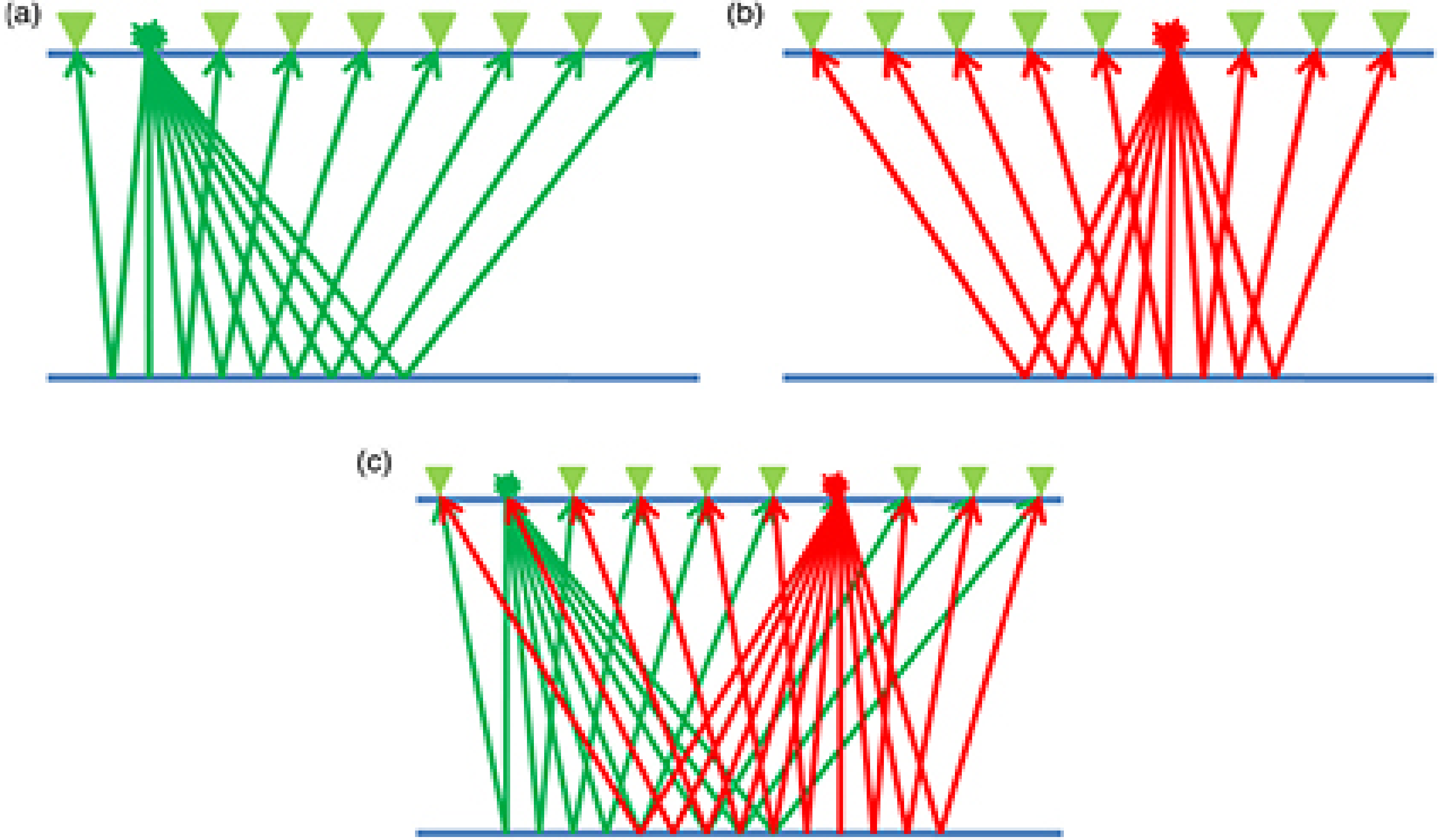
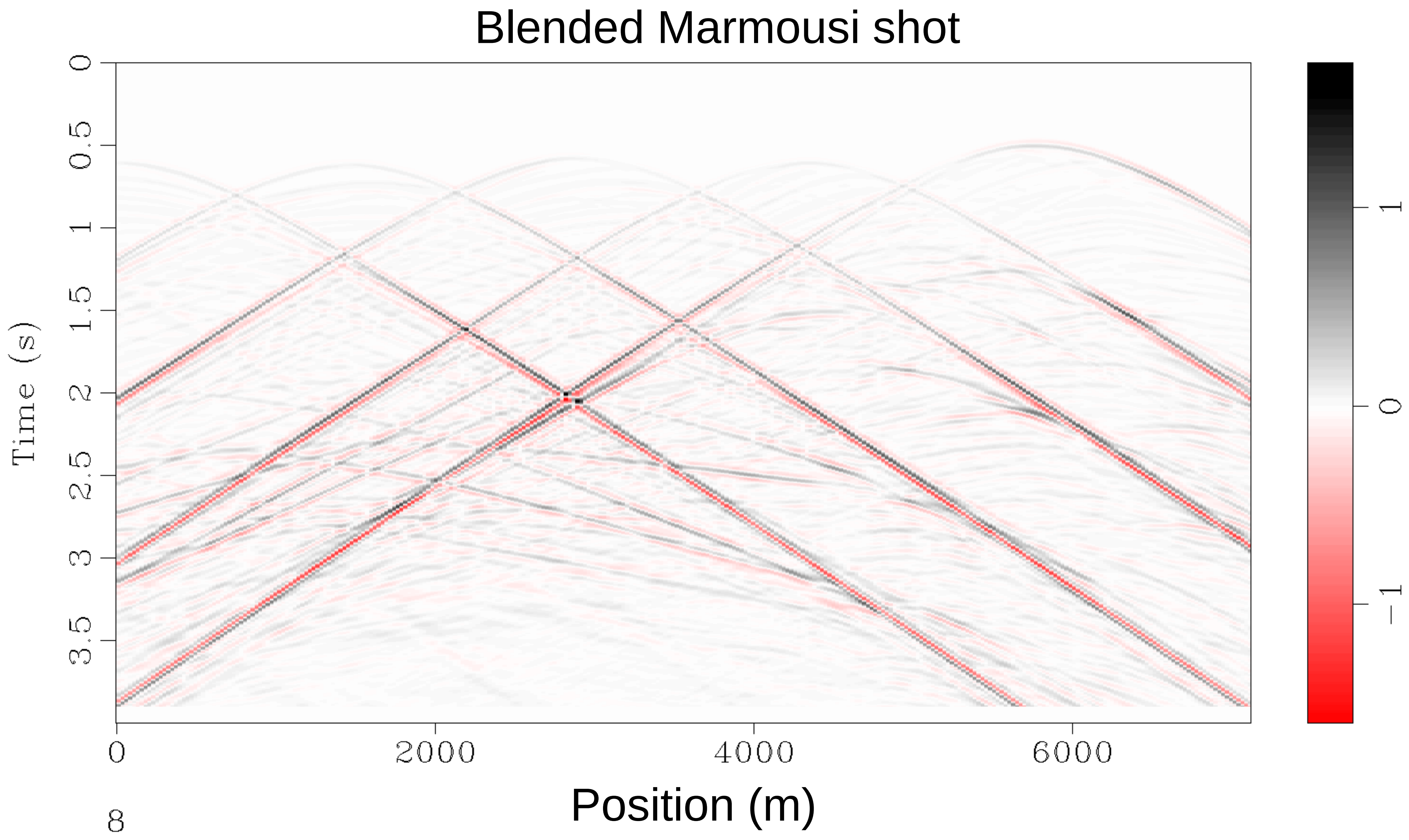
CREWES Annual Meeting

