
Adding OpenMP
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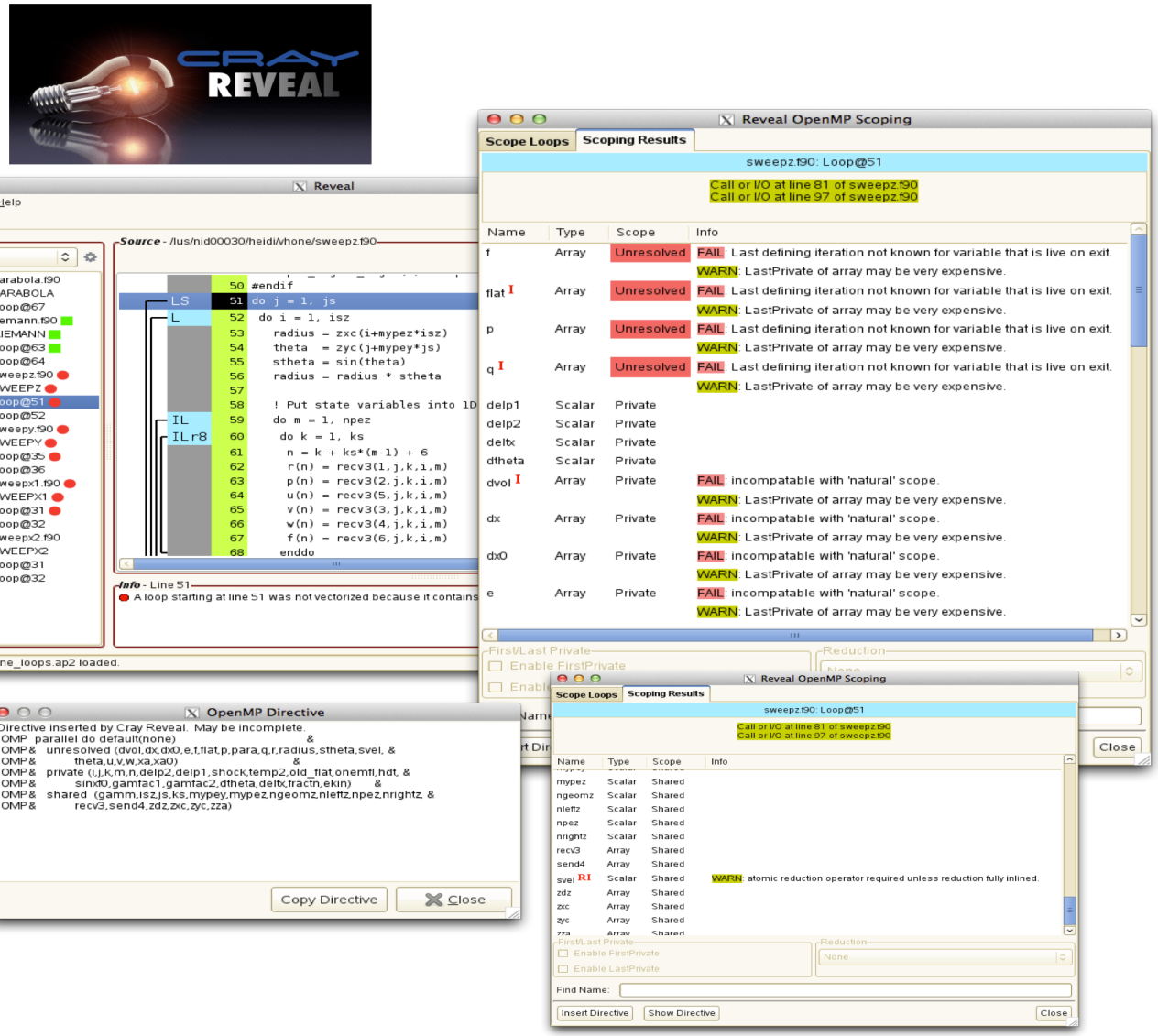
Reveal



- Reduce effort associated with adding OpenMP to MPI programs
- Get insight into optimizations performed by the Cray compiler
- Add OpenMP 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 for loop tuning

Approach to Adding Parallelism

1. Identify key high-level loops
2. Perform parallel analysis and scoping
3. Add OpenMP directive layer of parallelism
4. Analyze performance for further optimization, specifically vectorization of innermost loops
5. Port parallel loops to GPU with OpenMP target directives

