A new MARCS generation

Still 1D, LTE, MLT, but with updated opacities and an extended parameter range

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and more

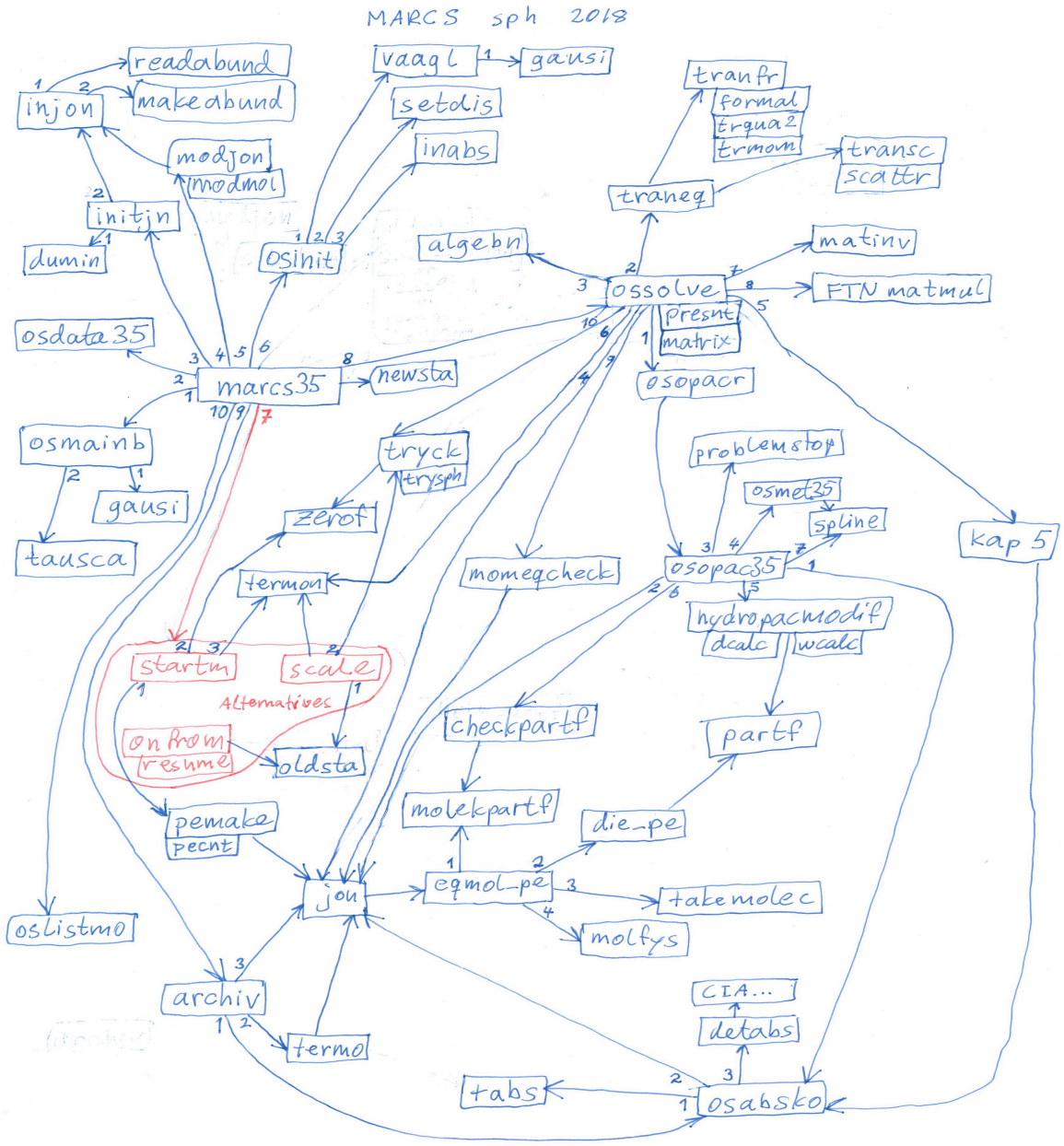
My background since 1981

- Stellar spectra of late-type stars
  - observed and synthetic
- Elemental abundances in stars
- Chemical evolution of the Galaxy
- Stellar parameter determinations
- Test fluxes for GAIA preparations and BCs
- Boundary conditions for ★ interior models
- MARCS contributor & www site

