Recent Advances in the Measurement of Rare-Earth Metal Oscillator Strengths Using Laser-Induced Plasmas

REHSE GROUP

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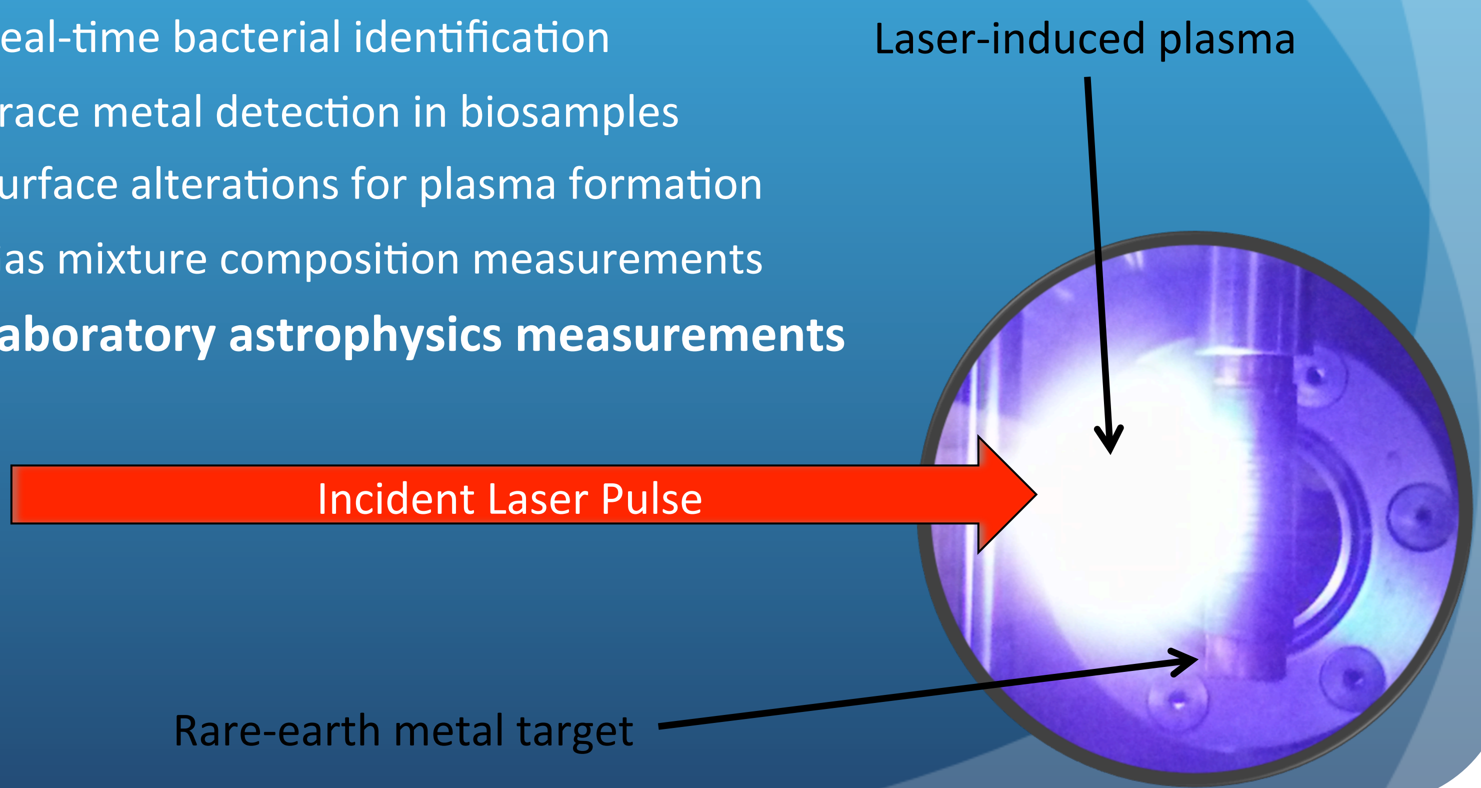
Laser-Induced Breakdown Spectroscopy

- What is LIBS
    - A laser-based atomic analysis technique
- What do we do with LIBS in our lab?
    - Real-time bacterial identification
    - Trace metal detection in biosamples
    - Surface alterations for plasma formation
    - Gas mixture composition measurements
    - **Laboratory astrophysics measurements**



