Spectral features in ADAS

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Special/Spectral features and tools for modelling them

Not all spectra can be treated as isolated lines

- Quasi-continuum of high-Z ions.
- Zeeman effect.
- Balmer series.
- He-like spectrum.
- Stark split spectrum.

All are controlled by a limited set of inputs which enables the feature to be embedded into a parametrized fitting scheme.

Spectral fitting tools for some of these features are being introduced into ADAS — many still in development so testers required

Normal line emission

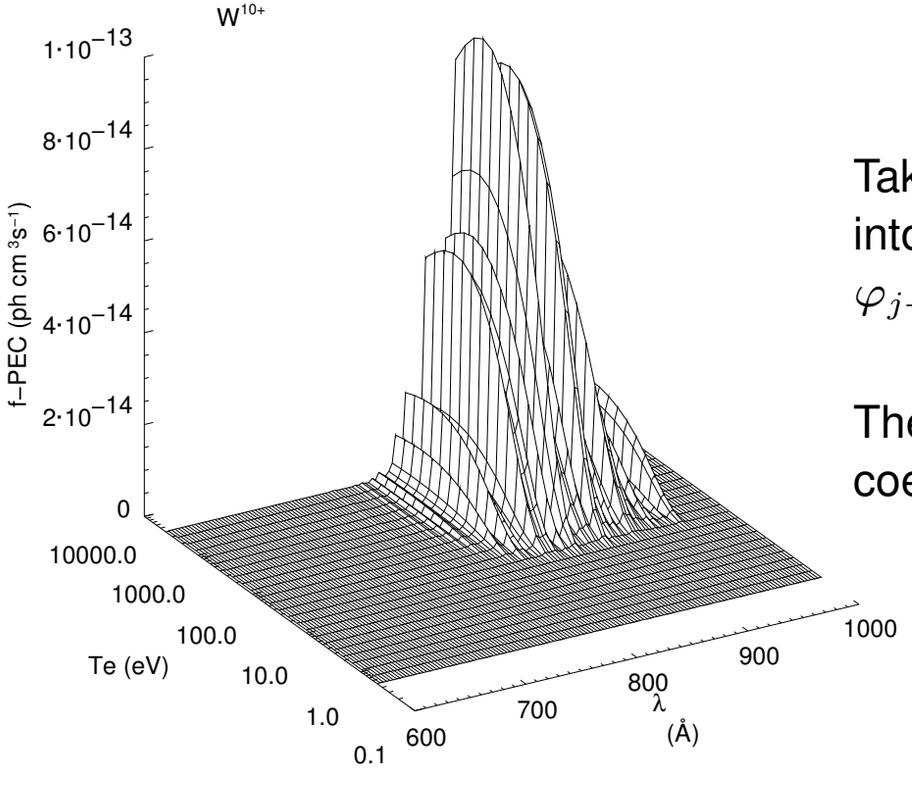
$$I(\lambda) = \int_{Rmin}^{Rmax} \mathcal{PEC}(r) N_e(r) N_z(r) \varphi_{j\rightarrow k}(\lambda)\, dr$$

The simplest line 'feature' is built-up from:

- Population calculation (`adas208`) for $\mathcal{PEC}$
- Measurement of electron density (and temperature) profiles
- Ionisation balance along line of sight (N_z)
  — either transport code or equilibrium balance (`adas405`)
- Spectral profile — plasma and instrumentation ($\varphi_{j\rightarrow k}(\lambda)$)

Feature photon emissivity coefficients

The $\mathcal{F} - \mathcal{PEC}$ is an extension of the familiar line emissivity coefficient.



For an individual line:

$$\varepsilon_{j\to k} = A_{j\to k} \sum_{\sigma=1}^{M} \mathcal{F}_{j\sigma}^{(\mathrm{exc})} N_e N_\sigma$$

Take a spectral interval, $[\lambda_0, \lambda_1]$, subdivided into N pixels and a normalised emission profile, $\varphi_{j\to k}(\lambda)$ for each line.

