Laboratory astrophysics at Malmö University

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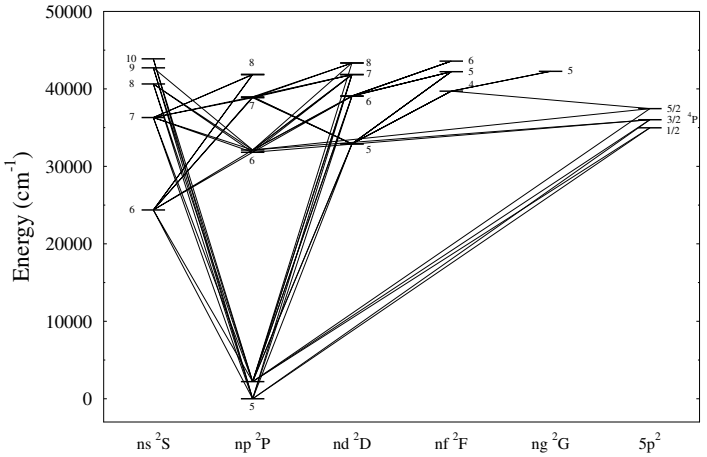
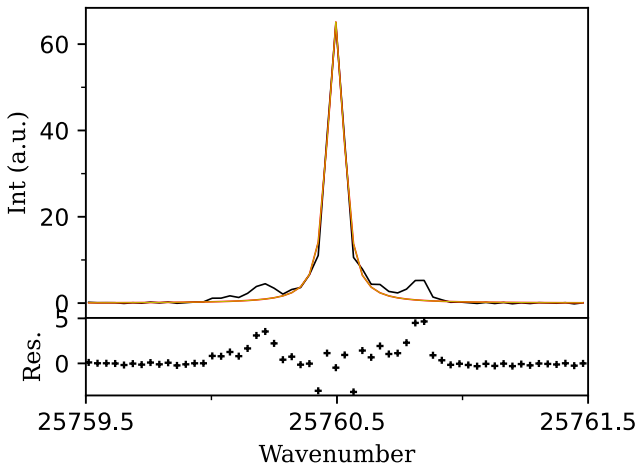
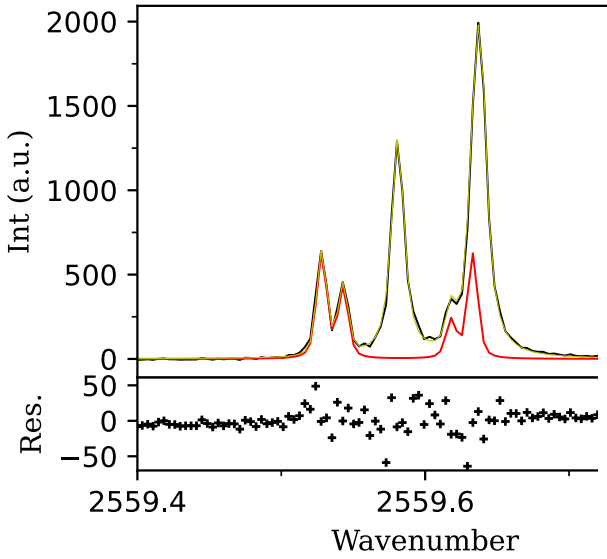
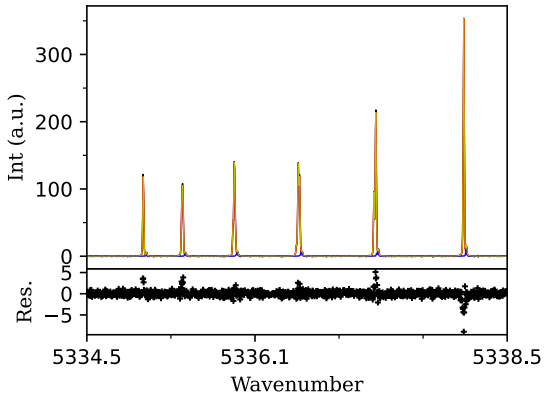


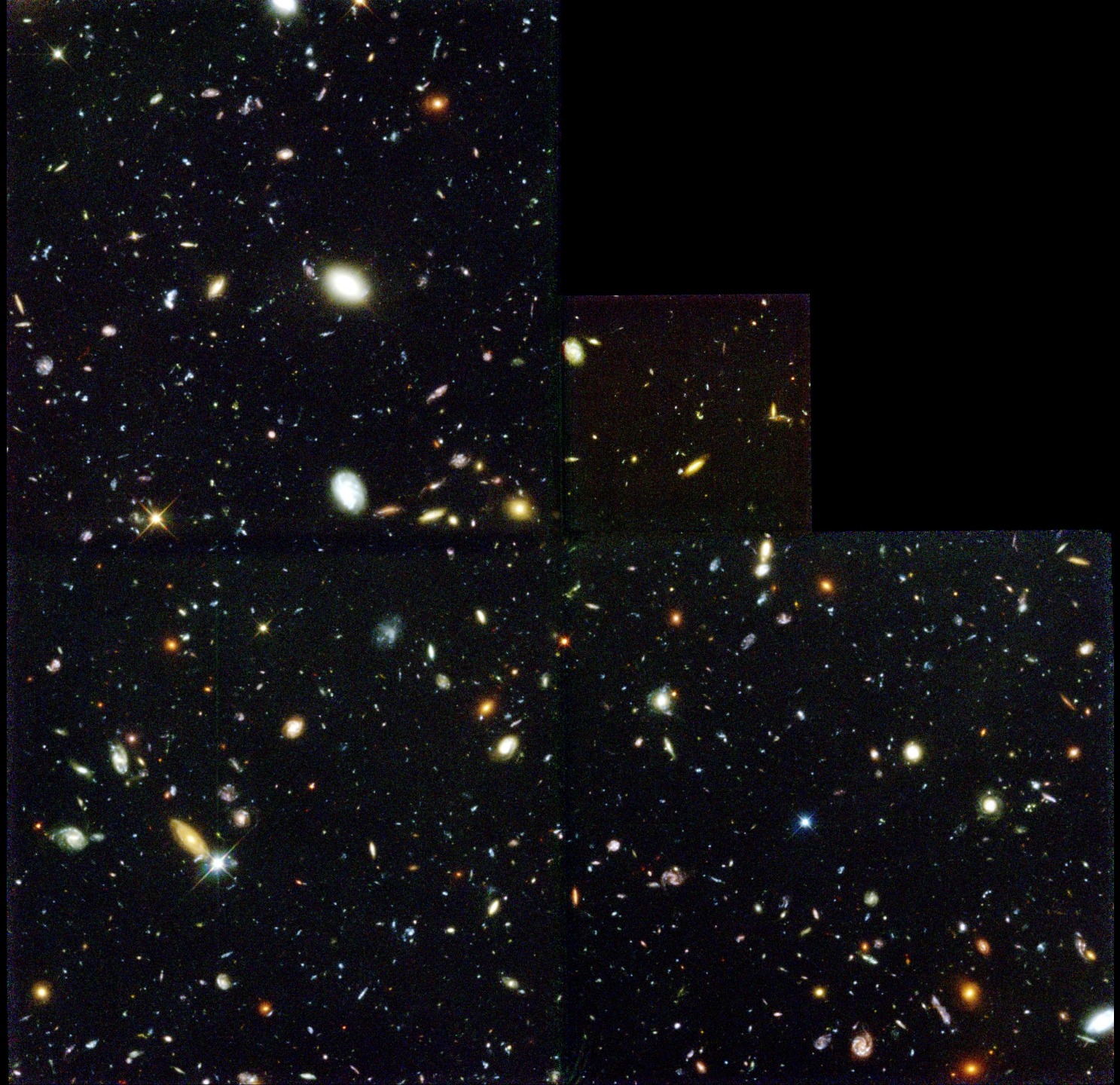






Laboratory astrophysics at Malmö University

- Motivation
- Laboratory measurements
- Infrared spectroscopy
- Some projects



ESO ELT

39 m main mirror

ANDES echelle spectrograph
0.4 -1.8 µm
R = 100 000

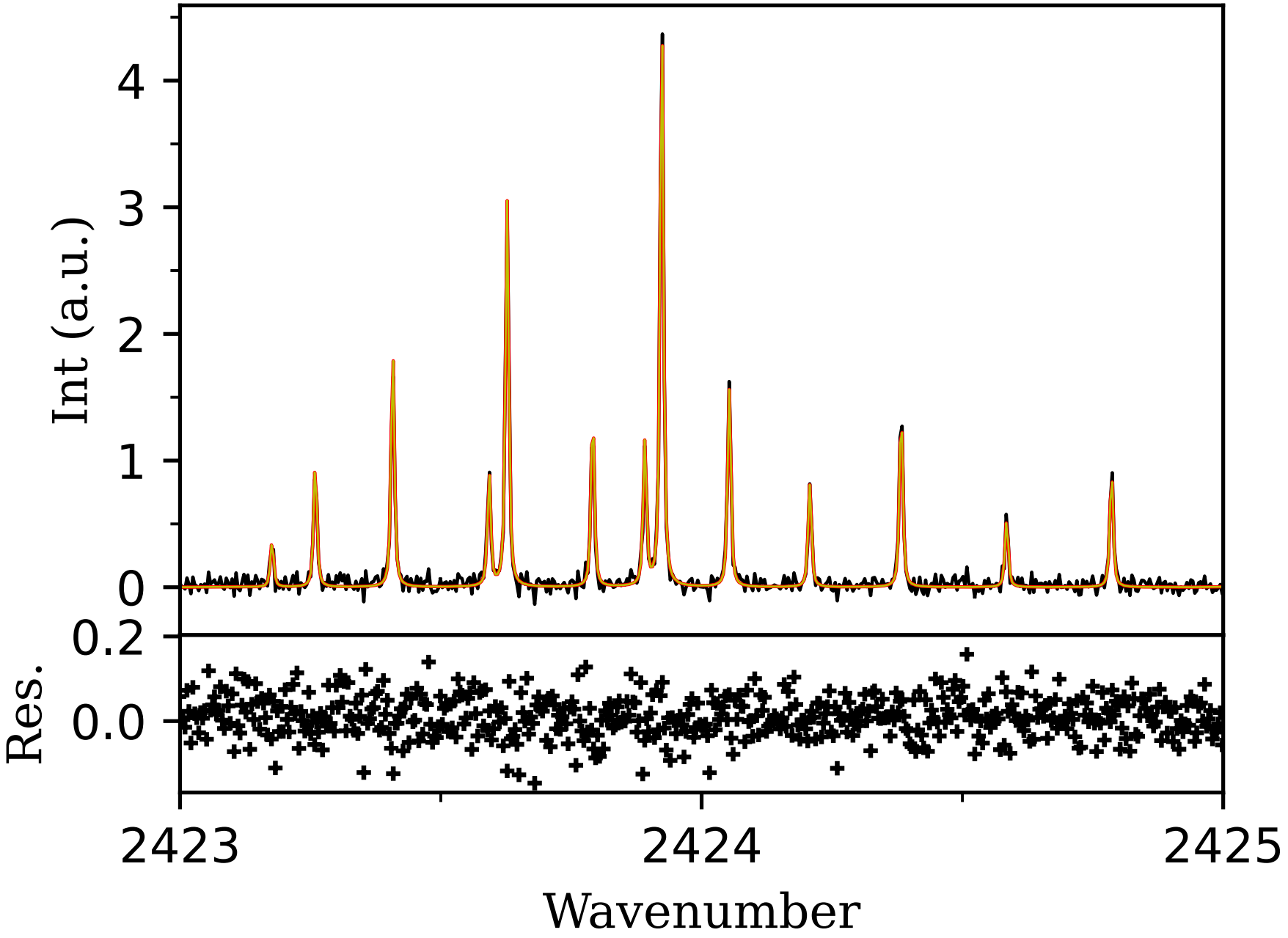
ESO ELT

39 m main mirror

ANDES echelle spectrograph
0.4 -1.8 µm
R = 100 000

However…

By G. Hüdepohl (atacamaphoto.com)/ESO - https://www.eso.org/public/images/potw2205a/, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=114846756


