What Is XSTAR?

A computer program for calculating the physical conditions and emission spectra of photoionized gases.

Written by Tim Kallman

http://heasarc.gsfc.nasa.gov/docs/software/xstar/xstar.html

Available as executable tool (e.g. in HEADAS)

or

In warmabs and photemis XSPEC local models
Why are we tinkering with XSTAR?

To extend Ji collisional non-equilibrium ionization code to photoionized plasmas, by taking advantage of the atomic data and physics from the equilibrium photoionization model of Xstar.

The expanded model will allow us to probe various physical processes in a wider range of astrophysical objects, such as colliding winds in X-ray binaries, outflows in AGNs and shock flows in the IGM.

Ji et al, Chandra Theory Proposal
Awarded Funding for A09
Compute Intensive

- Partly involves numerous XSTAR simulations
- Over wide range of physical parameters
- To generate table model for spectroscopic analysis
- Can be very time consuming

Example: 600 XSTAR jobs > 26 hours
Classical Approach - Serial Execution

**xstar2xspecc**

- **xstinitable**
- **xstar N times**
- **xstar2table**

Perl script

**Generate list of N jobs**

\[ \text{Job}_i = \text{XSTAR with } i\text{-th set of params} \]

**Collate spectra into table model (FITS file)**

- \( \text{CPU 1} \)

- **XSTAR}_2

- **XSTAR}_1
Each Job Independent  ➔  Easy Parallelism

\[ XSTAR_{N-k+1} \quad \ldots \quad XSTAR_{2k} \]

\[ XSTAR_{k+1} \quad \ldots \quad XSTAR_{k} \]

\[ XSTAR_1 \quad \ldots \quad XSTAR_{N-k+1} \]

\[ CPU_1 \quad \ldots \quad CPU_k \]

\[ k = \sim 25 \text{ on NE80 network} \]
\[ k = 52 \text{ on HYDRA beowulf cluster} \]
pvm_xstar

Bourne shell script – same form as xstar2xspec

system("xstar ...") ➞ pvm_spawn("xstar ...")

NET EFFECT
Performance Expectations

Amdahl’s Law Restated: can’t go faster than slowest part

Serial

Parallel

Individual XSTAR jobs still run serially

time

CPU 1

CPU 2

CPU 3

CPU 4
Experimental Results

Serial
(NE80 Linux)

600 XSTAR jobs \(\sim 26\) hours

4200 XSTAR jobs \(\sim 7.5\) days
(extrapolation)

Parallel
(HYDRA Beowulf)

4200 XSTAR jobs \(\sim 110\) minutes
(Li’s run from last night)

Compute time no longer inhibits asking of “interesting” questions, or answering them!
Increasing Parallelism

By parallelizing XSTAR Internals

Serial

Parallel

Break jobs into smaller pieces

Job 1  Job 2  Job 3  Job 4  Job 5

Job 1  Job 2  Job 3a  Job 3b

Job 4  Job 5

Δt  time

CPU 1  CPU 2  CPU 3  CPU 4
Wouldn’t That Be Hard?

- Profile code to see hot spots
- Insert OpenMP statements around key loops

```c
!$OMP PARALLEL
!$OMP DO
  do i=1,n
     x = w * (i - 0.5)
     sum = sum + f(x)
  end do
!$OMP END PARALLEL
```

- OpenMP in GCC 4.2: now widely applicable
- Ignored by non-OpenMP compilers (comments)