/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 1

```
001
002   module Reionization
003    use Precision
004    use AMLutils
005    implicit none
006
007   !This module puts smooth tanh
008   !The tanh function is in the v
009
010   !Rionization_zexp=1.5 has the
011   !the optical depth agrees with
012   !So tau and zre can be mapped
013   !However for generality the mo
014   !so could be easily modified f
015
016   !AL March 2008
017   !AL July 2008 - added trap for
018
019   !See CAMB notes for further di
020
021       character(LEN=*), param
022
023       real(dl), parameter ::
024        !if -1 set from YHe as
025
026       real(dl) :: Reionizatio
027       real(dl) :: Rionization
028
029       logical :: include_heli
030       real(dl) :: helium_full
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 1

```
001
002      module Reionization
003       use Precision
004       use AMLutils
005       implicit none
006
007      !This module puts smooth t
008      !The tanh function is in t
009
010      !Rionization_zexp=1.5 has
011      !the optical depth agrees
012      !So tau and zre can be map
013      !However for generality th
014      !so could be easily modifi
015
016      !AL March 2008
017      !AL July 2008 - added trap
018
019      !See CAMB notes for furthe
020
021       character(LEN=*), paramete
022
023       real(dl), parameter :: Rei
024       !if -1 set from YHe assumi
025
026       real(dl) :: Reionization_A
027       real(dl) :: Rionization_ze
028
029       logical :: include_helium_
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 31

```
031         real(dl) :: helium_full
032         real(dl) :: helium_full
033
034
035       type ReionizationParams
036             logical    :: Rei
037             logical    :: use
038             real(dl)   :: red
039             real(dl)   :: opt
040        end type ReionizationP
041
042        type ReionizationHisto
043   !These two are used by main co
044           real(dl) :: tau_star
045   !This is set from main code
046           real(dl) :: akthom,
047
048   !The rest are internal to this
049           real(dl) :: WindowVa
050
051        end type ReionizationH
052
053      real(dl), parameter :: R
054      real(dl), private, param
055
056      real(dl), private, exter
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 30

```
030
031       type ReionizationParams
032           logical    :: Reioniza
033           logical    :: use_opti
034           real(dl)   :: redshift
035           real(dl)   :: optical_
036           !Parameters for the se
037           real(dl)   :: helium_r
038           real(dl)   :: helium_d
039           real(dl)   :: helium_r
040       end type ReionizationParam
041
042       type ReionizationHistory
043           !These two are used by
044           real(dl) :: tau_start,
045           !This is set from main
046           real(dl) :: akthom, fH
047
048           !The rest are internal
049           real(dl) :: WindowVarM
050
051       end type ReionizationHisto
052
053       real(dl), parameter :: Rei
054       real(dl), private, paramet
055
056       real(dl), private, externa
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 57

```
057
058         Type(ReionizationParams),
059         Type(ReionizationHistory),
060
061     contains
062
063
064      function Reionization_xe(a, t
065      !a and time tau and redundant
066      !xe_recomb is xe(tau_start) f
067      !xe should map smoothly onto
068       real(dl), intent(in) :: a
069       real(dl), intent(in), option
070       real(dl) Reionization_xe
071       real(dl) tgh, xod
072       real(dl) xstart
073
074           if (present(xe_recomb)
075           xstart = xe_recomb
076           else
077           xstart = 0._dl
078           end if
079
080           xod = (ThisReionHist%W
081           if (xod > 100) then
082               tgh=1.d0
083           else
084               tgh=tanh(xod)
085           end if
086           Reionization_xe =(This
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 57

```
057
058         Type(ReionizationParams),
059         Type(ReionizationHistory),
060
061     contains
062
063
064      function Reionization_xe(a
065      !a and time tau and redund
066      !xe_recomb is xe(tau_start
067      !xe should map smoothly on
068       real(dl), intent(in) :: a
069       real(dl), intent(in), opti
070       real(dl) Reionization_xe
071       real(dl) tgh, xod
072       real(dl) xstart
073
074           if (present(xe_recomb)) th
075               xstart = xe_recomb
076           else
077               xstart = 0._dl
078           end if
079
080           xod = (ThisReionHist%Windo
081           if (xod > 100) then
082               tgh=1.d0
083           else
084               tgh=tanh(xod)
085           end if
086           Reionization_xe =(ThisReio
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 87

```
087
088          if (include_helium_ful
089
090           !Effect of Helium bec
091            xod = (1+helium_full
092            if (xod > 100) then
093               tgh=1.d0
094            else
095               tgh=tanh(xod)
096            end if
097
098           Reionization_xe =  Rei
099
100        end if
101
102     end function Reionization_xe
103
104     function Reionization_timeste
105     !minimum number of time steps
106     !Scaled by AccuracyBoost late
107     !steps may be set smaller tha
108      Type(ReionizationHistory) ::
109      integer Reionization_timeste
110
111      Reionization_timesteps = 50
112
113     end  function Reionization_ti
114
115     subroutine Reionization_ReadP
116      use IniFile
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 87

