Reveal

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Cray Compiler Optimization Feedback

OpenMP Assistance

MCDRAM Allocation Assistance

Reveal Overview

- **Reduce effort associated with adding OpenMP** to MPI programs when a pure MPI program no longer scales
- **Produce performance portable code** through OpenMP directives
- **Get insight into optimizations** performed by the Cray compiler
- Use as a first step to parallelize loops that will target GPUs
- Track requests to memory and evaluate the bandwidth contribution of objects within a program

When to Move to a Hybrid Programming Model

- **When code is network bound**
  - Increased MPI collective and point-to-point wait times
- **When MPI starts leveling off**
  - Too much memory used, even if on-node shared communication is available
  - As the number of MPI ranks increases, more off-node communication can result, creating a network injection issue
- **When contention of shared resources increases**

Approach to Adding Parallelism

1. **Identify key high-level loops**
   - Determine where to add additional levels of parallelism

1. **Perform parallel analysis and scoping**
   - Split loop work among threads

2. **Add OpenMP layer of parallelism**
   - Insert OpenMP directives

3. **Analyze performance for further optimization, specifically vectorization of innermost loops**
   - We want a performance-portable application at the end

The Problem – How Do I Parallelize This Loop?

- How do I know this is a good loop to parallelize?
- What prevents me from parallelizing this loop?
- Can I get help building a directive?

```
subroutine sweepz
…
do j = 1, js
 do i = 1, isz
   radius = zxc(i+mypez*isz)
   theta  = zyc(j+mypey*js)
   do m = 1, npez
    do k = 1, ks
     n = k + ks*(m-1) + 6
     r(n) = recv3(1,j,k,i,m)
     p(n) = recv3(2,j,k,i,m)
     u(n) = recv3(5,j,k,i,m)
     v(n) = recv3(3,j,k,i,m)
     w(n) = recv3(4,j,k,i,m)
     f(n) = recv3(6,j,k,i,m)
    enddo
   enddo
   …
   call ppmlr
   do k = 1, kmax
     n = k + 6
     xa (n) = zza(k)
     dx (n) = zdz(k)
     xa0(n) = zza(k)
     dx0(n) = zdz(k)
     e  (n) = p(n)/(r(n)*gamm)+0.5 &
        *(u(n)**2+v(n)**2+w(n)**2)
   enddo
   call ppmlr
…
 enddo
enddo
```

```
subroutine ppmlr

call boundary
call flatten
call paraset(nmin-4, nmax+5, para, dx, xa)

call parabola(nmin-4,nmax+4,para,p,dp,p6,pl,flat)
call parabola(nmin-4,nmax+4, para,r,dr,r6,rl,flat)
call parabola(nmin-4,nmax+4,para,u,du,u6,ul,flat)

call states(pl,ul,rl,p6,u6,r6,dp,du,dr,plft,ulft,&
            rlft,prgh,urgh,rrgh)
call riemann(nmin-3,nmax+4,gam,prgh,urgh,rrgh,&
             plft,ulft,rlft pmid umid)
call evolve(umid, pmid)  ← contains more calls

call remap ← contains more calls

call volume(nmin,nmax,ngeom,radius,xa,dx,dvol)

call remap ← contains more calls

return
end
```

Loop Work Estimates

Gather loop statistics using the Cray performance tools and the Cray Compiling Environment (CCE) to determine which loops have the most work

- **Helps identify high-level serial loops to parallelize**
  - Based on runtime analysis, approximates how much work exists within a loop

