

C_7^- and the Diffuse Interstellar Bands

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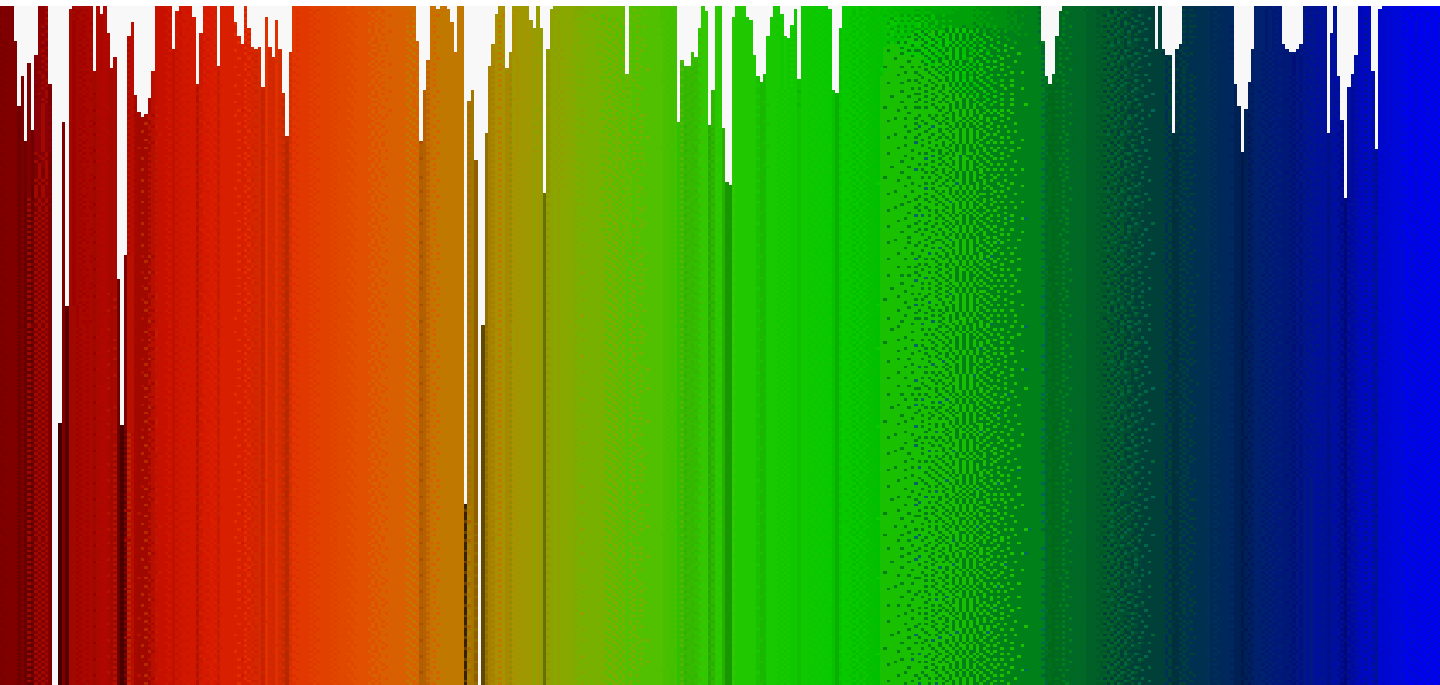
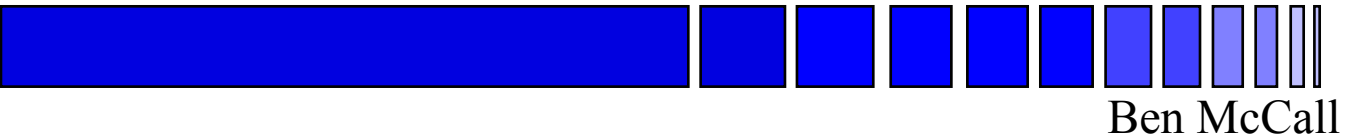
University of Chicago



Special Thanks to: John Maier

Marek Tulej

Diffuse Interstellar Bands



- ★ Sharp and broad (“diffuse”) bands
- ★ Range from $\sim 4430 \text{ \AA}$ to $\sim 8000 \text{ \AA}$
- ★ Seen in absorption against reddened stars
- ★ Associated with diffuse ($n \sim 10^3 \text{ cm}^{-3}$) clouds
- ★ Not all correlated; roughly increase with E_{B-V}
- ★ Long-standing astrophysical mystery!

Carrier Hypotheses



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- | | |
|-----------------|---|
| Small Molecules | <ul style="list-style-type: none">× CO_2, Na_2, $(\text{O}_2)_2$, NH_4, O^-, C^-× CH_4^+, H^-, HCOOH^+, H_2 |
| PAH ions | <ul style="list-style-type: none">✓ Abundance of C,H× No matching spectra (yet) |
| Carbon chains | <ul style="list-style-type: none">✓ Abundance of C✓ Similar to observed molecules (radio)✓ Internal conversion →
broadening without destruction✓ Convincing (?) match with C_7^- |