MARCS

(Model Atmospheres in a Radiative and Convective Scheme)

- is a FORTRAN code for the calculation of 1D (plane-parallell and spherical) hydrostatic model atmospheres in LTE
- Gustafsson et al. (1975) – ODF approximation
- Opacity sampling (OS) introduced in the 90's
- Gustafsson et al. (2008) – Uppsala web model grid
- Used in the calculation of synthetic spectra, chemical abundances and SEDs, and as boundary conditions for stellar interior models


MARCS sph 2018
readabund
injon
makeabund
vaagl
gausi
setdis
inabs
modjon
modmol
initjn
dumin
osinit
algebn
tranfr
formal
trqua2
trmom
transc
scattr
traneq
matinv
ossolve
FTN matmul
presnt
matrix
osopacr
osdata35
marcs35
newsta
osmainb
gausi
tausca
tryck
trysph
zerof
termon
problemstop
osmet35
spline
kap 5
momeqcheck
osopac35
hydropacmodif
dcalc
wcalc
startm
scale
Alternatives
on from
resume
oldsta
checkpartf
partf
pemake
pecnt
molekpartf
die_pe
jon
eqmol_pe
takemolec
molfys
oslistmo
archiv
termo
CIA...
detabs
tabs
osabsko

MARCS uses

- We make models tailored for our own projects, mainly abundance analyses
- Easy to produce extensive grids
- MARCS is currently in wide use
- > 50 000 models on the www site:
- T_{eff} 2500 − 8000 K, log g 5.5 − 0, [Fe/H] -5 - +1, varying [α/Fe]
- Included in the SME package (Piskunov & Valenti 2017)

Another generation, Why?

- Our opacities are getting old, much new good atomic and molecular data is available and forthcoming
- We want to make also A stars (Vega, Sirius)
- Selected for GAIA and possibly for PLATO, grids for APOGEE, large international projects

Developments

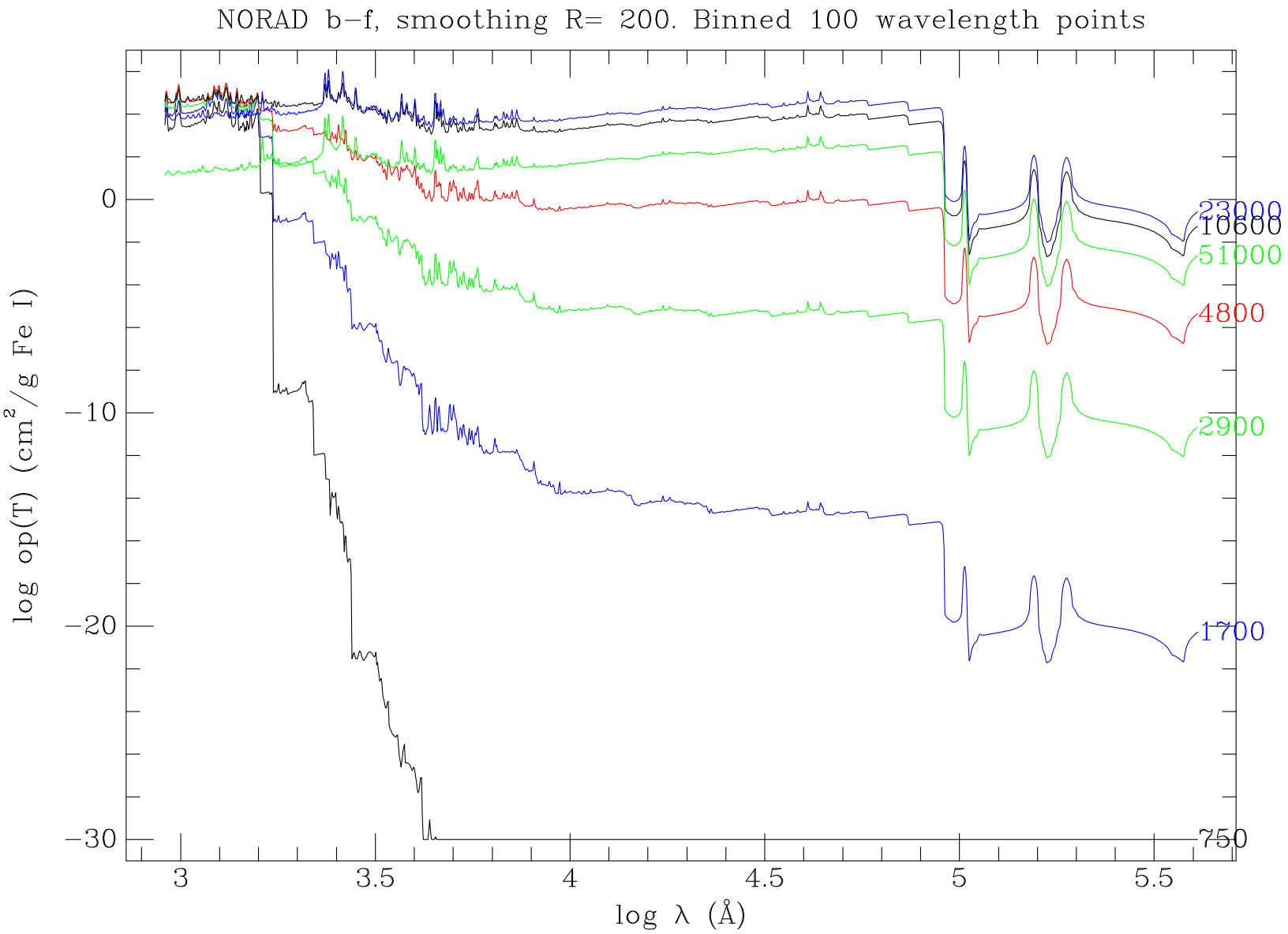
- Double precision introduced (not without some effort):
  – all models in spherical symmetry
- OS also for ”continuous” opacities:
  – the TOP (Bautista et al.) and NORAD (Nahar et al.) data bases contain 100’s of energy levels with detailed bound-free cross sections for each of many important atomic and ionic species. These contain resonances that may appear almost as spectral lines