Collect Loop Work Estimates

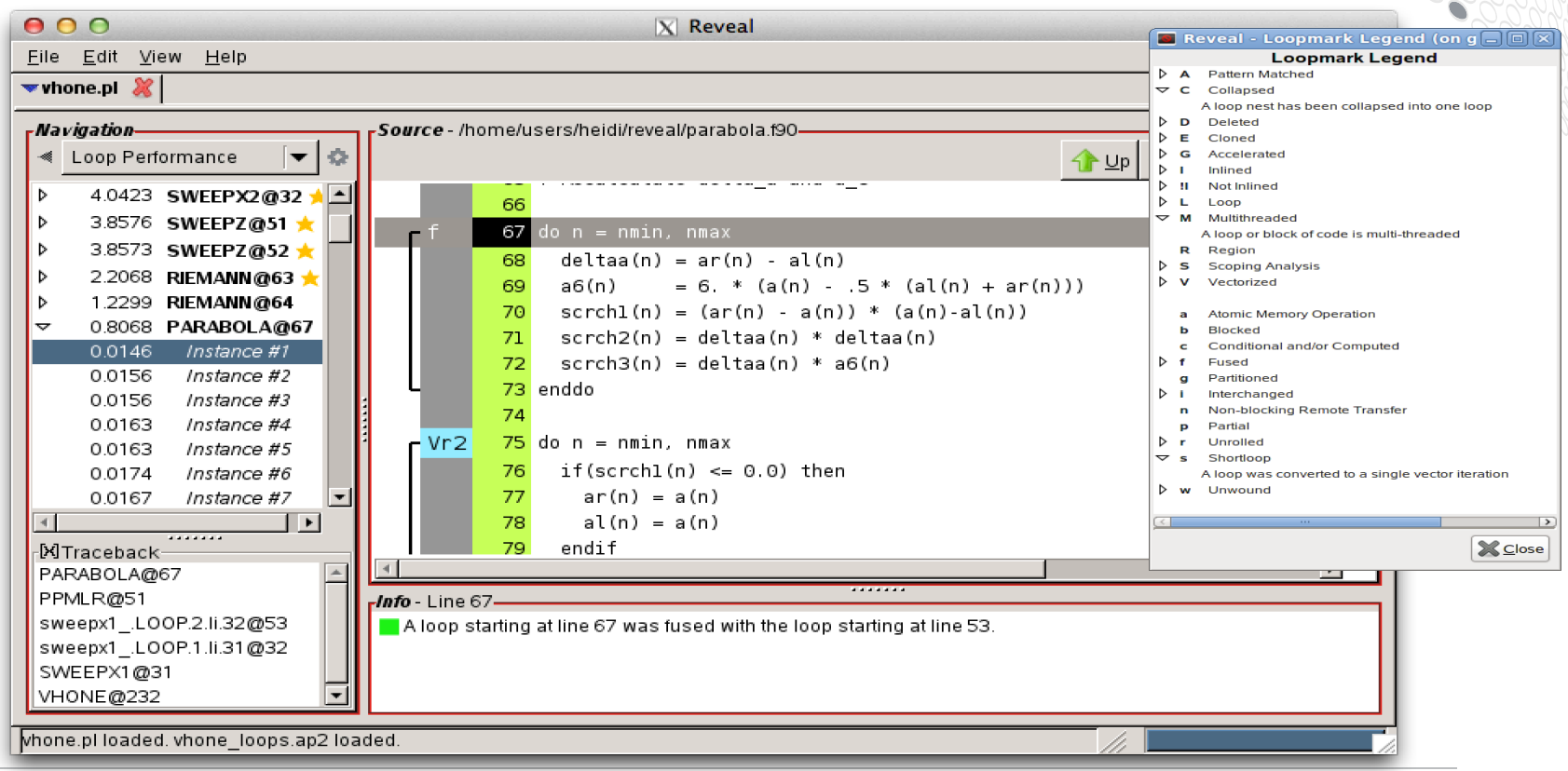
- Set up loop work estimates experiment with Cray compiler and Cray performance tools
  - `$ module load PrgEnv-cray perftools-lite-loops`
- Build program with Cray program library
  - `–h pl=/full_path/program.pl`
- Run program to get loop work estimates