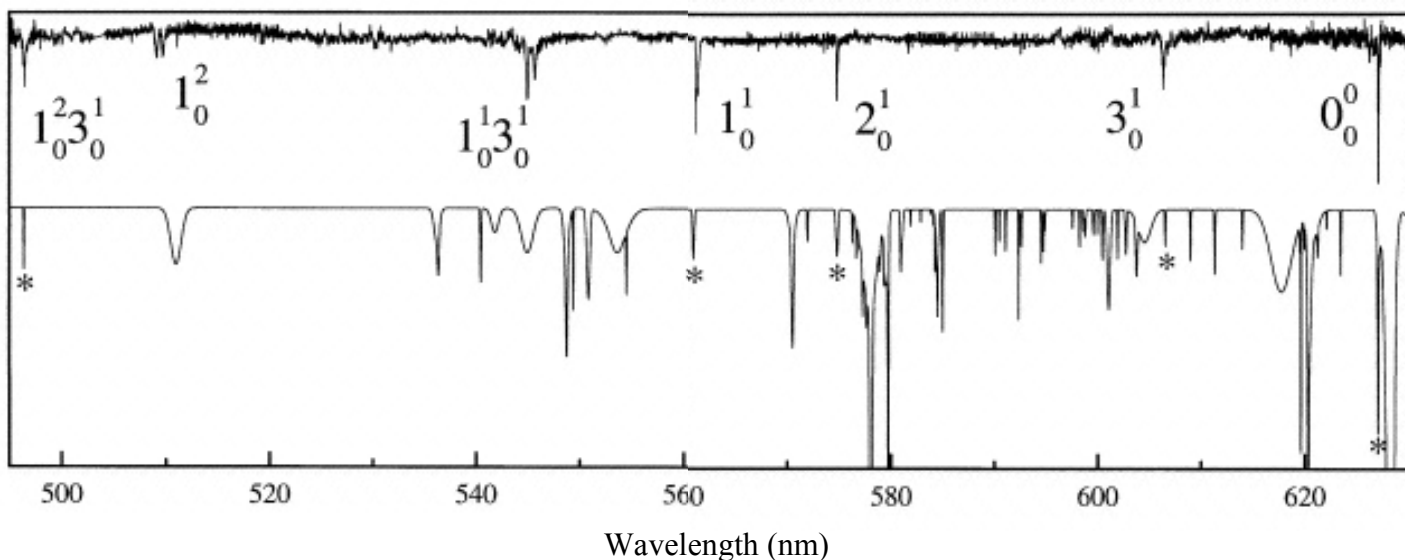
Identification of the carrier(s) is the key step in understanding DIBs

The C₇⁻ Hypothesis



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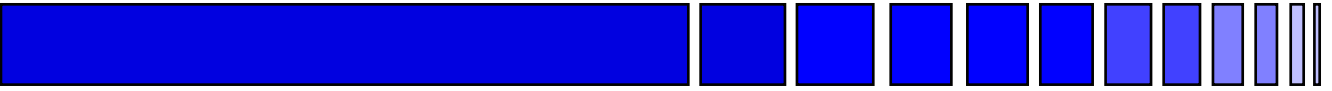
M. Tulej et al., *Astrophys. J.* 506, L69 (1998)



- ✓ Direct gas-phase comparison
- ✓ Match looks good
- ✓ Shows broadened B←X band
(internal conversion)

- ✗ Experimental uncertainties
in shape, width, & intensity
- ✗ Difficult to produce in models

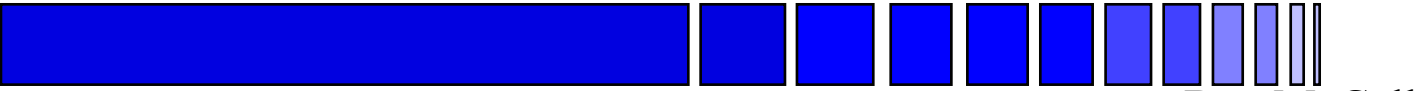
Criteria for C_7^-



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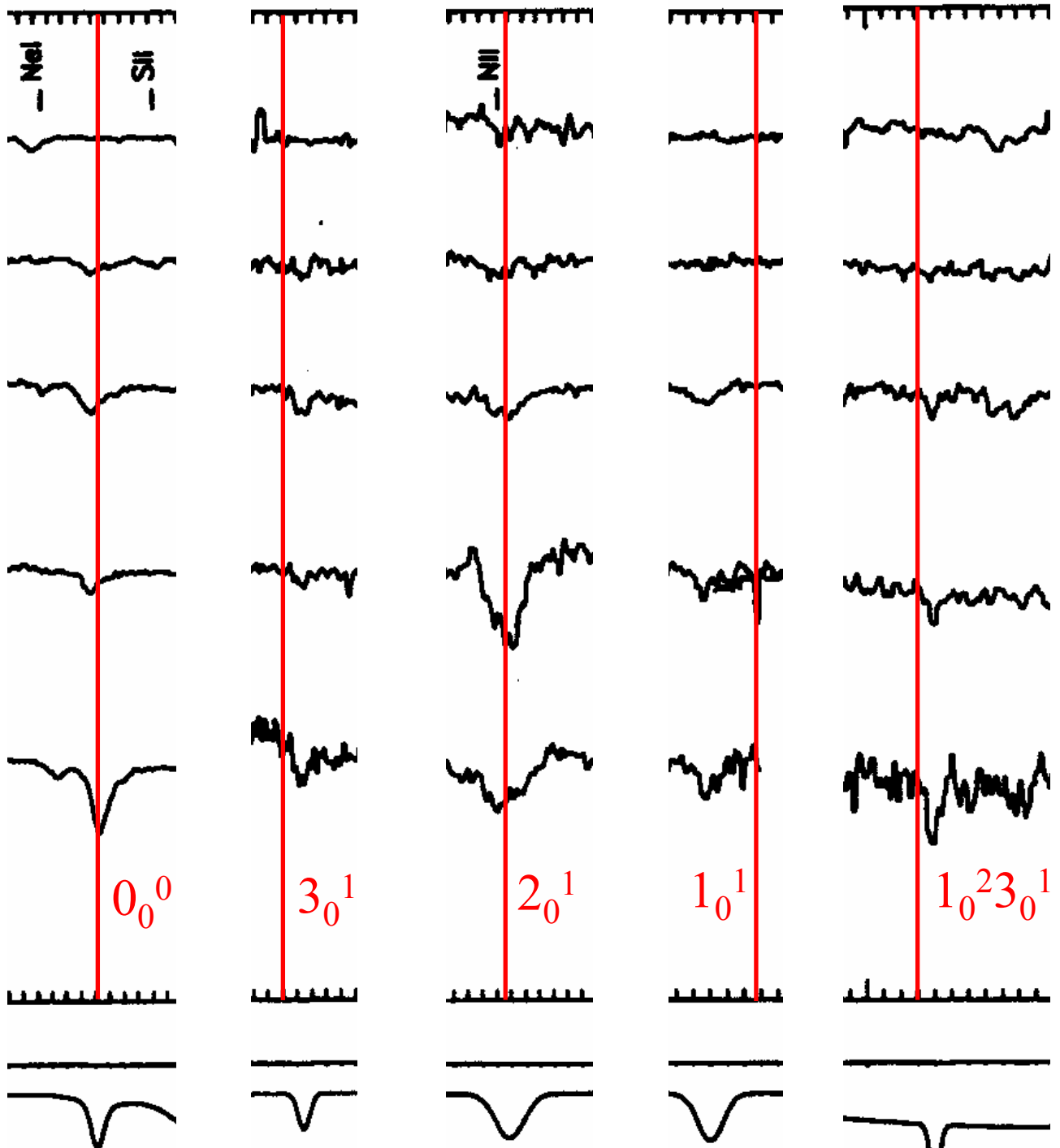
- ★ Existence in astronomical spectra (with sufficient S/N) of **all** $A \leftarrow X$ bands seen in laboratory
- ★ Relative intensities of DIBs same as in laboratory (matrix) measurements **and** same from star to star
- ★ Wavelength coincidence between DIBs and lab spectrum (but: experimental issues, temperature)
- ★ Similar FWHM of DIBs (possibly larger to shorter λ)
- ★ $B \leftarrow X$ transitions in DIBs (very broad \Rightarrow not very deep)