```
087
088        if (include_helium_fullrei
089
090            !Effect of Helium beco
091            xod = (1+ThisReion%hel
092            if (xod > 100) then
093                tgh=1.d0
094            else
095                tgh=tanh(xod)
096            end if
097
098            Reionization_xe =  Rei
099
100        end if
101
102     end function Reionization_
103
104     function Reionization_time
105     !minimum number of time st
106     !Scaled by AccuracyBoost l
107     !steps may be set smaller
108     Type(ReionizationHistory)
109     integer Reionization_times
110
111     Reionization_timesteps = 5
112
113     end  function Reionization
114
115     subroutine Reionization_Re
116     use IniFile
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 117

```
117     Type(ReionizationParams) ::
118     Type(TIniFile) :: Ini
119
120      Reion%Reionization = Ini_Re
121      if (Reion%Reionization) the
122
123       Reion%use_optical_depth =
124
125       if (Reion%use_optical_dept
126                 Reion%optical_de
127       else
128                 Reion%redshift =
129       end if
130
131       Reion%delta_redshift = Ini
132       Reion%fraction = Ini_Read_
133
134      end if
135
136    end subroutine Reionization_R
137
138    subroutine Reionization_SetPa
139     Type(ReionizationParams), ta
140     Type(ReionizationHistory), t
141
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 117