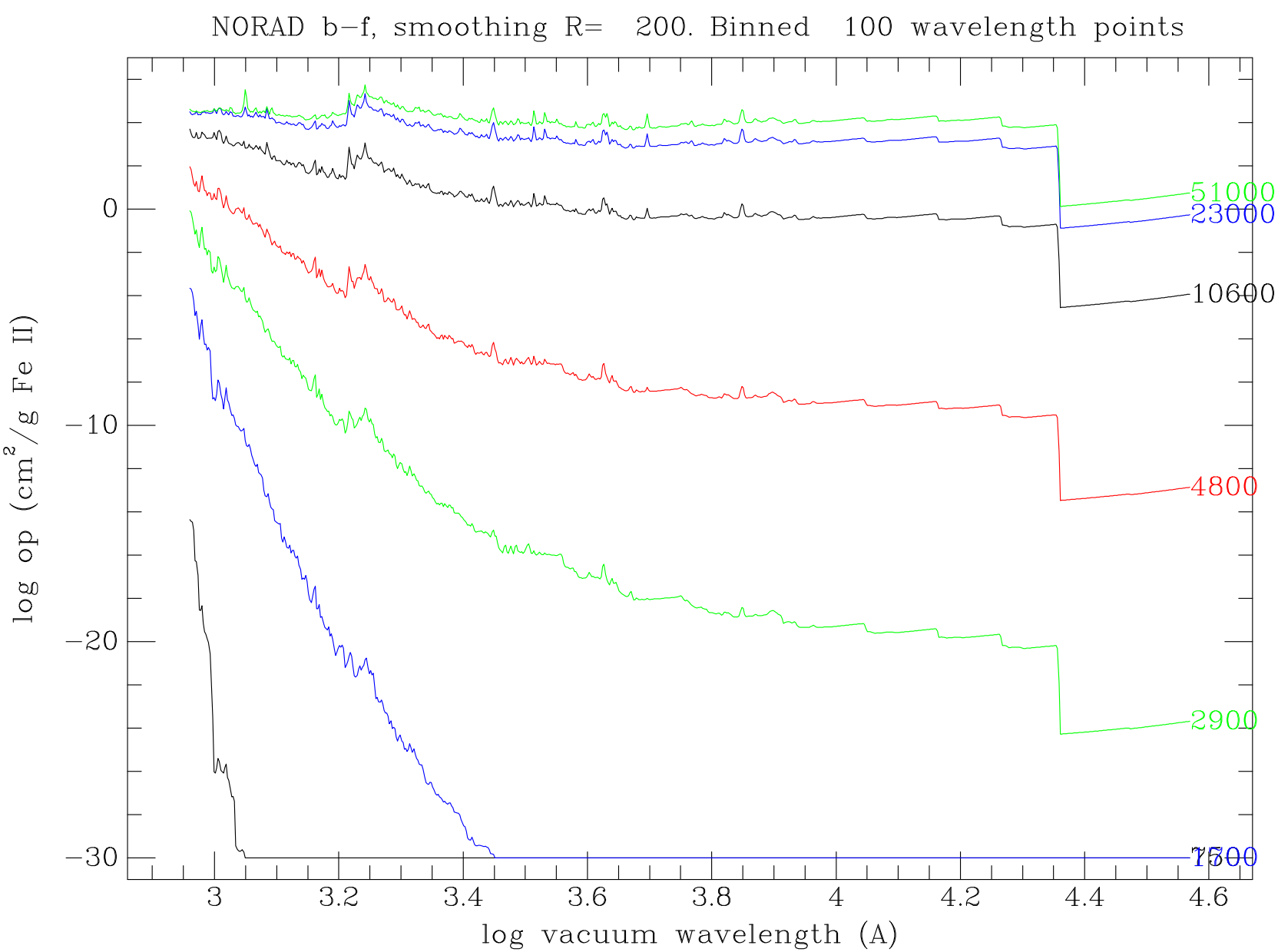
Our textbooks claimed that

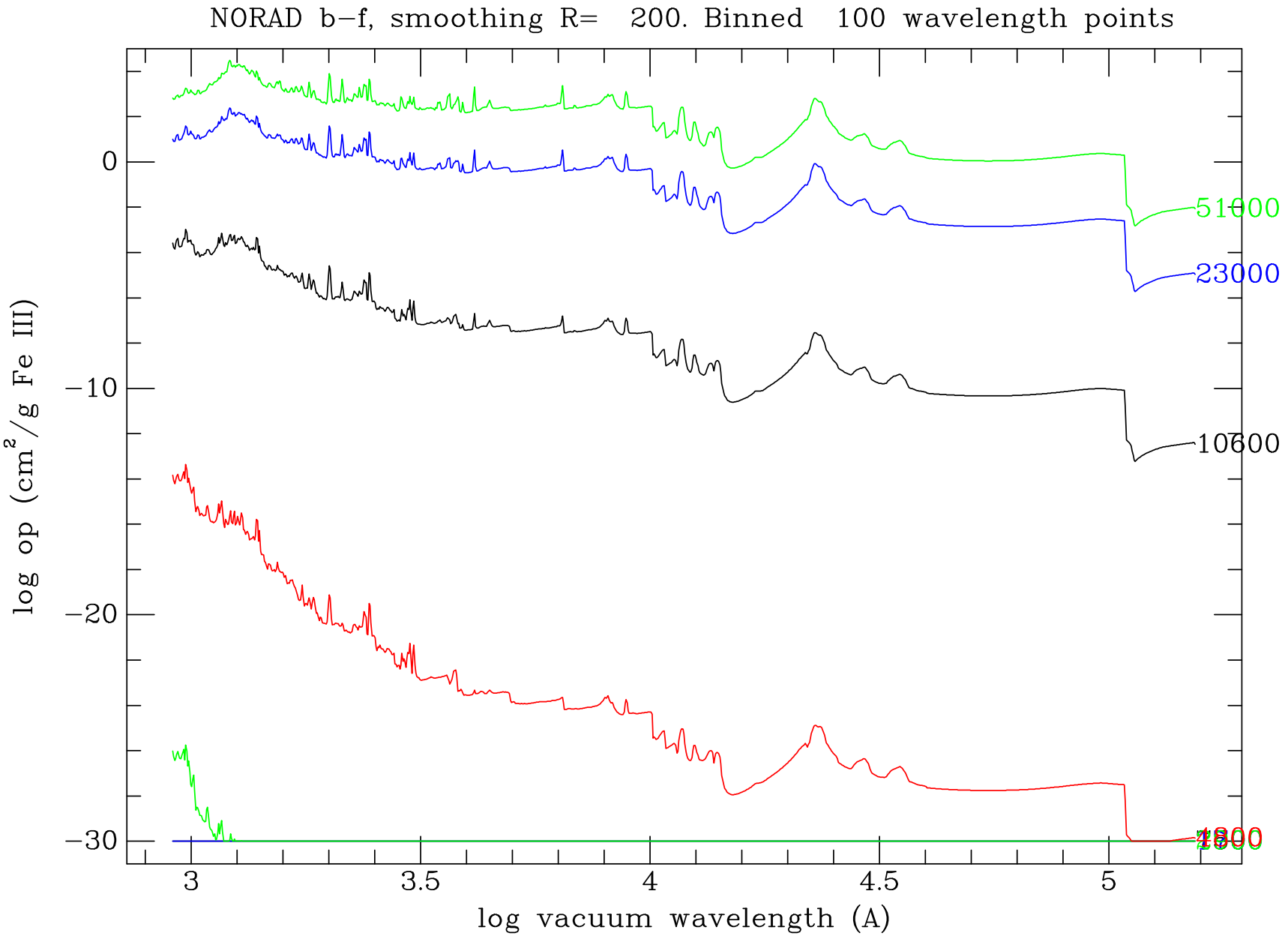
Continuous opacities are smoothly varying functions of wavelength with some sudden cutoffs