Existing DIB Measurements



Jenniskens & Désert, *Astron. Astrophys. Suppl. Ser.* 106, 39 (1994)

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Lab intensities: Tulej et al., *Astrophys. J.* 506, L69 (1998)

10

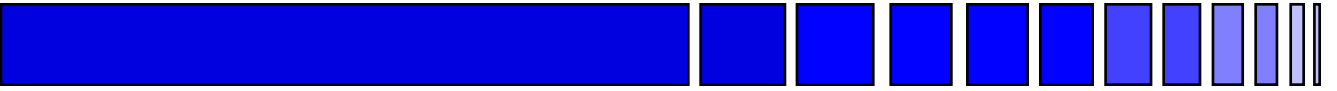
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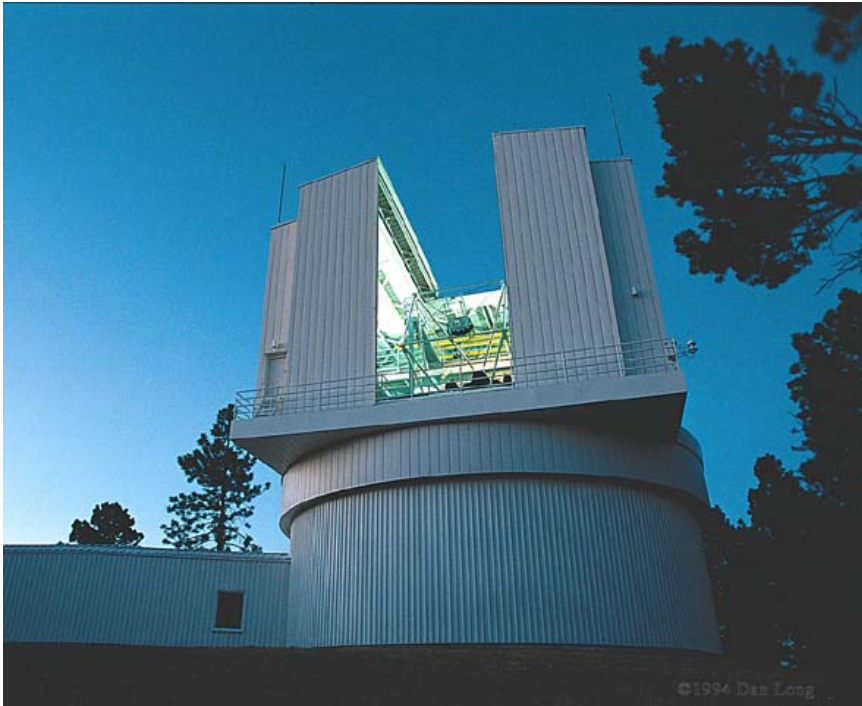
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1