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

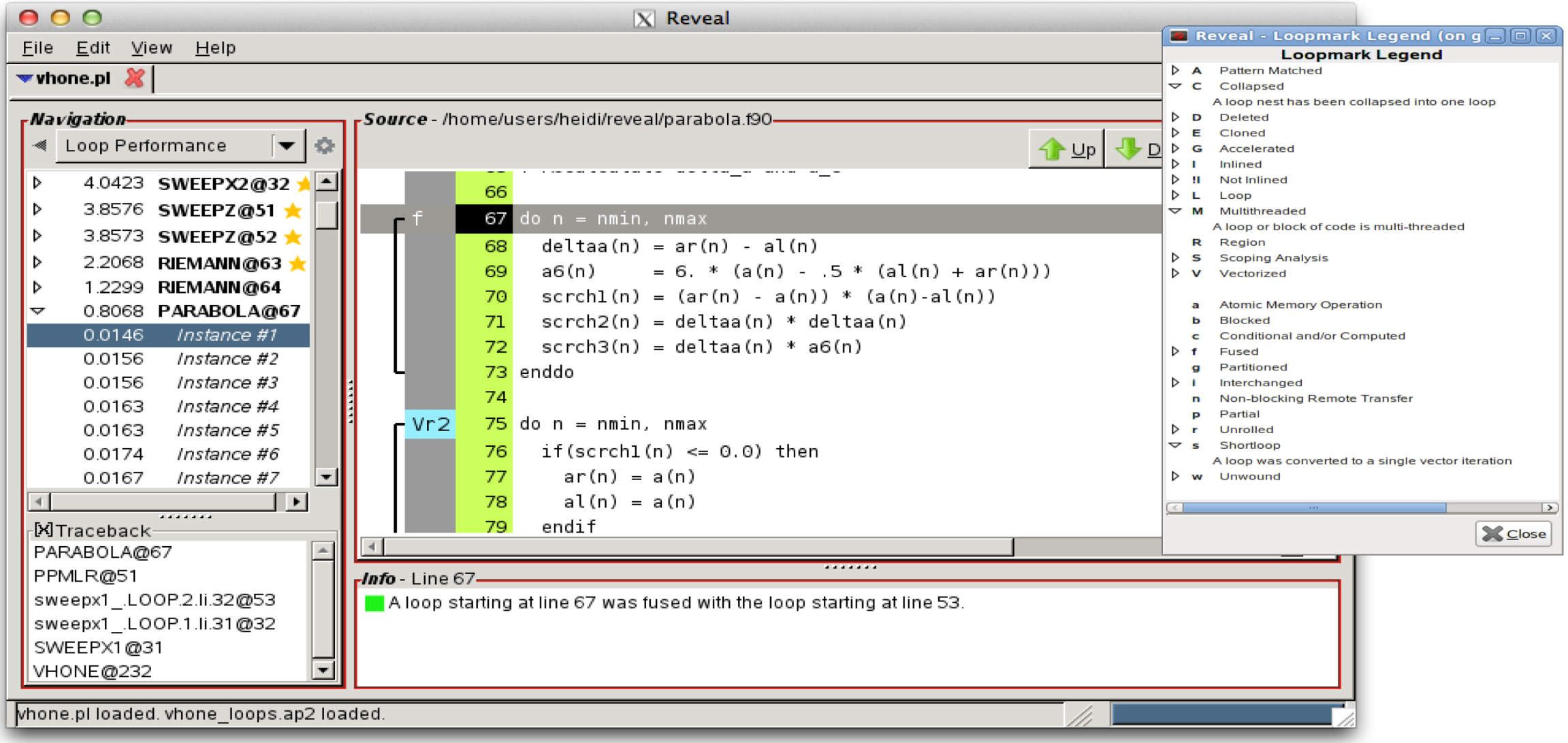
- Set up loop work estimates experiment with Cray compiler and Cray performance tools
  - `user@login> module load PrgEnv-cray perftools-lite-loops`
- Build program with Cray program library
  - `–h pl=/full_path/program.pl`
- Run program to get loop work estimates

Example Loop Statistics

Table 2: Loop Stats by Function

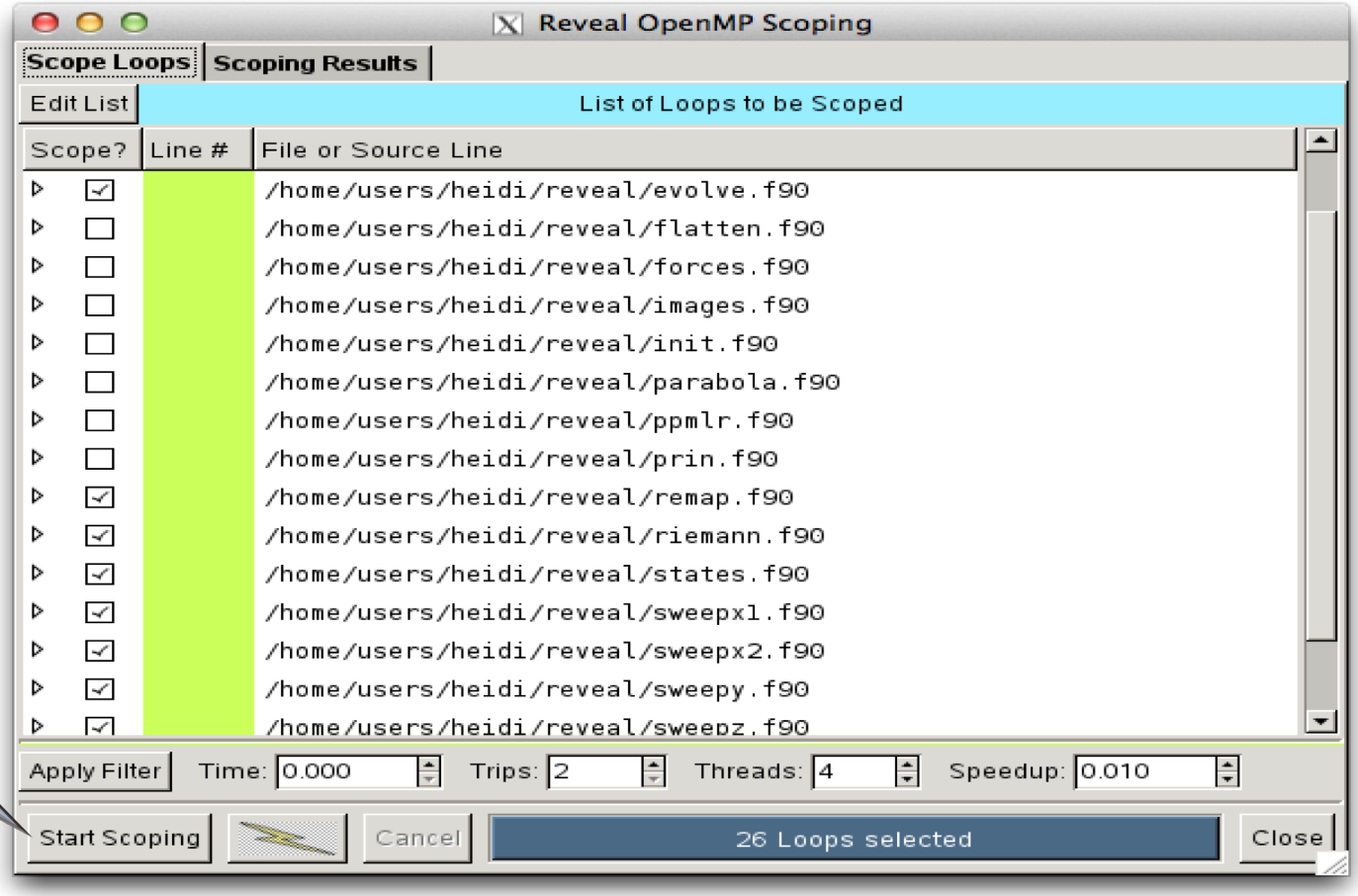
Loop Incl Time Total	Loop Hit	Loop Trips Avg	Loop Trips Min	Loop Trips Max	Function=/.LOOP[.] PE=HIDE
8.995914	100	25	0	25	sweepy_.LOOP.1.li.33
8.995604	2500	25	0	25	sweepy_.LOOP.2.li.34
8.894750	50	25	0	25	sweepz_.LOOP.05.li.49
8.894637	1250	25	0	25	sweepz_.LOOP.06.li.50
4.420629	50	25	0	25	sweepx2_.LOOP.1.li.29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