Int (a.u.)
4
3
2
1
0
Res.
0.2
0.0
2423
2424
2425
Wavenumber

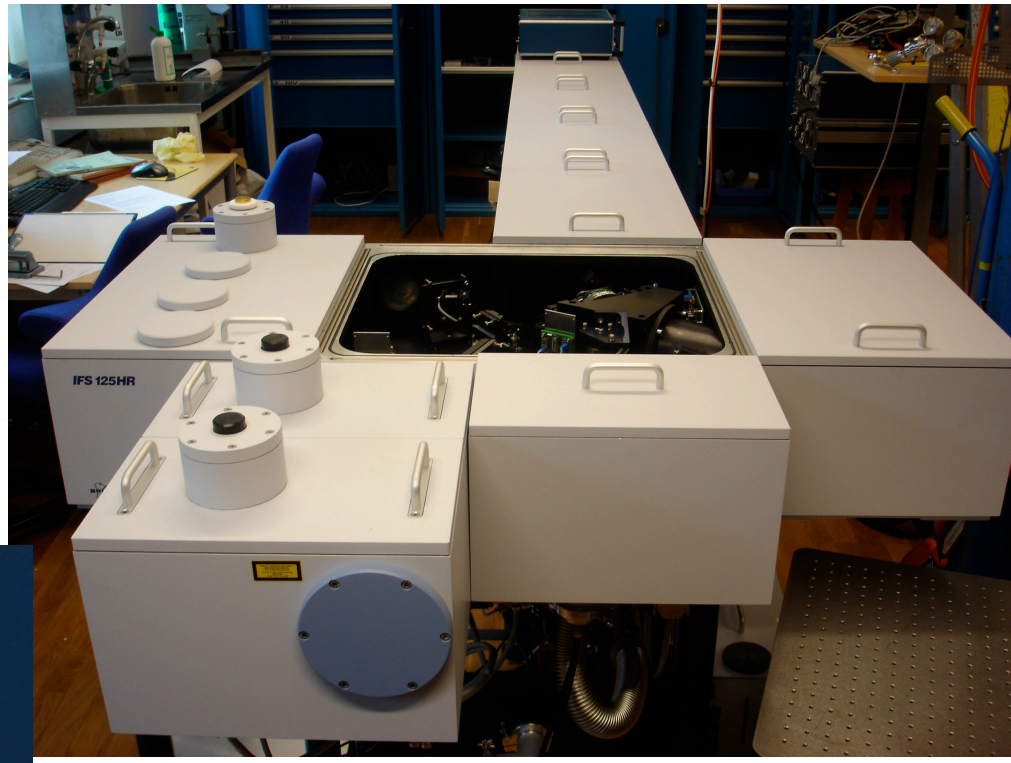
Laboratory measurements

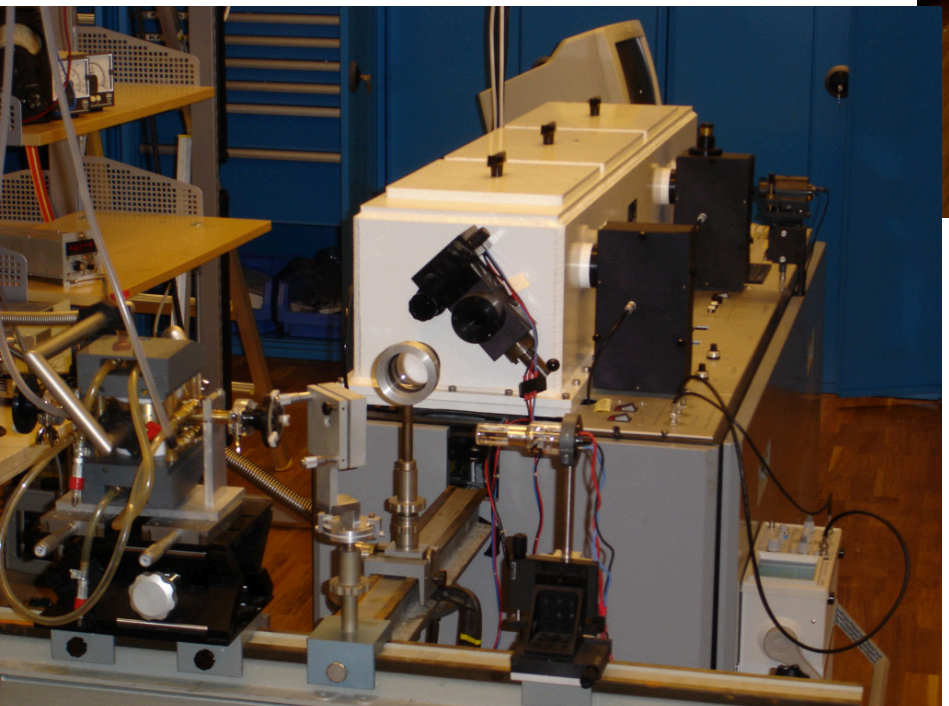
-Wavelengths

-Energy structure

-Line structure (hfs IS)