Apache Point Observatory



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3.5 meter
telescope

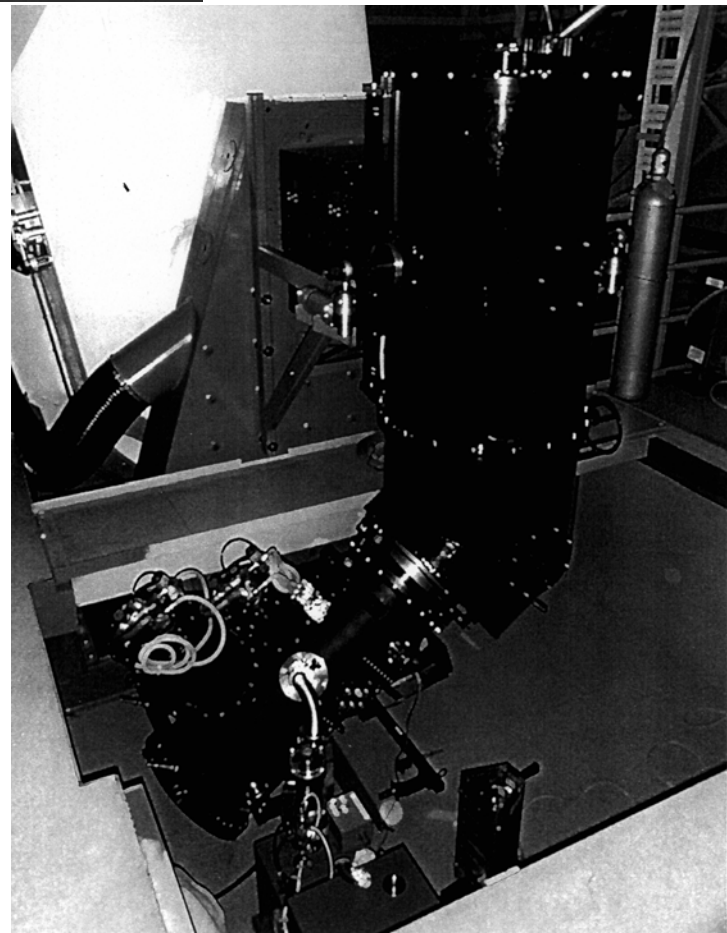
Astrophysical
Research
Consortium

Facility Echelle
Spectrometer:

$< 4000 \text{ \AA}$ to $> 10000 \text{ \AA}$
in single exposure

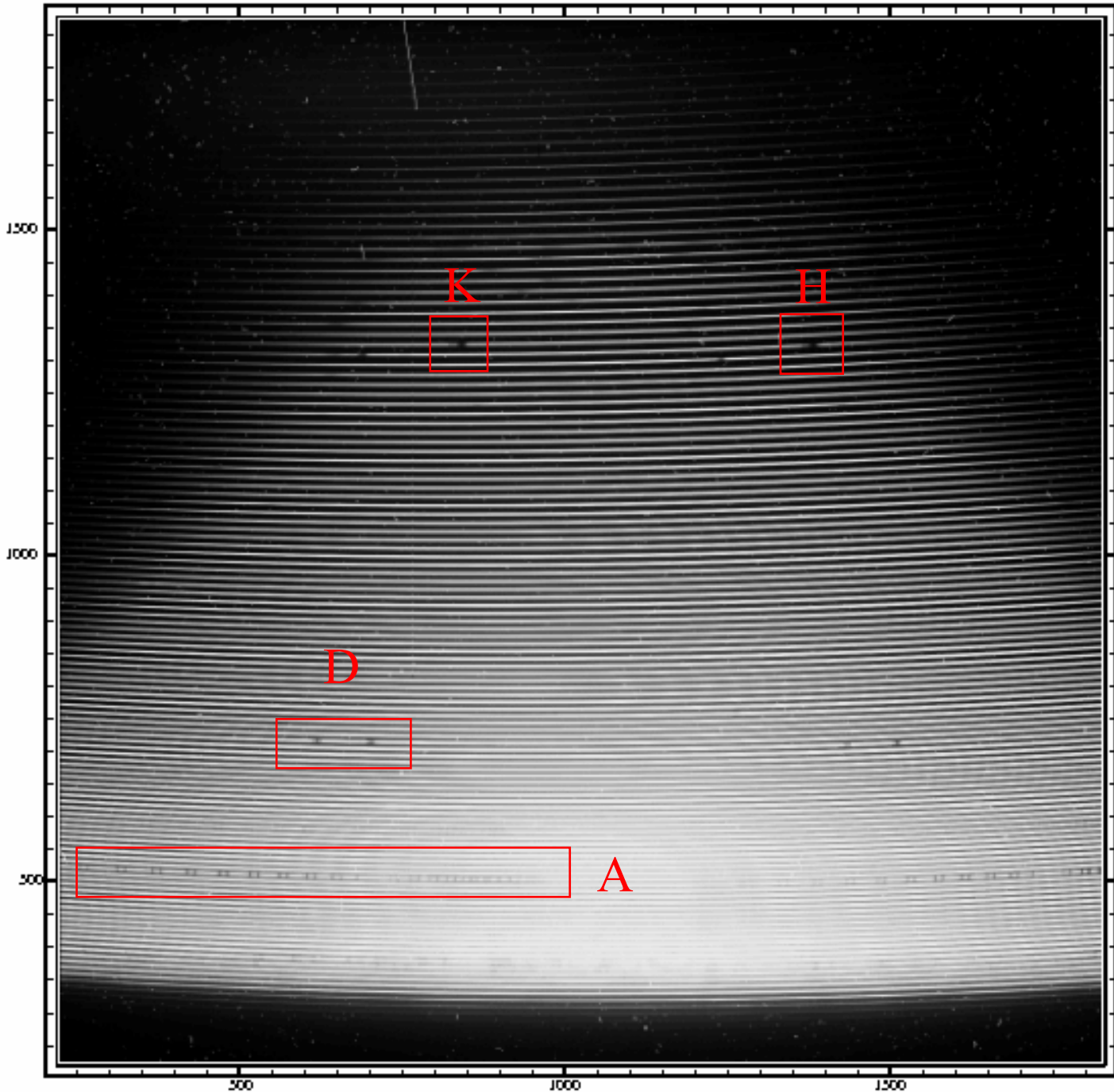
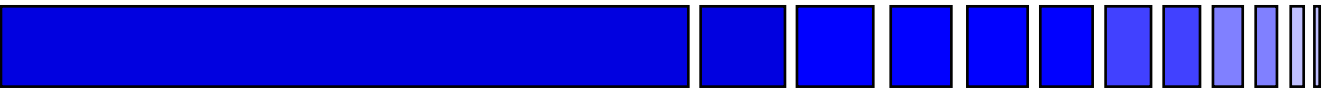
High resolution
($\lambda / \Delta\lambda \sim 37,500$)