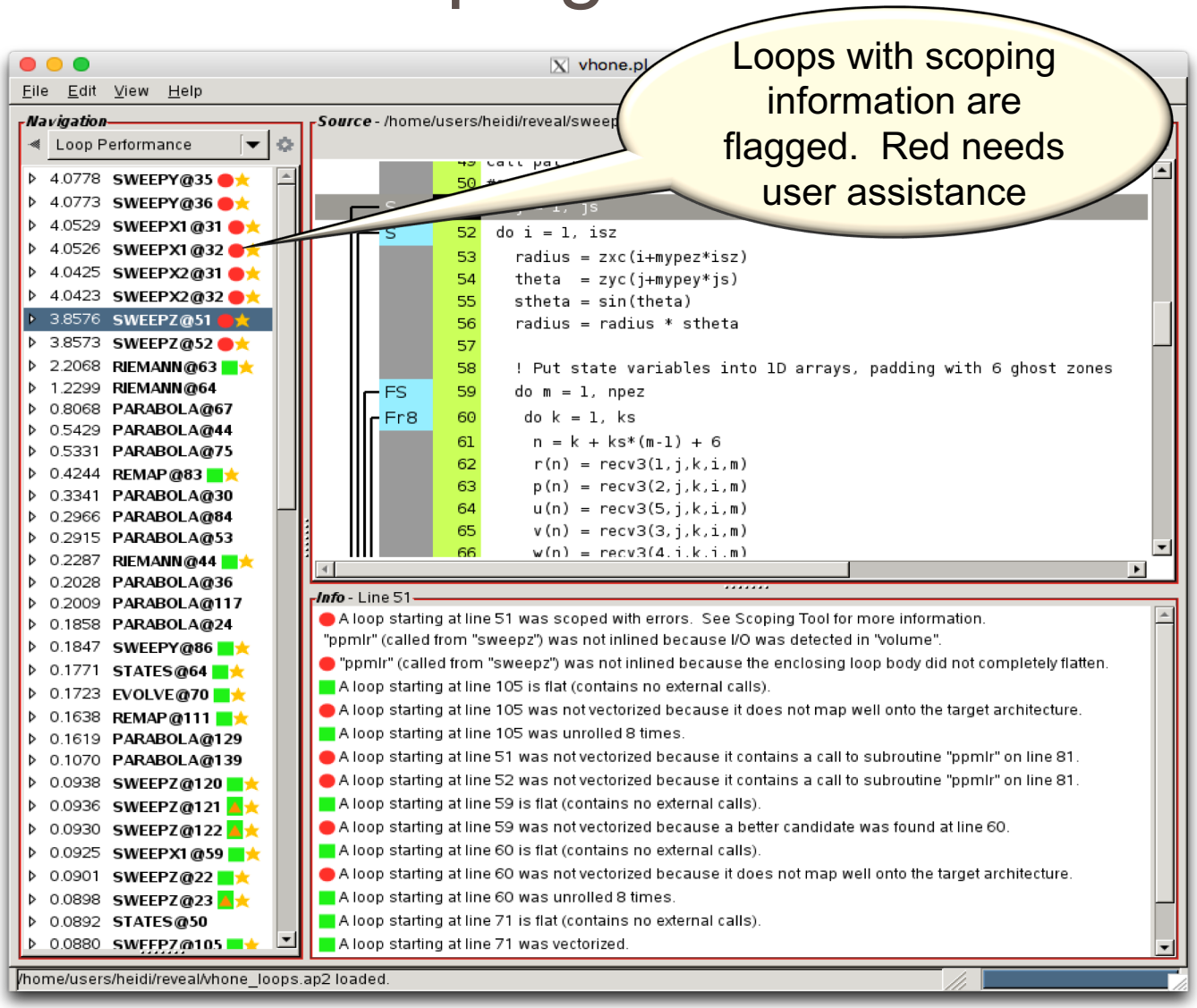


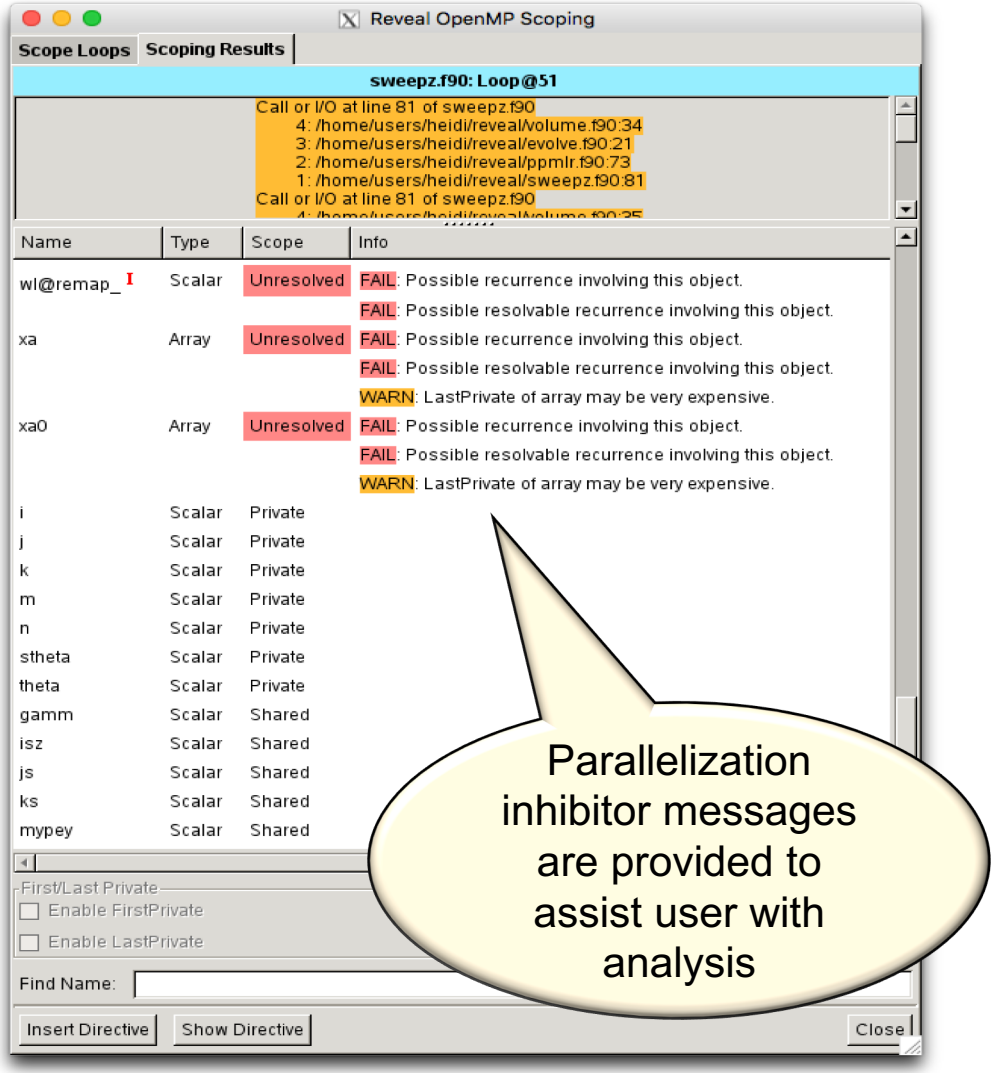
Scope Selected Loop(s)