-Transition probabilities



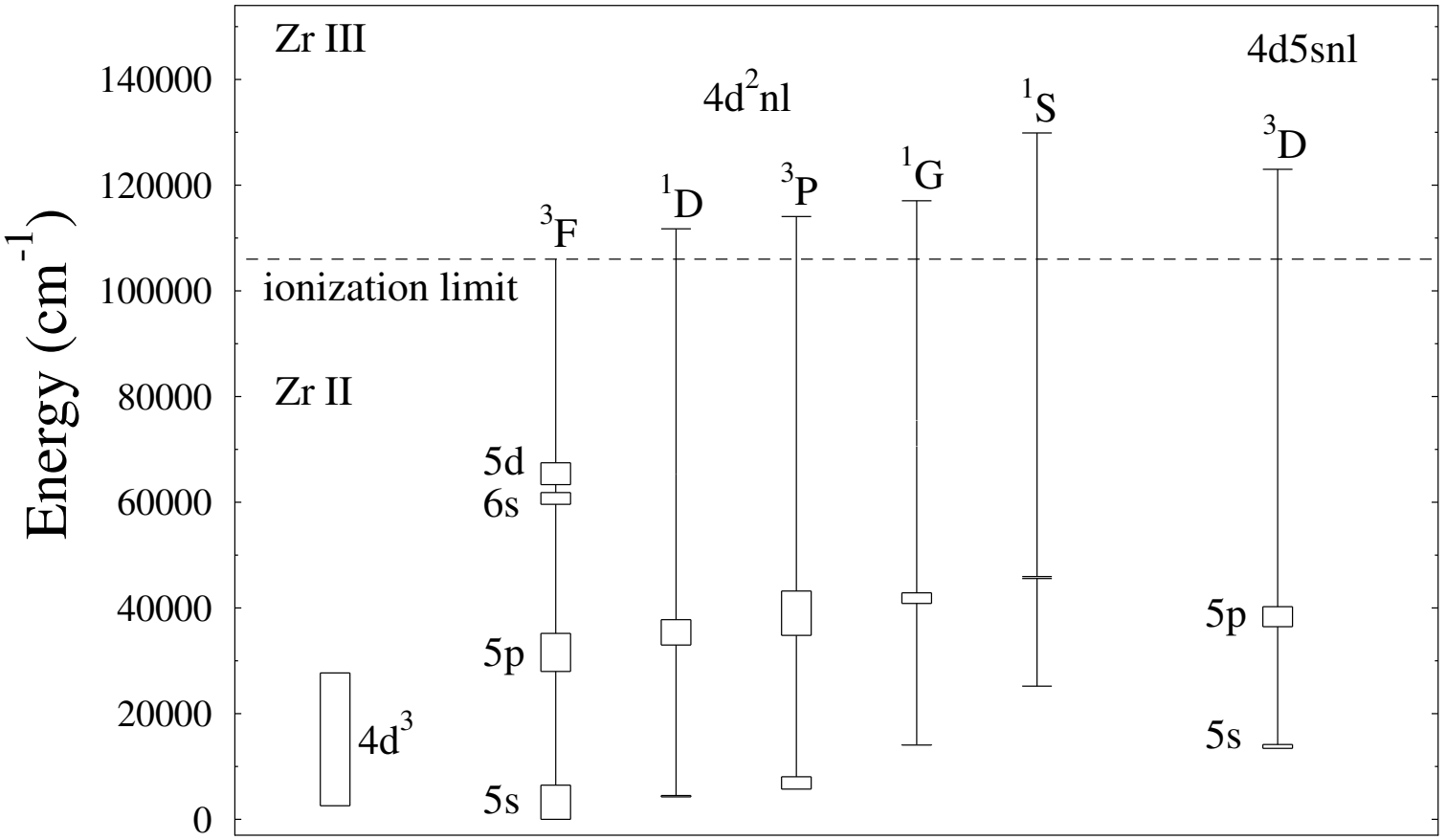


2 000-50 000 cm^{-1}

$5\mu m$ – 2000 Å

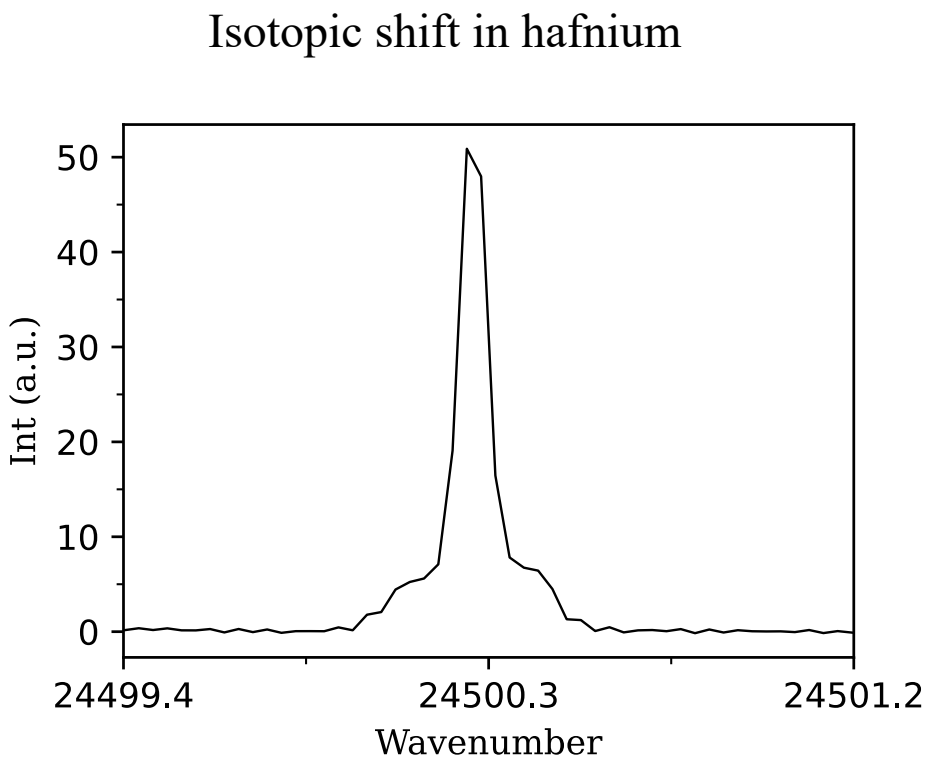
R ~10^6

Wavelengths and energies



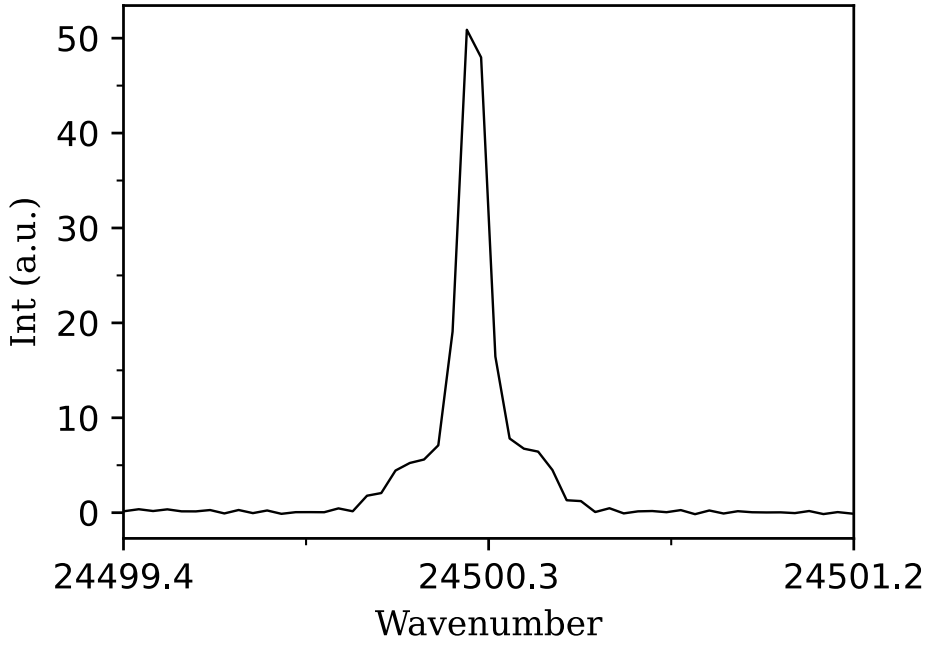
Partial energy level diagram of Zr II

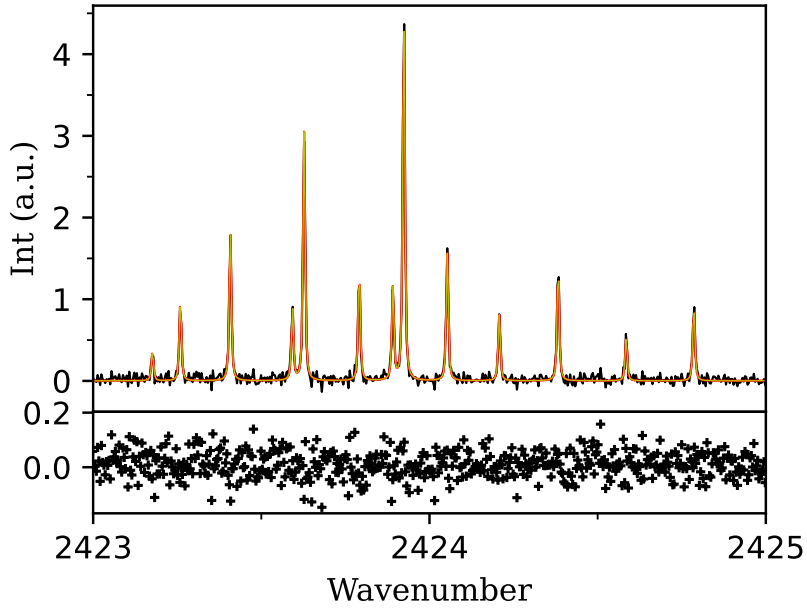
Line structure



Line structure

Isotopic shift in hafnium

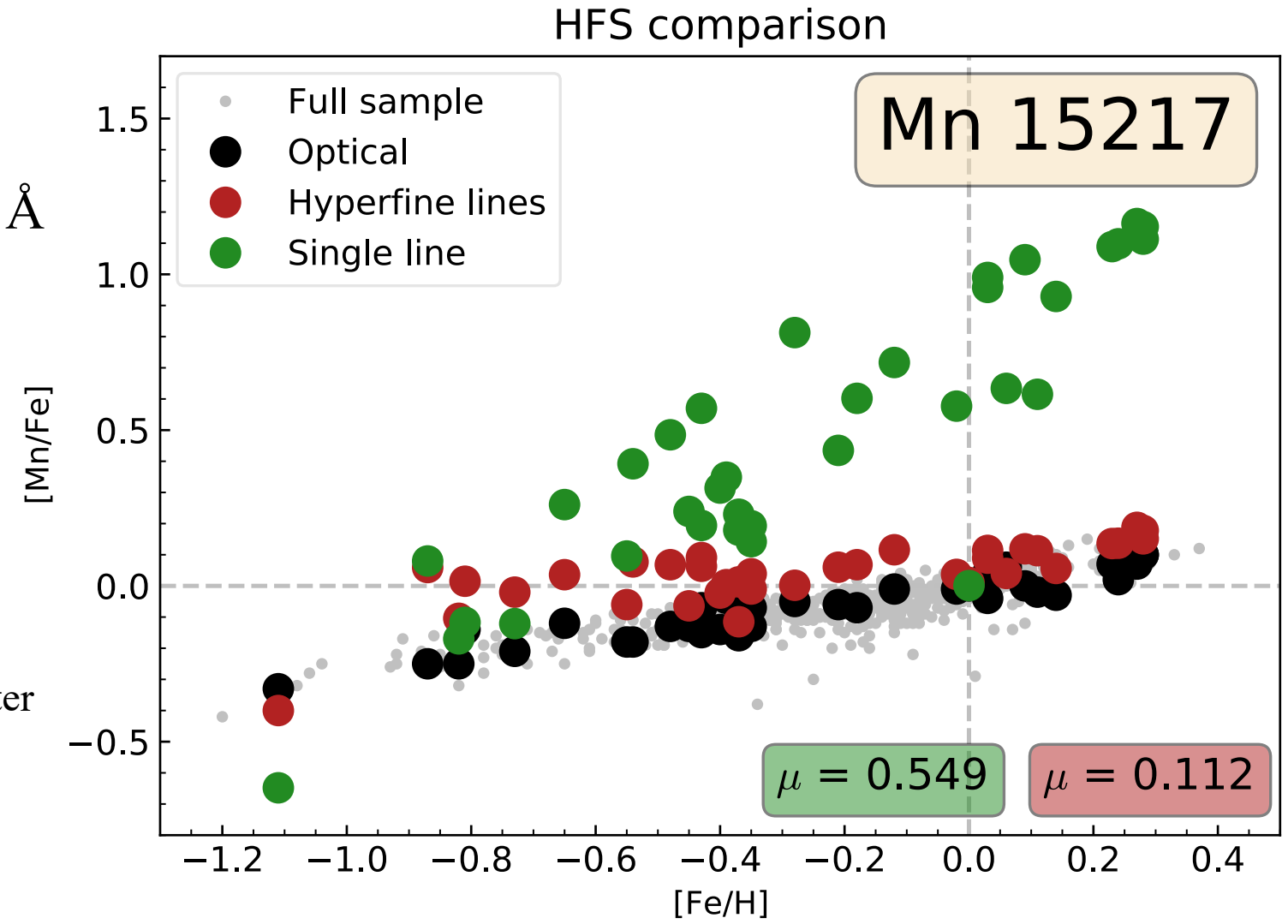




Hyperfine structure in indium

Hyperfine structure

Mn I 15217 Å



Montelius, Master thesis (2021)

Transition probabilites

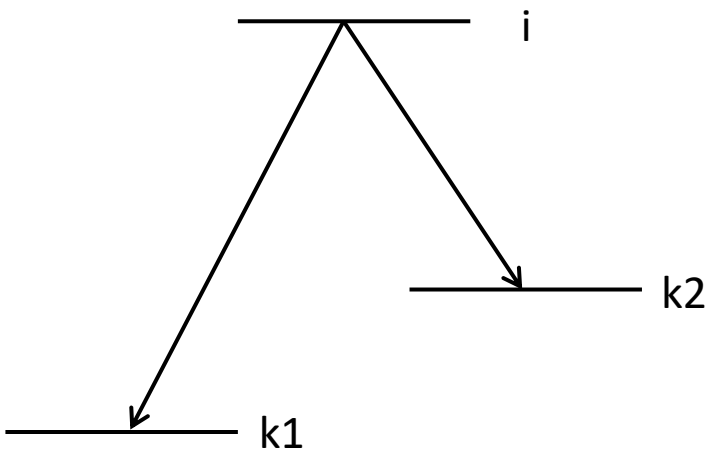
Combine relative line intensities with radiative lifetimes

branching fractions:

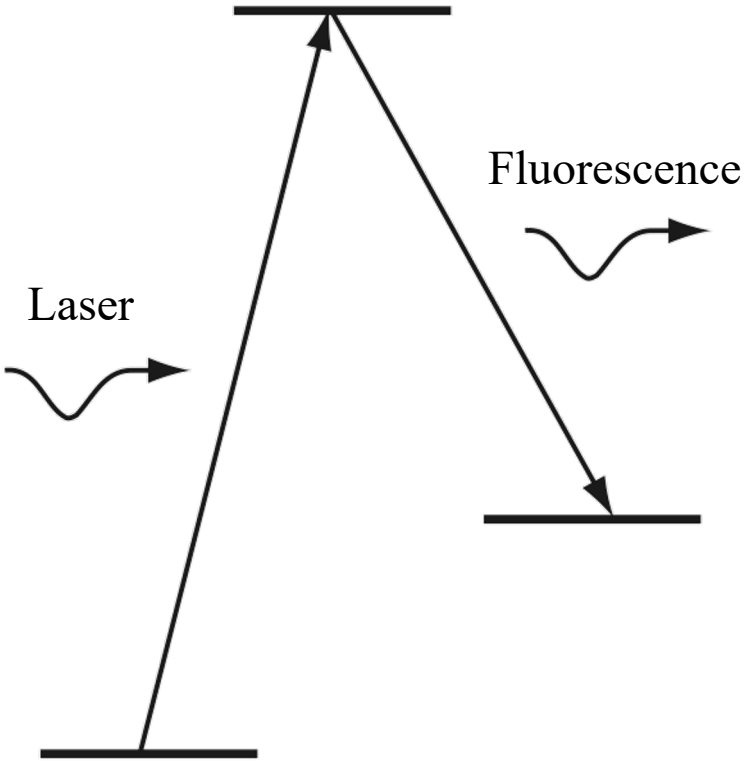
$$BF_{ik} = I_{ik} / \Sigma_k I$$

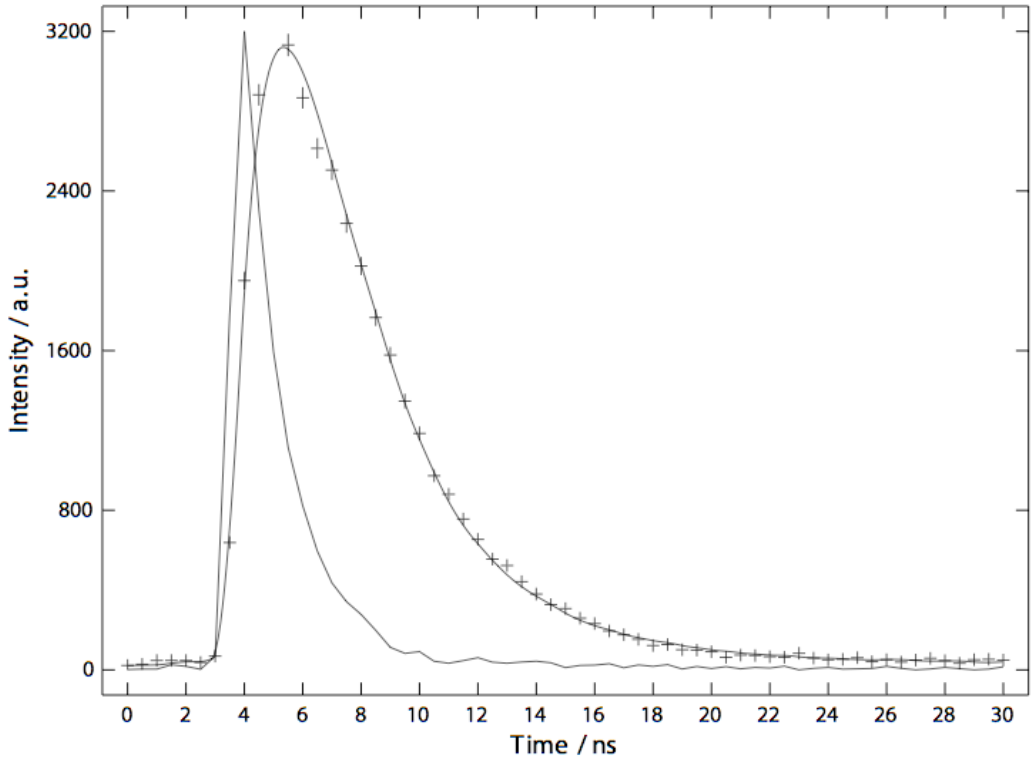
Transition probabilities:

$$A_{ik} = Bf_{ik} / \tau_i$$



Lifetimes





Ta III (Fivet et. al. J. Phys. B: At. Mol. Opt. Phys. 41, 2008, 015702)

Why IR?

Scattering $\propto \lambda^{-4}$

Look at dusty and dense areas like the center of the Galaxy.