Dec 3 2020

Blending

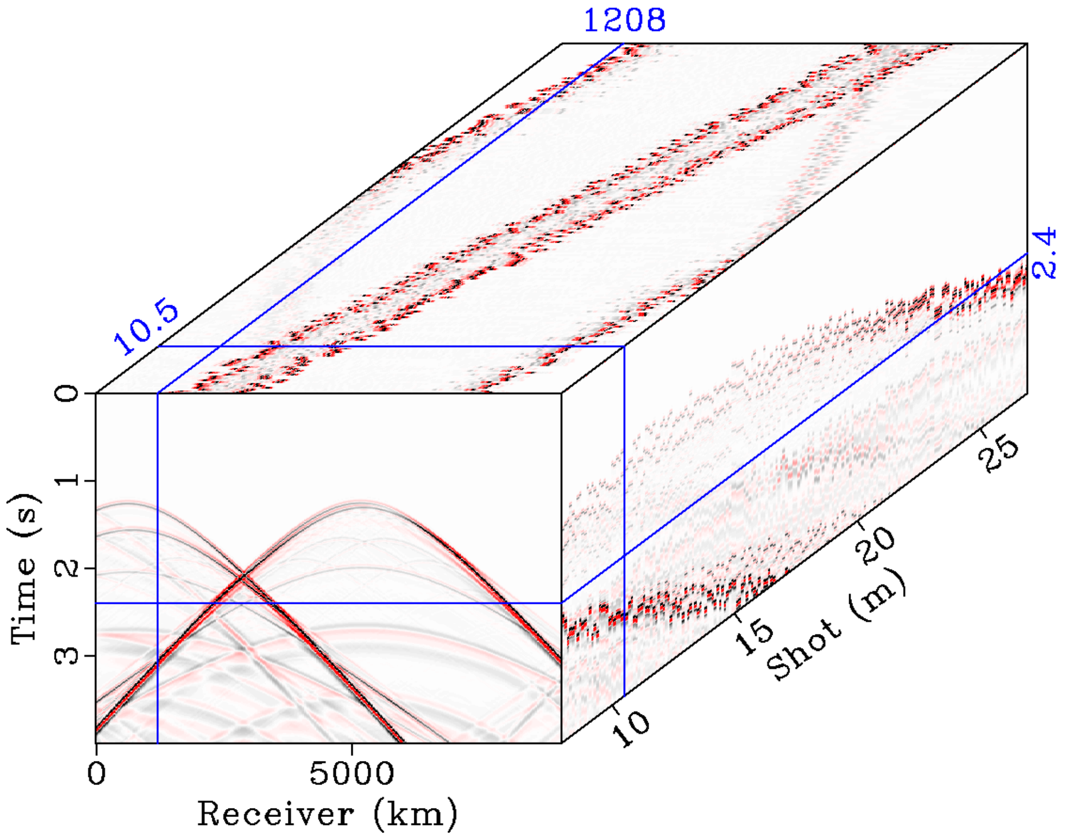


Blended acquisition

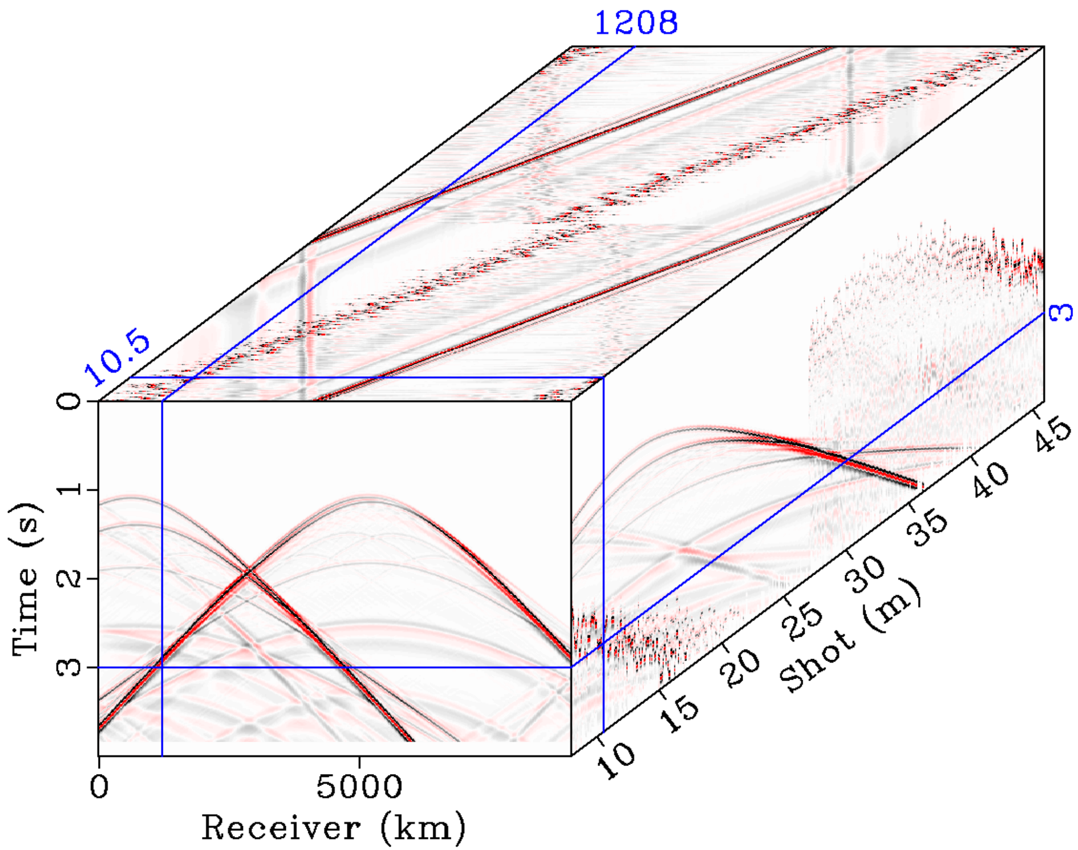


Blending and the importance of time dithering

Blended Data



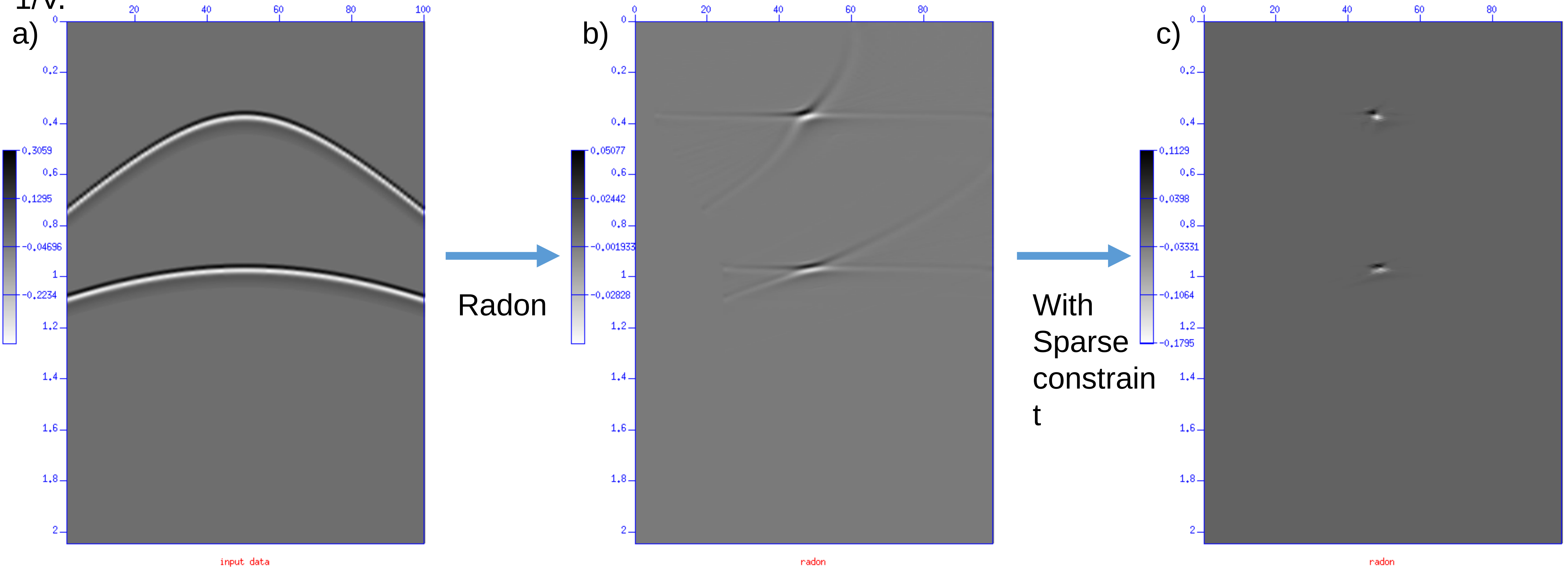