- Trigger dependence analysis
- scope loops above given threshold

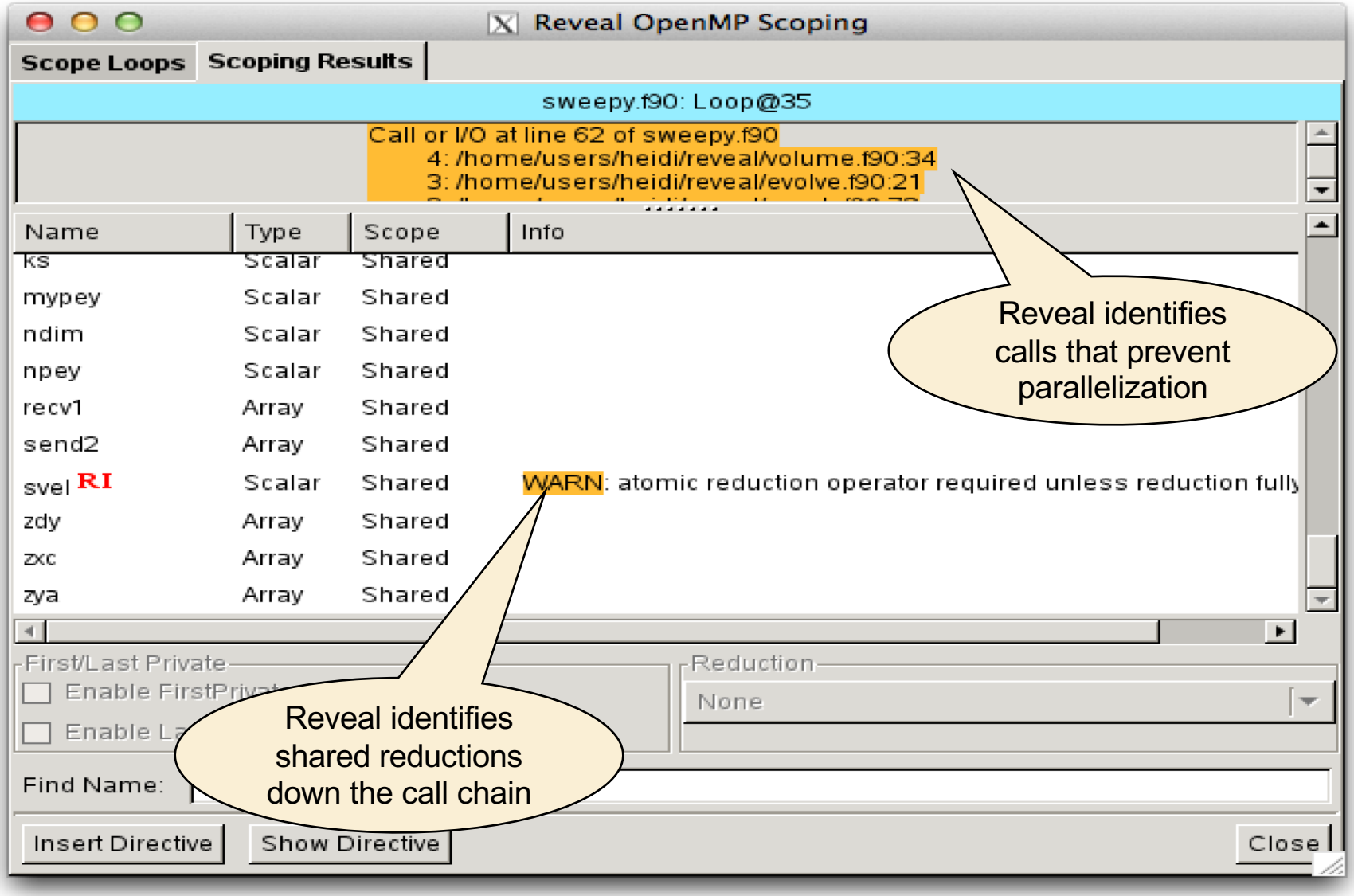