Example Loop Statistics

Table 2: Loop Stats by Function

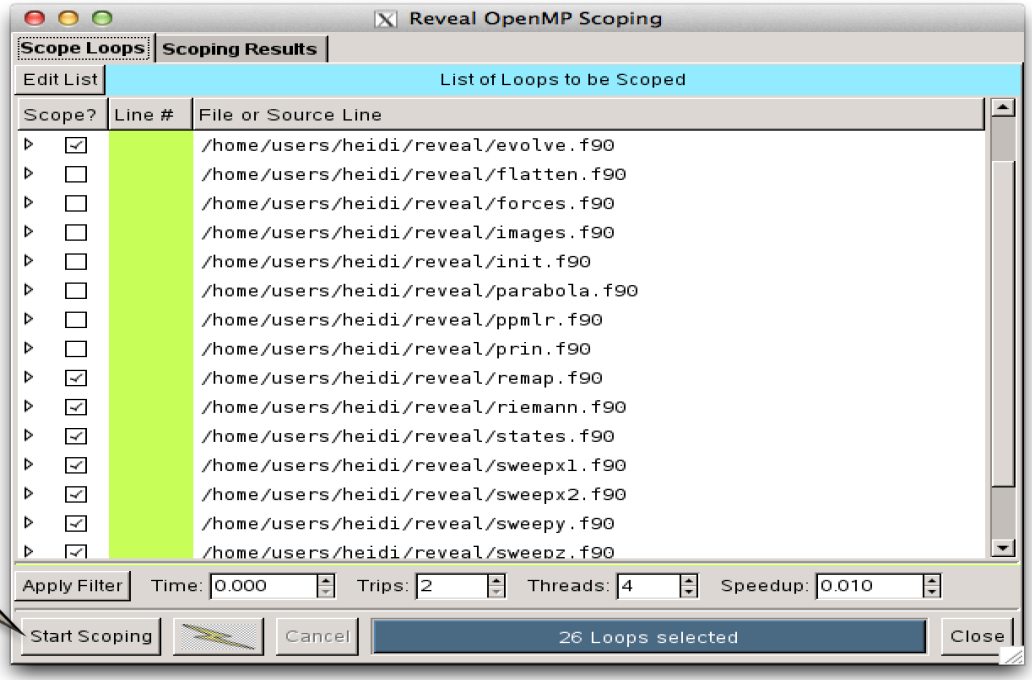
Loop Incl Time Total	Loop Hit	Loop Trips Avg	Loop Trips Min	Loop Trips Max	Function=/.LOOP[.] PE=HIDE
8.995914	100	25	0	25	sweepy_.LOOP.1.li.33
8.995604	2500	25	0	25	sweepy_.LOOP.2.li.34
8.894750	50	25	0	25	sweepz_.LOOP.05.li.49
8.894637	1250	25	0	25	sweepz_.LOOP.06.li.50
4.420629	50	25	0	25	sweepx2_.LOOP.1.li.29
4.420536	1250	25	0	25	sweepx2_.LOOP.2.li.30
4.387534	50	25	0	25	sweepx1_.LOOP.1.li.29
4.387457	1250	25	0	25	sweepx1_.LOOP.2.li.30
2.523214	187500	107	0	107	riemann_.LOOP.2.li.63