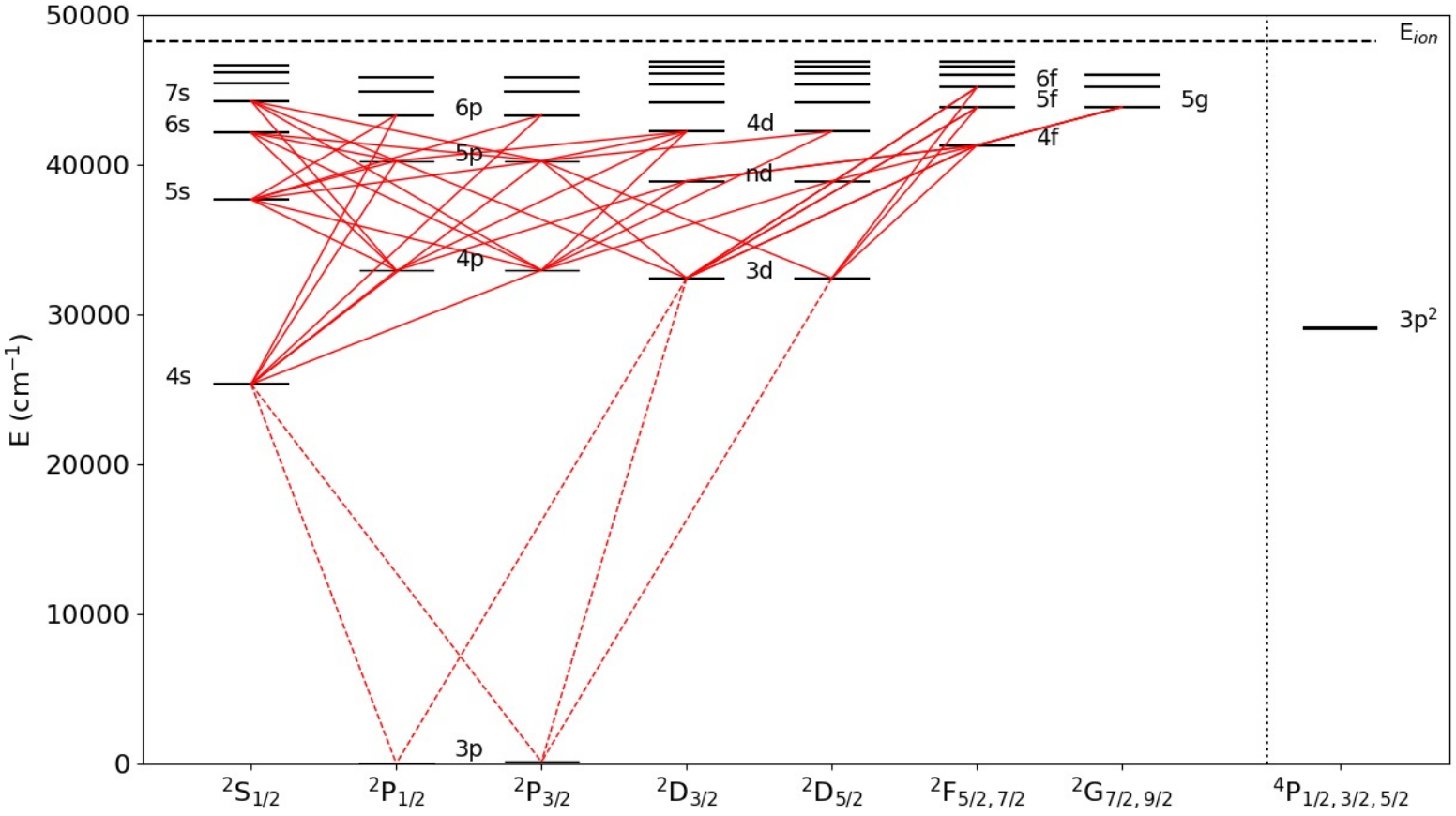
The Sun looks red at sunset and sunrise, and the sky is blue.

Cool stars to find small planets

High red shifts

Adaptive optics works better

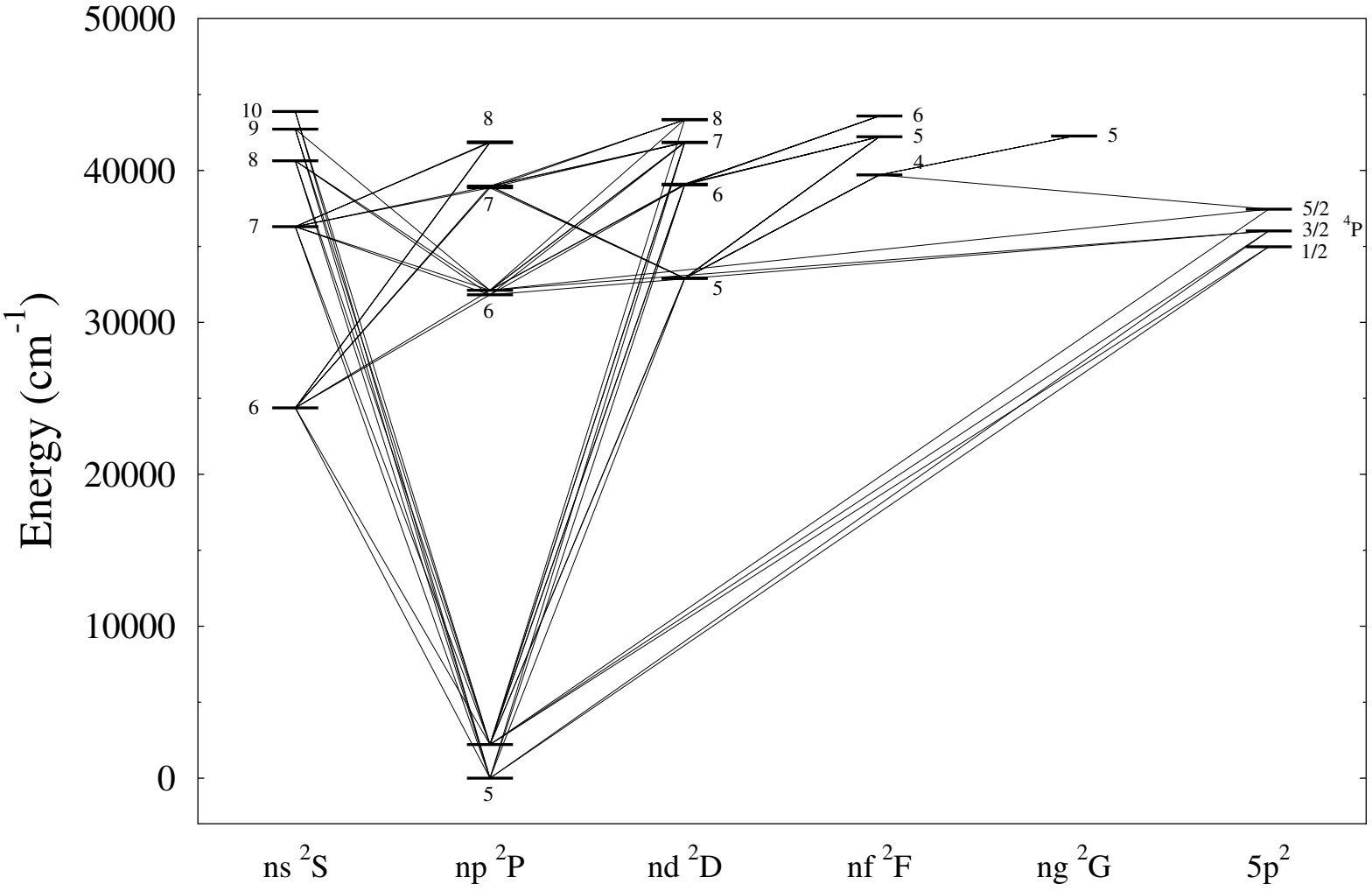
What lines fall in the IR?



Al I (Z=13)

Ground configuration $3s^2\ 3p$

What lines fall in the IR?



In I (Z=49)

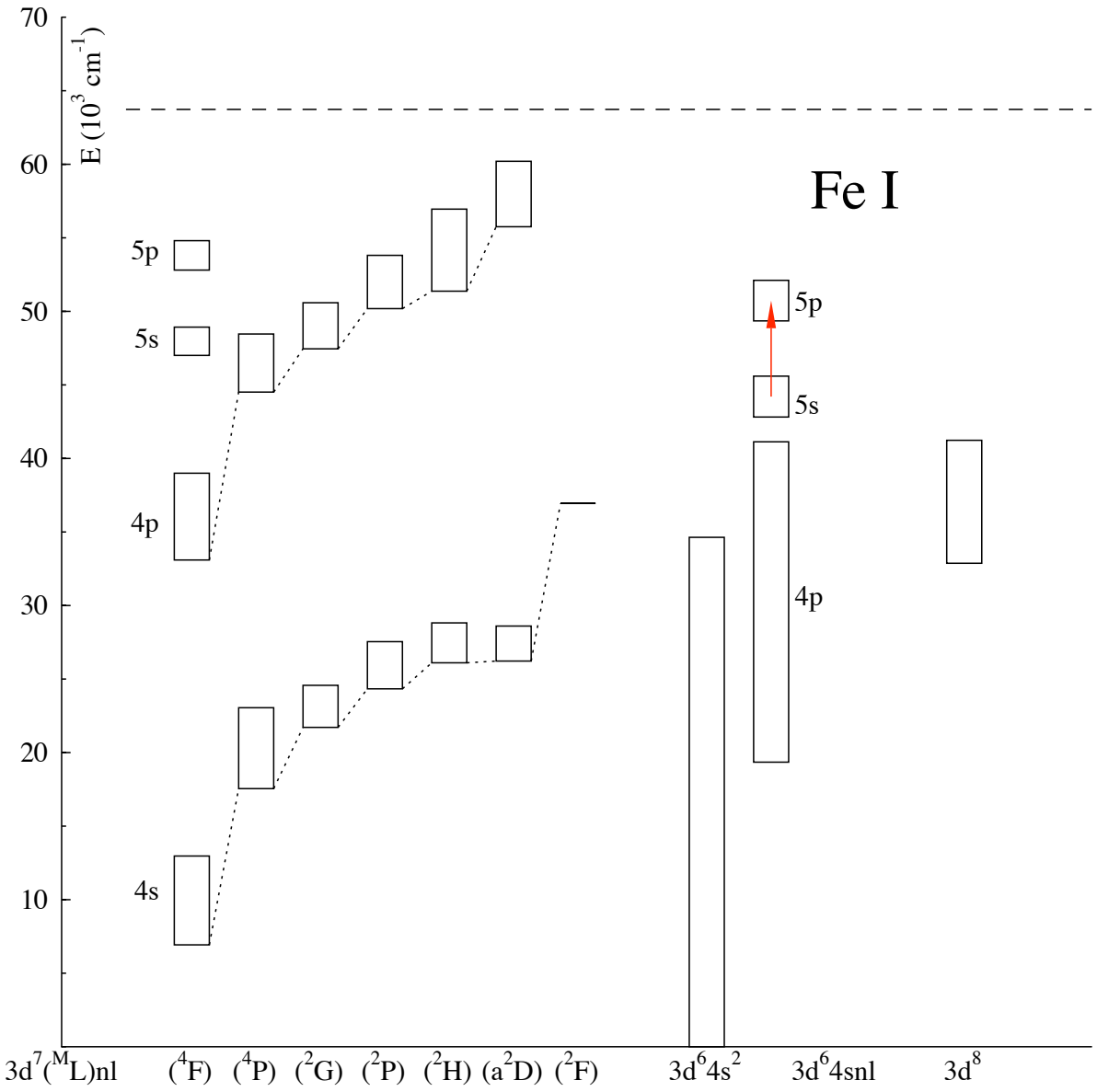
Ground configuration $5s^2\ 5p$

What lines fall in the IR?

