The VALD Database

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and the **VALD** team

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T. Ryabchikova

INASAN, Moscow, Russia

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N. Piskunov, U. Heiter, H.C. Stempels

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Further input has been taken from the VALD and VAMDC homepages at http://vald.astro.univie.ac.at/~vald/php/vald.php and http://www.vamdc.eu/.

Further information at http://www.astro.uu.se/valdwiki/FrontPage.

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The VALD Team I

- **Locations of VALD Team and Servers**
  - Vienna: Inst. for Astronomy (founding site, main server site)
  - Uppsala: Observatory (mirror site, now main developer site)
  - Moscow: Institute of Astronomy RAS (mirror site, now main data collection site)
  - non-public mirror sites: GSFC, STSI Baltimore, AIP Potsdam (VALD-2, US sites no longer maintained for practical reasons)
- **Team Members of VALD-2**

  P. Barklem, F. Kupka, N.E. Piskunov, T.A. Ryabchikova, H.C. Stempels, W.W. Weiss
- **Collaborators & Data providers of VALD-2**

  CCP7, NIST, R.L. Kurucz, C.R. Cowley (initially, followed by many more in the mean time → VALD-3)

The VALD Team II

- **Team Members of VALD-3 (Software, Core Team)**
  - Uppsala: N. Piskunov, U. Heiter, H.C. Stempels, P. Barklem, O. Kochukhov (+ VAMDC team: T. Marquart, S. Regandell)
  - Moscow: T. Ryabchikova, Yu. Pakhomov, R. Kildiyarova
  - Vienna: F. Kupka, T. Rank-Lüftinger, W.W. Weiss (previous members: L. Fossati, N. Nesvacil, M. Obbrugger, Ch. Stütz)
- **Members of the VALD-3 data providing teams**
  - Univ. of Wisconsin: J.E. Lawler, E.A. Den Hartog, et al. (REE)
  - Lund University: Lund team (Fe peak, Th+U)
  - DREAM Database: E. Biemont, et al. (REE)
  - Univ. of Montpellier: B. Plez (molecules)

VALD Publications

Main publications on VALD-1 and VALD-2

- VALD-1: Piskunov N.E., Kupka F., Ryabchikova T.A., Weiss W.W., Jeffery C.S., A&AS 112, 525 (1995)
- VALD-2: Kupka F., Piskunov N.E., Ryabchikova T.A., Stempels H.C., Weiss W.W., A&AS 138, 119 (1999)
- VALD-2/Overview: Ryabchikova T.A., Piskunov N.E., Stempels H.C., Kupka F., Weiss W.W., Physica Scripta T83, 162 (1999)
- **VALD-3: datasets online, publications in preparation**

VALD Concepts and Facilities I

Goal of the VALD project

- compile accurate and complete line lists
  → for stellar atmospheres & spectroscopy
- evaluate line lists → provide a ranking
- provide a database which features
  - expandability with respect to data and contents
  - simple access through “customized” extraction software
  - fast access to individual data entries
  - an overview of parameters from different sources
  - compilation of data references and provision of quality criteria
  - to extract sets of best data according to data ranking lists

VALD Concepts and Facilities II

General architecture

- Standard data format
  - units which are common in astrophysics
  - one record with fixed length per spectral line
- Semi-direct access (compressed binary line lists)
- Ranking (for merging data)
- Multiple extraction layers within VALD-2:
  - access files / merge VALD data
  - prepare output for applications
  - remote access (EMS)
  - Web interface for EMS

VALD Concepts and Facilities III

File format of VALD-2 data

- each line of each list: 1 record, fixed length
- junks of 1024 lines: compressed, index file (λ sorted), compression factor ~ 25...40

One VALD-2 Data record is one VALD line

- Mandatory entries (no defaults)
  - central λ, species identifier, log(*gf*), E_i, J_i, E_k, J_k
- Optional entries (defaults exist)
  - g_i, g_k, $\log(\Gamma_r)$, $\log(\Gamma_s)$, $\log(\Gamma_w)$, terms (i,k), accuracy, comments (multiplets, e.g.)
  - flags (links to specific data for a line & to other data bases)

VALD Concepts and Facilities IV

Ranking Lists

- generic extraction constraints
  - wavelength window: species + J values + $\Delta E_k < 0.1\%$ → $\Delta\lambda$
  - max. spectrum number
  - max. excitation potential
- extraction constraints for merging line data
  - VALD internal index number (switch list status to on / off)
  - element range of list
  - ranking for λ, *gf*, E_i, E_k, $\langle g_{eff} \rangle$, Γ_r, Γ_s, Γ_w, level classification
- VALD default ranking or user defined ranking

VALD Concepts and Facilities V

Extraction constraints & ranking

- Line found in different source lists ?