Pseudo Deblended Data



Sparse Hyperbolic Radon Transform

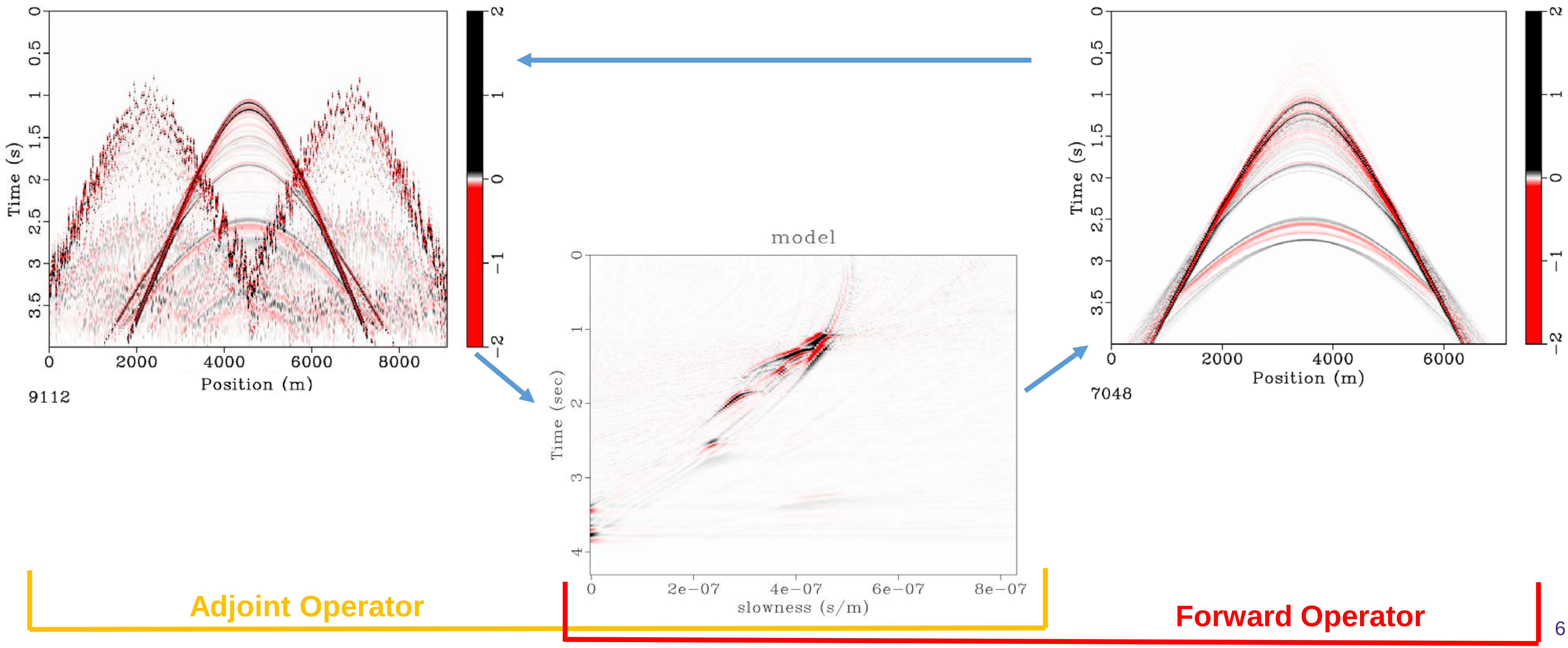
$$u(p,\tau) = \int_{h_1}^{h_2} d(h, t = \sqrt{\tau^2 + p^2 h^2})dh$$

where u(p,t) is the radon space data, p is the slowness, t is the two way travel time, h1 is the upper offset limit, h2 the lower offset limit, and d is the data space to be transformed. The slowness p is then defined as the inverse of velocity 1/V.