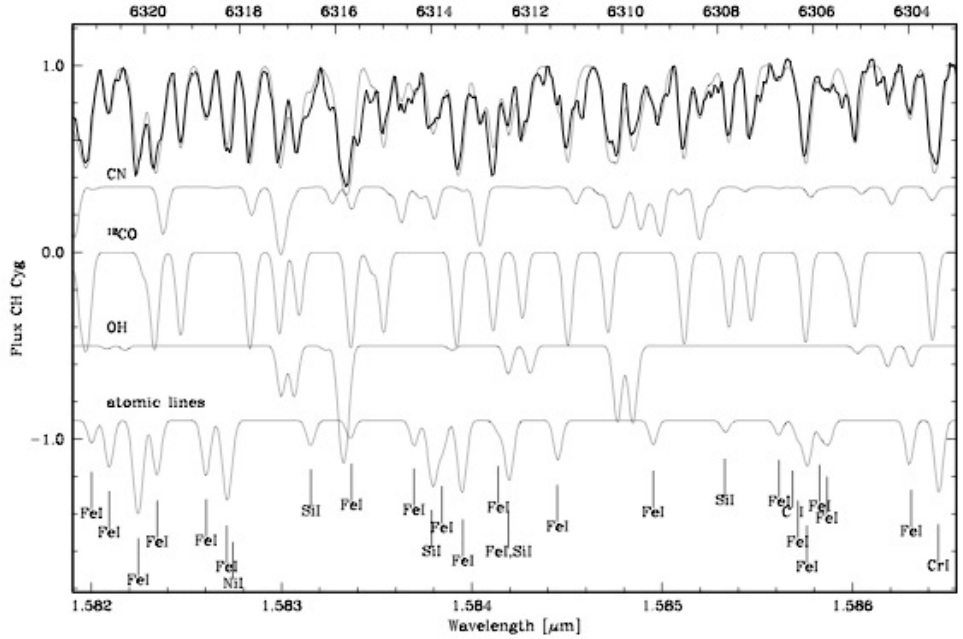
Fe I

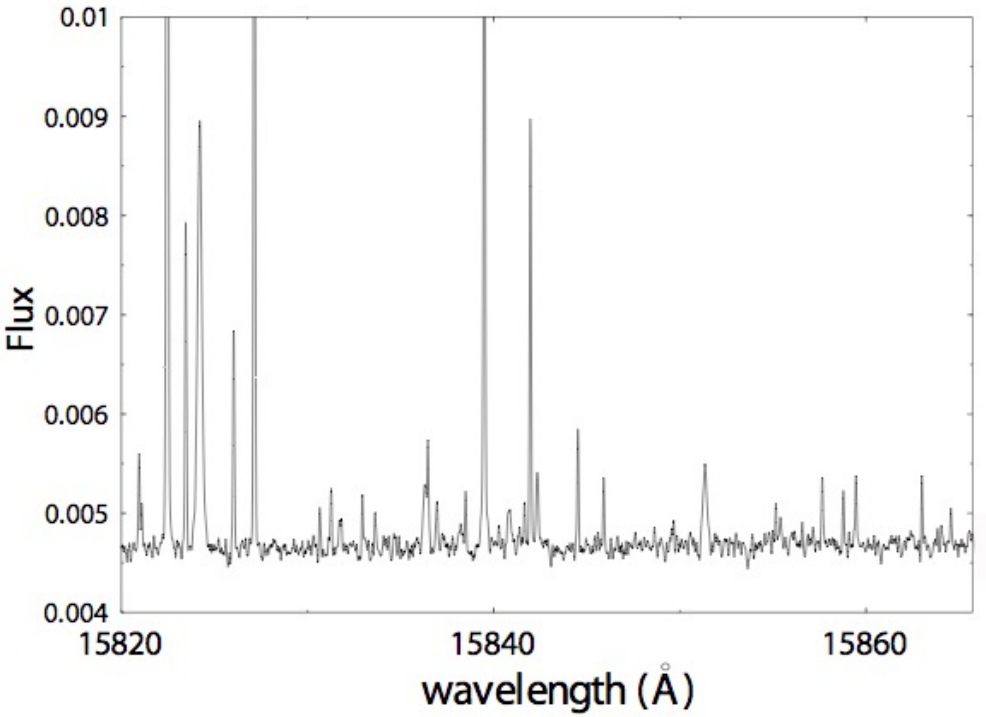
Ground configuration

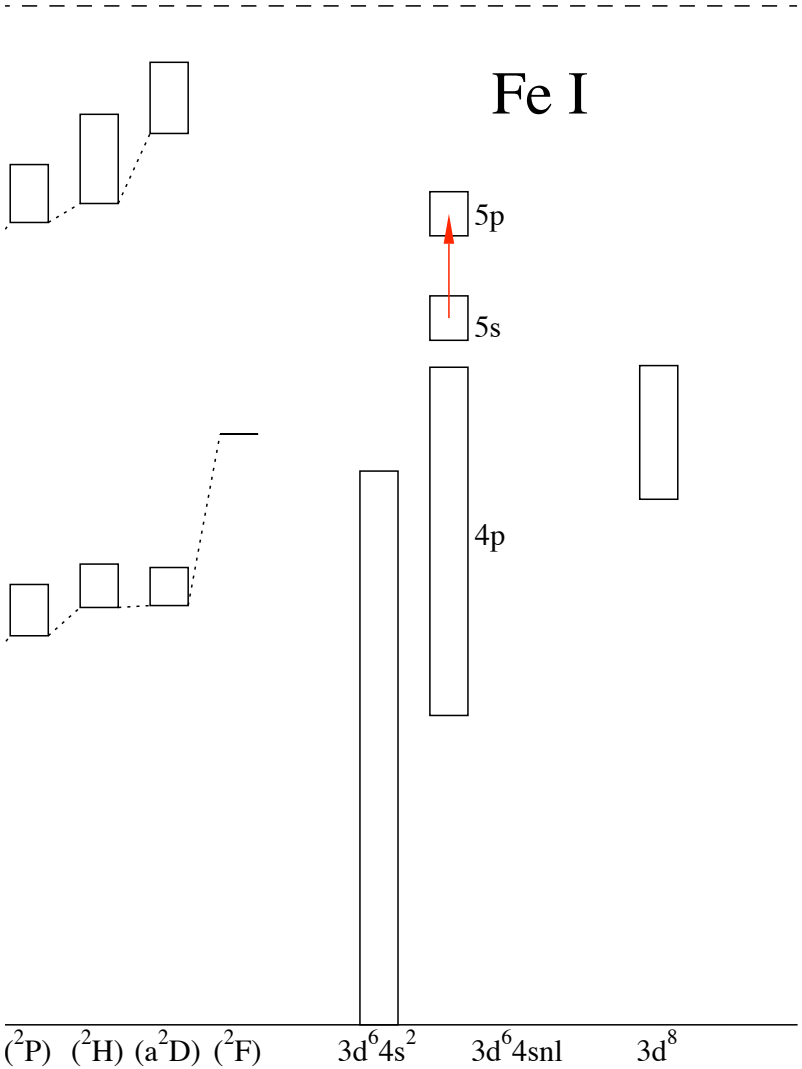
$3d^6\ 4s^2$



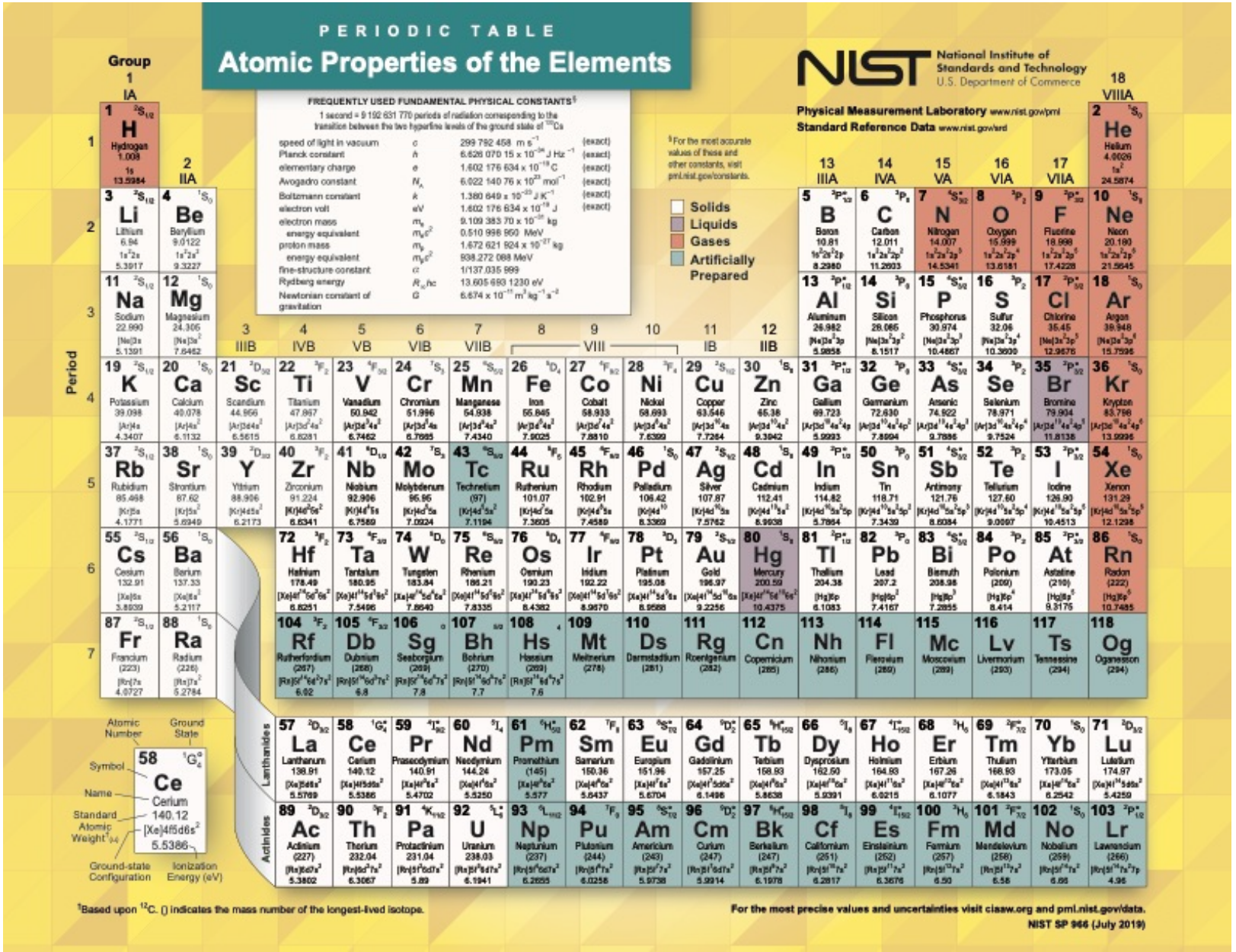
e IR?


6320
6318
6316
6314
6312
6310
6308
6306
6304
1.0
0.0
−1.0
Flux CH Cyg
CN
^{13}CO
OH
atomic lines
FeI
SiI
Fe,SiI
NiI
CrI
1.582
1.583
1.584
1.585
1.586
Wavelength [μm]


0.01
0.009
0.008
0.007
0.006
0.005
0.004
Flux
15820
15840
15860
wavelength (Å)