  → choose for each atomic parameter the value from the list with the highest ranking

- Line lists
  - homogeneous, high quality → high ranking
  - inhomogeneous or low quality → low ranking
  - VALD made lists for homogenization → usually high ranking
  - separate line lists usually correspond to separate data files

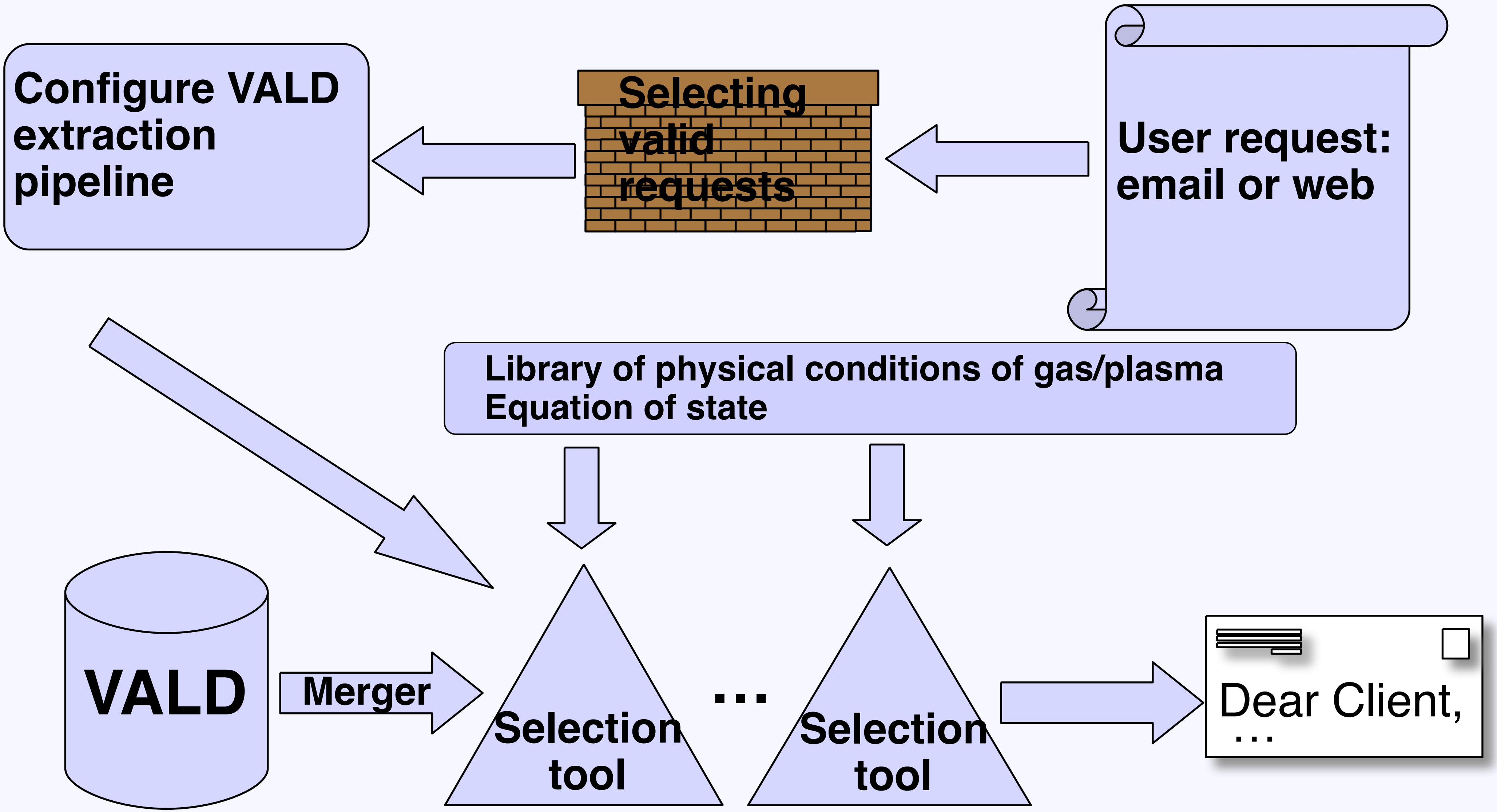
VALD Concepts and Facilities VI

Quality determination based on

- Error estimates from original sources
- Intercomparison of existing, alternative sources
- Applications in astrophysics (user feedback)
- Reranking possible
- General guidelines
  - prefer experimental data over calculations
    (with few exceptions such as the work of Uyling & Raassen)
  - prefer data with individual error estimates

VALD Structure

VALD from outside...



VALD-3 and the Current Status of VALD

- **General status of VALD-3:**
  - Over 150 line lists, over 66 million atomic lines provided by all major spectroscopy centers across the world
  - Mirror sites in Vienna, Uppsala and Moscow
  - Close to 1500 users from more than 50 countries, on average 30 requests processed per day
- **VALD-3 integration into VAMDC:**
  - many VALD features available now available through VAMDC portal
  - Uppsala node and Moscow node have VAMDC server software running (with / without predicted level lines), integration of Vienna node in preparation
  - Detailed, deep referencing (referencing inside merged lists)

The VALD-3 Release I

- data is still sorted as a function of wavelength and
- still stored in a special compressed format with semi-direct access