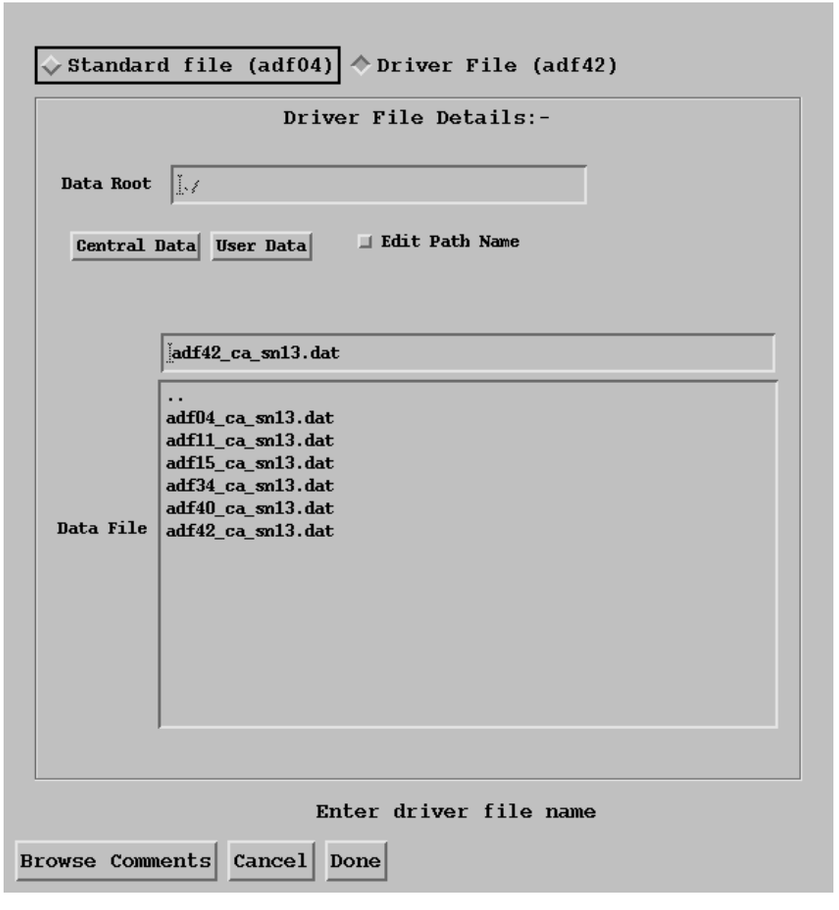
The envelope feature photon emissivity coefficient is:

$$\mathcal{F}\_\mathcal{PEC}_{\sigma,i}^{(\mathrm{exc})[0,1]} =$$

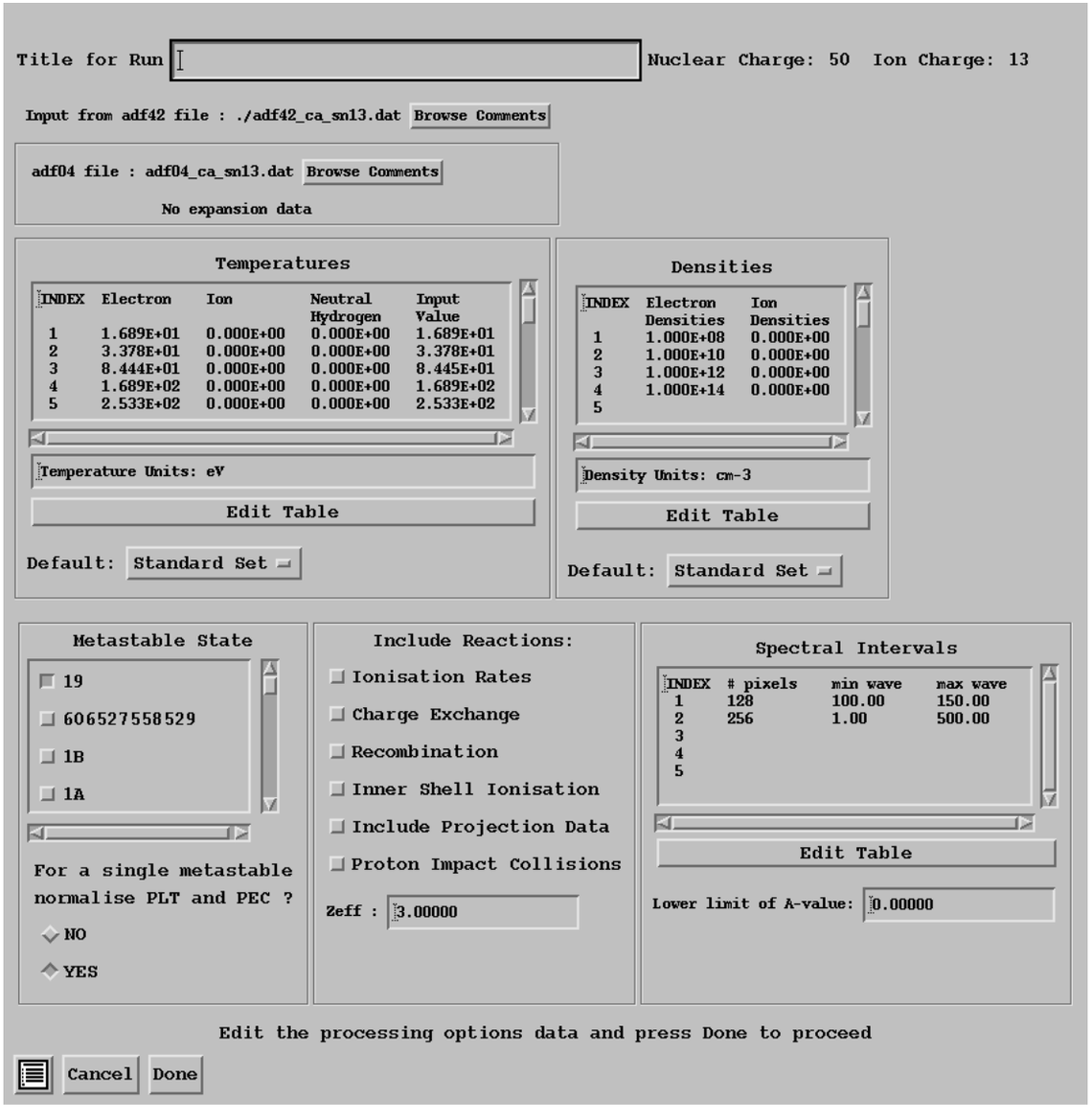
$$\sum_{j,k;\lambda_{j\to k}\in[0,1]} \mathcal{PEC}_{\sigma,j\to k}^{(\mathrm{exc})} \int_{\lambda_i}^{\lambda_{i+1}} \varphi_{j\to k}(\lambda)\, d\lambda,$$