Review Scoping Results

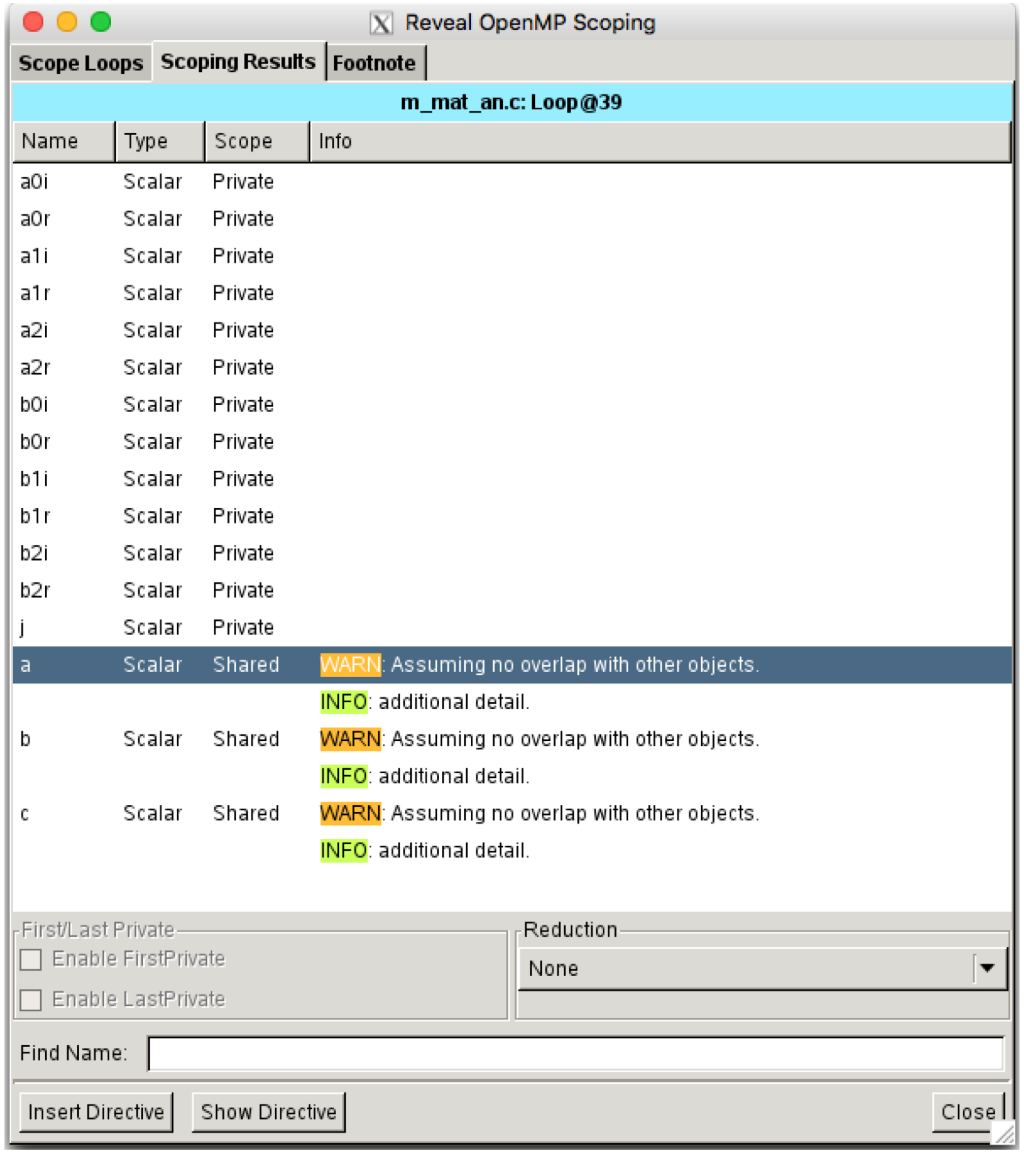


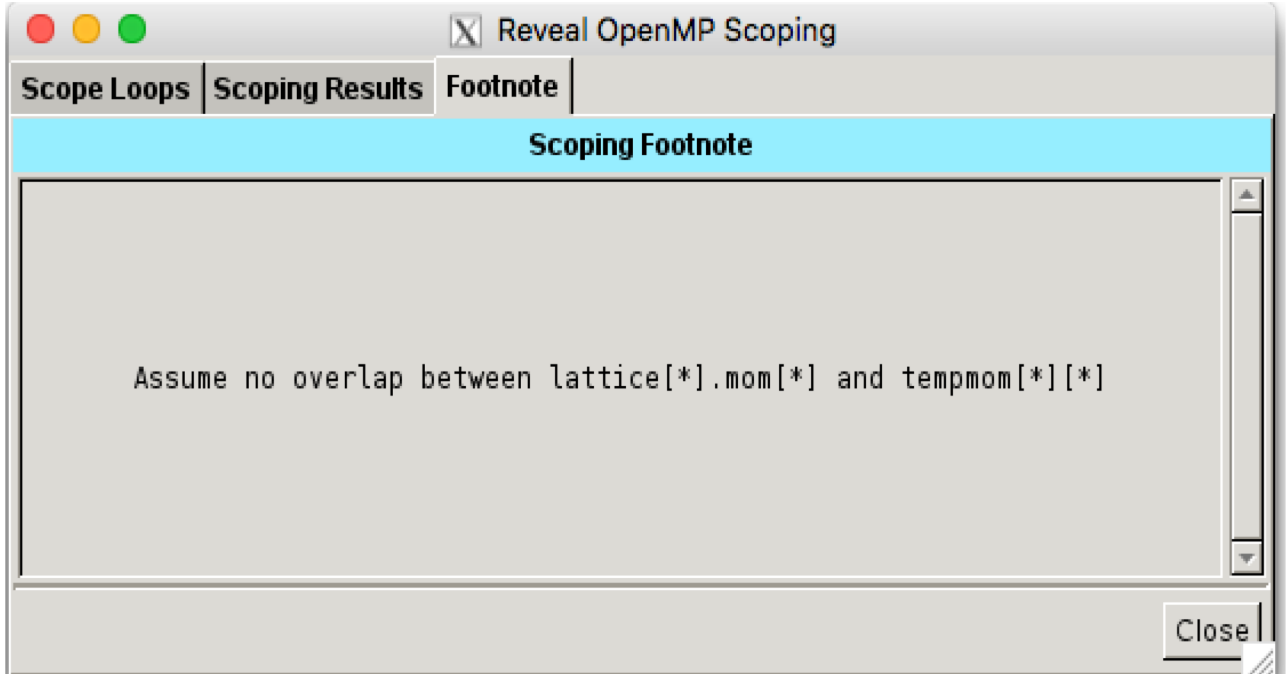