- stored data (changes & additions indicated) contains:
  - species, wavelengths (Å, vac), level energies (now cm^{-1}), total angular momentum quantum number, log *gf,* Landé-factors, damping constants, accuracy in log *gf,* data reference, full level designation and term name
- publishing a new dataset in VALD means adding a new data file
- data description stored in various support files (list of species, configuration file)
- configuration file stores ranks for every field in each file
- reference data of each data set provided in BibTeX format

The VALD-3 Release II

- in addition to many smaller new lists from data providers previously mentioned VALD-3 containts the
- New Kurucz Calculations (2006-2010) for Fe-peak elements
- Model-based selection improved:
  - for a set P-T-[abundance] VALD-3 solves the equation of state and estimates the contribution to opacities,
  - if a sequence of P-T is available (e.g. model atmosphere), VALD-3 will solve the radiative transfer to predict the line strength.

The VALD-3 Release III

Number of lines in new (experimental and predicted) and old (total) Kurucz data:

	new		old
	exp	pred	
Sc I	15546	737992	191253
Sc II	3436	116491	49811
Sc V	2180	645368	130563
Ti I	33815	4758992	867399
Ti II	8188	835027	264867
Ti III	4090	499739	23742
V I	23342	7043556	1156790
V II	18389	3932853	925330
V III	9892	966528	284003
Cr I	35315	2582957	434773
Cr II	58996	6970052	1304043
Cr III	23150	5535931	990951
Mn I	16798	1481464	327741
Mn II	31437	4523390	878996
Mn III	17294	10525088	1589314