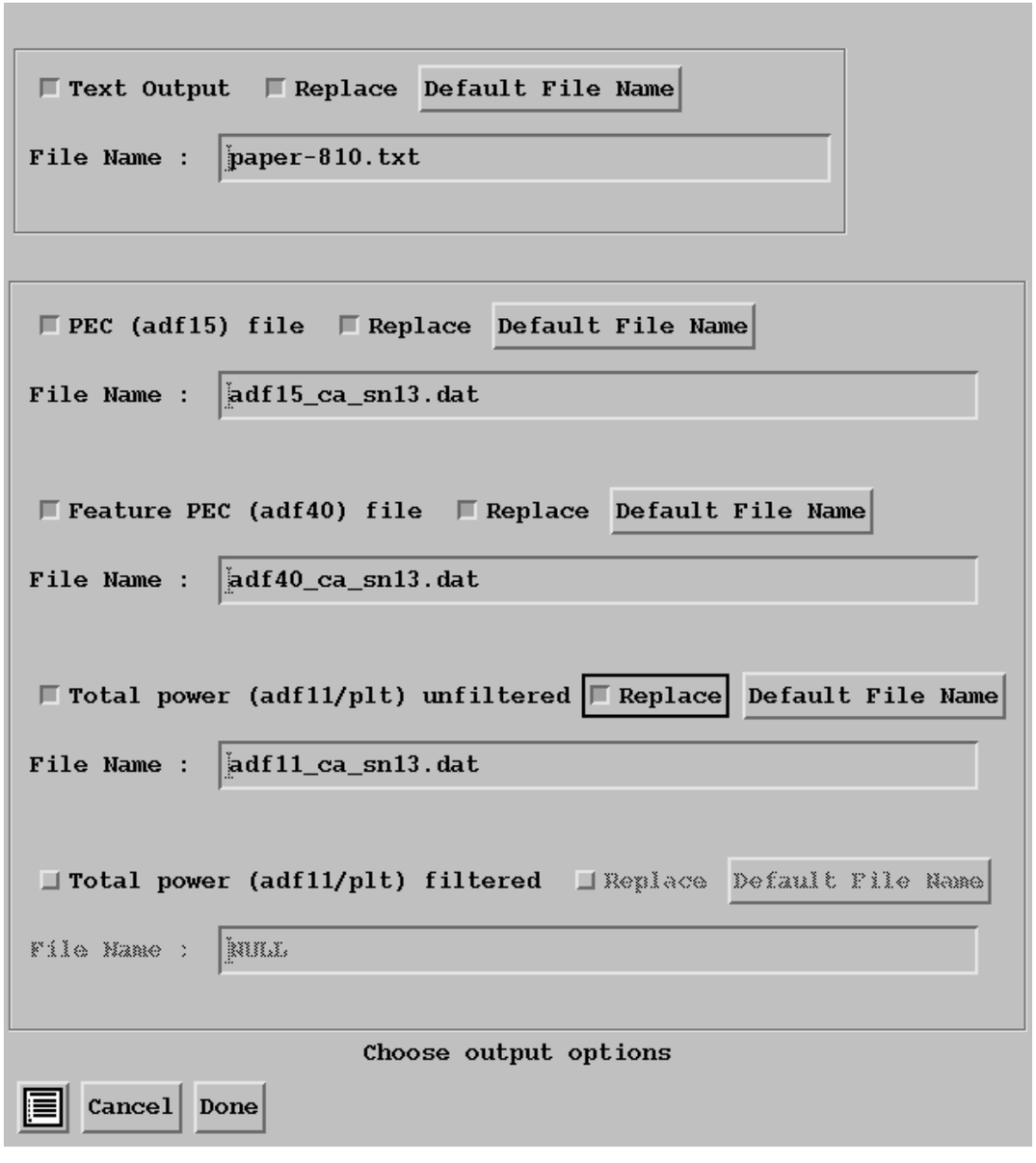
Generating spectral and power data — ADAS810

An *adf42* driver file, made by `adas8xx_create_drivers.pro`, is used by ADAS810 to generate *adf11*/plt, *adf15* and *adf40* datasets.