Review Scoping Results (continued)

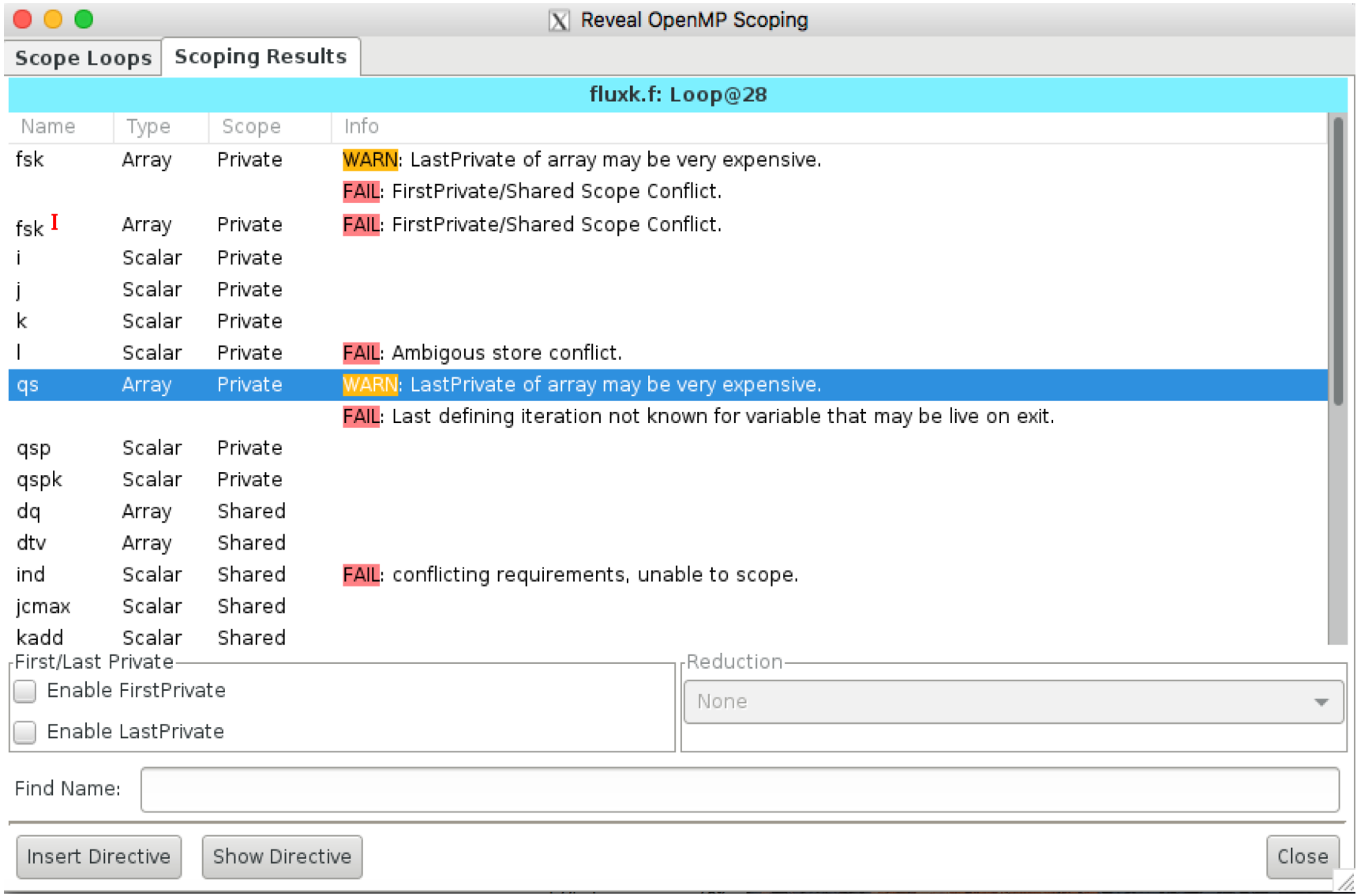


Review Scoping Results (continued)