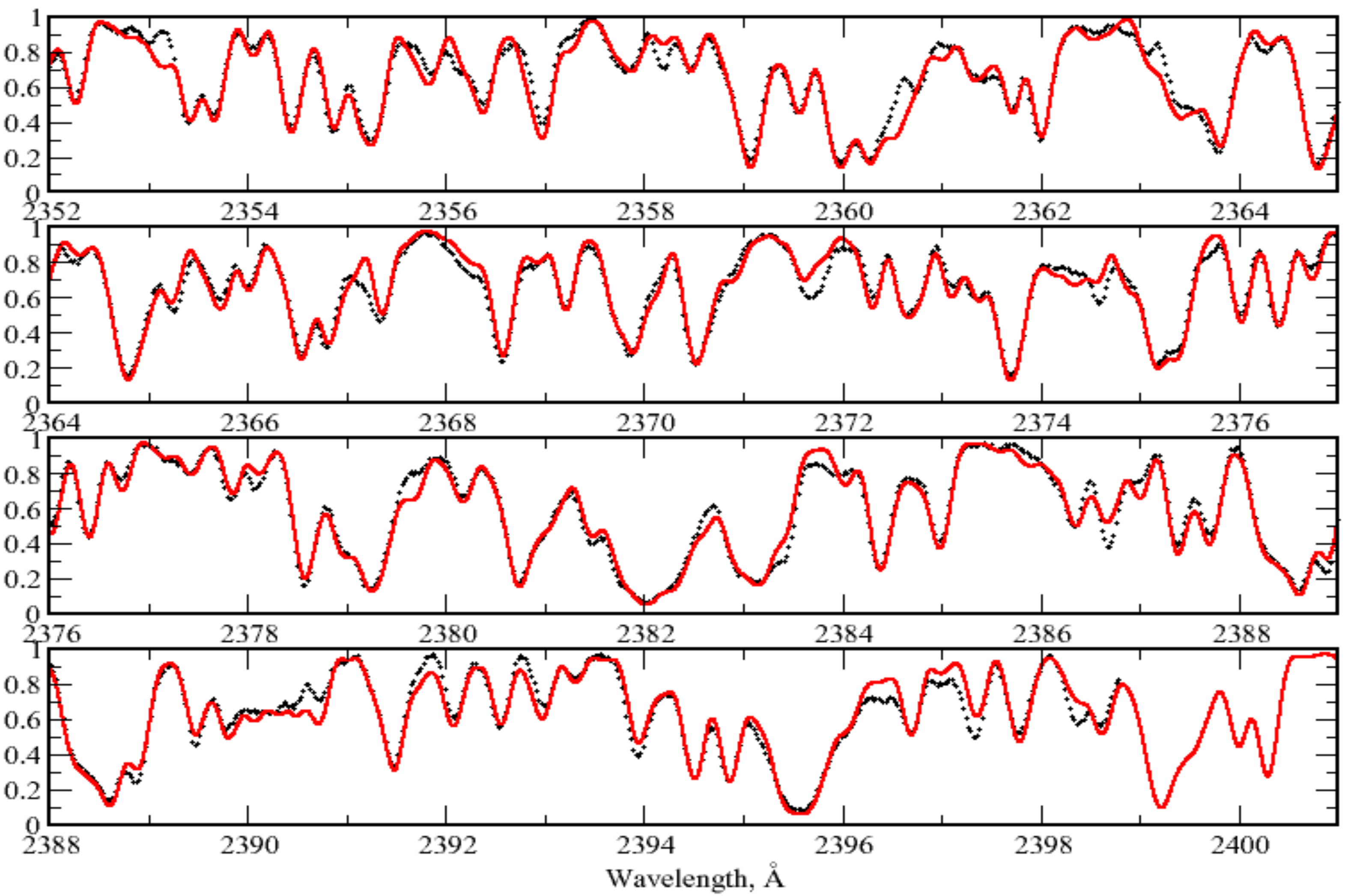
	new		old	
	exp	pred		
Fe I	93508	6029023	789176	
Fe II	103357	7615097	1264969	
Fe III	37199	9548787	1604934	
Co I	15441	3771900	546130	
Co II	23355	10050728	1361114	
Co III	9356	11515139	2198940	
Ni I	9663	732160	149925	
Ni II	55590	3645991	404556	
Ni III	21251	11120833	1309729	
Total	623360	115185086	21778816	5.3/1

(example by courtesy of T. Ryabchikova)