Laborator

- There is curren
  - Nucleosynth
    – but a spec
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  - Rare-earth r
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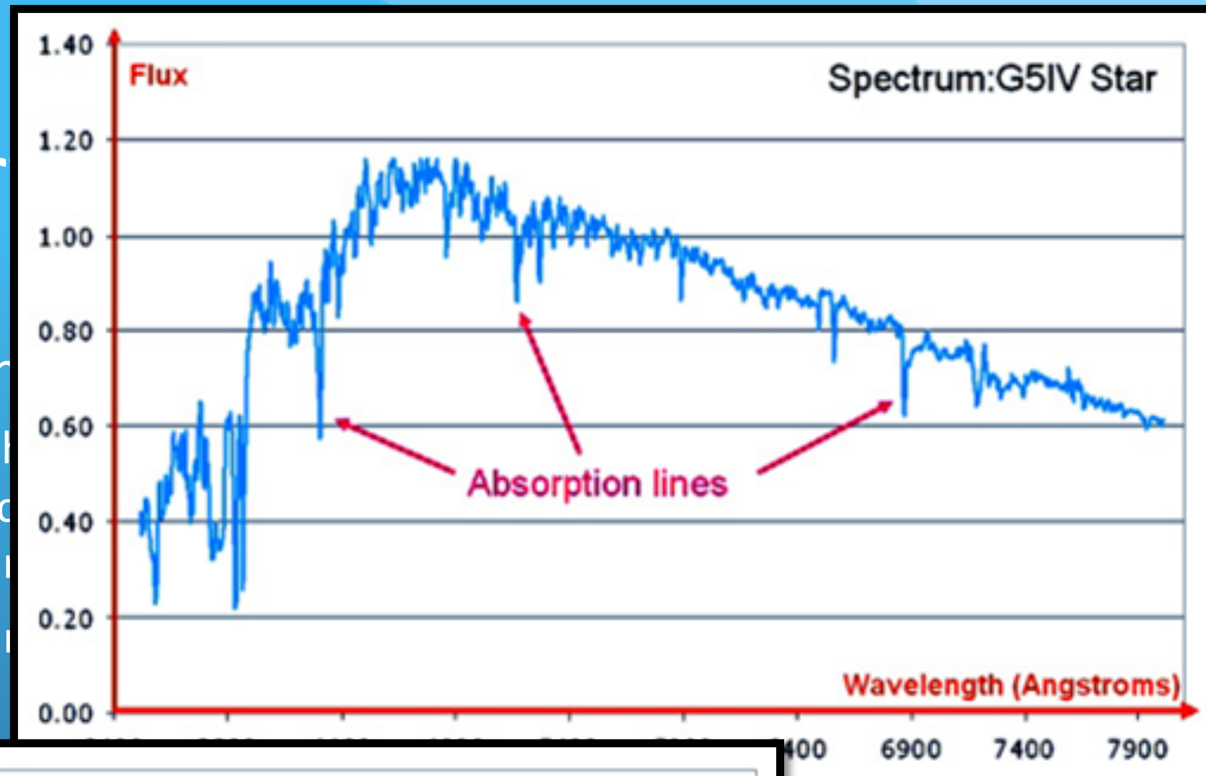
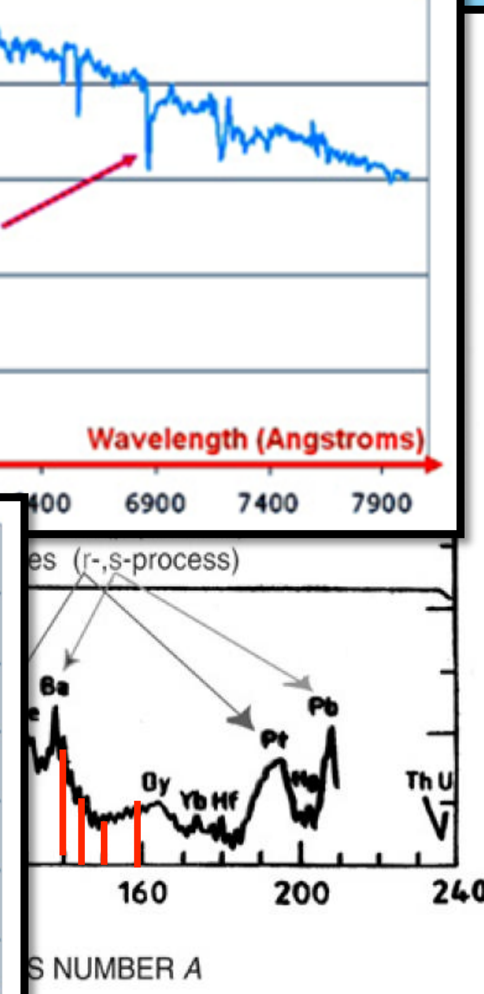
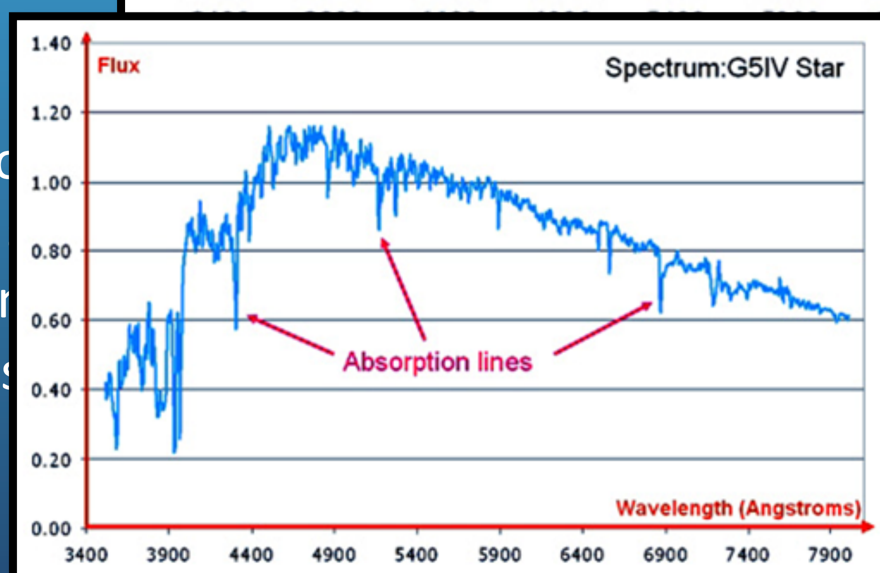
  oscillator
  absorption
  oscillator s