Denoising – sparse radon transform

$$\left|\left|S_{pdb} - Rm\right|\right|_2^2 + \mu\left|\left|m\right|\right|_1^1$$



Radon Denoising

$$S_{pdb} = S_{bl}\Gamma^H$$

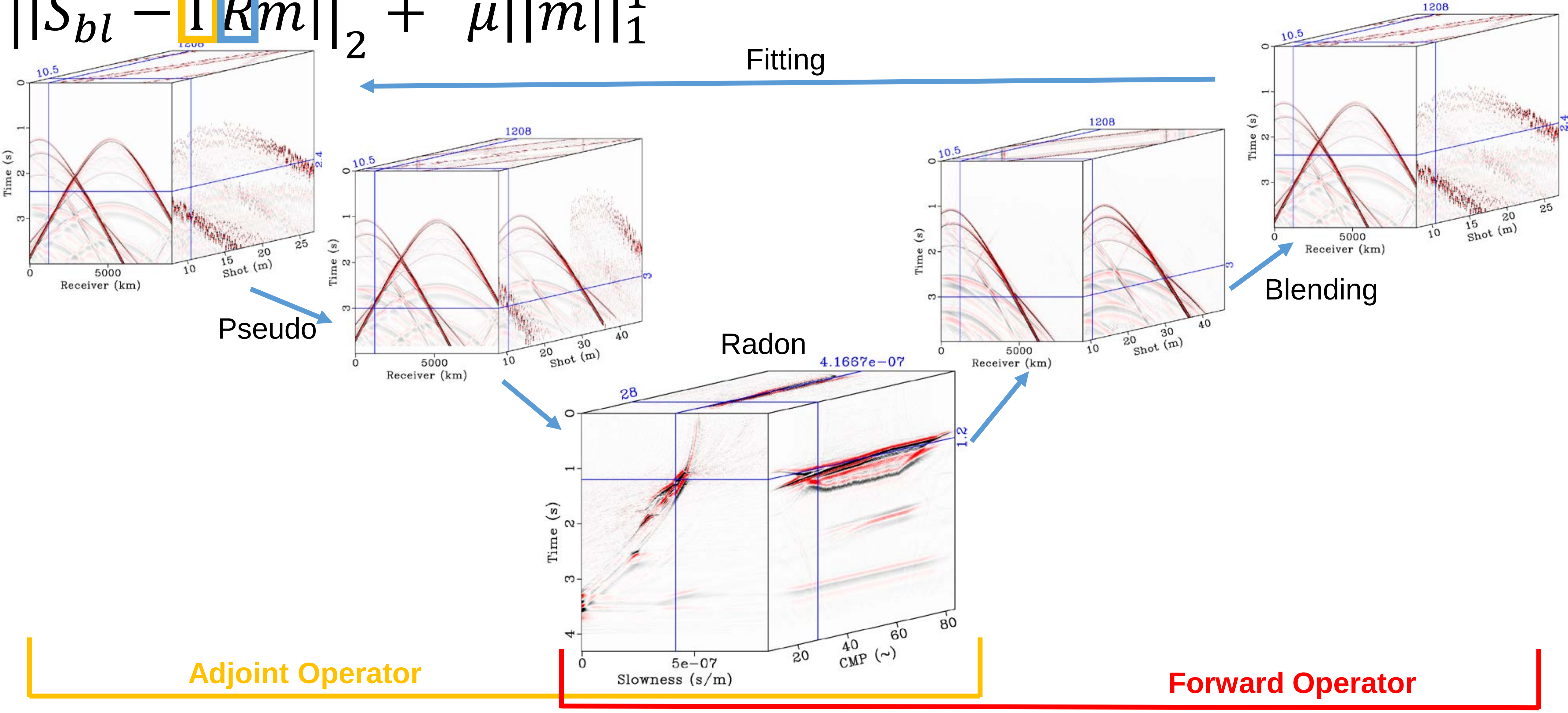
$$||S_{pdb} - Rm||_2^2 + \mu||m||_1^1$$

Radon Inversion

$$||S_{bl} - \Gamma Rm||_2^2 + \mu||m||_1^1$$

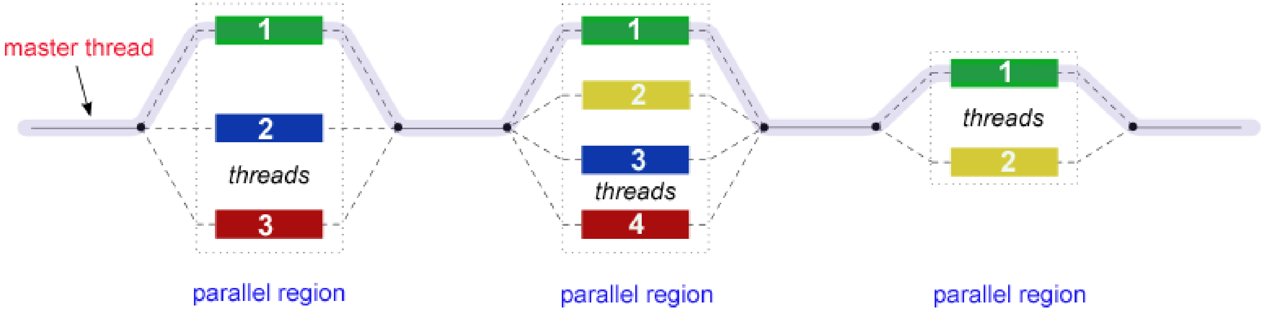
Sparse Inversion

$$||S_{bl} - \Gamma R m||_2^2 + \mu ||m||_1^1$$



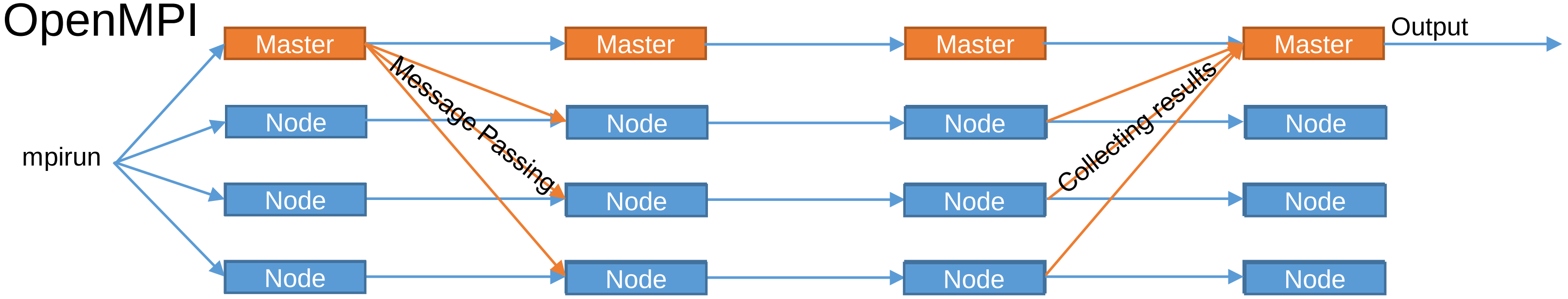
Parallel programming methods

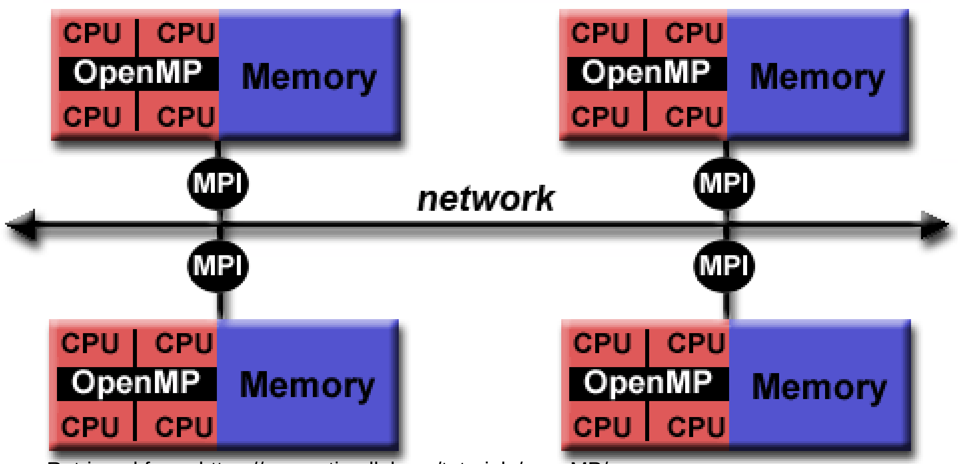