The VALD-3 Release IV

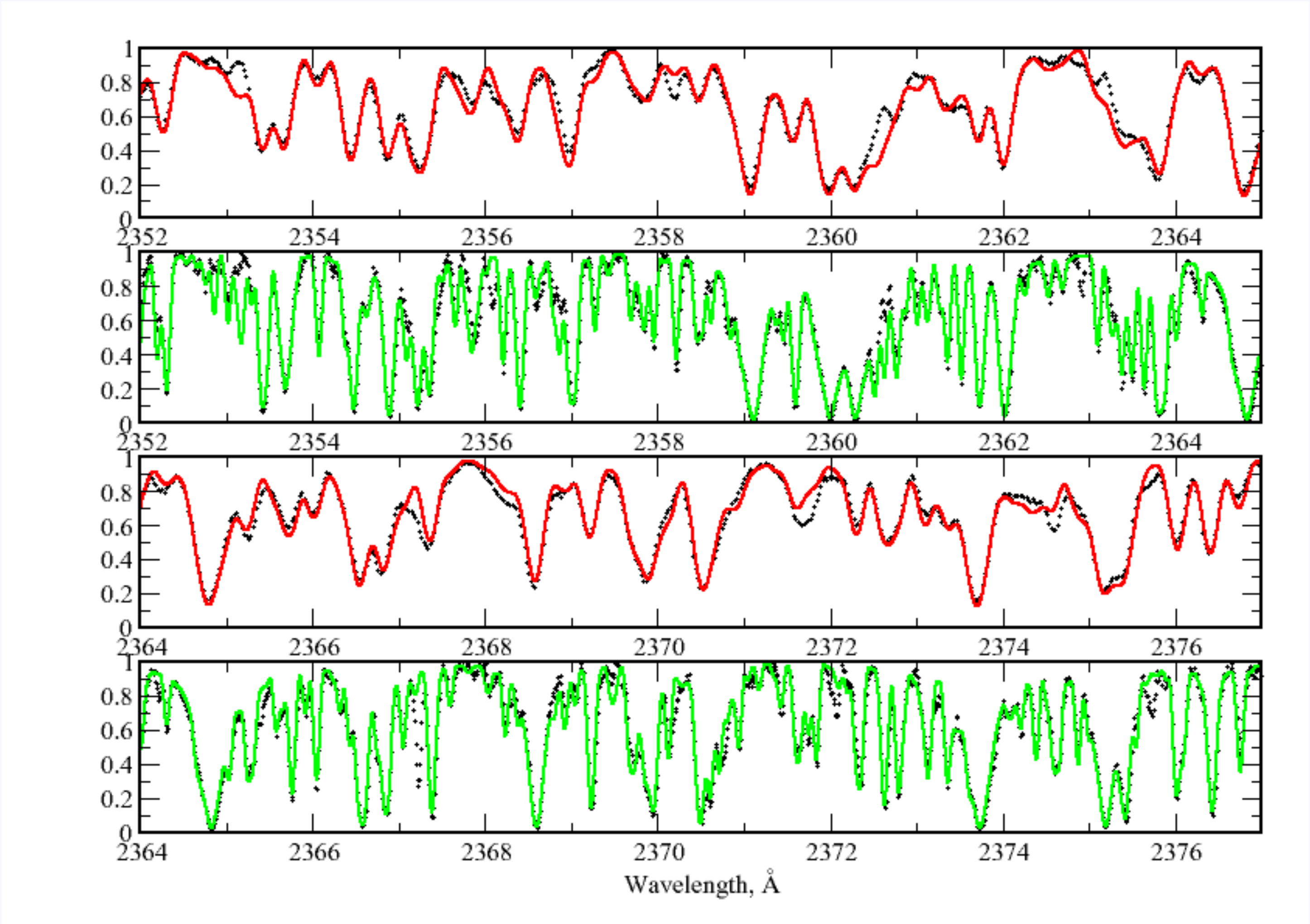
- new sources in addition to VALD 2:
  - New Kurucz Calculations (2006-2010) for Fe-peak elements,
  - Raassen & Uylings calculations (Cr 2, Fe 2, Co 2, Mn 3)
  - D.R.E.A.M. data (La 3, Ce 2+3, Pr 2, Nd 2, Sm 2+3, Gd 3, Ho 3, Er 2+3, Tm 2+3, Yb 2+3, Lu 2+3, Th 3)
  - Wisconsin data (Fe peak, rare earths, Hf 2, Pt 1)
  - Imperial College experimental data (Ti 1+2, Mn 1)
  - Lund experimental data (various ions from Mg 1 to U 2)
  - Lund theoretical calculations (Nb 3, Sb 1, Ce 3, Bi 2)
  - ISAN theoretical calculations (Pr 3, Nd 3, Eu 3, Tb 3, Dy 3, Pt 3)
  - VdW broadening (by P. Barklem) (various ions from Li 1 to Ba 2)
  - NIST data (C 1-6, N 1-7, O 1-8, Ne 1-9, Na 1, Mg 1, Ga 1-3)
  - Molecular data: currently only TiO (Plez, Schwenke), MgH (Kurucz)