ADAS801 — review or enter processing parameters




Text Output
Replace
Default File Name
File Name :
paper-810.txt
PEC (adf15) file
Replace
Default File Name
File Name :
adf15_ca_sn13.dat
Feature PEC (adf40) file
Replace
Default File Name
File Name :
adf40_ca_sn13.dat
Total power (adf11/plt) unfiltered
Replace
Default File Name
File Name :
adf11_ca_sn13.dat
Total power (adf11/plt) filtered
Replace
Default File Name
File Name :
NULL
Choose output options
Cancel
Done

IDL (and fortran) routines to access $\mathcal{F} - \mathcal{PEC}$ data

```
IDL> read_adf40,file='/home/adas/adas/adf40/fpec40#w/fpec40#w_ic#w10.dat', fulldata=al

IDL> help, all, /st

   ESYM            STRING    'W '
   IZ0             LONG                74
   IS              LONG                10
   IS1             LONG                11
   NBLOCK          LONG                 3
   NPIX            LONG      Array[3]
   WAVE_MIN        DOUBLE    Array[3]
   WAVE_MAX        DOUBLE    Array[3]
   NTE             LONG      Array[3]
   TE              DOUBLE    Array[14, 3]
   NDENS           LONG      Array[3]
   DENS            DOUBLE    Array[7, 3]
   FPEC            DOUBLE    Array[512, 14, 7, 3]
   TYPE            STRING    Array[3]
```

```
c  energy levels
c  -------------
c
c   lv      configuration    (2S+1)L(w-1/2)      energy (cm^-1)
c  ---   ------------------ --------------      --------------
c    1   60963A52B53C          (1)5(  5.0)            0.0
c    2   60963A52B53C          (3)1(  2.0)         4224.0
c    3   60963A52B53C          (3)3(  3.0)         6625.0
                        .
                        .
                        .
                        .
c 1187   9964A52B53C            (3)2(  2.0)       2062983.4
c 1188   9964A52B53C            (1)3(  3.0)       2072988.6
c 1189   9964A52B53C            (3)2(  1.0)       2073570.9
c 1190   9964A52B53C            (3)1(  0.0)       2080288.6
C
C
C
c-------------------------------------------------------------------------------
C
c  superstage partition information
c  ================================
c
c  element symbol   : W
c  parent template  :
c  partition level  :  1
c  superstage label : 10
c
c  tabulation       : feature photon emissivity coefft (te,ne)
c  units            : ph. emis coef(cm^3 s^-1 pixel^-1); te (ev); ne (cm^-3)
c
c  feature photon emissivity wvln. ranges
c  --------------------------------------
c
c   isel   npix       wvlen range (A)    chrge rnge   type  ispb nspb
c                    wvmin       wvmax    zmn  zmx          ispp nspp     tg pr wr
c  ----- ------- ---------------------- ----------   ----- ---- ----     -- -- --
c      1    128      1.0000     10.0000    10   10   excit   1    1       1  3  1
c      2    128     10.0000    100.0000    10   10   excit   1    1       2  2  3
c      3    512      1.0000  10000.0000    10   10   excit   1    1       3  1  2
c-------------------------------------------------------------------------------
c
c  code     : adas810
c  producer : Adam Foster
c  date     : 15/05/09
c
c-------------------------------------------------------------------------------
```

Interpolate onto our plasma conditions of interest

```
IDL> wave=adas_vector(low=all.wave_min[0], high=all.wave_max[0], $
                      num=all.npix[0], /linear)

IDL> file = '/home/adas/adas/adf40/fpec40#w/fpec40#w_ic#w10.dat'
ILD> read_adf40, file=file, block=1, te=te, dens=dens, data=fpec_w10
```

For fortran call `xxdata_40.for` to read in the data and `e3spln.for` to interpolate these on the temperature and density pairs of interest.

Hyperfine effects

ADAS603 — Zeeman/Paschen-Back effect

The spectral feature is the connected set of spectrum lines from magnetic field perturbation of multiplet components for a specified $LS \rightarrow L'S'$.

- $\lambda_{LSJM-L'S'J'M'}$
- Depends on magnetic field **B**.
- Polarisation depends on whether $M = M', M'+1, M'-1$
- Emissivities are proportional ro viewing angle.

Three IDL routines to retrieve the component data:

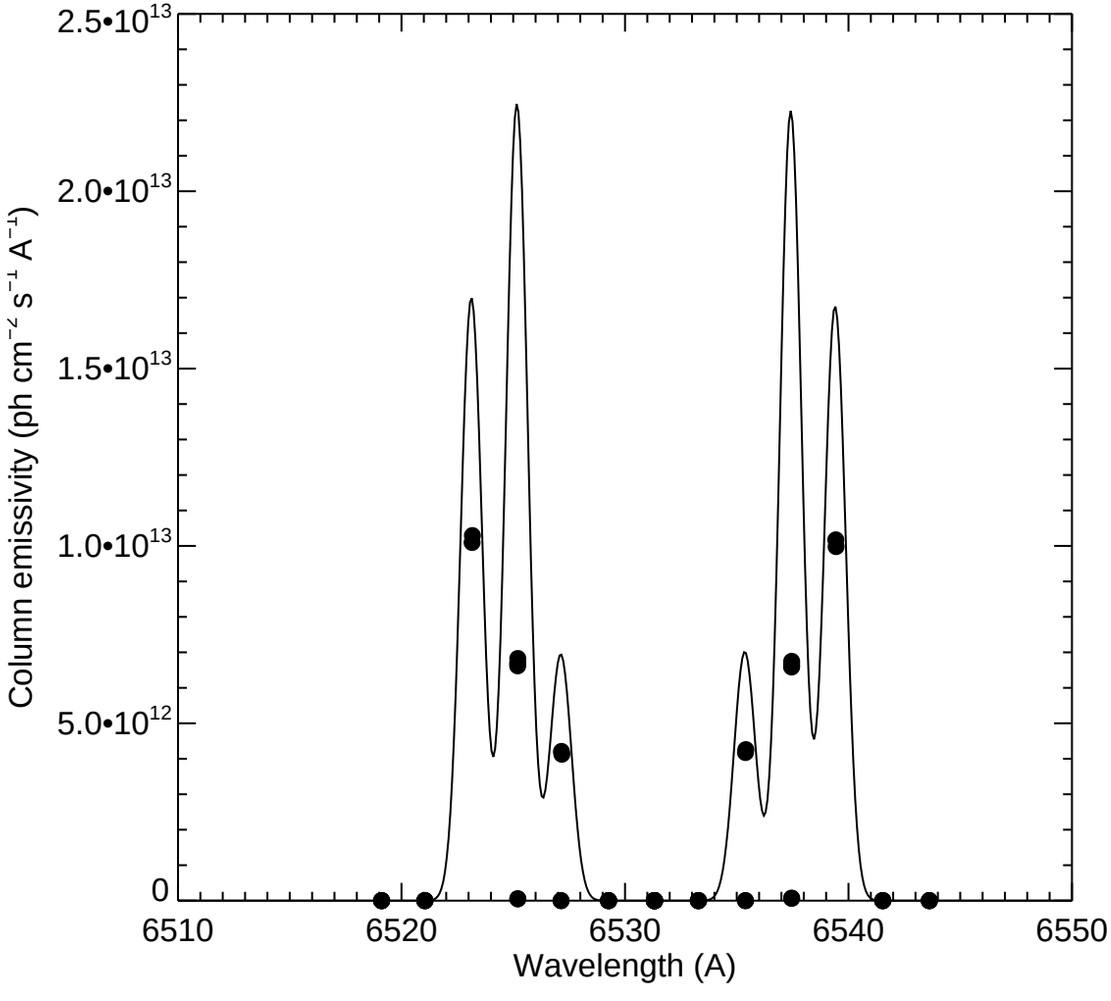
- `adas603_get_multiplets.pro` lists available elements and transitions.
- `adas603_get_hdlike.pro` for H-like (H, D, T, He, C and Ne)
- `adas603_get_zeeman.pro` for other ions

Hyperfine effects

ADAS305 — Stark split beam emission

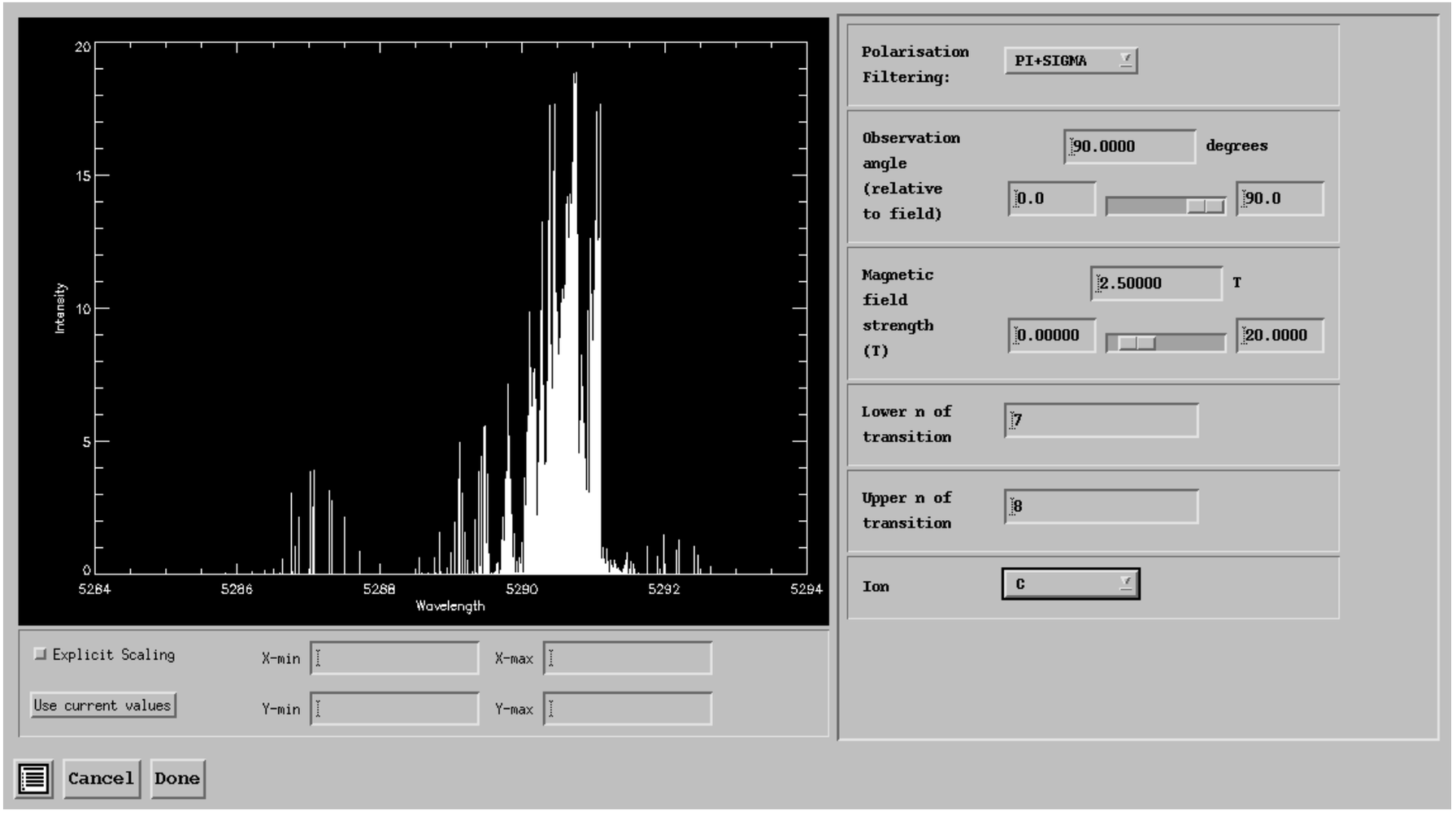
A non-interactive code which calculates the hydrogen Balmer-α spectrum split into components due to the plasma magnetic field and arbitrary electric fields.

```
beam   = {mass : 2.0, energy : 40.0e3, te : 10.0, density : 4.27e9, $
          dc_x : 0.0, dc_y : 0.0, dc_z : 1.0}
plasma = {mass : 2.0, te : 8e3, density : 5.0e13, zeff : 2.0}
bfield = {value : 3.3915, dc_x : 0.788, dc_y : 0.0053, dc_z : 0.6152}
efield = {value : 0.0000, dc_x : 1.000, dc_y : 0.0000, dc_z : 0.0000}
obs    = {dc_x : 0.8701, dc_y : -0.047, dc_z : 0.4905, sigma : 0.00, pi : 1.0}

wave_min = 6510
wave_max = 6550
npix     = 500

adas305_get_stark,  beam           = beam,          $
                    plasma         = plasma,        $
                    bfield         = bfield,        $
                    efield         = efield,        $
                    obs            = obs,           $
                    n_lower        = 2,             $
                    n_upper        = 3,             $
                    wave_comp      = wave_comp,     $
                    emiss_comp     = emiss_comp,    $
                    wave_min       = wave_min,      $
                    wave_max       = wave_max,      $
                    npix           = npix,          $
                    emiss_doppler  = demiss   , /doppler  ; , /nocheck


wave  = adas_vector(low=wave_min,high=wave_max,num=npix, /linear)
dwave = wave[1]-wave[0]

plot, wave, demiss/dwave, $
      xtitle = 'Wavelength (A)', $
      ytitle = 'Column emissivity (ph cm!u-2!n s!u-1!n A!u-1!n)'

plots, wave_comp, emiss_comp, psym=sym(1)
```