View Source and Optimization Information

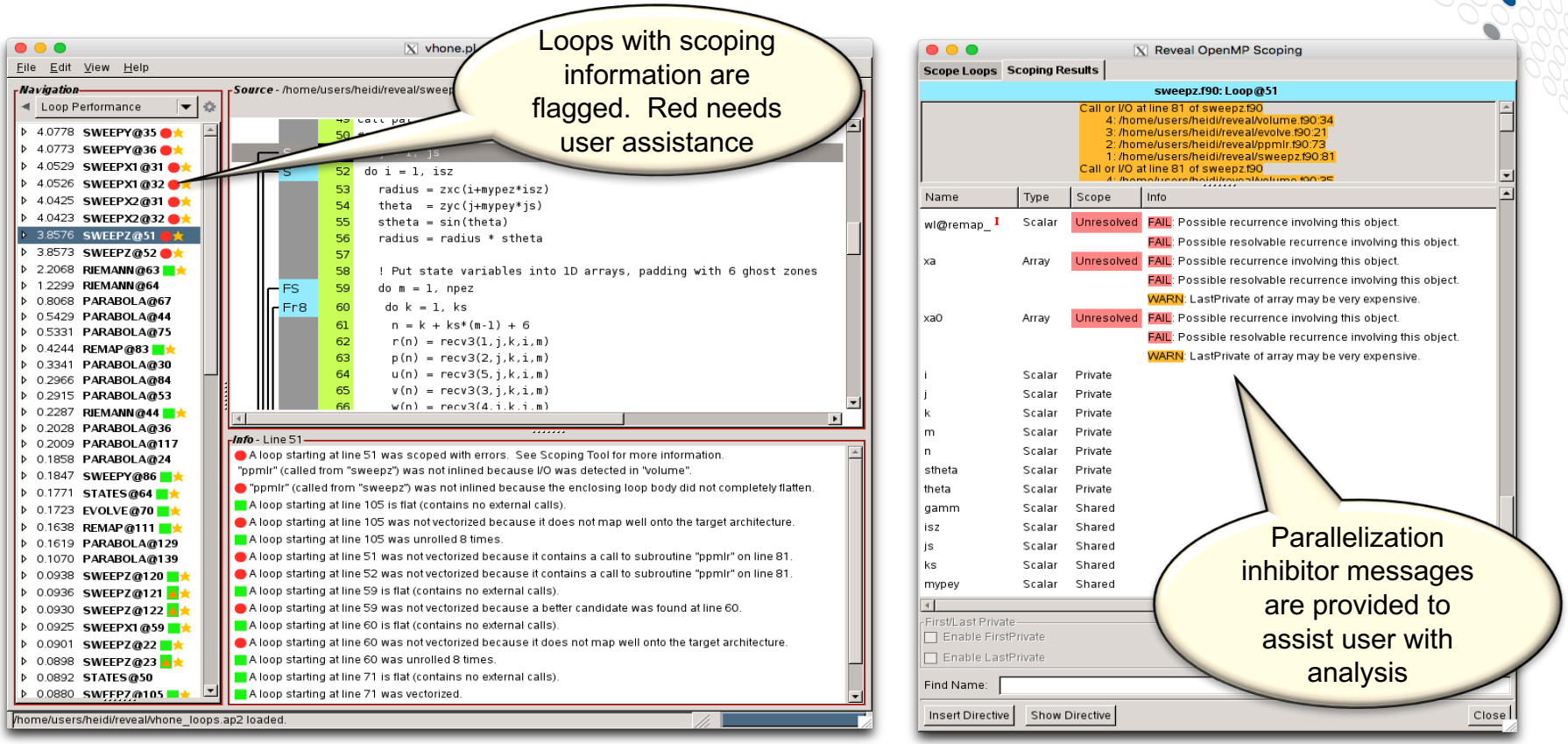


Scope Selected Loop(s)