OpenMP



Retrieved from: https://computing.llnl.gov/tutorials/openMP/

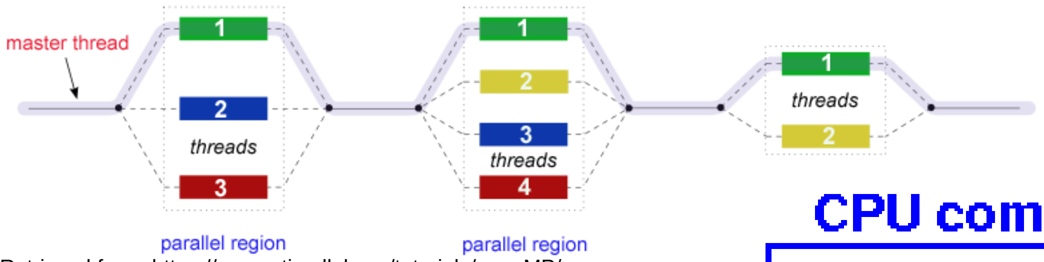
OpenMPI





Retrieved from: https://computing.llnl.gov/tutorials/openMP/

CUDA



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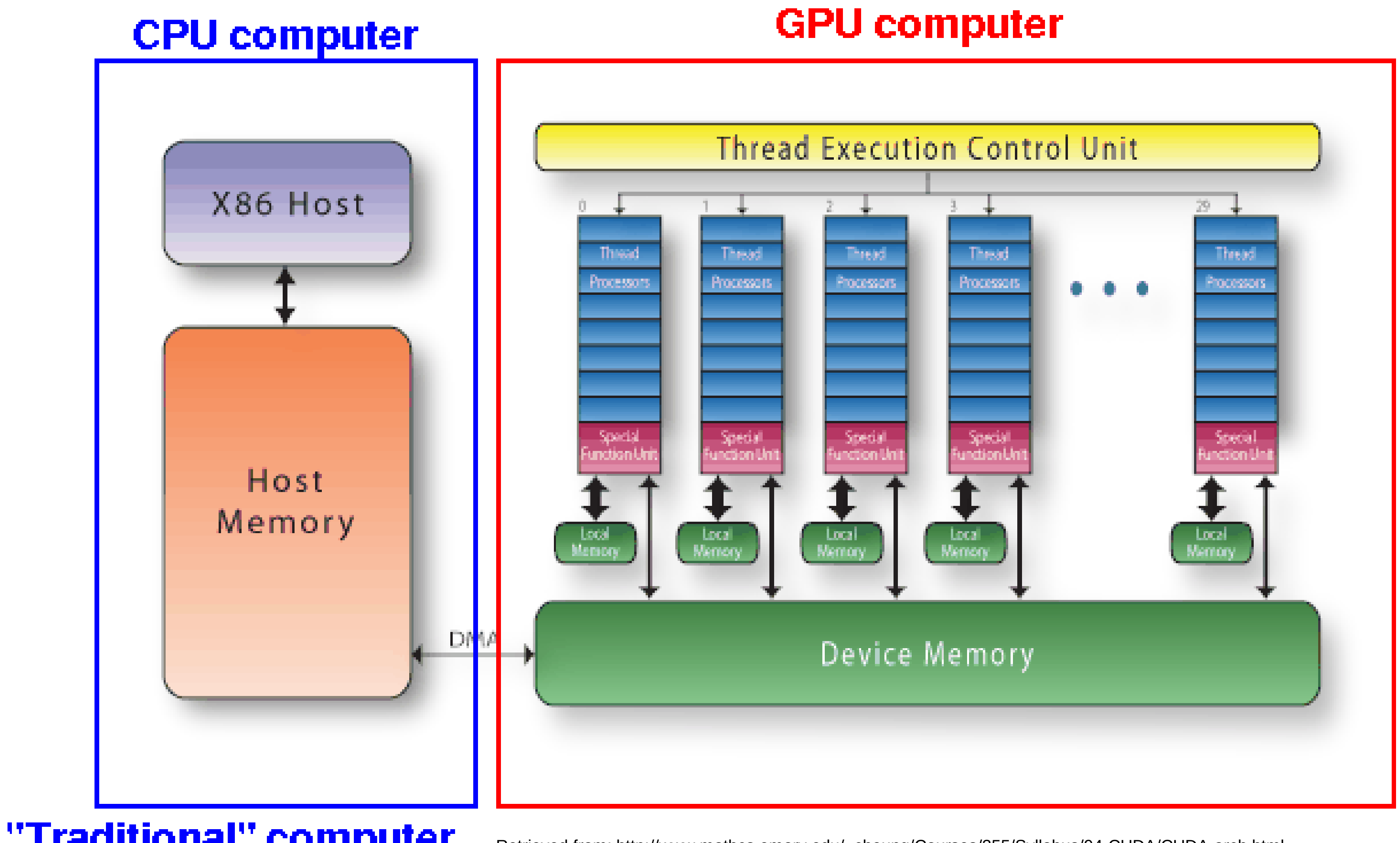


Retrieved from: http://www.mathcs.emory.edu/~cheung/Courses/355/Syllabus/94-CUDA/CUDA-arch.html

API specifics

Key things to note:

OpenMP

- Simplest to implement limited speedup due to overhead in single threaded portions
- Works on practically any multi-thread CPU

OpenMPI

- Most complex to implement requiring extensive modification to pre-existing code
- Designed originally for multi-server applications
- Can be used on a single system rather than a cluster for significant performance boost in many scenarios
- Main limitation is excessive data transfers slows execution significantly

CUDA

- Very easy to implement but requires a Nvidia GPU
- User must be aware of architecture nuances and limitations
- Most effective when memory access is sequential