High sensitivity



Echelle Image

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Fraunhofer Lines

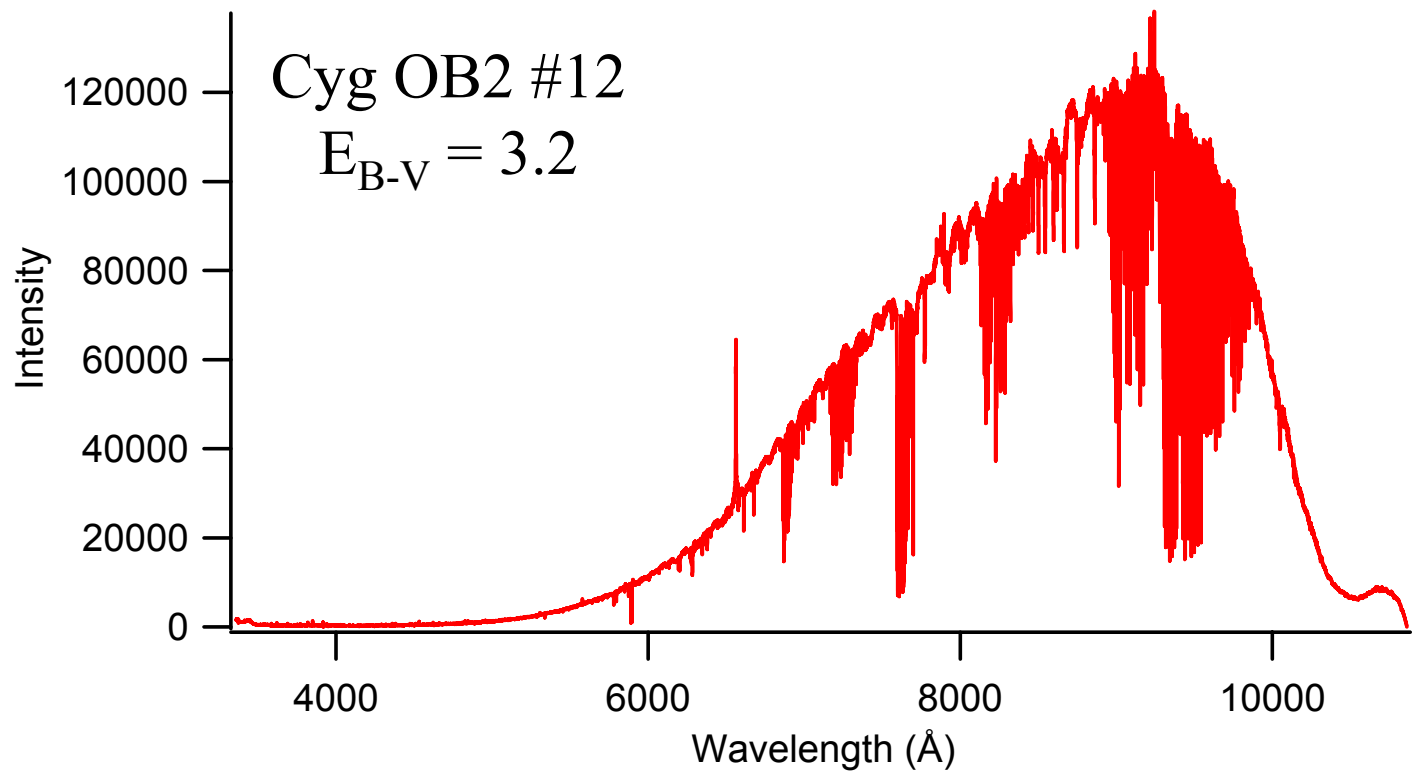
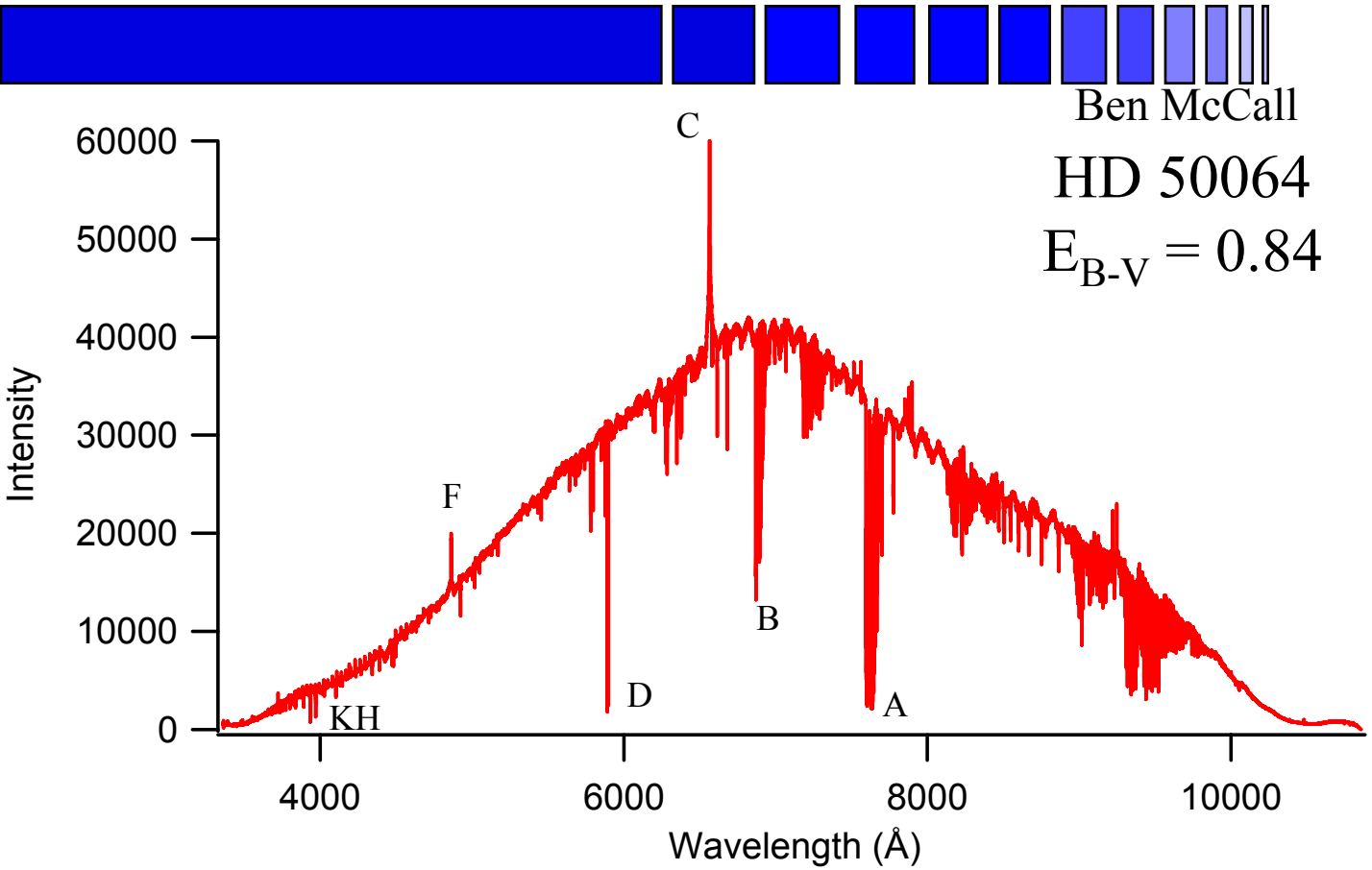
A: O₂ ~ 7650 Å