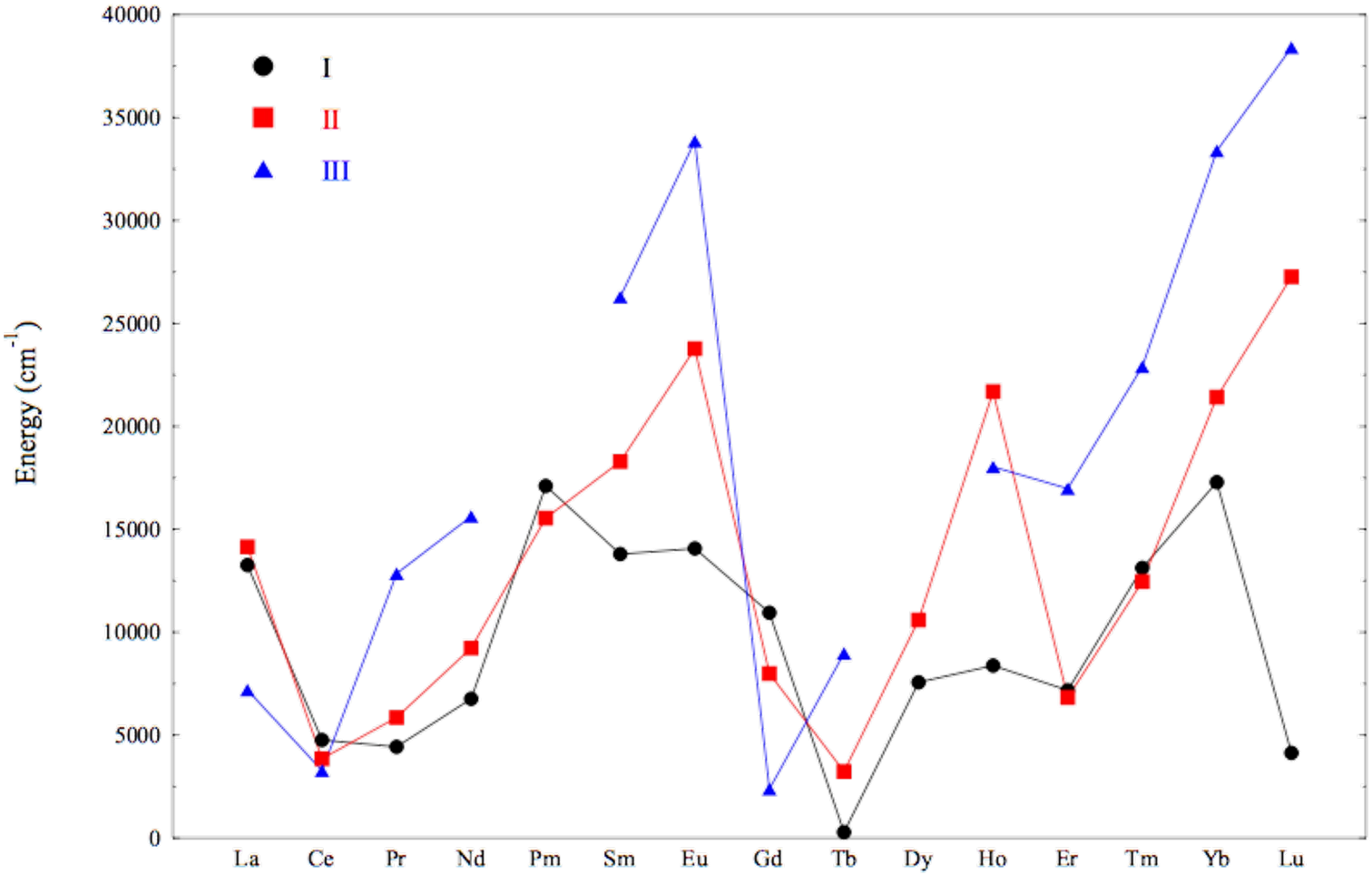

Fe I
5p
5s
4p
(^{2}P)
(^{2}H)
(a^{2}D)
(^{2}F)
3d^{6}4s^2
3d^{6}4snl
3d^8

What lines fall in the IR?



What lines fall in the IR?

The Lanthanides competing configurations 4f, 5d, and 6s

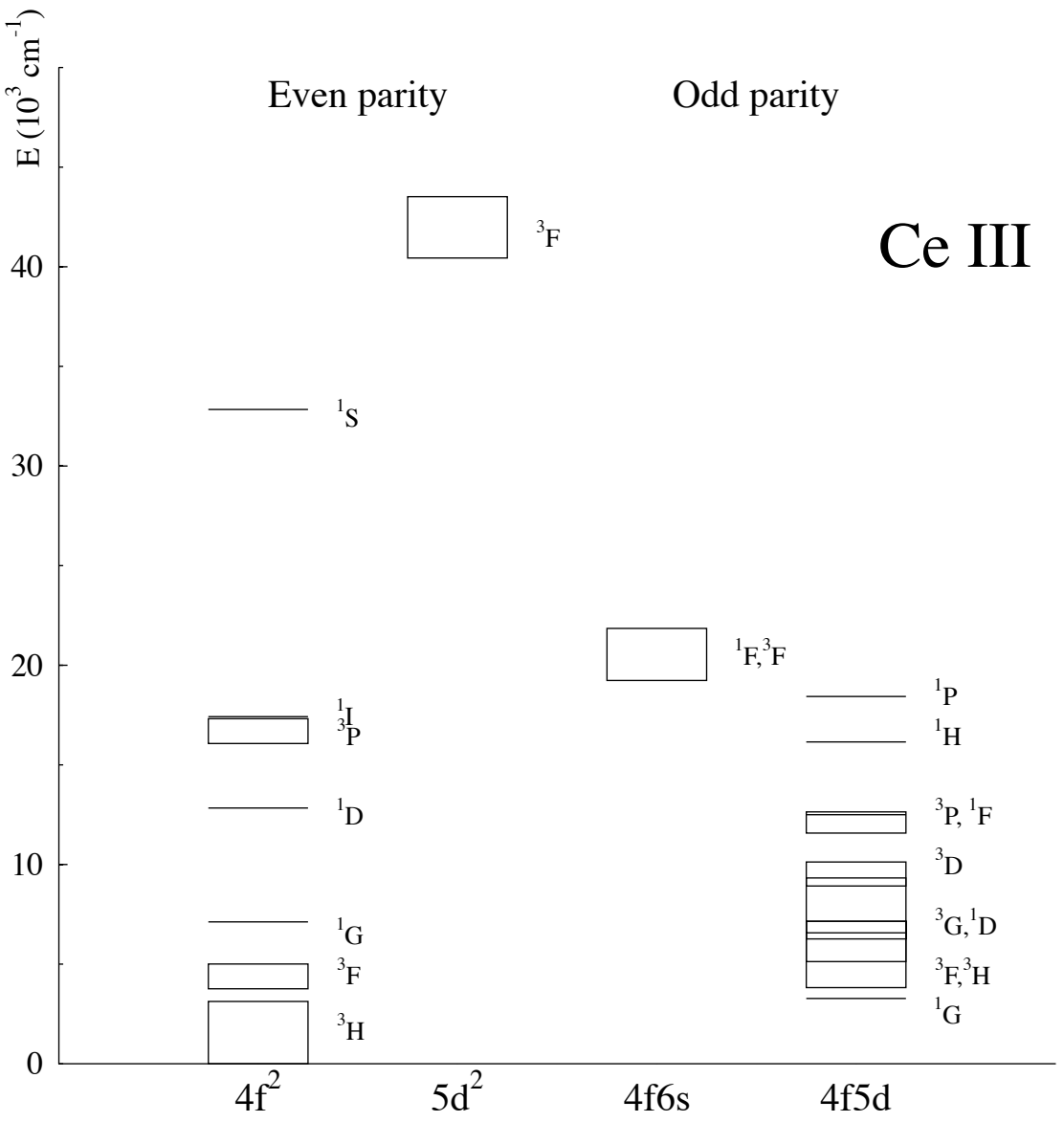


What lines fall in the IR?

The Lanthanides

Ce III

Ground configuration $4f^2$



Indium (Z=49)
In I

Three electron system

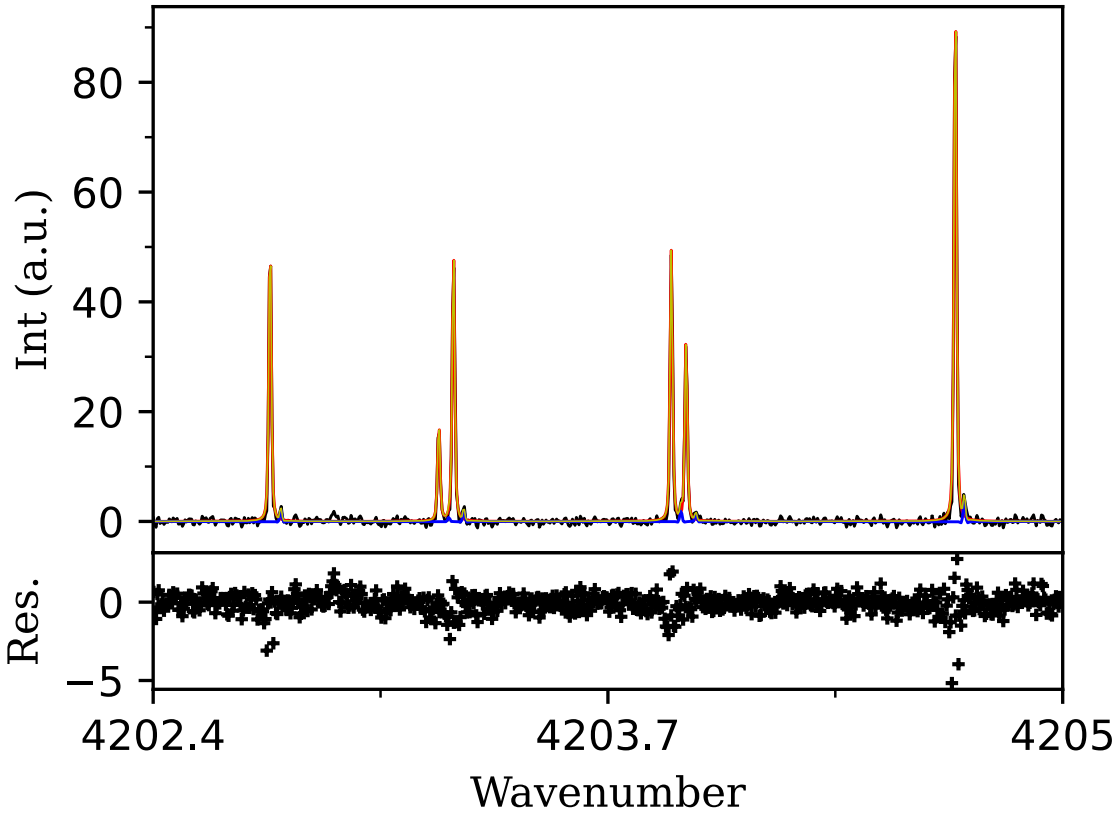
Ground configuration: $5s^2\ 5p$

I = 9/2

Magnetic moment $5.54\mu_N$

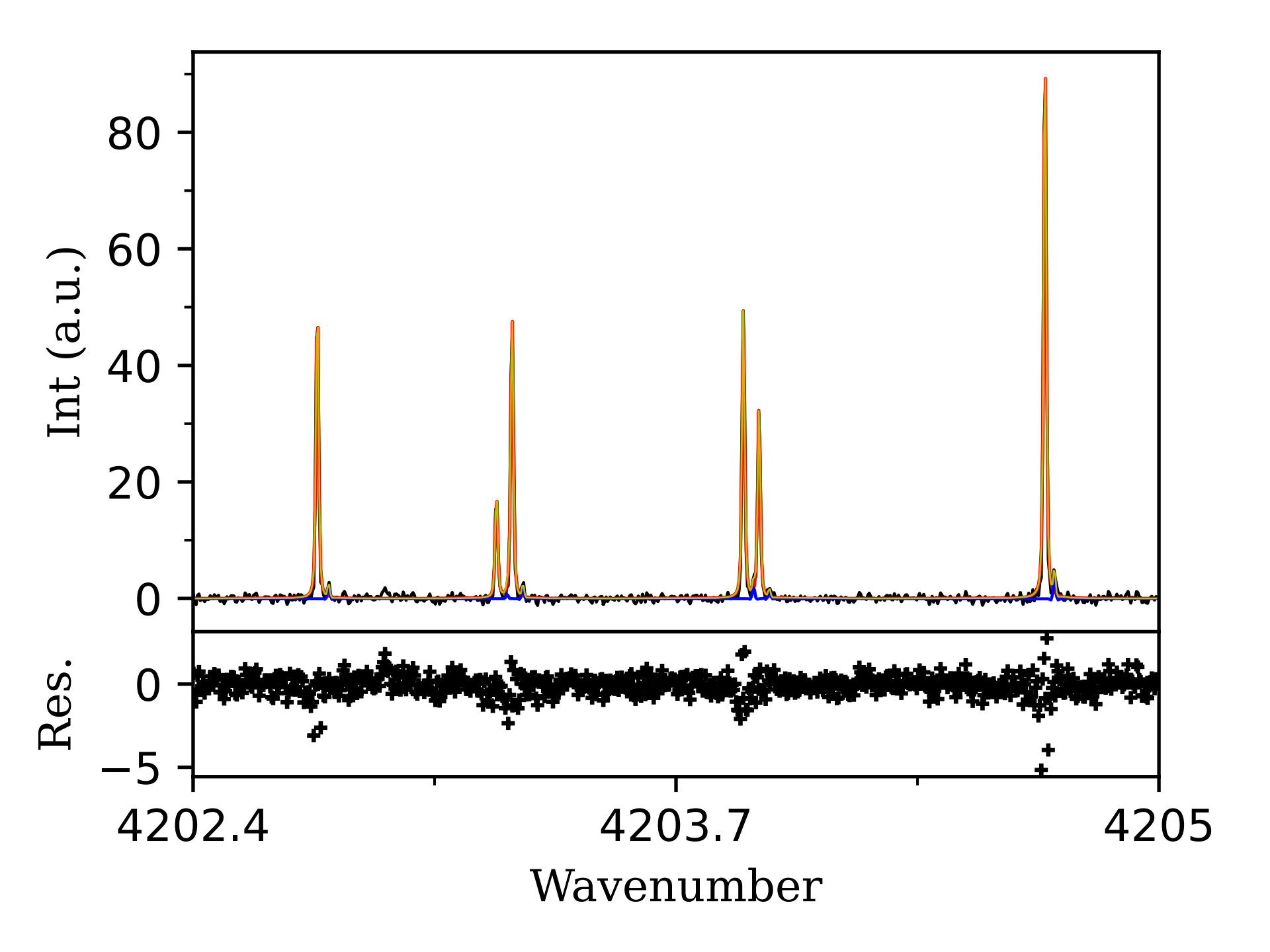
Giving rise to large hfs patterns

Two isotopes ^{113}In (4%) and ^{115}In (96%). Isotopic shift in this line is 27 mK