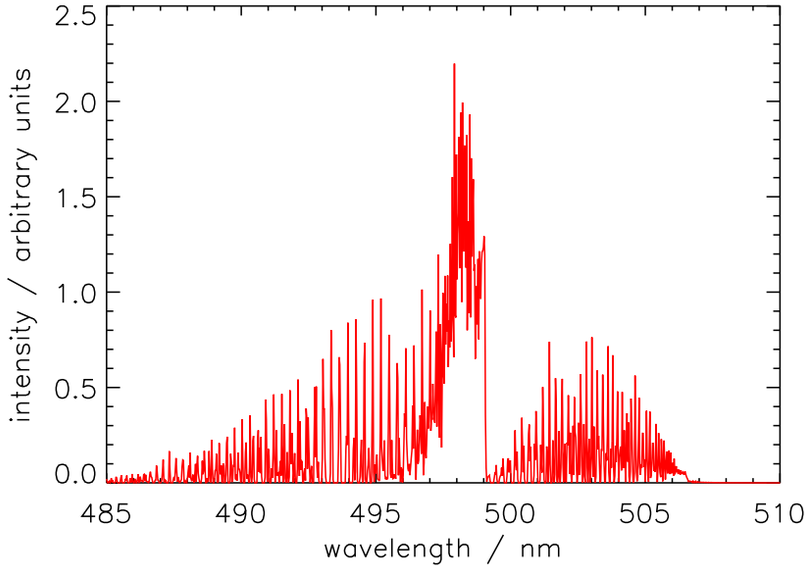

2.5•10^13
2.0•10^13
1.5•10^13
1.0•10^13
5.0•10^12
0
Column emissivity (ph cm^-2 s^-1 A^-1)
6510
6520
6530
6540
6550
Wavelength (A)