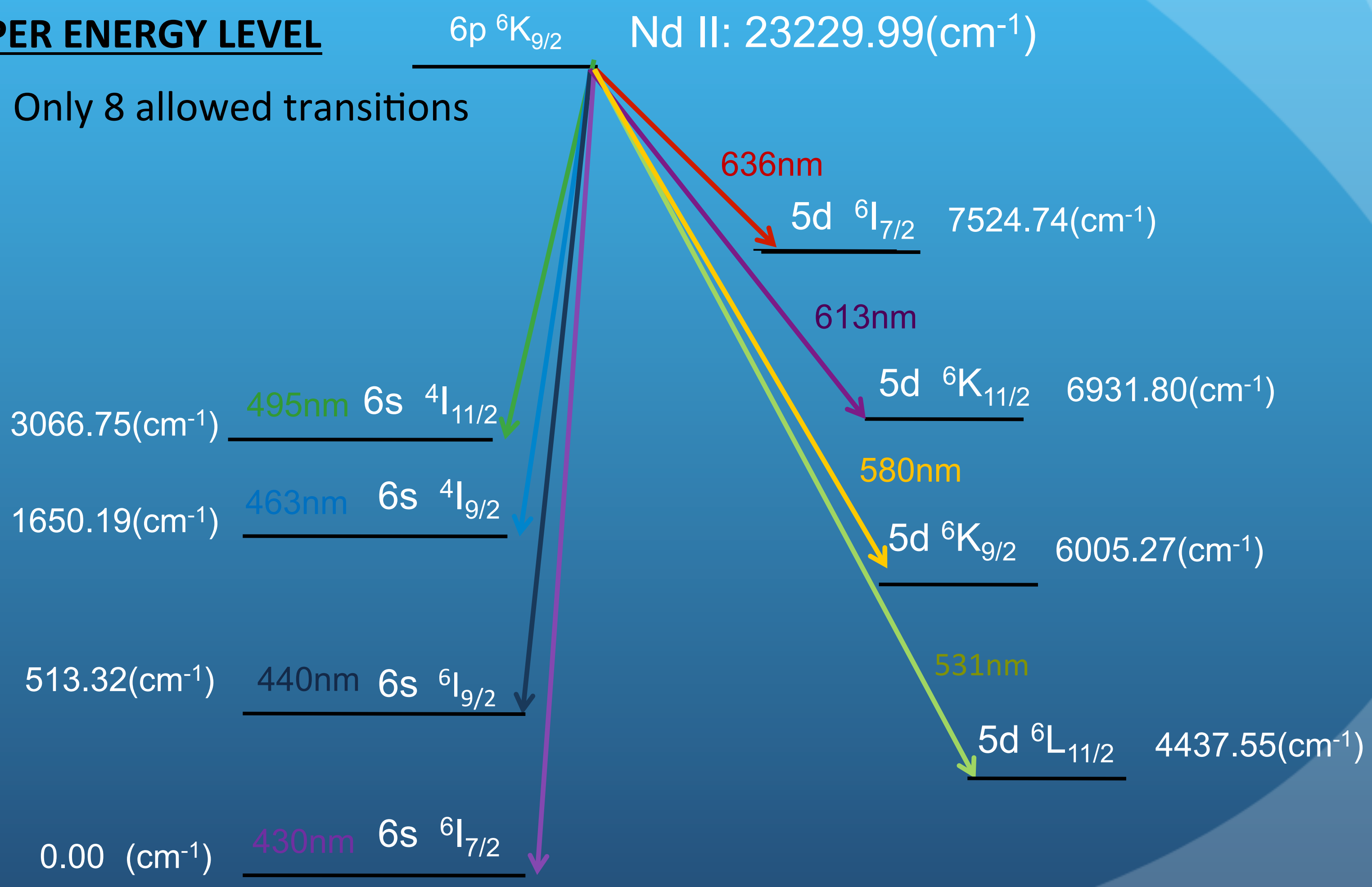




Branching Ratios (Fractions)