```
117     Type(ReionizationParams) :
118     Type(TIniFile) :: Ini
119
120     Reion%Reionization = Ini_R
121     if (Reion%Reionization) th
122
123         Reion%use_optical_dept
124
125         if (Reion%use_optical_
126             Reion%optical_dept
127         else
128             Reion%redshift = I
129         end if
130
131         Reion%delta_redshift =
132         Reion%fraction = Ini_R
133
134         Reion%helium_redshift
135         Reion%helium_delta_red
136         Reion%helium_redshifts
137             Reion%helium_redsh
138
139     end if
140
141     end subroutine Reionizatio
142
143     subroutine Reionization_Se
144     Type(ReionizationParams),
145     Type(ReionizationHistory),
146
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 142

```
142       ReionHist%WindowVarMid
143       ReionHist%WindowVarDelt
144         Rionization_zexp*(1._
145
146     end subroutine Reionization_S
147
148     subroutine Reionization_Init(
149      use constants
150      Type(ReionizationParams), ta
151      Type(ReionizationHistory), t
152      real(dl), intent(in) :: akth
153      integer, intent(in) :: Feedb
154      real(dl) astart
155
156       ReionHist%akthom = akthom
157       ReionHist%fHe =  YHe/(mas
158
159       ReionHist%tau_start=tau0
160       ReionHist%tau_complete=ta
161
162       ThisReion => Reion
163       ThisReionHist => ReionHis
164
165       if (Reion%Reionization) t
166
167           if (Reion%optical_
168            write (*,*) 'WARN
169
170
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 147

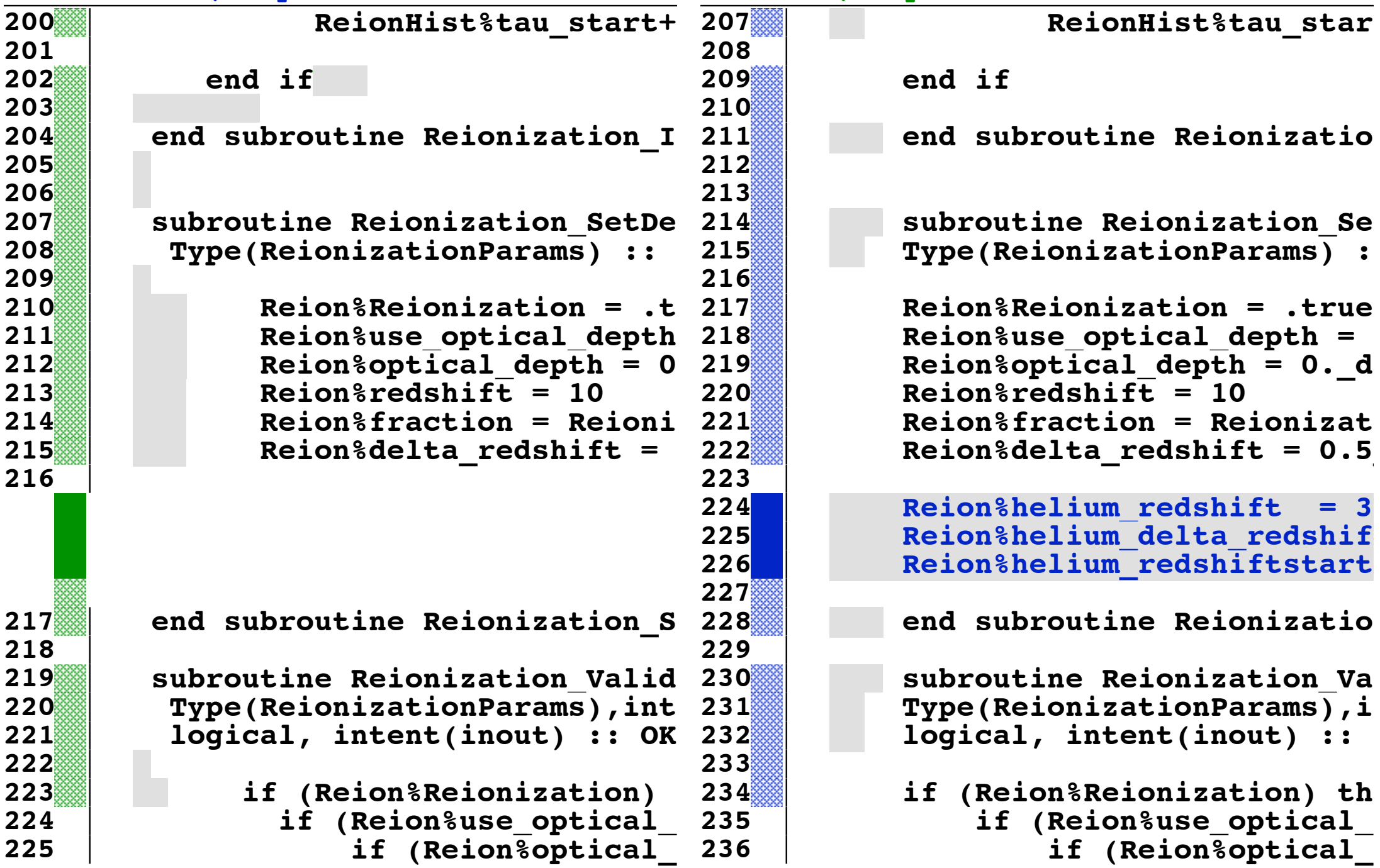
```
147       ReionHist%WindowVarMid = (
148       ReionHist%WindowVarDelta =
149           Rionization_zexp*(1._d
150
151     end subroutine Reionizatio
152
153     subroutine Reionization_In
154       use constants
155       use errors
156       Type(ReionizationParams),
157       Type(ReionizationHistory),
158       real(dl), intent(in) :: ak
159       integer, intent(in) :: Fee
160       real(dl) astart
161
162       ReionHist%akthom = akthom
163       ReionHist%fHe =  YHe/(mass
164
165       ReionHist%tau_start=tau0
166       ReionHist%tau_complete=tau
167
168       ThisReion => Reion
169       ThisReionHist => ReionHist
170
171       if (Reion%Reionization) th
172
173           if (Reion%optical_dept
174            write (*,*) 'WARNI
175
176
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 171

```
171          if (Reion%use_optic
172            .or. .not.Reio
173           Reion%Reionizat
174          end if
175
176        end if
177
178      if (Reion%Reionization) t
179
180          if (Reion%fraction==Re
181                Reion%fractio
182
183          if (Reion%use_optical_d
184           call Reionization_SetF
185           if (FeedbackLevel > 0)
186          end if
187
188          call Reionization_SetPa
189
190        !this is a check, agrees
191          if (FeedbackLevel > 1)
192            Reionization_GetOp
193
194        !Get relevant times
195          astart=1.d0/(1.d0+Reion
196          ReionHist%tau_start = m
197            !Time when a very sm
198
199          ReionHist%tau_complete
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 177