That's what's in MARCS now

In reality they often look like hedge hogs

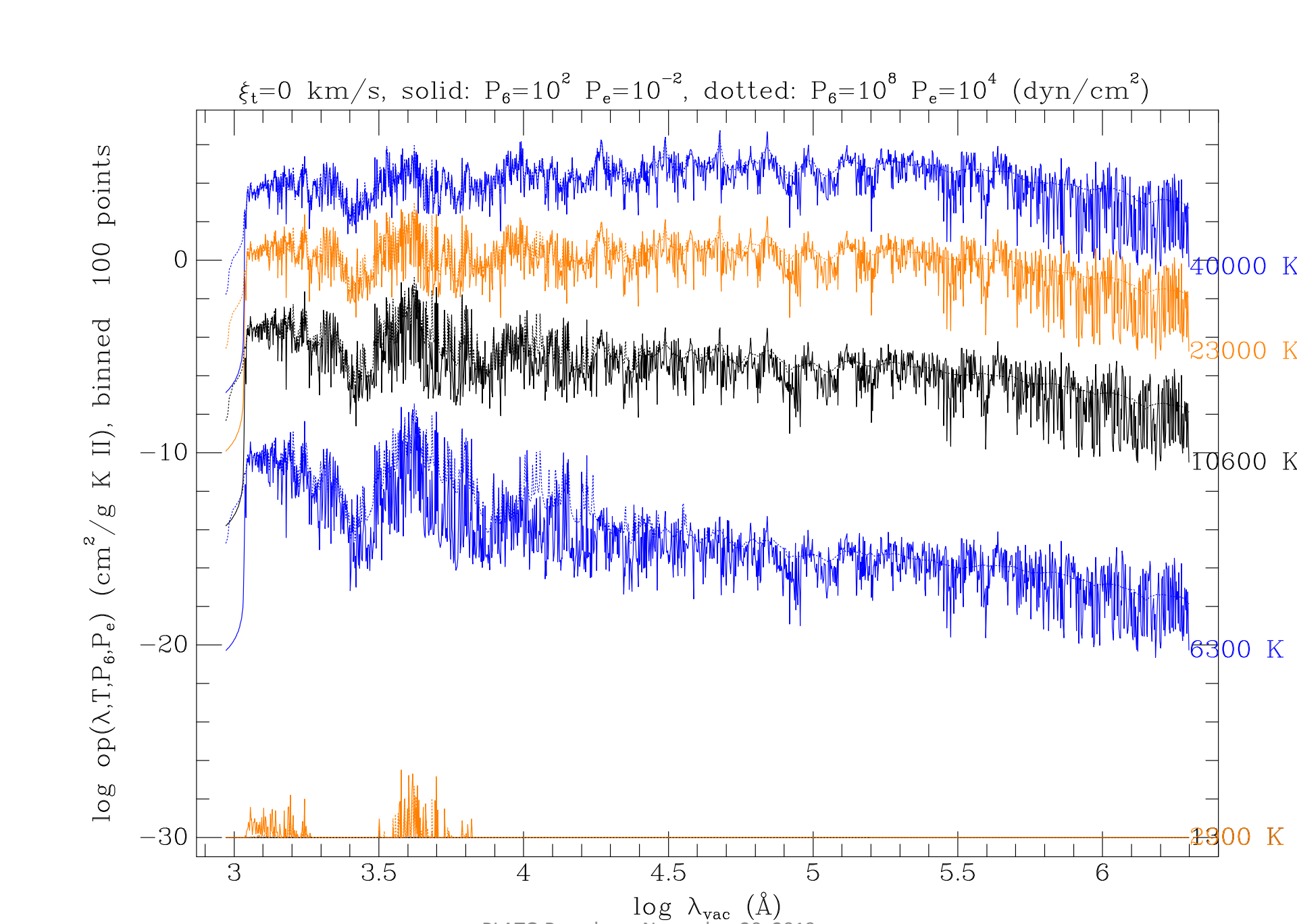

NORAD b−f, smoothing R= 200. Binned 100 wavelength points
log op(T) (cm²/g Fe I)
0
−10
−20
−30
3
3.5
4
4.5
5
5.5
log λ (Å)
23000
10600
51000
4800
2900
1700
750