VALD-3 in Action I



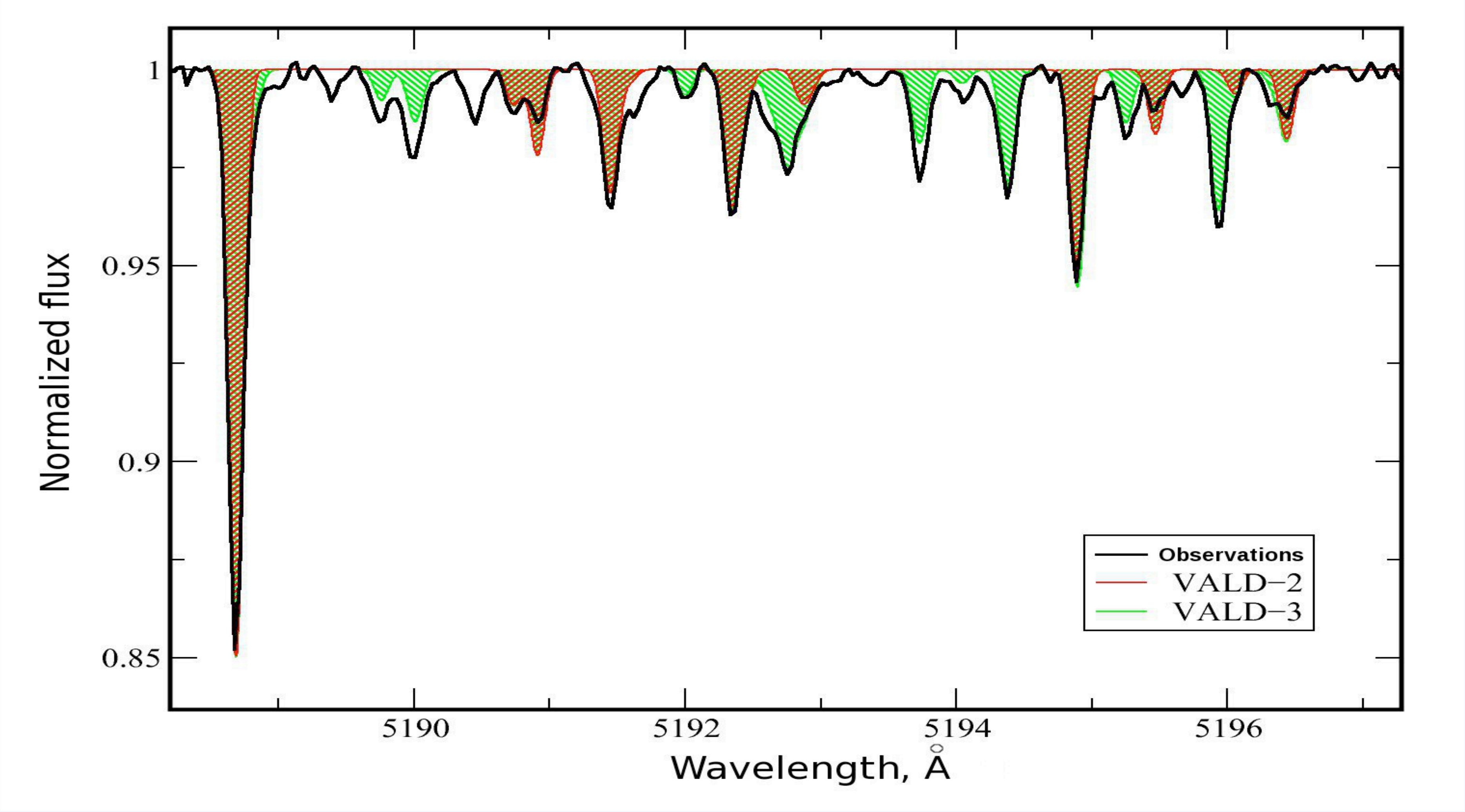
Sirius A (GHRS@HST): fit to UV region observations (by courtesy of John Landstreet), example courtesy of T. Ryabchikova.