```
177          if (Reion%use_optical_
178            .or. .not.Reion%us
179           Reion%Reionization
180          end if
181
182        end if
183
184        if (Reion%Reionization) th
185
186          if (Reion%fraction==Re
187           Reion%fraction = 1
188
189          if (Reion%use_optical_
190           call Reionization_
191           if (global_error_f
192           if (FeedbackLevel
193          end if
194
195          call Reionization_SetP
196
197          !this is a check, agre
198          if (FeedbackLevel > 1)
199            Reionization_GetOp
200
201          !Get relevant times
202          astart=1.d0/(1.d0+Reio
203          ReionHist%tau_start =
204          !Time when a very smal
205
206          ReionHist%tau_complete
```


/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 200
/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 207
200 ReionHist%tau_start+
201
202 end if
203
204 end subroutine Reionization_I
205
206
207 subroutine Reionization_SetDe
208 Type(ReionizationParams) ::
209
210 Reion%Reionization = .t
211 Reion%use_optical_depth
212 Reion%optical_depth = 0
213 Reion%redshift = 10
214 Reion%fraction = Reioni
215 Reion%delta_redshift =
216
217 end subroutine Reionization_S
218
219 subroutine Reionization_Valid
220 Type(ReionizationParams),int
221 logical, intent(inout) :: OK
222
223 if (Reion%Reionization)
224 if (Reion%use_optical_
225 if (Reion%optical_
207 ReionHist%tau_star
208
209 end if
210
211 end subroutine Reionizatio
212
213
214 subroutine Reionization_Se
215 Type(ReionizationParams) :
216
217 Reion%Reionization = .true
218 Reion%use_optical_depth =
219 Reion%optical_depth = 0._d
220 Reion%redshift = 10
221 Reion%fraction = Reionizat
222 Reion%delta_redshift = 0.5
223
224 Reion%helium_redshift = 3
225 Reion%helium_delta_redshif
226 Reion%helium_redshiftstart
227
228 end subroutine Reionizatio
229
230 subroutine Reionization_Va
231 Type(ReionizationParams),i
232 logical, intent(inout) ::
233
234 if (Reion%Reionization) th
235 if (Reion%use_optical_
236 if (Reion%optical_

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 226

```
226                     include_helium_
227                  OK = .false.
228                  write(*,*) 'Optic
229                end if
230             else
231                if (Reion%redshift
232                  include_helium_f
233                  OK = .false.
234                  write(*,*) 'Re
235                end if
236             end if
237             if (Reion%fraction/= R
238                  OK = .false.
239                  write(*,*) 'Re
240             end if
241             if (Reion%delta_redshi
242             !Very narrow windows l
243             !Very broad likely to
244                  OK = .false.
245                  write(*,*) 'Re
246             end if
247
248
249          end if
250
251       end  subroutine Reionization
252
253
254       function Reionization_doptdep
255         real(dl) :: Reionization_do
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 237

```
237                     include_helium
238                  OK = .false.
239                  write(*,*) 'Op
240                end if
241             else
242                if (Reion%redshift
243                  include_helium
244                  OK = .false.
245                  write(*,*) 'Re
246                end if
247             end if
248             if (Reion%fraction/= R
249                  OK = .false.
250                  write(*,*) 'Reioni
251             end if
252             if (Reion%delta_redshi
253                  !Very narrow windo
254                  !Very broad likely
255                  OK = .false.
256                  write(*,*) 'Reioni
257             end if
258          end if
259
260       end  subroutine Reionizati
261
262
263       function Reionization_dopt
264         real(dl) :: Reionization_d
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 256

```
256       real(dl), intent(in) :: z
257       real(dl) a
258
259       a = 1._dl/(1._dl+z)
260
261       Reionization_doptdepth_dz =
262
263     end function Reionization_dop
264
265   function Reionization_GetOptDe
266     Type(ReionizationParams), tar
267     Type(ReionizationHistory), ta
268     real(dl) Reionization_GetOptD
269
270       ThisReion => Reion
271       ThisReionHist => ReionHist
272       Reionization_GetOptDepth = r
273           Reionization_tol, 20,
274
275   end function Reionization_GetO
276
277     subroutine Reionization_zreFr
278     !General routine to find zre
279     !Not used for Rionization_zex
280       Type(ReionizationParams) ::
281       Type(ReionizationHistory) ::
282       real(dl) try_b, try_t
283       real(dl) tau
284       integer i
285
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 265

```
265       real(dl), intent(in) :: z
266       real(dl) a
267
268       a = 1._dl/(1._dl+z)
269
270       Reionization_doptdepth_dz
271
272     end function Reionization_
273
274     function Reionization_GetO
275     Type(ReionizationParams),
276     Type(ReionizationHistory),
277     real(dl) Reionization_GetO
278
279       ThisReion => Reion
280       ThisReionHist => ReionHist
281       Reionization_GetOptDepth =
282           Reionization_tol, 20,
283
284     end function Reionization_
285
286     subroutine Reionization_zr
287     !General routine to find z
288       use Errors
289       Type(ReionizationParams) :
290       Type(ReionizationHistory)
291       real(dl) try_b, try_t
292       real(dl) tau
293       integer i
294
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 286