D: Na I ~ 5890 Å

H: Ca II ~ 3968 Å

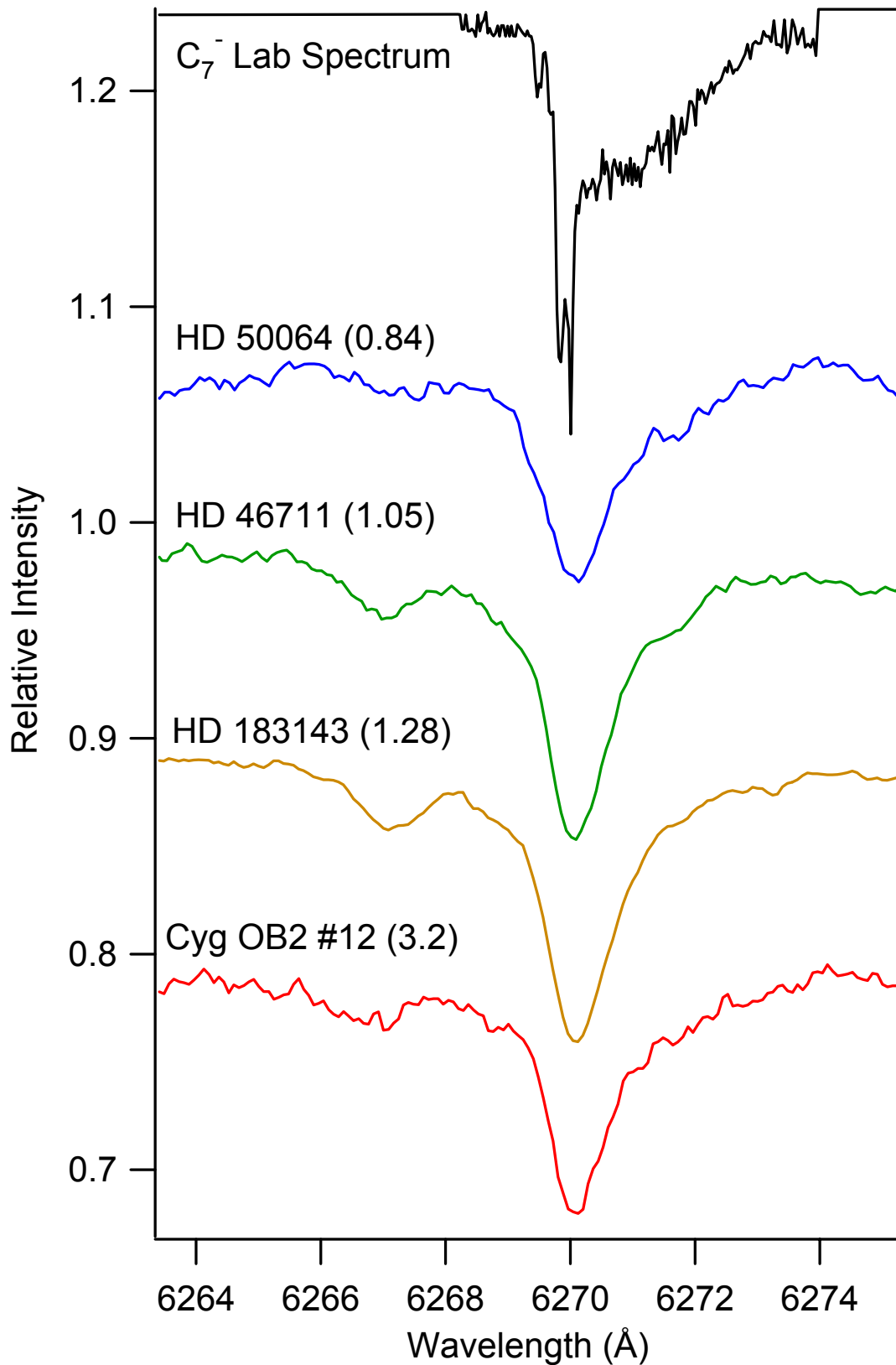
K: Ca II ~ 3934 Å

Stellar Spectra



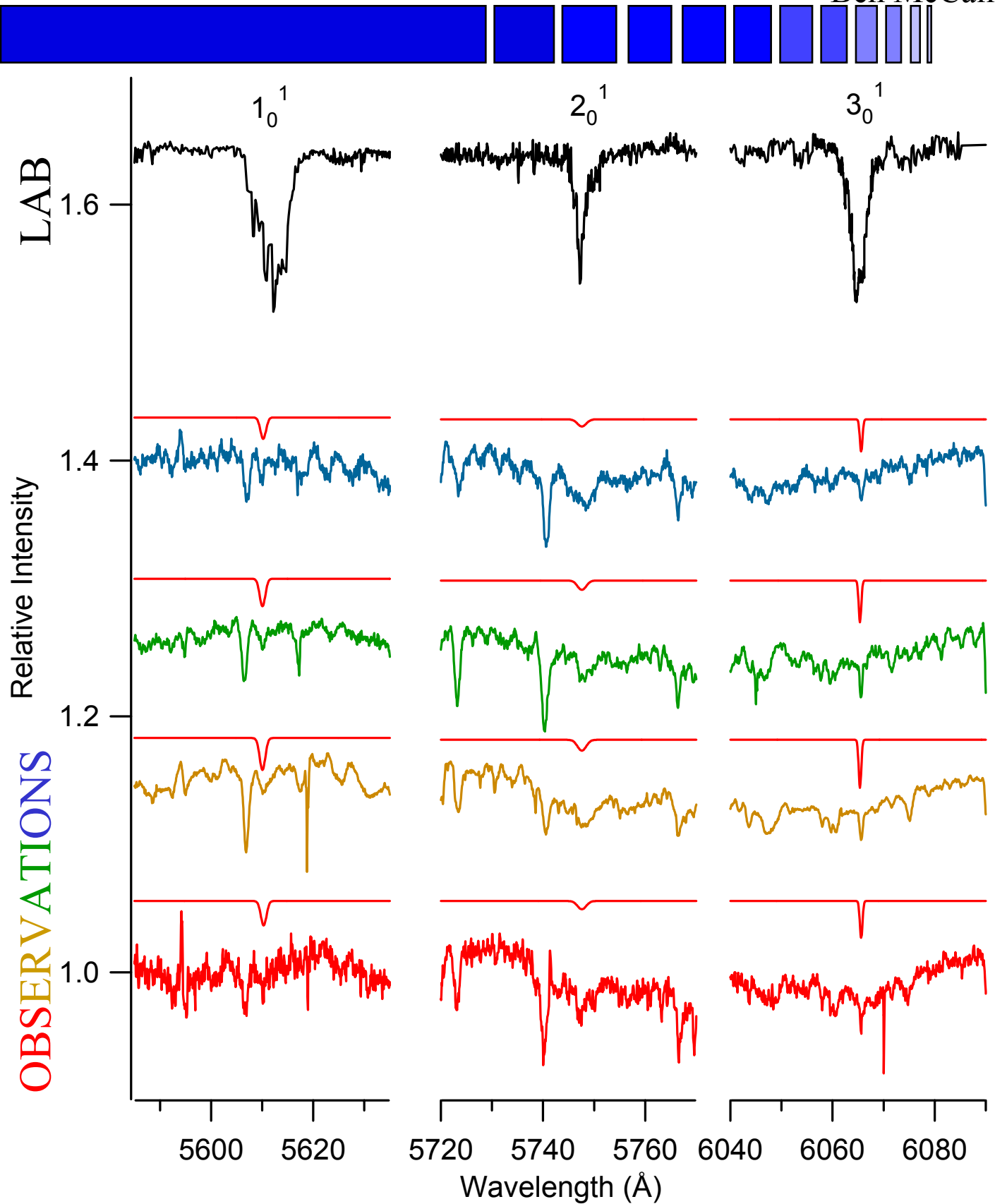