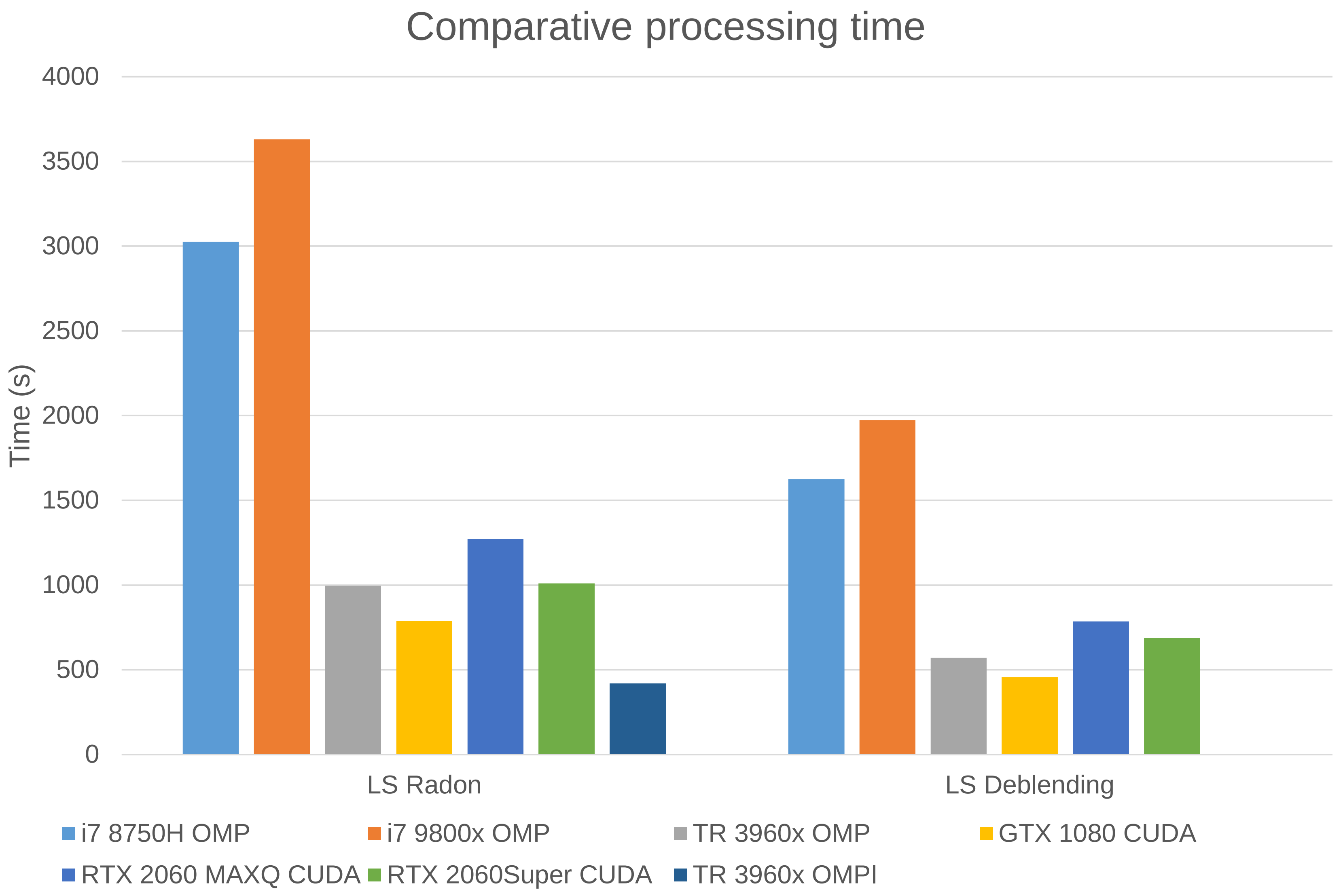
Algorithm 1 Radon pseudo code

function RADON
    #PRAGMA OMP PARALLEL FOR ▷ insert for parallelization of loop
    for q = slowness **do**
        for h = offset **do**
            $moveout = h^2 * q$
            for it = 0 to nt **do**
                $time = \sqrt{(it * dt)^2 + moveout}$
                $model[iqNt + it] += data[ihNt + INT(time/dt)]$
            end for
        end for
    end for
end function

Algorithm 2 CUDA Radon pseudo code

__global__
function CUDA_ RADON
    int it = blockIdx.x * blockDim.x + threadIdx.x
    int iq = blockIdx.y * blockDim.y + threadIdx.y
    int ih = blockIdx.z * blockDim.z + threadIdx.z
    if (iq >= nq || ih >= nh || it >= nt) return
    int ihNt = ih*nt
    int iqNt = iq*nt
    double timemax = dt*nt
    double $moveout = h^2 * q$
    double $time = \sqrt{(it * dt)^2 + moveout}$
    $atomicAdd(\&model[iqNt + it], data[ihNt + INT(time/dt)])$
end function

Performance results



Conclusion

- All APIs have good points and draw backs
- CUDA is easy to implement with significant computational advantages for scientific processing
- GPUs are easier to upgrade and price to performance is better than CPU
- Multi GPU is much easier than multi CPU
- openMP is still easiest to implement and is recommended for small workloads
- openMPI is useable for single system parallelization but uses significant amounts of RAM due to allocation per node

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