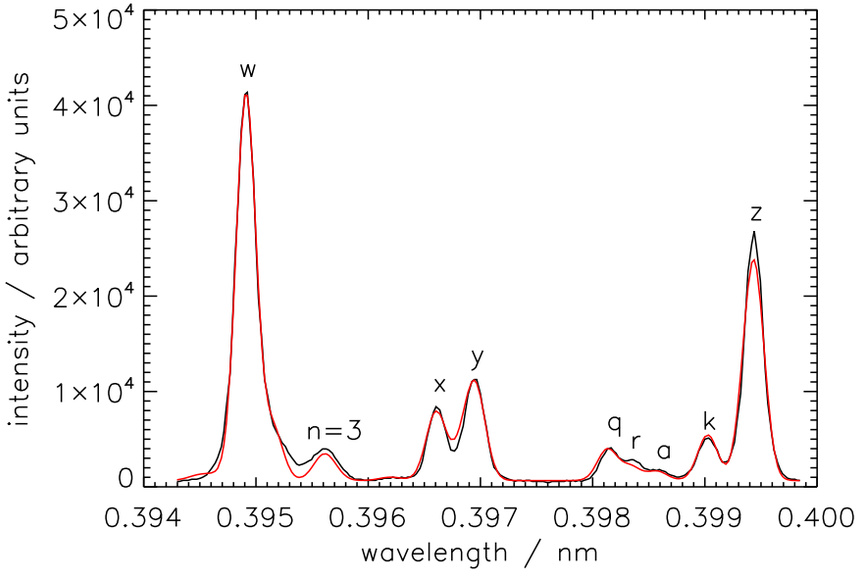
Hyperfine effects — explore with ADAS605

