Improving the Spectroscopic Atomic Line Database

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Inadequate IR log(*gf*)s in the Literature

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
–	45	7	–	26	51	–	4	–	1

J. C. Pickering et al. Can J Phys 89 pp. 387 (2011)

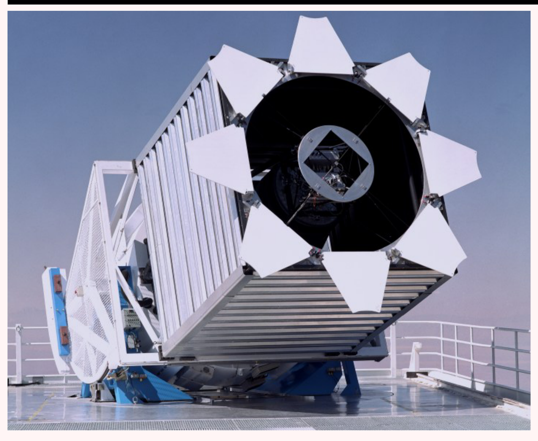
- Fe I: Fuhr et al.* list only 51 transitions with $\lambda > 1$ µm **Uncertainties are typically 25 to 50%**.
- Ni I, Zn I: only approximate log(*gf*)s are known^
- Other important elements have no laboratory log(*gf*)s

* Fuhr & Weise, J. Phys. Chem. Ref. Data 35:1669 (2006)
^ Lennard et al., Ap. J. 197:517 (1975)
Johansson & Contreras, Ark. Fys. 37:513 (1968)

In the RAVE wavelength region, "only 11 Fe I lines have laboratory oscillator strength measurements."
Boeche et al., Astronomical Journal 142:193 (2011)

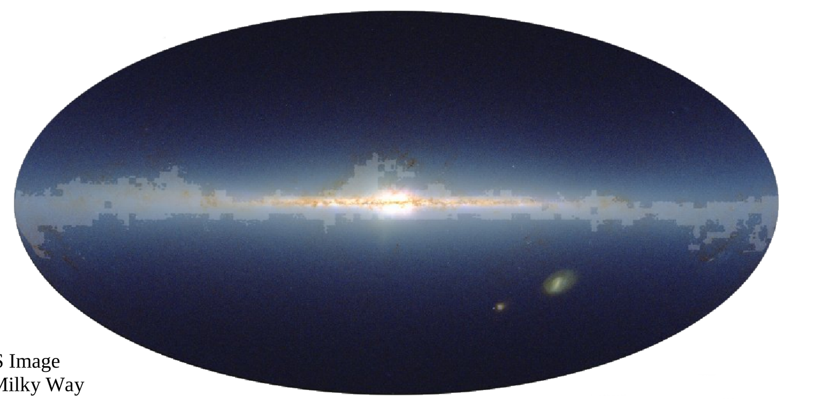
"We also emphasise in this paper the lack of precise laboratory measurements in the near-infrared."
Bigot and Thévenin, MNRAS 372:609 (2006) in relation to GAIA

SDSSIII / APOGEE

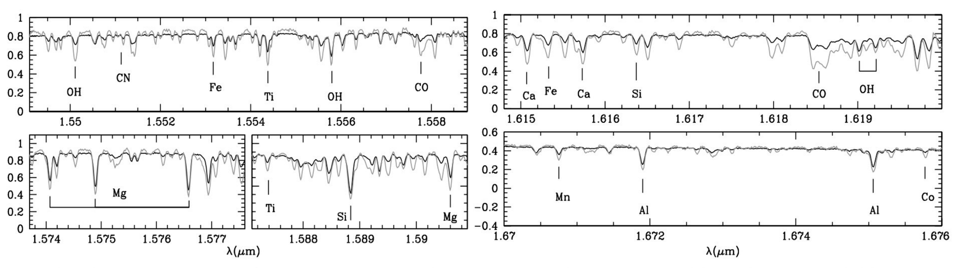


Duration	Spring 2011 to Summer 2014
Spectra	Measuring 1.51µm < λ < 1.7µm Resolving power ~30,000 S/N Ratio greater than 100
Targets	Abundances for 100,000 evolved stars 15 elements - Fe most important
Precision	Metal abundances to ~0.1 dex Radial velocities to < 0.3 km s^{-1}