VALD-3 in Action II



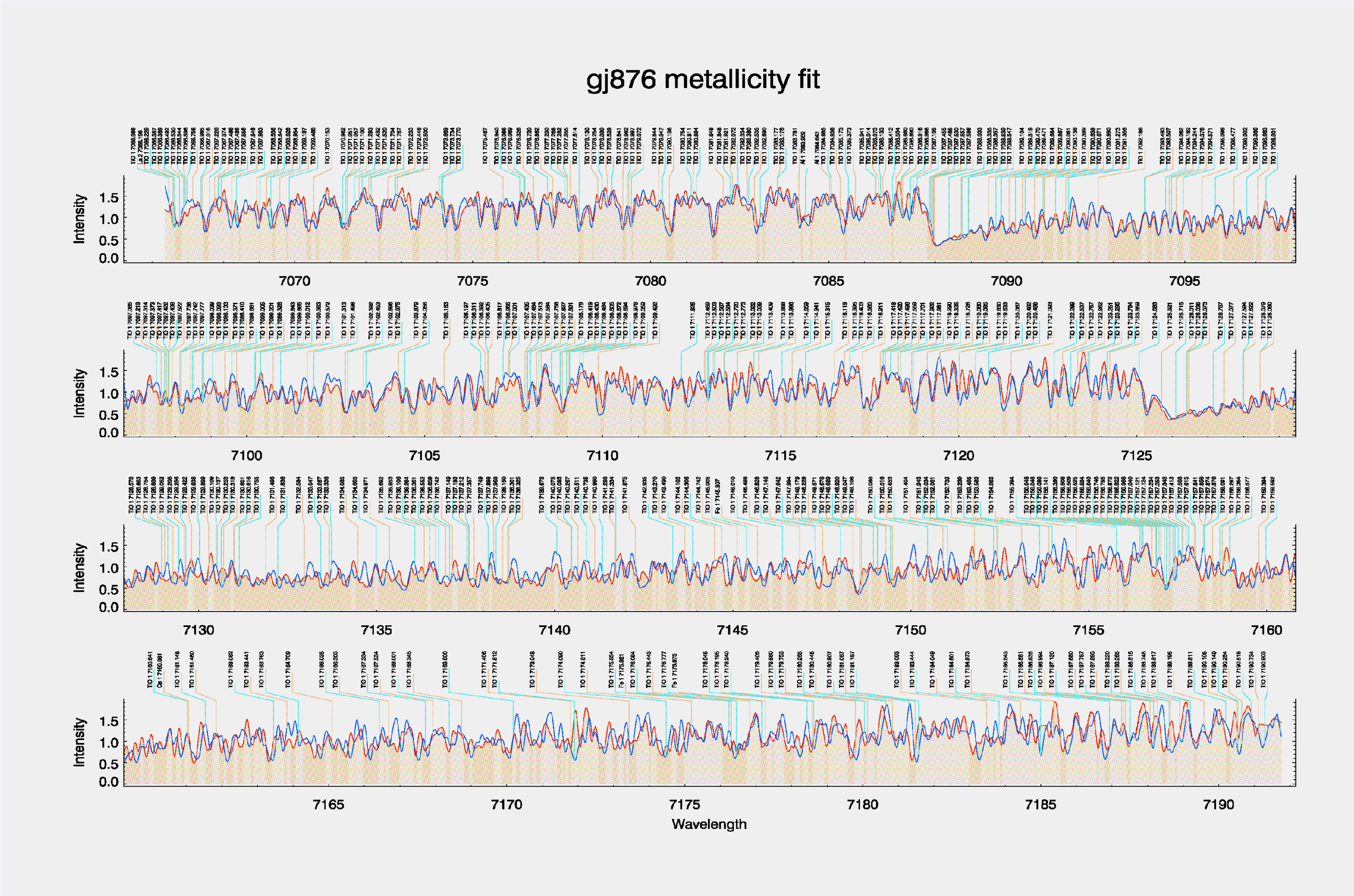
Fit to the observations in UV region. GHRS: R=25000 (Sirius A, red line in panel 1 and 3) and R=114000 (HD 72660, green line in panel 2 and 3), observations by John Landstreeet, the example is shown by courtesy of T. Ryabchikova.

VALD-3 in Action III



Solar composition star 21 Peg (T_{eff}=10400 K): fit to optical region observations, example courtesy of T. Ryabchikova.

VALD-3 in Action IV



Molecular lines in the near infrared spectrum of the M dwarf GJ876, (example courtesy of N. Piskunov & the VALD team).

VALD-3 Shortcomings

- Limited range of ionization stages (neutral up to 8 times).
- Only simple molecules will be included in VALD-3 (basically diatomics: TiO, MgH, planned: CO, CN, CH, FeH).
- Generally missing data include collisional transition probabilities, advanced broadening approximations.
- VALD consortium has no manpower or expertise to fix these deficiencies !

→ possible solution: access VAMDC data resources !

...THANK YOU FOR YOUR TIME !