<u>UPPER ENERGY LEVEL</u>

- Only 8 allowed transitions



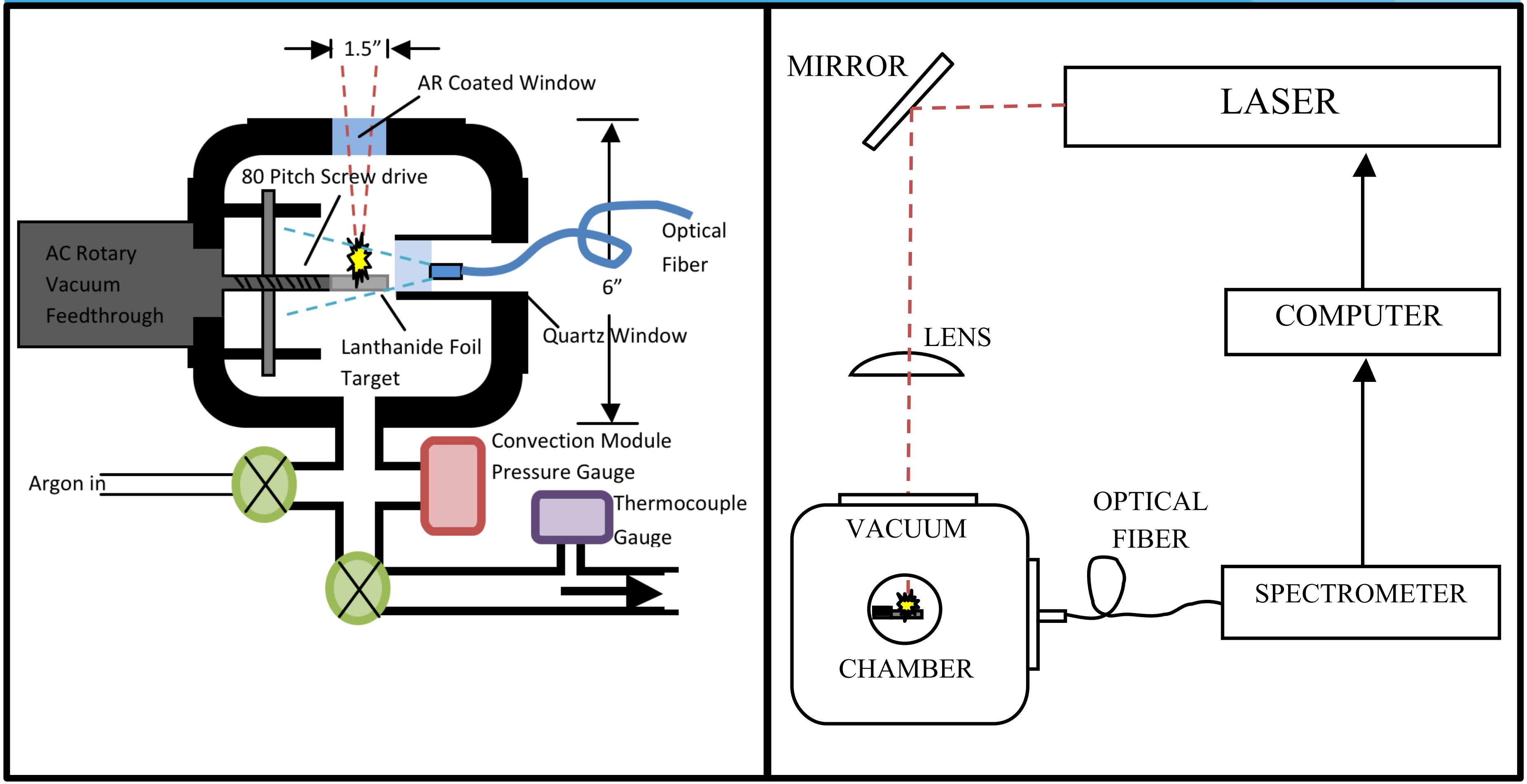
Oscillator Strengths

- The lifetime and the probability of a transition are required to determine the oscillator strength of a given transition
- ALL transitions from an upper energy level must be observed in order to determine oscillator strengths

$$\beta_{ki} = \frac{A_{ki}}{\sum_i A_{ki}} = \frac{I_{ki}}{\sum_i I_{ki}} = A_{ki}\tau_k$$

$$f_{ki} = \left(-1.5\times10^{-7}\right)\lambda^2 \frac{g_i}{g_k}\frac{\beta_{ki}}{\tau_k}$$