```
286       try_b = 0
287       try_t = Reionization_maxz
288       i=0
289       do
290            i=i+1
291            Reion%redshift = (try_t
292            call Reionization_SetPa
293            tau = Reionization_GetO
294
295            if (tau > Reion%optical
296                      try_t = Reio
297               else
298                      try_b = Reio
299            end if
300            if (abs(try_b - try_t)
301            if (i>100) call mpiStop
302       end do
303
304
305        if (abs(tau - Reion%optical
306         write (*,*) 'Reionization_
307         write (*,*) 'tau =',tau, '
308         write (*,*) try_t, try_b
309         call mpiStop()
310       end if
311
312     end subroutine Reionization_z
313
314
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 295

```
295       try_b = 0
296       try_t = Reionization_maxz
297       i=0
298       do
299            i=i+1
300            Reion%redshift = (try_
301            call Reionization_SetP
302            tau = Reionization_Get
303
304            if (tau > Reion%optica
305                try_t = Reion%reds
306            else
307                try_b = Reion%reds
308            end if
309            if (abs(try_b - try_t)
310            if (i>100) call Global
311       end do
312
313
314       if (abs(tau - Reion%optica
315            write (*,*) 'Reionizat
316            write (*,*) 'tau =',ta
317            write (*,*) try_t, try
318            write (*,*) '(If runni
319            call GlobalError('Reio
320       end if
321
322     end subroutine Reionizatio
323
324
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 315

```
315
316      subroutine Reionization_SetFr
317       Type(ReionizationParams) ::
318       Type(ReionizationHistory) ::
319
320     ! This subroutine calculates t
321
322     ! This implementation is appro
323
324          real(dl) dz, optd
325          real(dl) z, tmp, tmpHe
326          integer na
327
328          Reion%redshift = 0
329
330          if (Reion%Reionization .
331
332              !Do binary search t
333              !This is general me
334              call Reionization_z
335
336            if (.false.) then
337              !Use equivalence wit
338               optd=0
339               na=1
340               dz=1._dl/2000/Reio
341               tmp = dz*Reion%fra
342               tmpHe = dz*(Reion%
343               z=0
344               do while (optd < R
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 325

```
325
326        subroutine Reionization_Se
327        Type(ReionizationParams) :
328        Type(ReionizationHistory)
329
330        ! This subroutine calculat
331
332        ! This implementation is a
333
334          real(dl) dz, optd
335          real(dl) z, tmp, tmpHe
336          integer na
337
338          Reion%redshift = 0
339
340          if (Reion%Reionization .an
341
342              !Do binary search to f
343              !This is general metho
344              call Reionization_zreF
345
346              if (.false.) then
347                !Use equivalence w
348                optd=0
349                na=1
350                dz=1._dl/2000/Reio
351                tmp = dz*Reion%fra
352                tmpHe = dz*(Reion%
353                z=0
354                do while (optd < R
```

/Users/lp1opa/Compare/camb_simdata/reionization.f90, Top line: 345

```
345                     z=na*dz
346                     if (include_he
347                     optd=optd+ tmp
348                     else
349                     optd=optd+tmp*
350                     end if
351                     na=na+1
352                 end do
353             end if
354         else
355             Reion%Reionization =
356         end if
357
358     end  subroutine Reionization_
359
360
361
362 end module Reionization
363
364
```

/Users/lp1opa/Compare/camb_des/reionization.f90, Top line: 355

```
355                     z=na*dz
356                     if (include_he
357                         optd=optd+
358                     else
359                         optd=optd+
360                     end if
361                     na=na+1
362                 end do
363             end if
364         else
365             Reion%Reionization = .
366         end if
367
368     end  subroutine Reionizati
369
370
371
372 end module Reionization
373
374
```