Eisenstein et al., Astronomical Journal 142:72 (2011)



2MASS Image of the Milky Way



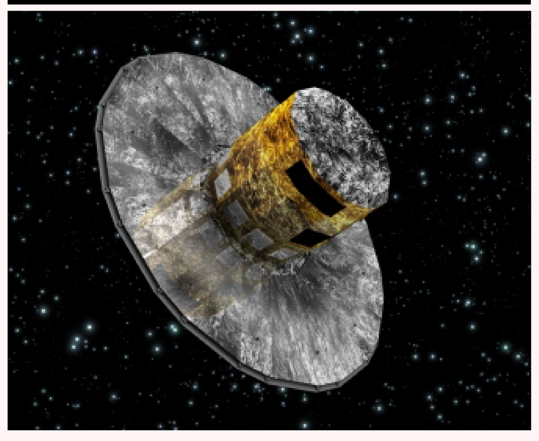
Simulated APOGEE spectra for two giant stars with T_{eff} = 4000 K, log g = 1.0, and [Fe/H] = −1.0 (solid line) and 0.0 (gray line). Reproduced from Figure 10 in Eisenstein et al., Astronomical Journal 142:72 (2011)

AAO / RAVE

Duration	2003 to end of 2012
Spectra	Measuring 841 nm < λ < 879.5 nm Resolving power ~7,500
Targets	600,000 stars (abundances for ~36,000) Ca II triplet + Mg, Al, Si, Ti, Fe, Ni
Precision	Chemical abundances to ~0.2 dex Radial velocities to < 2 km s^{-1}

Boeche et al., Astronomical Journal 142:193 (2011)

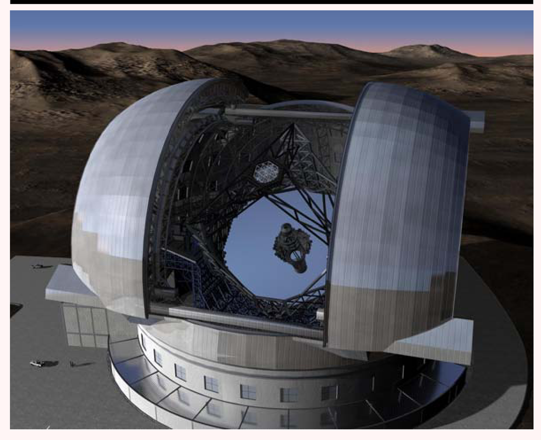
GAIA



Duration	2013 to 2018 (nominal 5 year mission)
Spectra	Measuring 847 nm < λ < 874 nm Resolving power 11,500
Targets	Several million stars Ca II triplet and Fe I most important
Precision	Metal abundances to ~0.2 dex Radial velocities to ~1 km s^{-1}

Bigot and Thévenin, MNRAS 372:609 (2006)

E-ELT / SIMPLE



First Light	Estimated early 2020s
Spectra	Measuring 0.84 µm < λ < 2.5 µm Resolving power ~130,000 Limiting Magnitude ~20
Targets	Atmospheres of exoplanets Population III stars, QSOs, GRBs Chemical enrichment in early galaxy Chemical enrichment in early universe

Origlia et al., The Messenger 140 (2010)

The Imperial College Spectroscopy Group

We specialise in providing new laboratory data for astronomy and astrophysics. These include

- Large-scale studies of energy levels, oscillator strengths and line wavelengths from **infra-red to vacuum ultra violet**.
- Measurements of neutral (I), singly- (II), and doubly-ionised (III) spectra, particularly for iron-group elements
- Examples such as Co I & II, V I & II, Mn I & II, Fe I & II, Cr III.

These aid **Galactic surveys**, studies of low-mass, chemically peculiar, and hot stars, and studies of variation in the fine-structure constant.

We also provide accurate measurements of line broadening effects such as hyperfine structure needed for **modern stellar spectral analyses**.