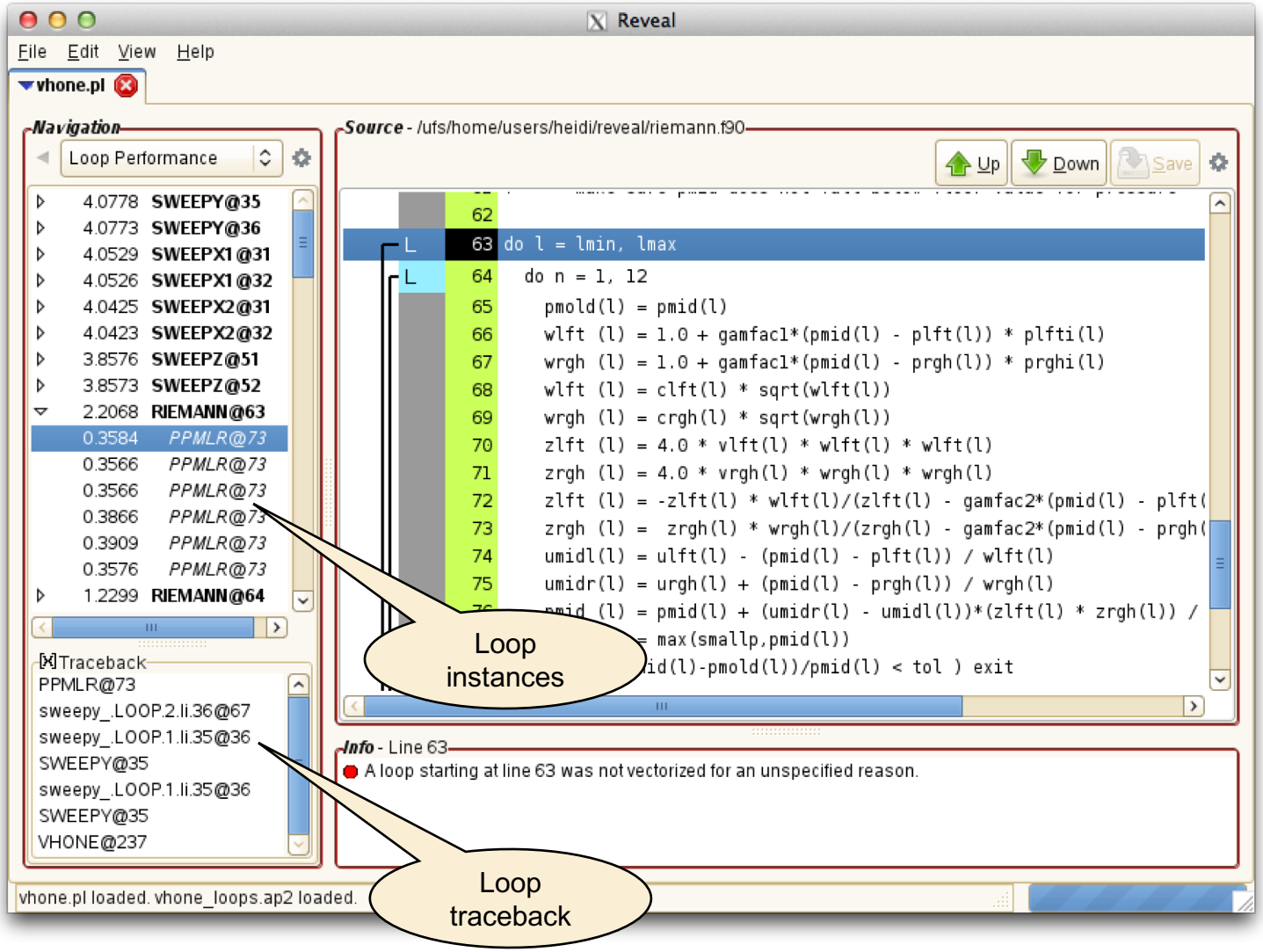




Review Scoping Results (continued)



View Loops through Call Chain



Generate OpenMP Directives

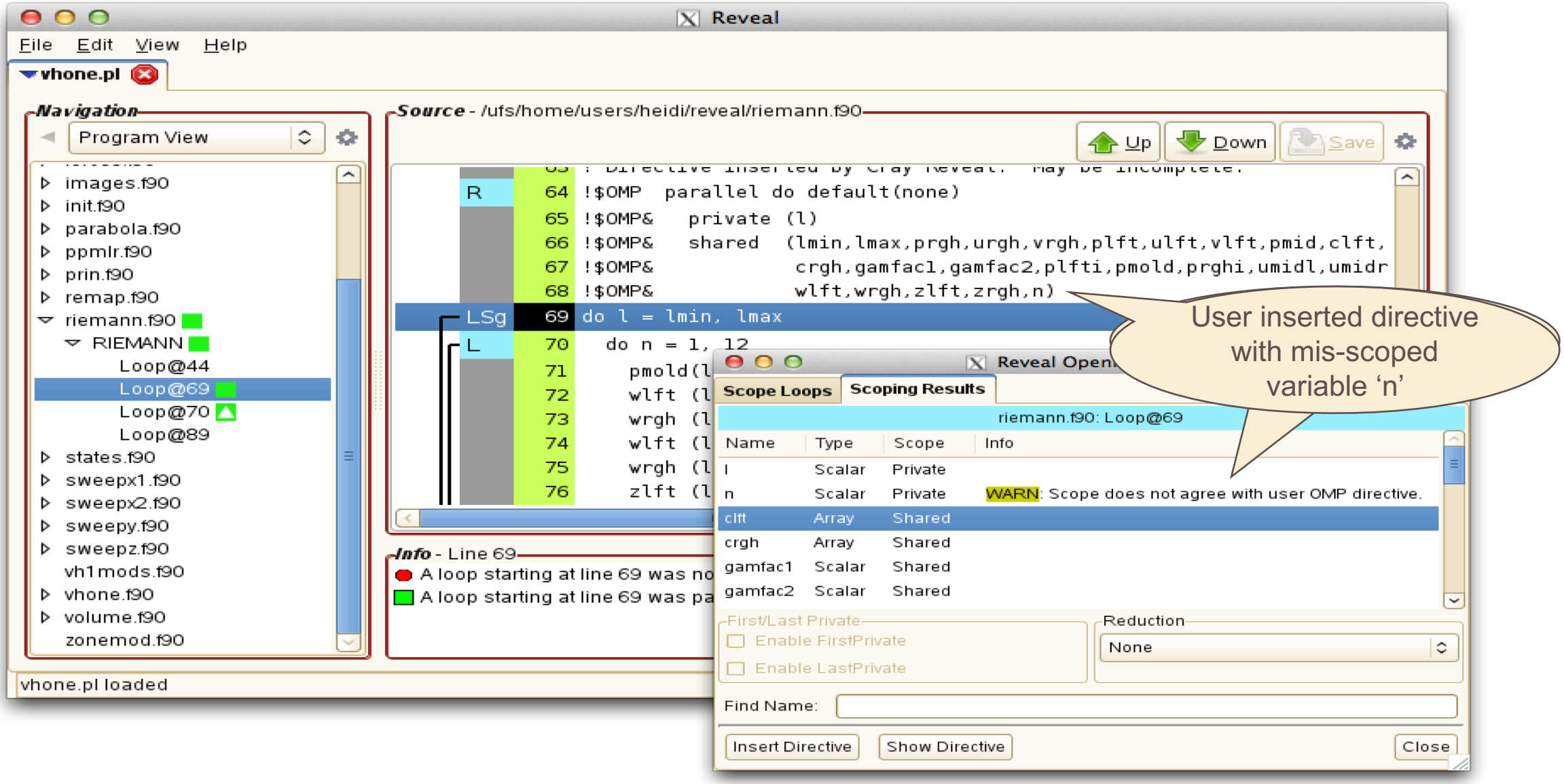
```
! Directive inserted by Cray Reveal.  May be incomplete.
!$OMP  parallel do default(none)                                        &
!$OMP&   unresolved (dvol,dx,dx0,e,f,flat,p,para,q,r,radius,svel,u,v,w,  &
!$OMP&              xa,xa0)                                              &
!$OMP&   private (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
```