C₇⁻ Origin Band

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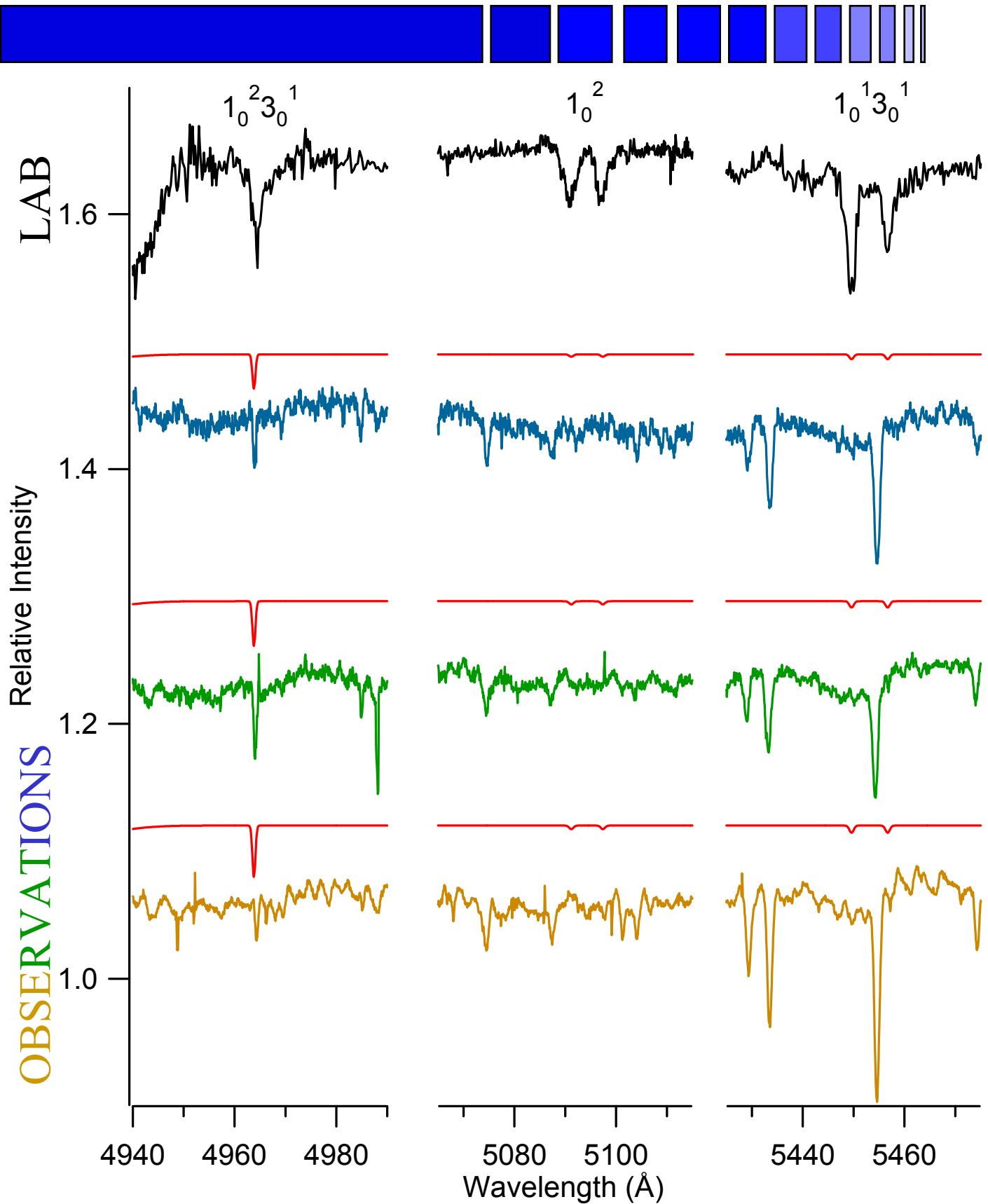
$\lambda\lambda$ 5610, 5748, 6065