Intercombination line $5s^2\ 6p\ ^2P_{3/2} - 5s\ 5p^2\ ^4P_{5/2}$

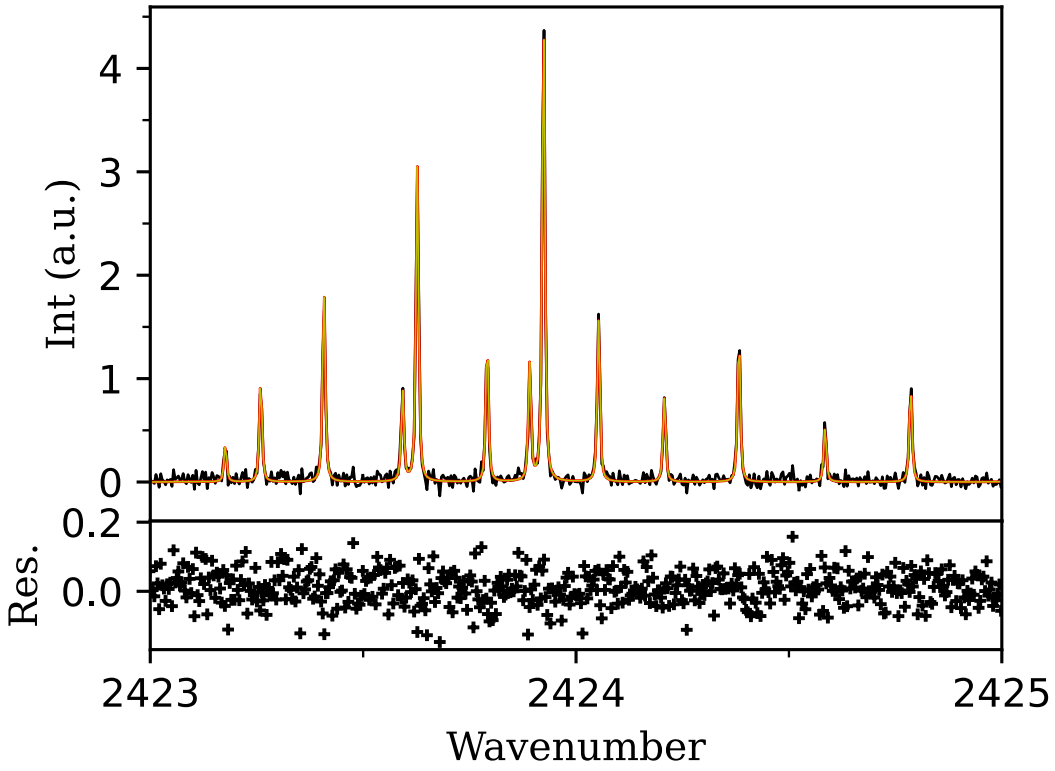
29 levels derived from 73 spectral lines. Hfs constants A and B for 19 levels


Int (a.u.)
80
60
40
20
0
Res.
0
−5
4202.4
4203.7
4205
Wavenumber

Indium (Z=49)
In II

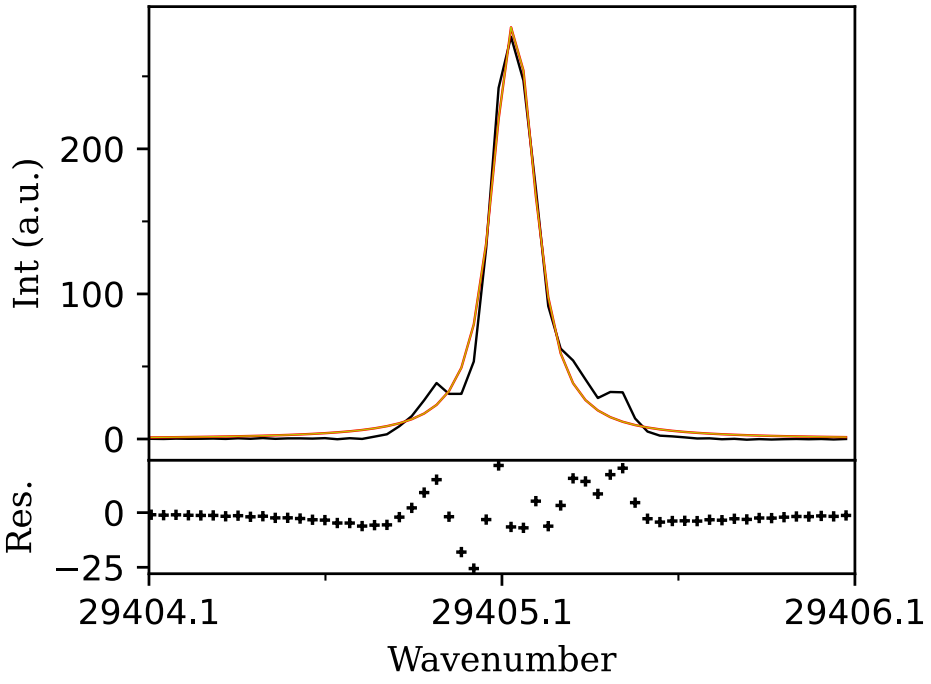
Two electron system. Ground configuration $5s^2$

37 spectral lines used to determine hfs constants A and B for 21 levels.



$5s6d\ ^3D_3 - 5s7p\ ^3P_2$

Hafnium (Z=72)
Hf II



Three electron system.

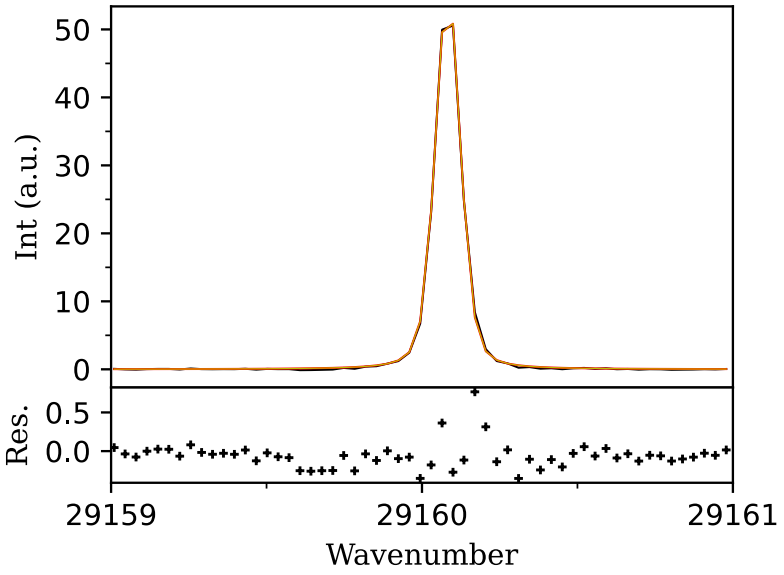
Ground configuration $5d6s^2$

Hafnium has six naturally occuring isotopes (two odd)

FTS spectra from 2000 – 50 000 cm^{-1} (5000 – 200 nm)

10 000 spectra lines

133 levels …

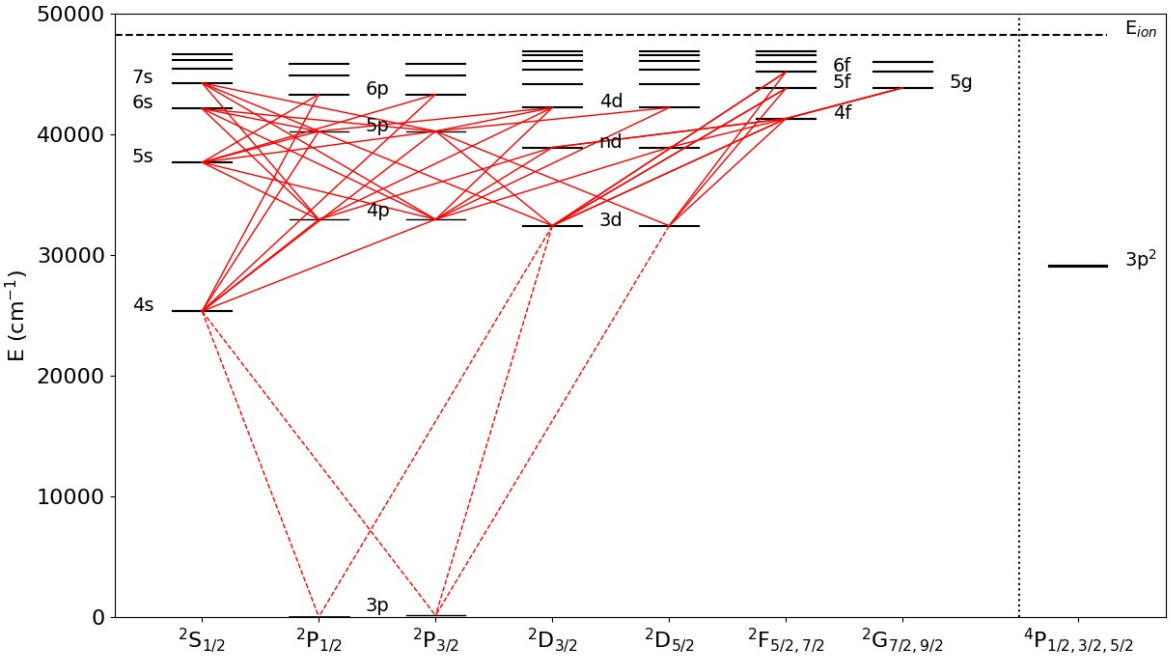


Aluminium (Z=13)
Al I

Ground configuration $3s^2\ 3p$

Oscillator strengths for 12 lines in the NIR and optical spectral regions, with an accuracy between 2 and 11%

Branching fractions for an additional 16 lines



Burheim et al. A&A, 672, A197 (2023)