A pedagogical tool to explore the response to feature inputs



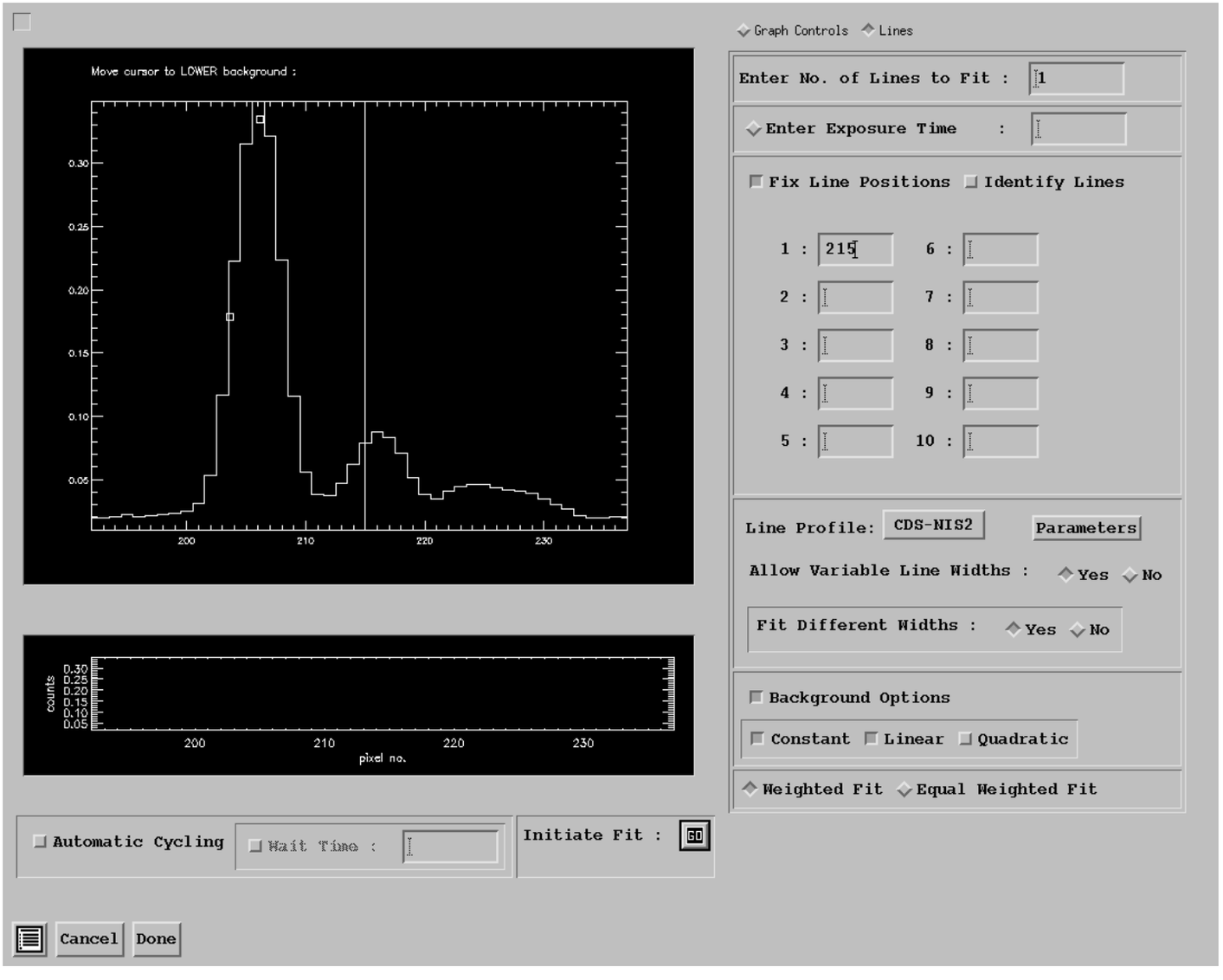
Other features



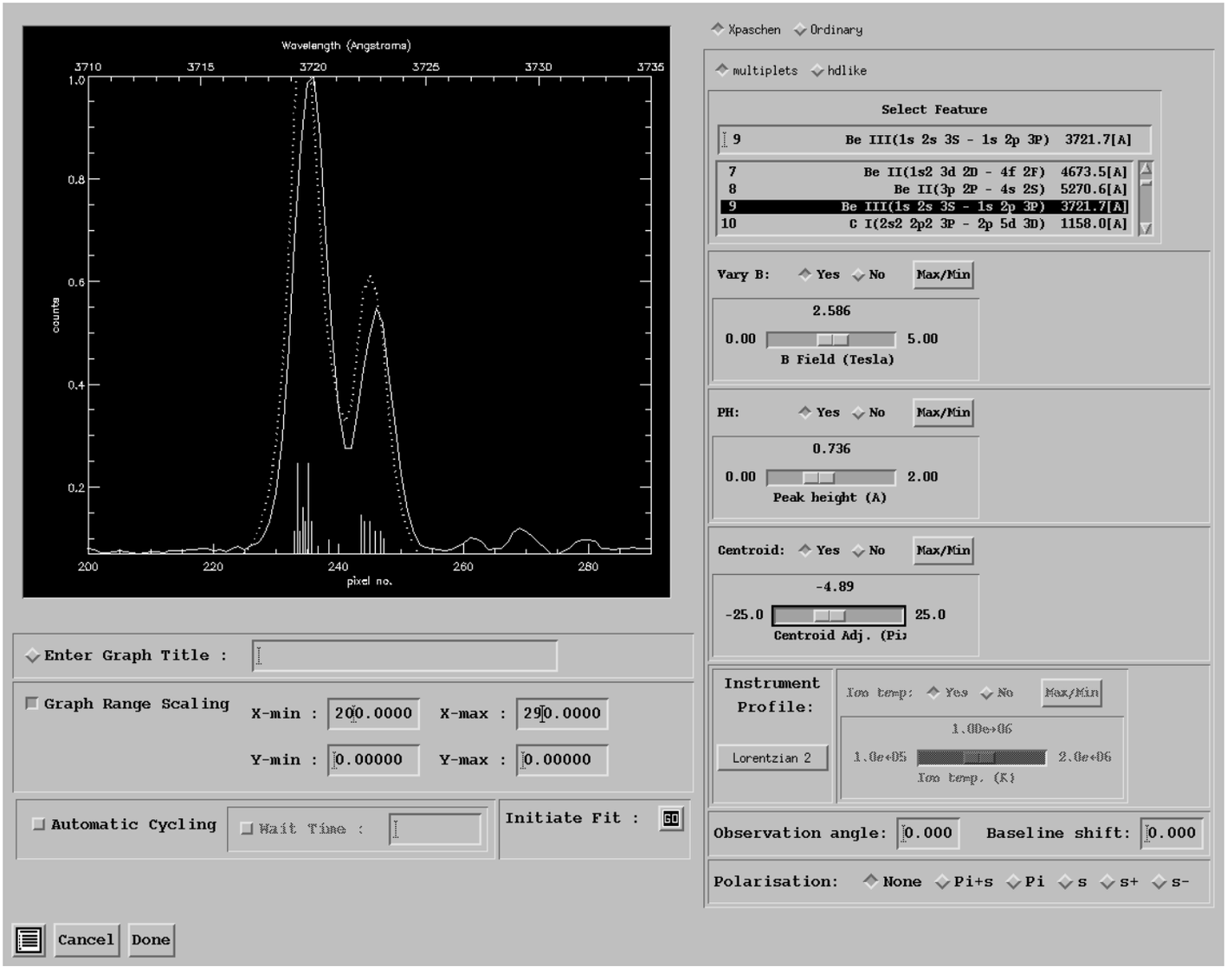


- CALCAT/Pickett code for diatomic band features (not in central ADAS)
  — ADAS series 9 is a more complete picture
- Atomic data for He-like DR feature present in ADAS
  — specialized population code `adas218` awaiting integration.
- PPP code for series has been used in the past.

ADS602 — line fitting code



ADS603 — Zeeman feature line fitting code



ADAS future development — afg/ffs

afg — ADAS feature generator
ffs — functions for spectral fitting

```
Model                          |    IDL ffs coding
====================           |    ====================
                               |
(model martin                  |     model    = obj_new('ffs_model', modelname='mymodel', /debug)
    (+                         |     parser   = obj_new('ffs_parser', file='my.mdl', /debug)
        (gaussian g1)          |
        (gaussian g2)          |     ffsfit   = obj_new('ffs_fit', /debug)
        (gaussian g3)          |     data     = {x:wave, y:em_dp, error:(sqrt(em_dp)>0.01)}
    )                          |     isok     = ffsfit->apply(model, data)
)                              |     final    = *(model->getresult())
                               |     residual = (final.intensity - em_dp) / em_dp
                               |
(setval g1.pos 5287.0)         |
(setval g1.area 1.0e6)         |
(setval g1.fwhm 0.2)           |
                               |
(setval g2.pos 5290.0)         |
(setval g2.area 1.0e11)        |
(setval g2.fwhm 0.7)           |
                               |
(setval g3.pos 5291.0)         |
(setval g3.area 1.0e11)        |
(setval g3.fwhm 0.7)           |
```