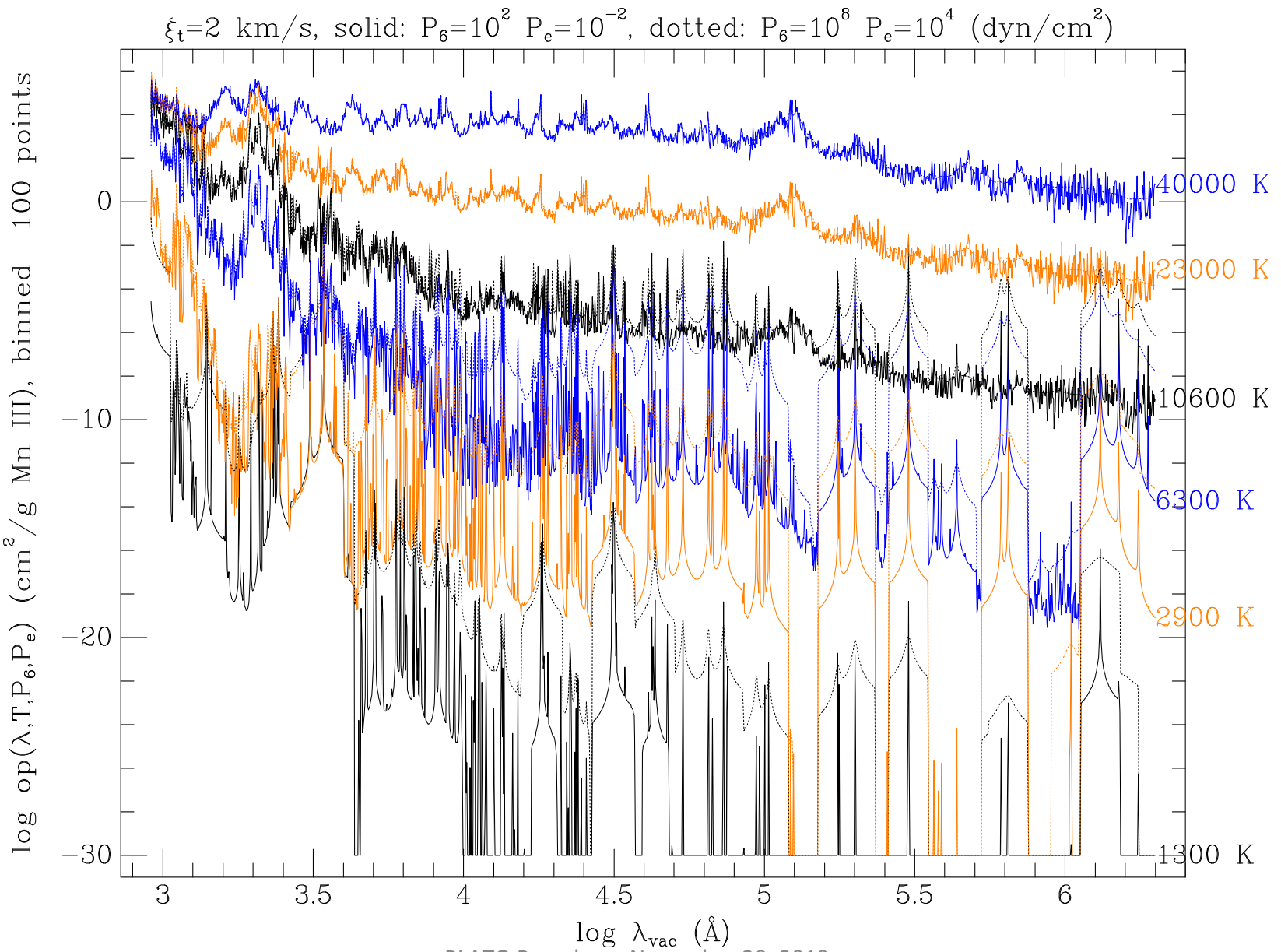

NORAD b−f, smoothing R= 200. Binned 100 wavelength points
log op (cm²/g Fe II)
0
−10
−20
−30
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
log vacuum wavelength (A)
51000
23000
10600
4800
2900
1500


NORAD b−f, smoothing R= 200. Binned 100 wavelength points
log op (cm²/g Fe III)
0
−10
−20
−30
3
3.5
4
4.5
5
log vacuum wavelength (A)
51000
23000
10600
4800

Metal line data from VALD 3

- The latest VALD data for neutral, singly and doubly ionized metals were assembled
- For several iron-peak species over a million lines are available between 910 A and 200 micrometers
- These were tabulated for each of 197 species as log opacity(T,P_6,P_e,ξ_t) for > 150 000 wavelength points
- P_e is a ”new” parameter to enable A star models where quadratic Stark broadening becomes important


ξt=0 km/s, solid: P6=10^2 Pe=10^-2, dotted: P6=10^8 Pe=10^4 (dyn/cm^2)
log op(λ,T,P6,Pe) (cm^2/g K II), binned 100 points
0
−10
−20
−30
3
3.5
4
4.5
5
5.5
6
log λvac (Å)
40000 K
23000 K
10600 K
6300 K
2300 K


ξ_t=2 km/s, solid: $P_6=10^2$ $P_e=10^{-2}$, dotted: $P_6=10^8$ $P_e=10^4$ (dyn/cm^2)
log op(λ,T,P_6,P_e) (cm^2/g Mn III), binned 100 points
log λ_{vac} (Å)
40000 K
23000 K
10600 K
6300 K
2900 K
1300 K
0
−10
−20
−30
3
3.5
4
4.5
5
5.5
6

Summing of opacities

- A model grid is made for a specific composition
- The ”equation of state” is computed for the chemical composition and all metallic line species are added in one table for all combinations of T, P_6 and P_e at one ξ_t and all wavelength points
- The contiuous species are similarly merged into one table
- The molecular opacities which are only T dependent are used individually in the final model calculation

MARCSism for PLATO

- We need to know the stars around which our planets evolve
- 3D LTE models are beginning to appear, e.g., the Stagger grid by Collet, Aplund and colleagues
- MARCS is old-fashioned, 1D, LTE, but can be made in large amounts with small parameter increments
- Can be used for simulating PLATO data and testing PLATO data reductions
- The differential effects of changes (e.g. in individual elemental abundances, T_{eff} or log g) can be easily mapped

Auxiliary tools

- MARCS web site in Uppsala (since 2008)
- New web site in Montpellier (by new year?)
- Our synthetic spectrum codes are using the MARCS data and subroutines (+ any desired line list):
- Turbospectrum in Montpellier – on www
- BSYN in Uppsala

MARCS fluxes ≠ spectra (Plez 2008)