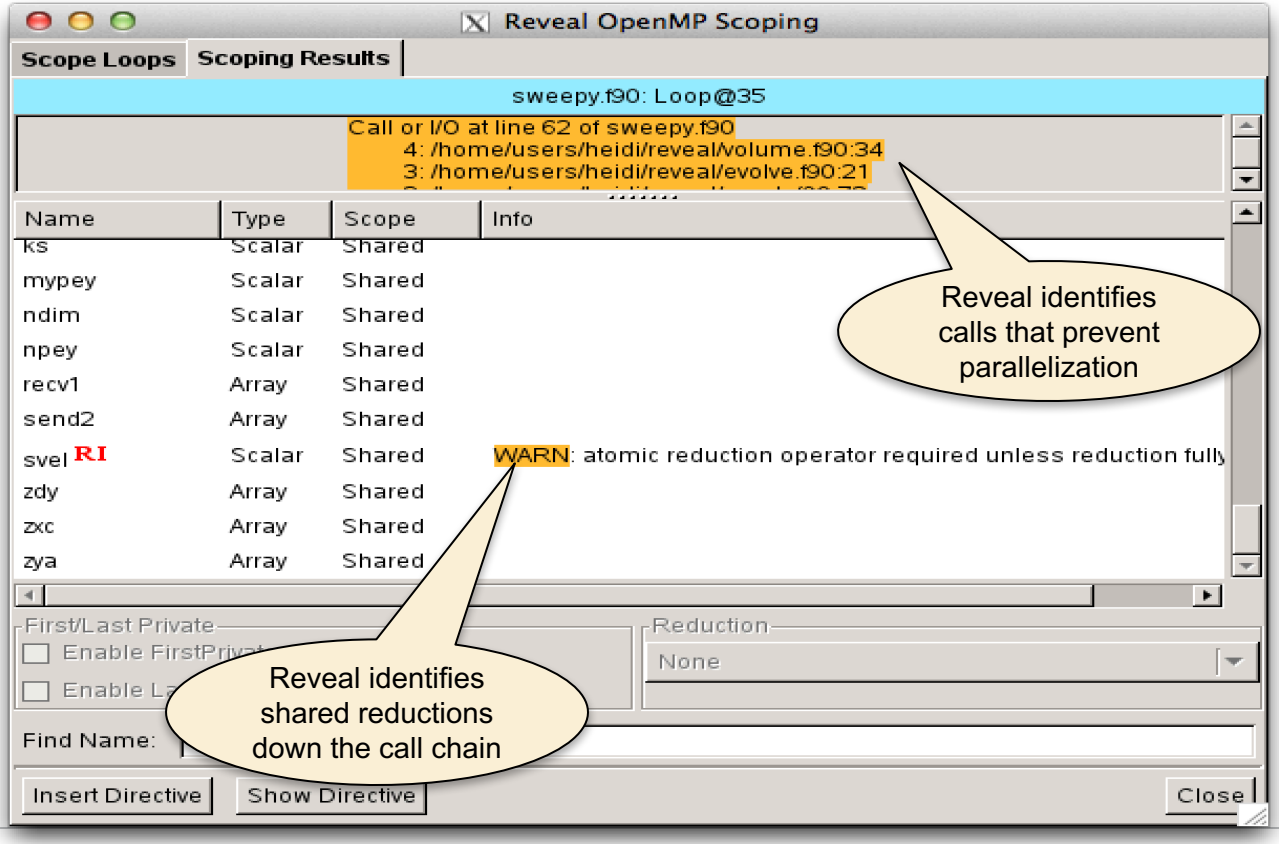
- Trigger dependence analysis
- scope loops above given threshold