We operate two Fourier transform spectrometers and collaborate with NIST (USA) for IR studies

Imperial College Spectrometers

- Visible/UV FTS measures 1900 Å to 8000 Å
- UV/VUV FTS measures 1400 Å to 4000 Å
- Wavelengths and energy levels accurate to better than 1:10^7 (30 ms^{-1}, 0.15 mÅ at 1500 Å)
- Resolving power 2 million at 2000 Å
- log(*gf*) values accurate to a few percent

NIST IR-visible Spectrometer

- Sensitive up to λ = 5 µm; R = 4 million at 1 µm
- Wavelengths and energy levels accurate to better than 1:10^8 (3 ms^{-1}, 10 Å at 1 µm)

Providing accurate log(*gf*)s

Emission Transition Probabilities (A_{21})

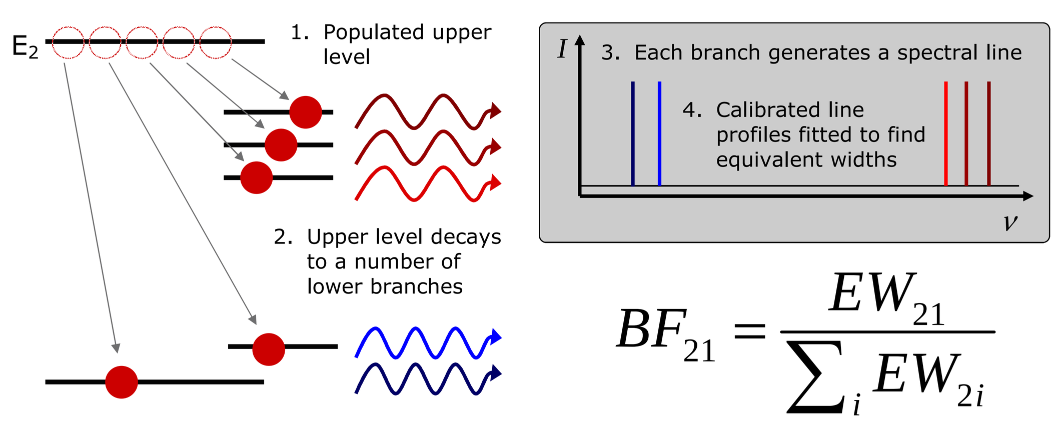
$$A_{21} = \frac{BF_{21}}{\tau_2}$$

- Upper level branching fractions (BF_{21})
- Upper level radiative lifetime (τ_2)
- $\log(g_1 f) = \log\left[1.49919 \cdot \frac{g_2 A_{21}}{\sigma^2}\right]$

Branching fractions are found from FTS line spectra by measuring the strength of all emission lines from a target upper level.

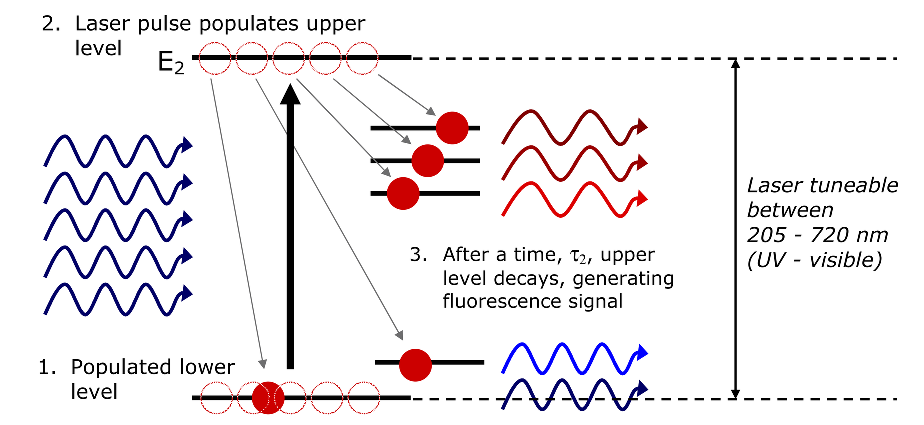
Lifetimes are found from laser induced fluorescence data by measuring the time delay between a laser pulse that populates an upper level and emission from that level.