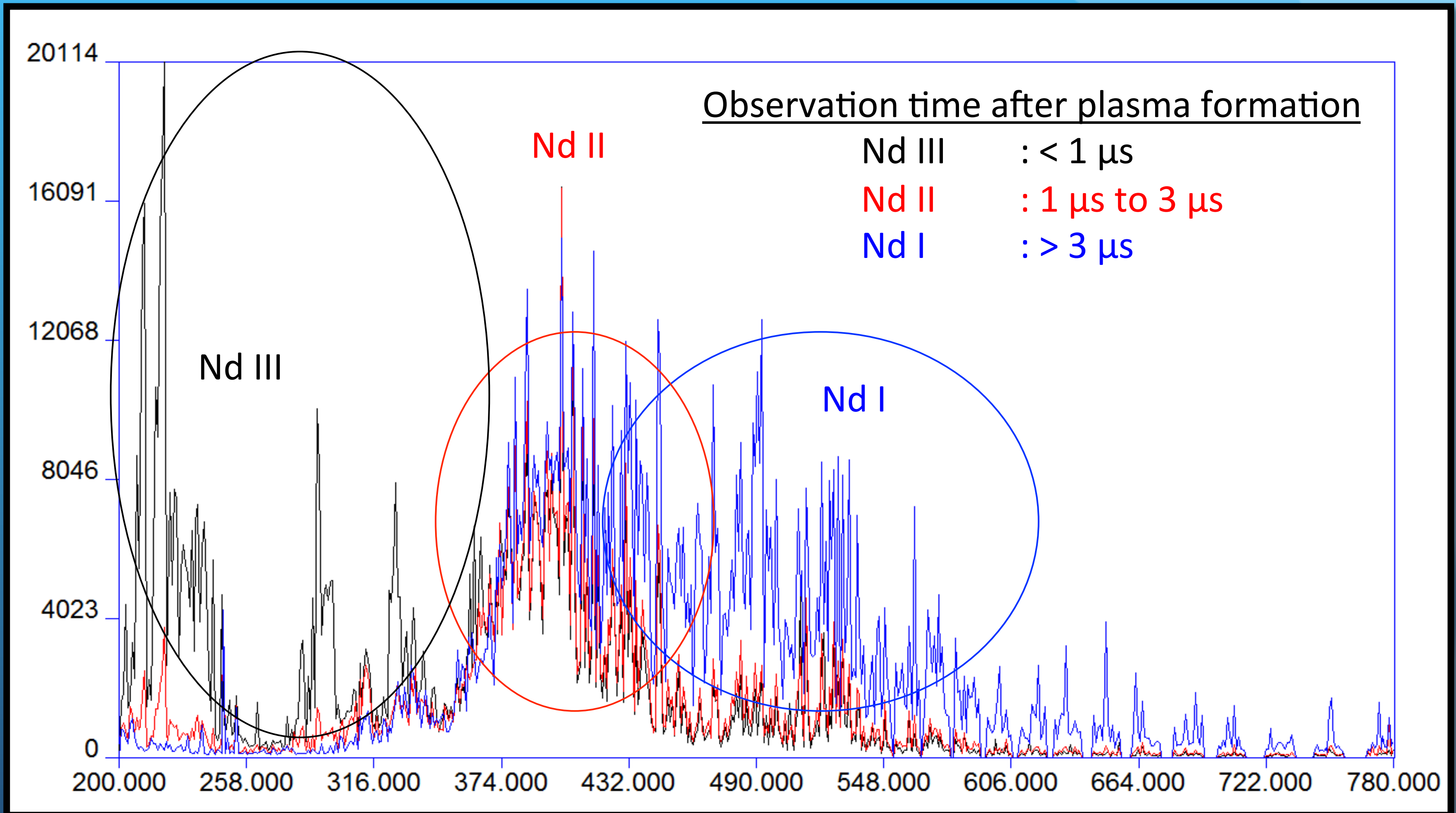
Experimental Design



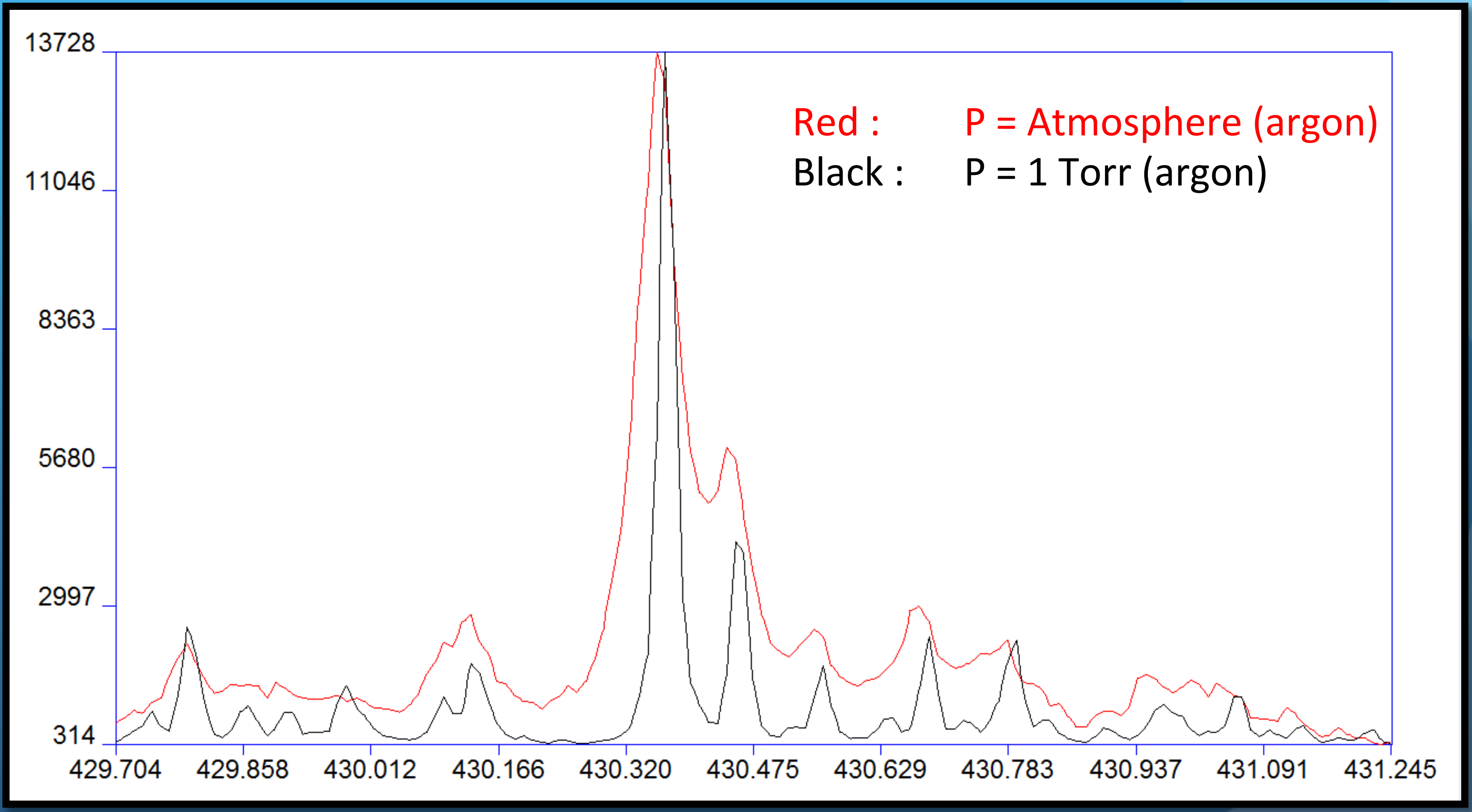
Parameter Investigation

- Plasma expansion and decay over time – when should we observe the plasma?
- Environmental pressure for creation of the laser-induced plasma
- Target composition – optically thin plasma, (no self-absorption) decay due to spontaneous emission only
- I varied multiple experimental parameters to obtain the best regime for measurements