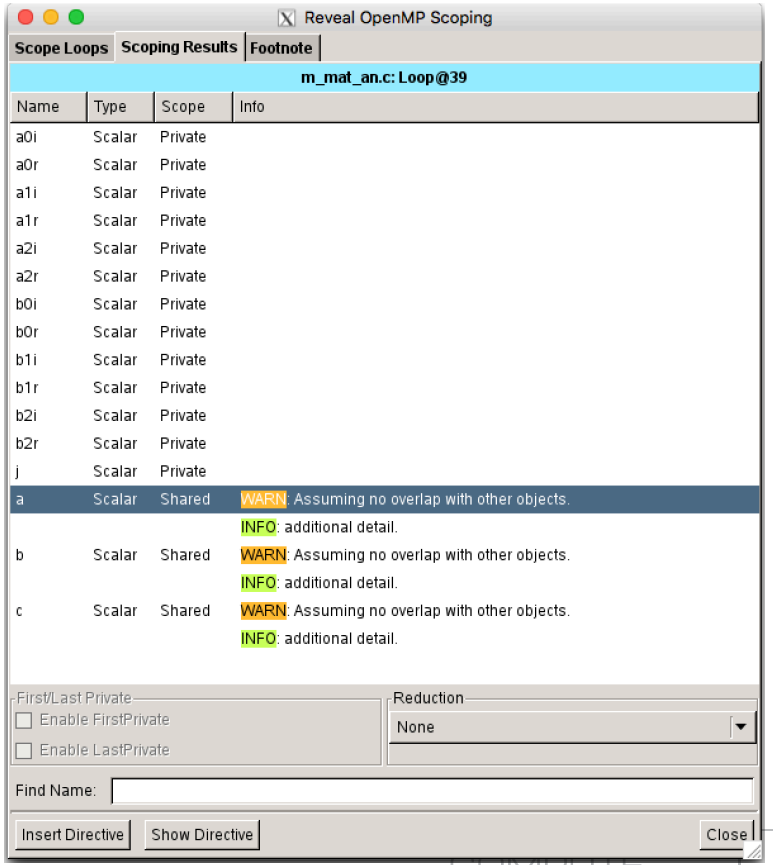
Review Scoping Results

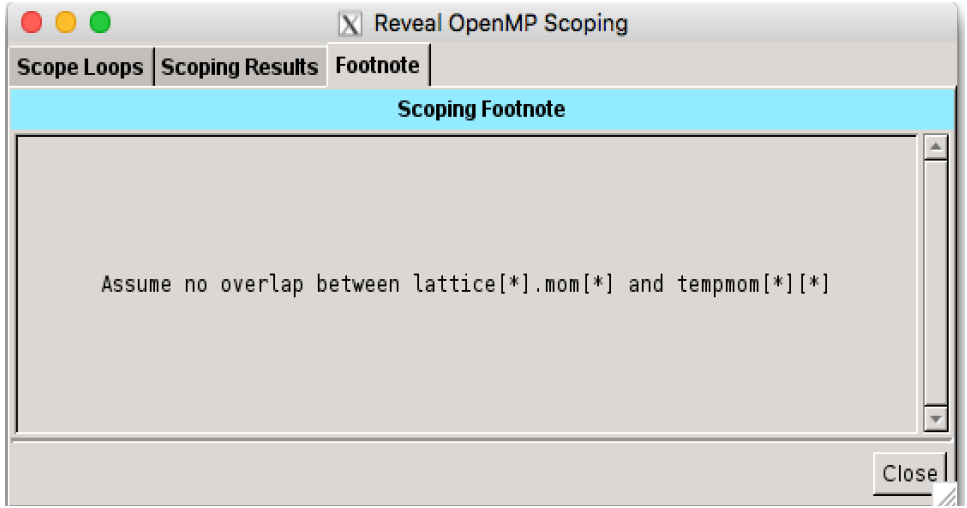


Review Scoping Results (continued)



Review Scoping Results (continued)





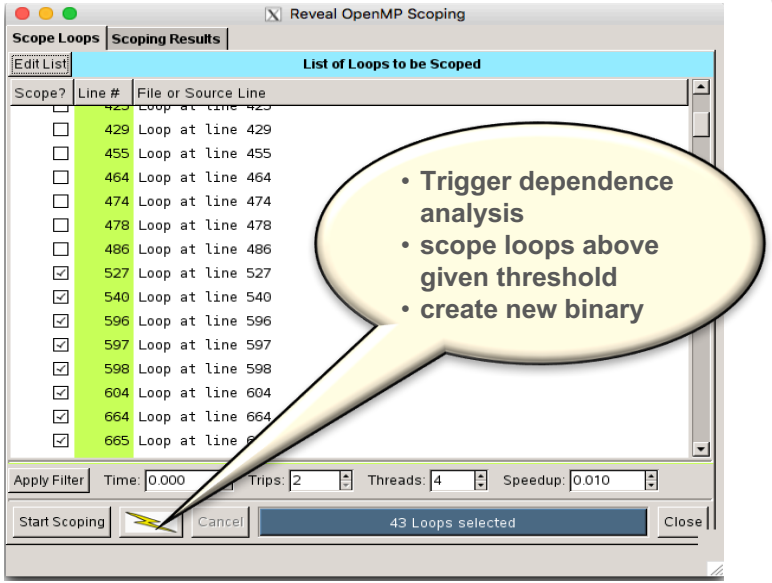
Generate OpenMP Directives

```
! Directive inserted by Cray Reveal.  May be incomplete.
!$OMP  parallel do default(none)                                        &
!$OMP&   unresolved (dvol,dx,dx0,e,f,flat,p,para,q,r,radius,svel,u,v,w,  &
!$OMP&          xa,xa0)                                                 &
!$OMP&   private (i,j,k,m,n,$$_n,delp2,delp1,shock,temp2,old_flat,       &
!$OMP&          onemfl,hdt,sinxf0,gamfac1,gamfac2,dtheta,deltx,fractn,   &
!$OMP&          ekin)                                                   &
!$OMP&   shared  (gamm,isy,js,ks,mypey,ndim,ngeomy,nlefty,npey,nrighty, &
!$OMP&          recv1,send2,zdy,zxc,zya)
do k = 1, ks
 do i = 1, isy
  radius = zxc(i+mypey*isy)

  ! Put state variables into 1D arrays, padding with 6 ghost zones
  do m = 1, npey
   do j = 1, js
    n = j + js*(m-1) + 6
    r(n) = recv1(1,k,j,i,m)
    p(n) = recv1(2,k,j,i,m)
    u(n) = recv1(4,k,j,i,m)
    v(n) = recv1(5,k,j,i,m)
    w(n) = recv1(3,k,j,i,m)
    f(n) = recv1(6,k,j,i,m)
   enddo
  enddo

  do j = 1, jmax
   n = j + 6
```