FTS Branching Fractions (BF_{21})



$$BF_{21} = \frac{EW_{21}}{\sum_i EW_{2i}}$$

LIF Radiative Lifetimes (τ_2)



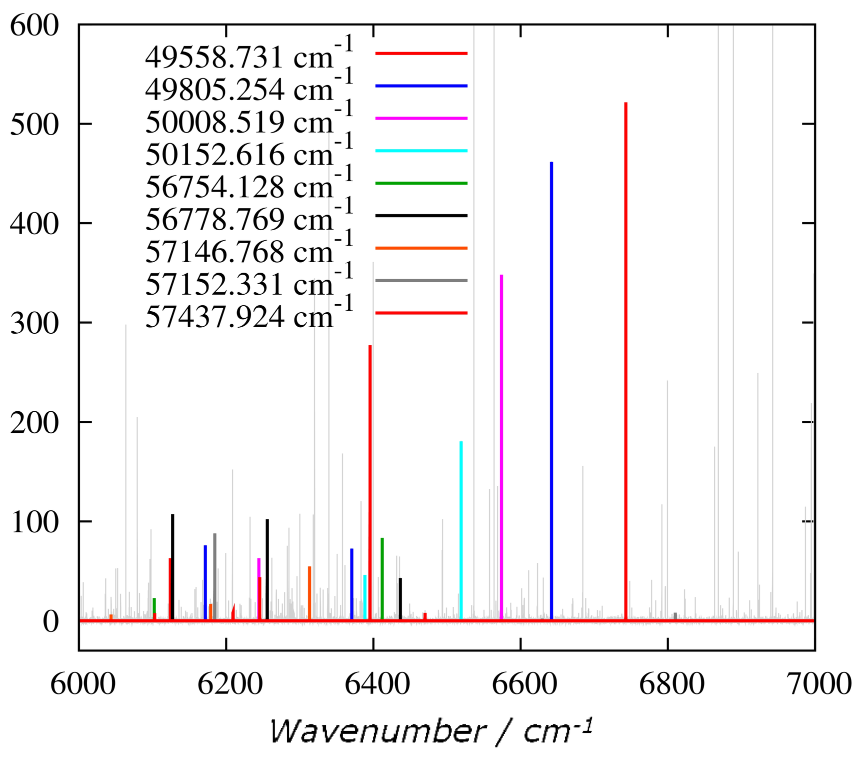
Delay between laser pulse and fluorescence detection gives τ_2

IR log(*gf*)s in the H-band

We are currently measuring Fe I log(*gf*)s in the H-band (1.5 to 1.7 µm). BF data have been derived from spectra taken on the NIST IR/vis FTS (in collaboration with G. Nave) and IC UV FTS. Lifetimes are being measured by E. den-Hartog at U. Wisconsin, Madison, WI, USA.

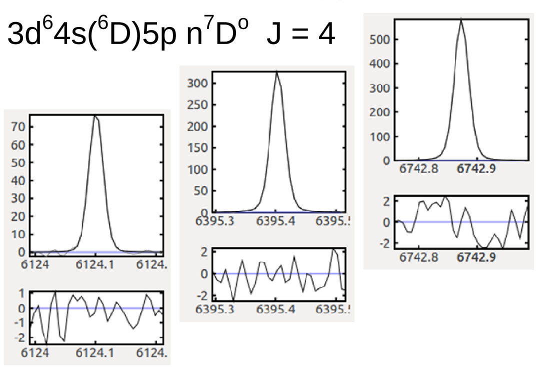
These data will provide several tens of new Fe I log(*gf*)s for lines important to the analysis of SDSSIII/APOGEE spectra, but can also be extended to include more lines on request.

H-Band spectra for SDSSIII/APOGEE



The 49588.731cm^{-1} Upper Level

3d^{6}4s(^{6}D)5p n^{7}D^o J = 4



- Extract all lines from a single upper level
- Calibrate line intensities
- Fit line profiles to get BFs

σ / cm^{-1}	BF / %
6124.10169	7 ± 3
6395.40329	32 ± 2
6742.87349	60 ± 2

We can provide new laboratory measured atomic data

including oscillator strengths, wavelengths, and energy levels for many target elements and for lines between 5 µm and 1400 Å. Hollow cathode lamps and Penning sources are available to study neutral (I), singly- (II), and doubly-ionised (III) spectra.

More information is available online:
www.sp.ph.ic.ac.uk/~julietp/FTS
www.sp.ph.ic.ac.uk/~mruffoni

Please contact us to discuss your requirements:

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Royal Astronomical Society, National Astronomy Meeting, 27-30 March 2012, Manchester, UK