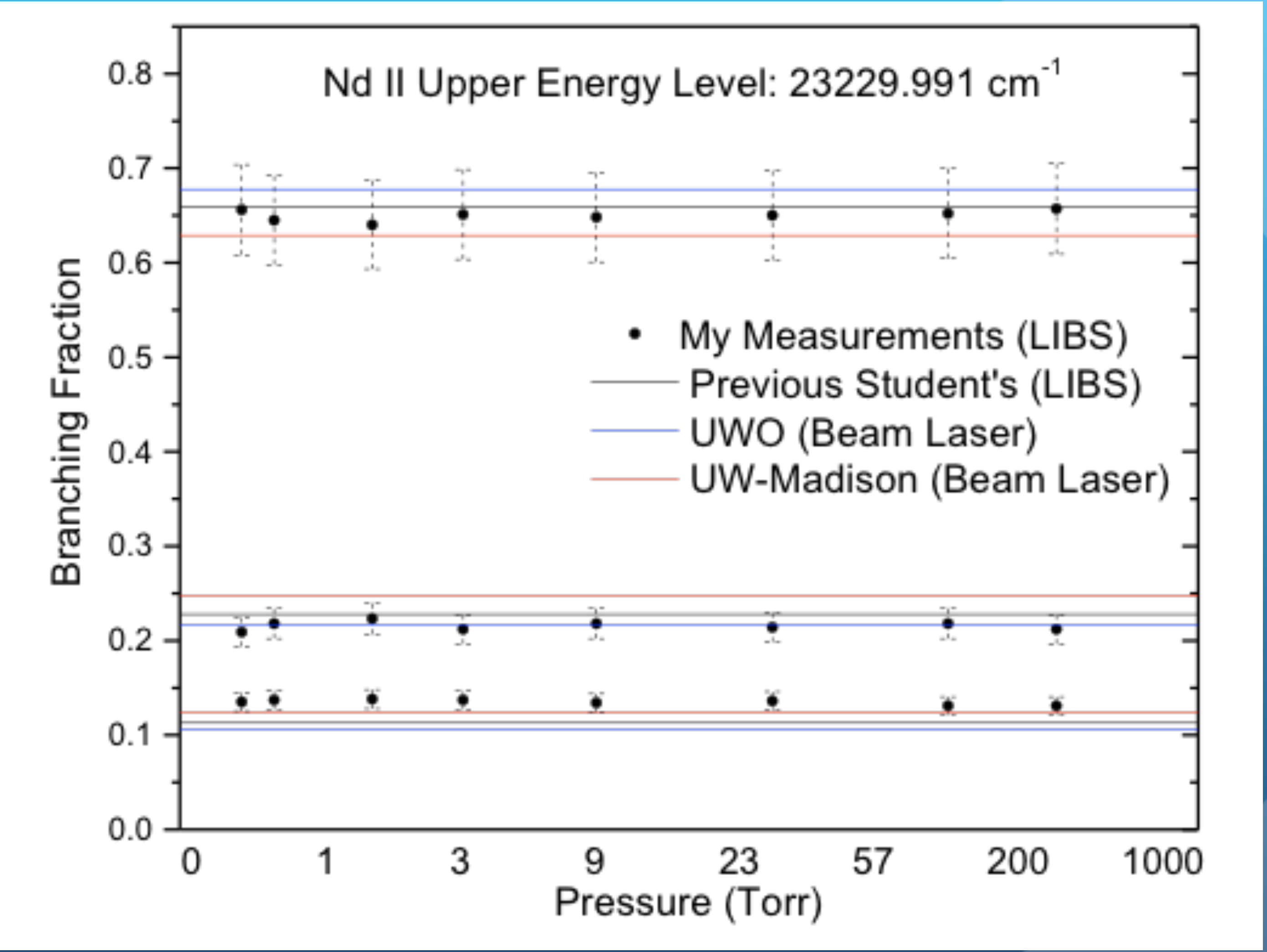
Observation Time – Nd I, II, and III



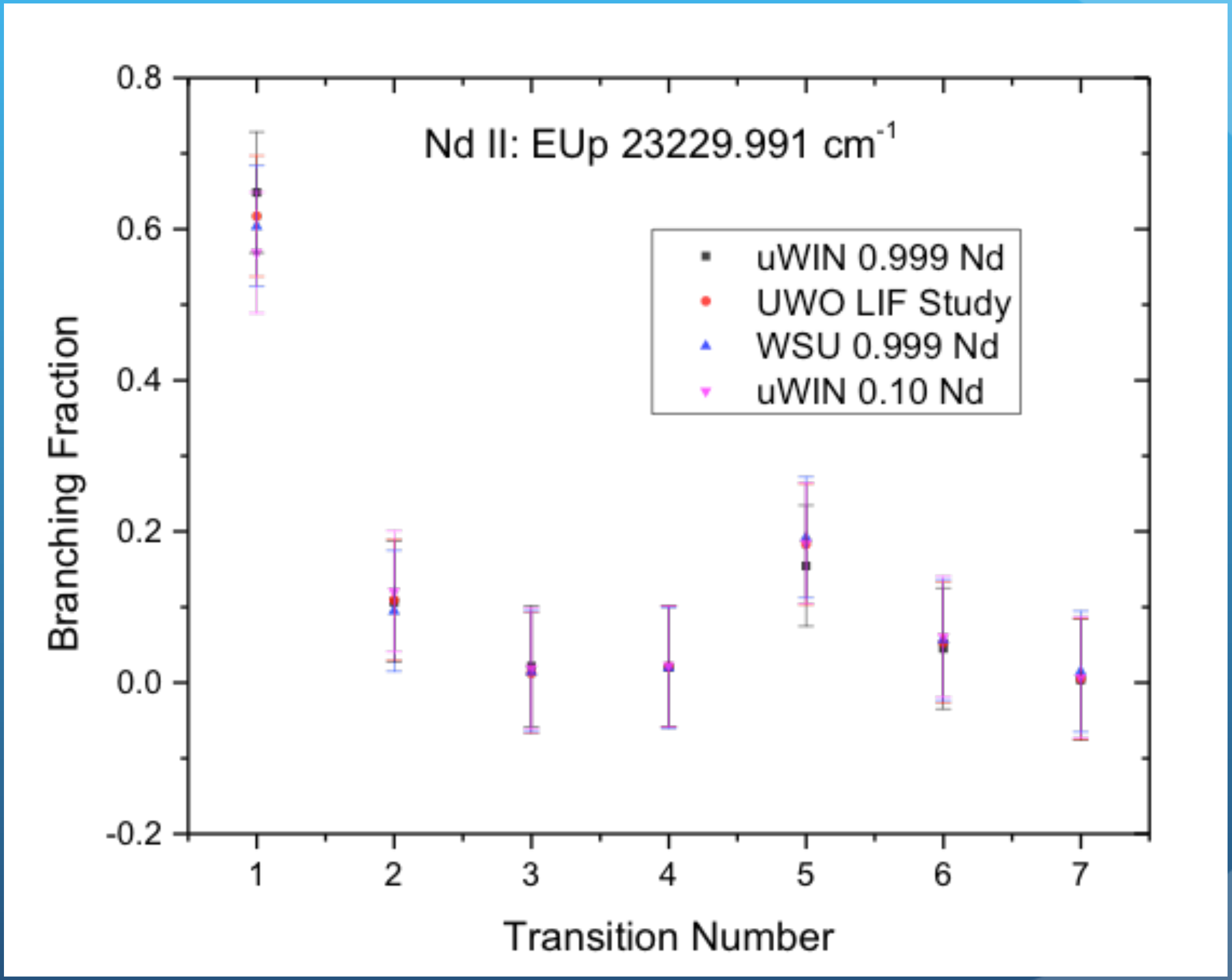
Effect of Pressure



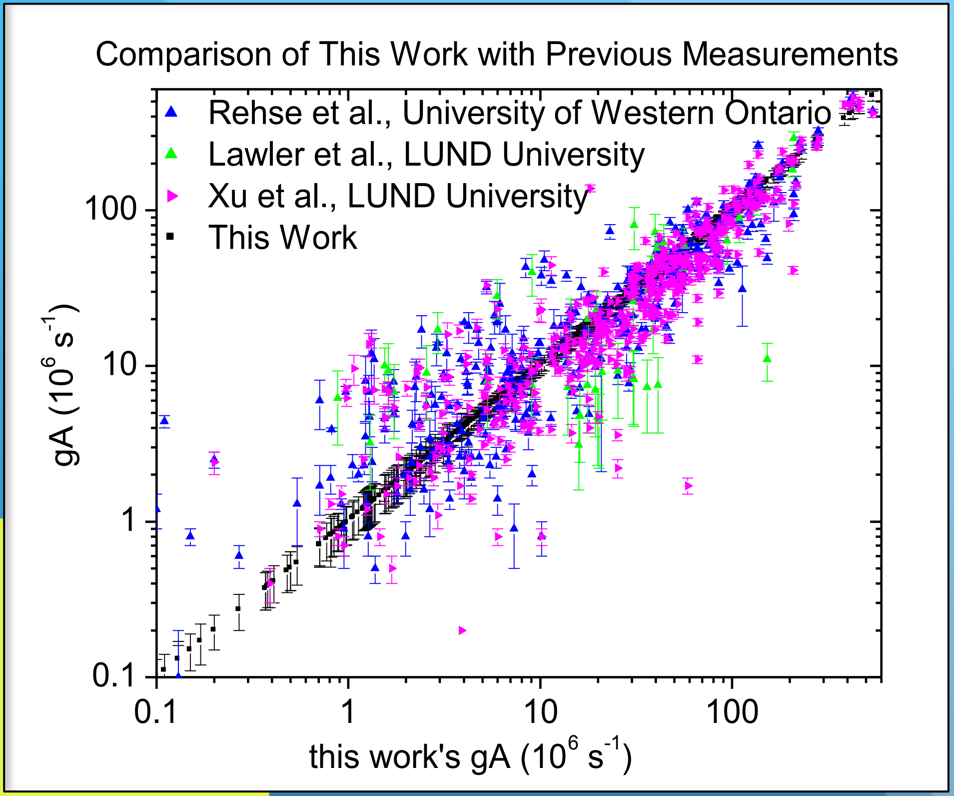