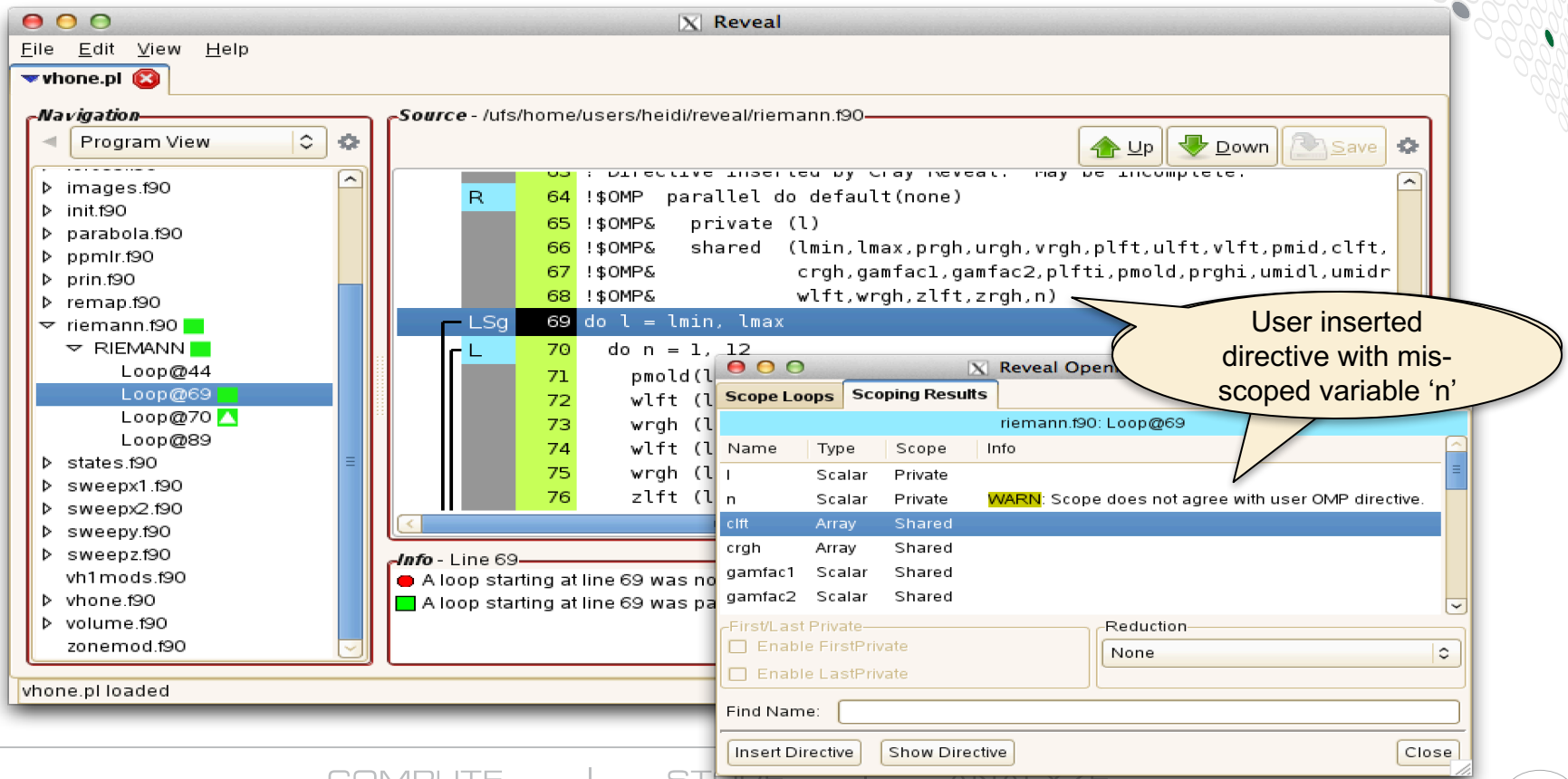
Reveal generates OpenMP directive with illegal clause marking variables that need addressing