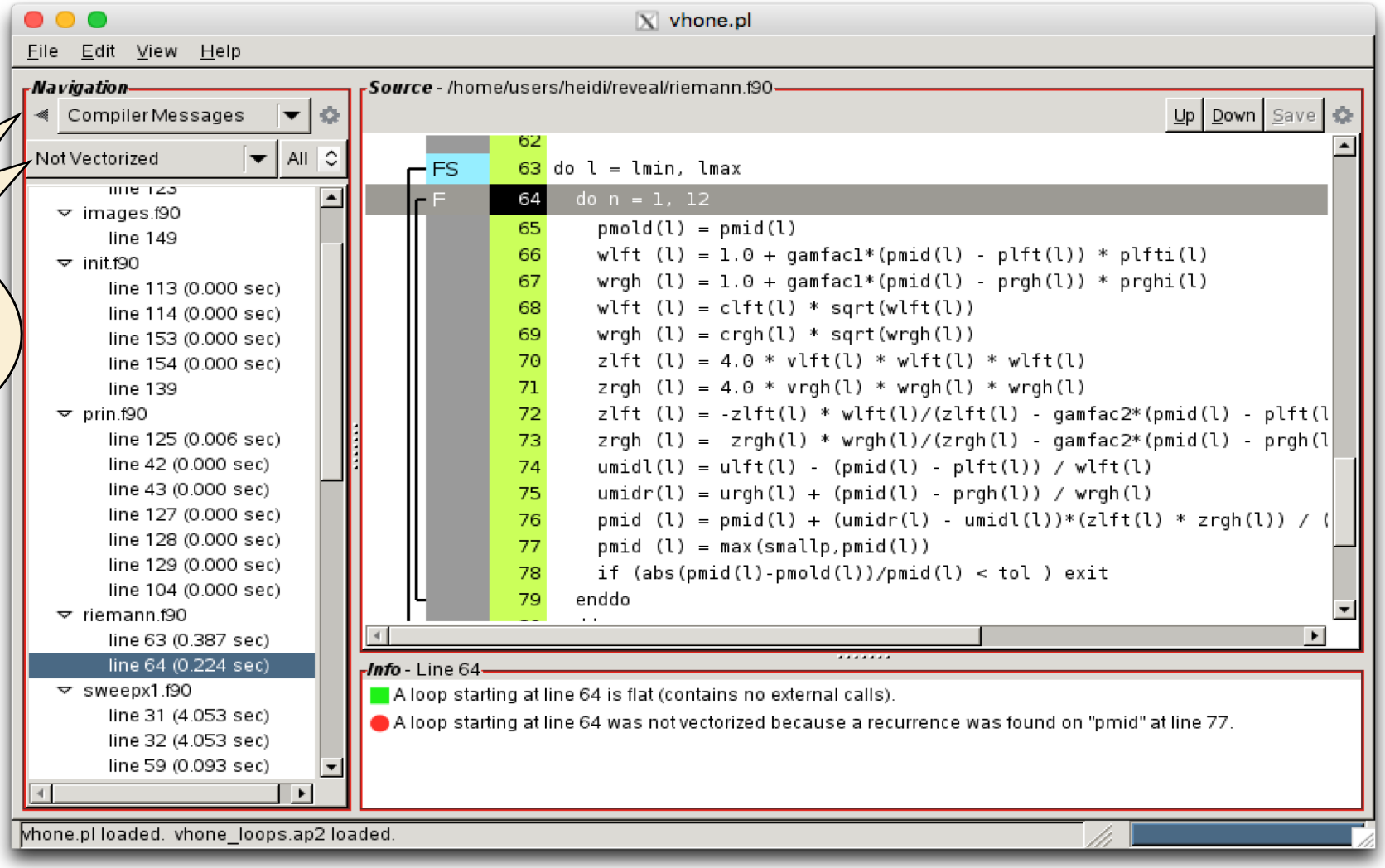
Reveal generates OpenMP directive with illegal clause marking variables that need addressing

Validate User Inserted Directives



Look For Vectorization Opportunities

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



QUESTIONS?