Silicon Z=14
Si I and Si II

Ground configuration

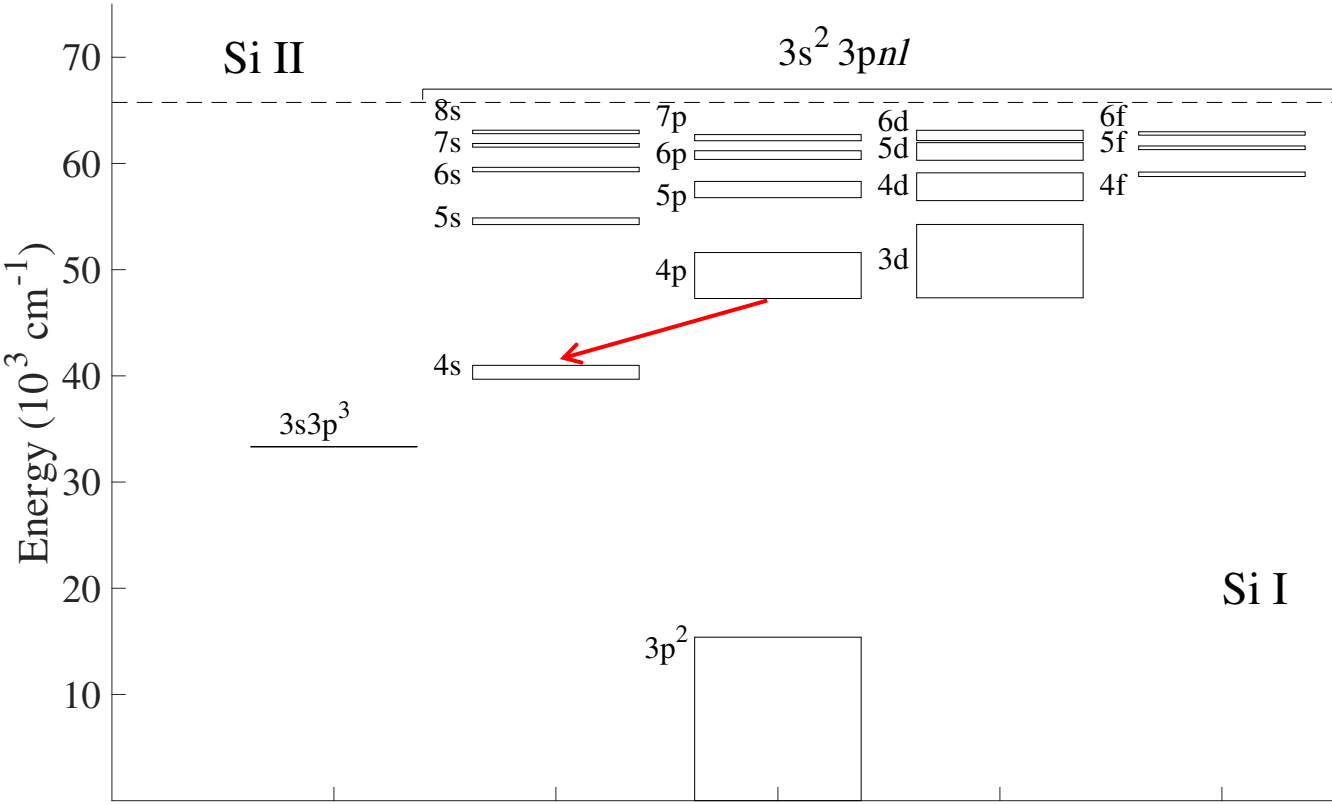
$3s^2\ 3p^2$

We report 17 log *gfs* for $3s^2\ 3p4s$- $3s^2\ 3p4p$ IR-lines.

Derived by combining experimental BFs and lifetimes calculated with GRASP2K.

1500 Si I and 500 Si II theoretical log *gf*s

Accepted by A&A



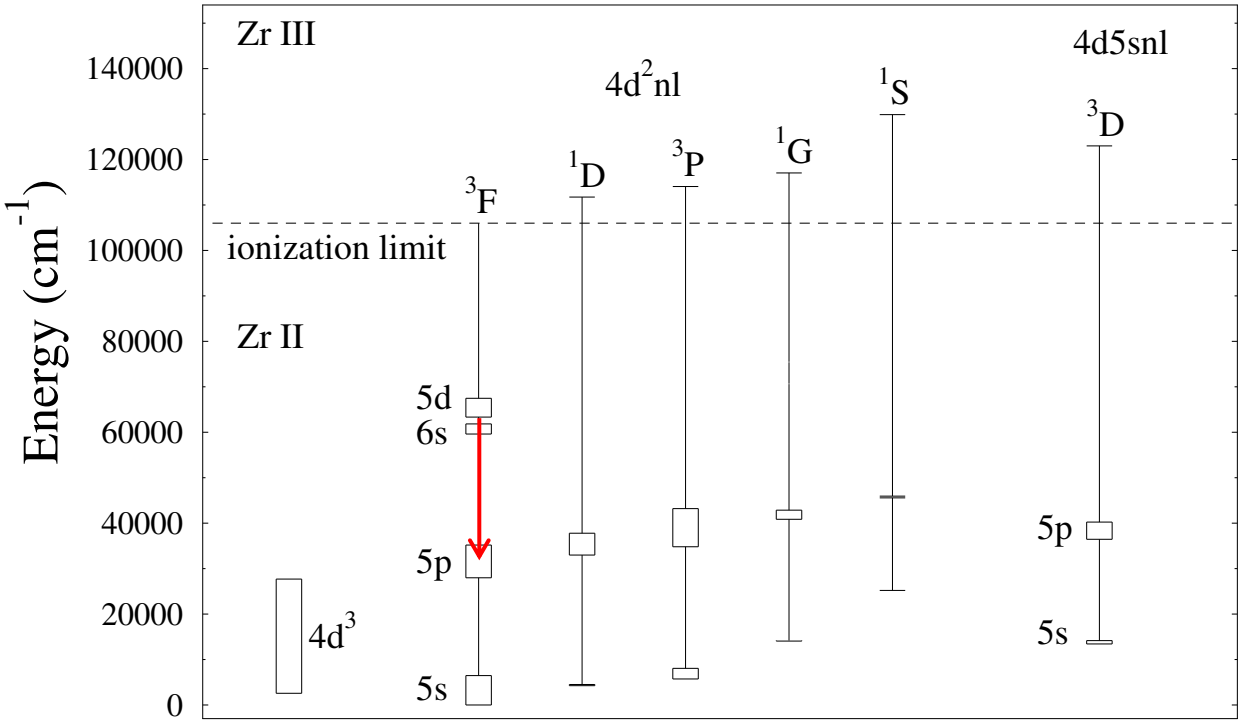
Zirconium (Z=40)
Zr II (Poster Burheim et. al.)

Three electron system (Zr II)

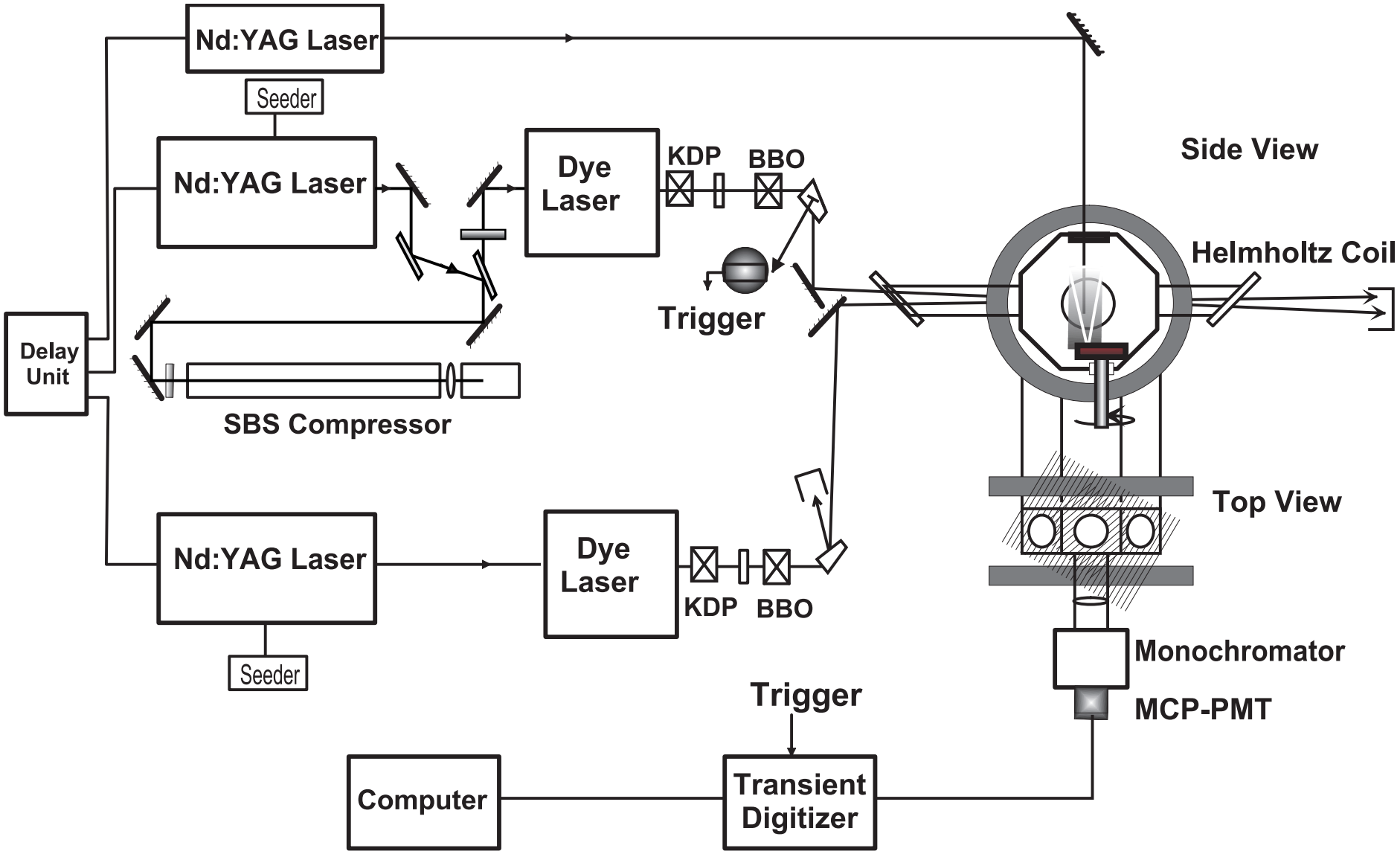
Ground configuration $4d^3$

New energy levels 6s and 5d

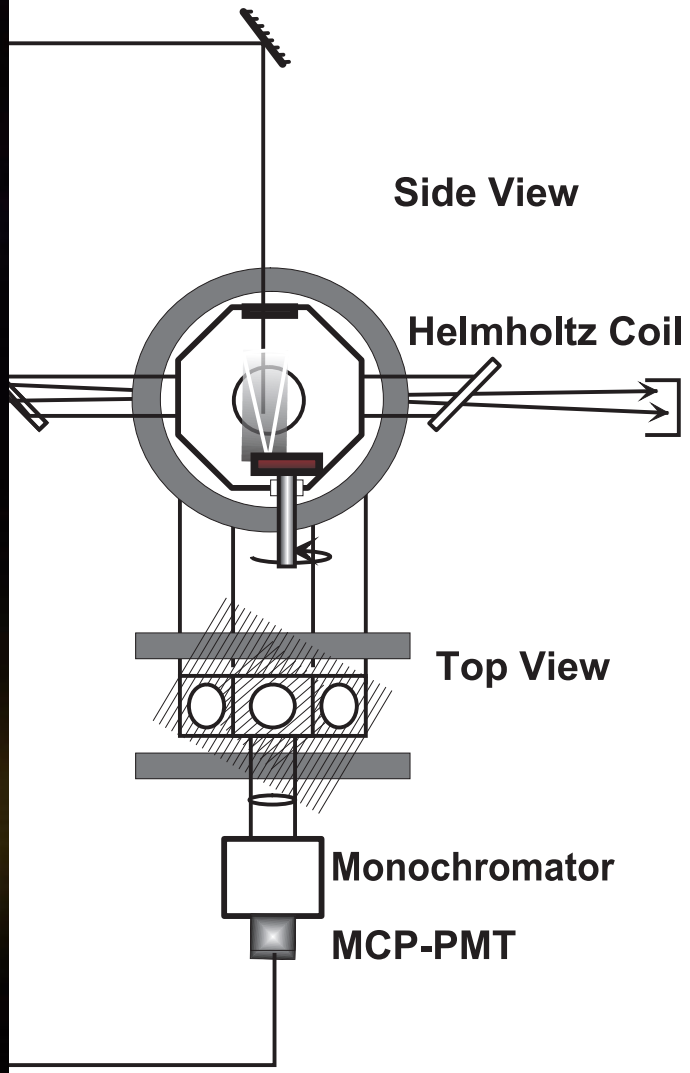
Wavelengths and BFs for 106 lines from 20 levels



Lifetimes


Nd:YAG Laser
Seeder
Nd:YAG Laser
Dye Laser
KDP
BBO
Side View
Helmholtz Coil
Trigger
Delay Unit
SBS Compressor
Nd:YAG Laser
Dye Laser
KDP
BBO
Top View
Seeder
Monochromator
MCP-PMT
Trigger
Computer
Transient Digitizer

Lifetimes



Laboratory astrophysics at Malmö University

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