Reveal Auto-Parallelization

- **Minimal user time investment includes time to set up and run optimization experiment**
  - Collect loop work estimates
  - Build program library
  - Click button in Reveal
  - Run experimental binary,
  - Compare against original program
- **Even if experiment does not yield a performance improvement, Reveal will provide insight into parallelization issues**
- **Use on X86 hardware or Armv8 hardware**

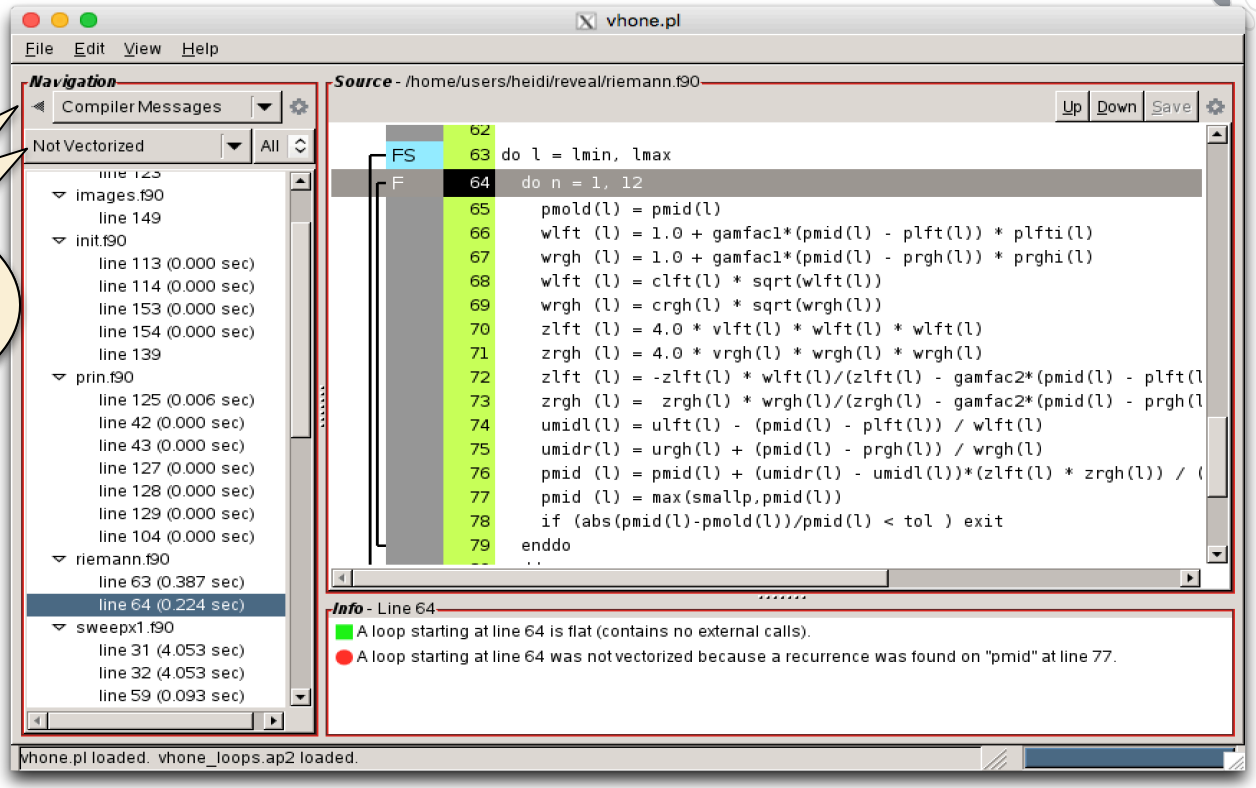


Validate User Inserted Directives



Look For Vectorization Opportunities

Choose “Compiler Messages” view to access message filtering, then select desired type of message

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