Relative Intensities with Various Pressures



Target Composition – 10 % Nd & 99.9% Nd



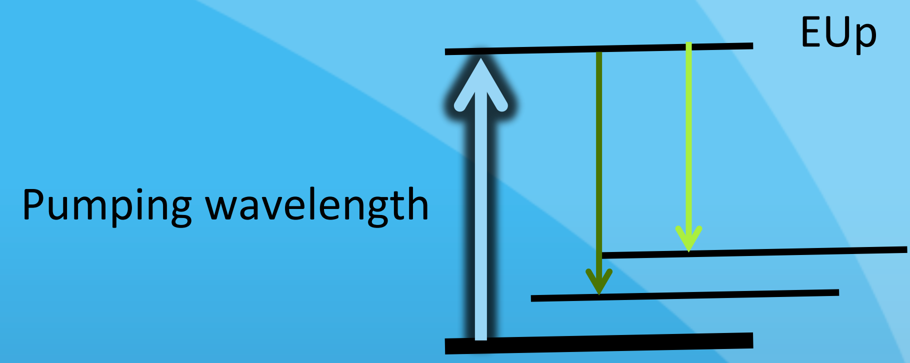
Results

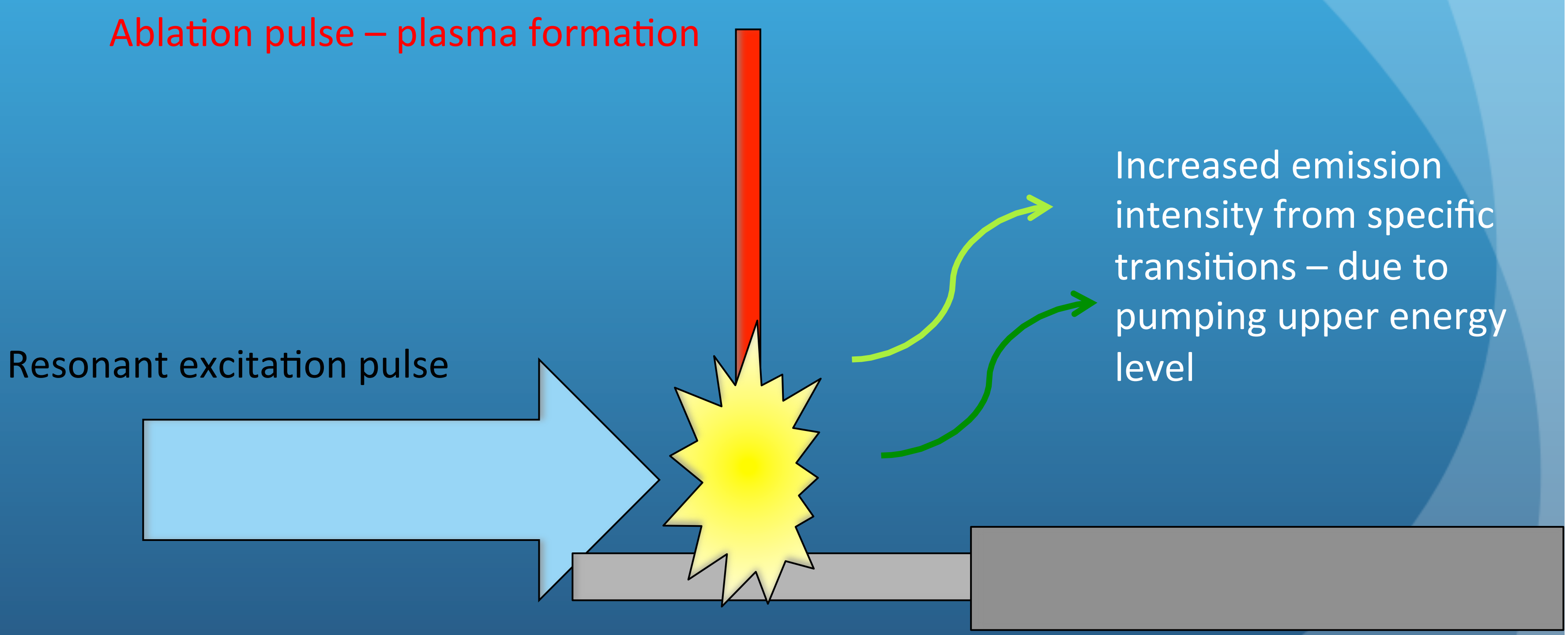


Results obtained include:

- Pr II – 60 upper energy levels with 425 transitions
- Nd I – 74 upper energy levels with 83 transitions
- Nd II – 24 upper energy levels with 179 transitions
- Nd III – 1 upper energy level with 2 transitions
- Sm I – 45 upper energy levels with 75 transitions
- Sm II – Over 100 upper energy levels with over 500 transitions
- Sm III – 12 upper energy levels with 30 transitions
- Gd I – 90 upper energy levels with 179 transitions
- Gd II – Over 100 upper energy levels with over 600 transitions
- Gd III – 4 upper energy levels with 24 transitions
- Cu I – 70 upper energy levels with over 300 transitions
- Cu II – 28 upper energy levels with 150 transitions
- Fe I – Over 100 upper energy levels with over 700 transitions
- Fe II – Over 100 upper energy levels with over 700 transitions

LIBS – LIF


EUp
Pumping wavelength


Ablation pulse – plasma formation
Resonant excitation pulse
Increased emission intensity from specific transitions – due to pumping upper energy level

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  - *University of Windsor* Faculty of Science

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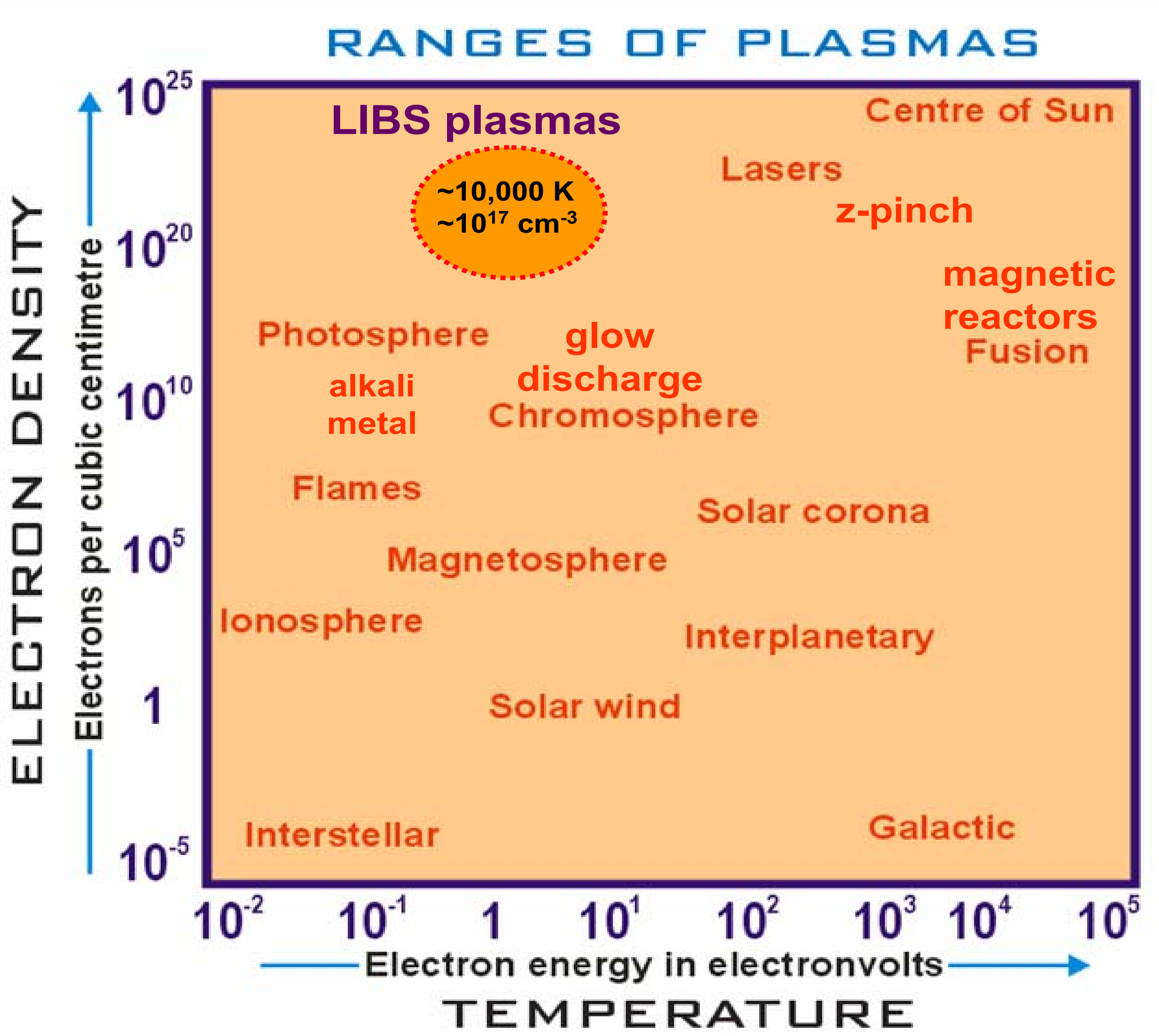

RANGES OF PLASMAS
LIBS plasmas
~10,000 K
~10^17 cm^-3
Centre of Sun
Lasers
z-pinch
magnetic reactors
Fusion
Photosphere
glow discharge
alkali metal
Chromosphere
Flames
Solar corona
Magnetosphere
Ionosphere
Interplanetary
Solar wind
Interstellar
Galactic
ELECTRON DENSITY
Electrons per cubic centimetre
10^25
10^20
10^10
10^5
1
10^-5
10^-2
10^-1
1
10^1
10^2
10^3
10^4
10^5
Electron energy in electronvolts
TEMPERATURE