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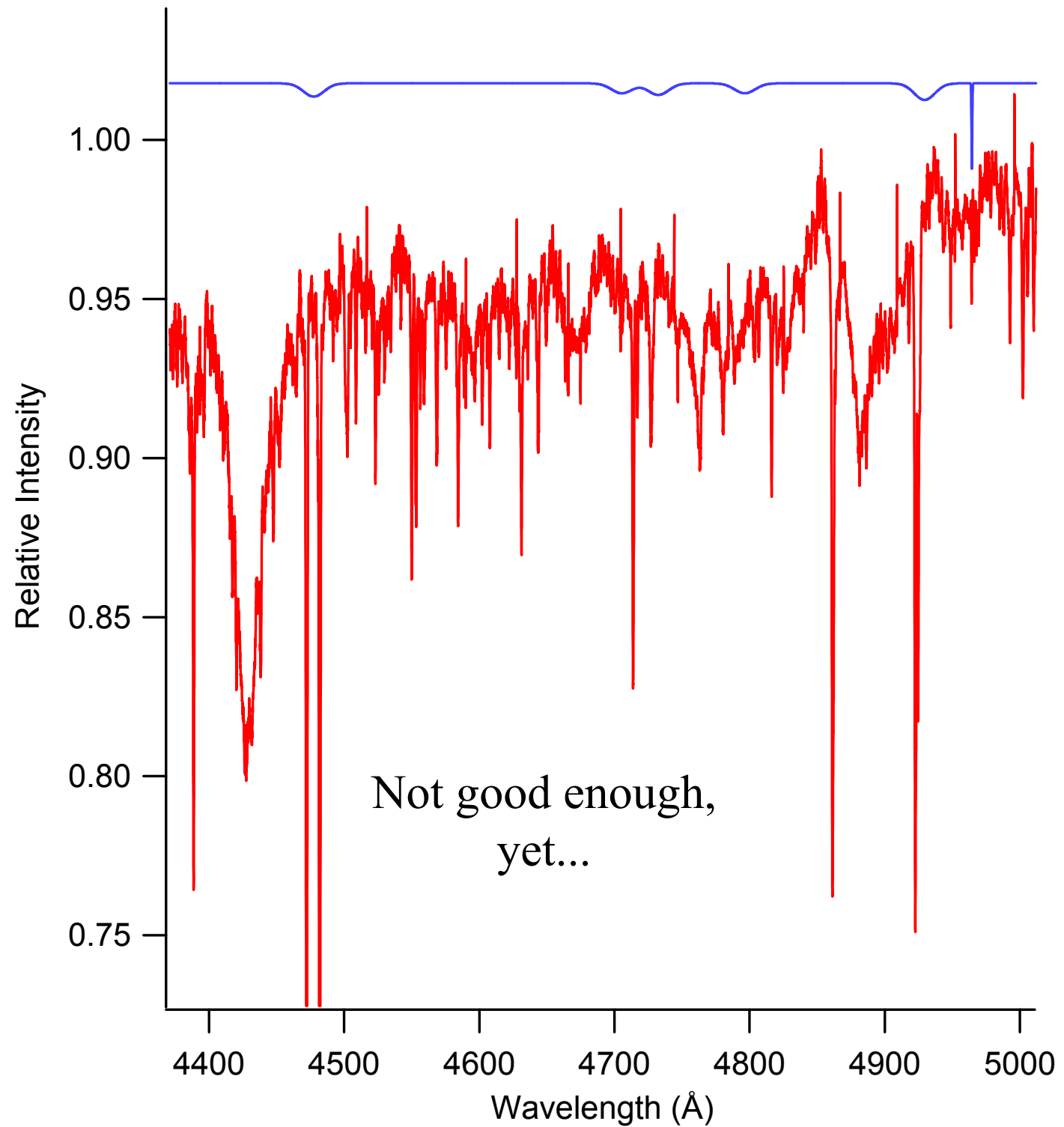
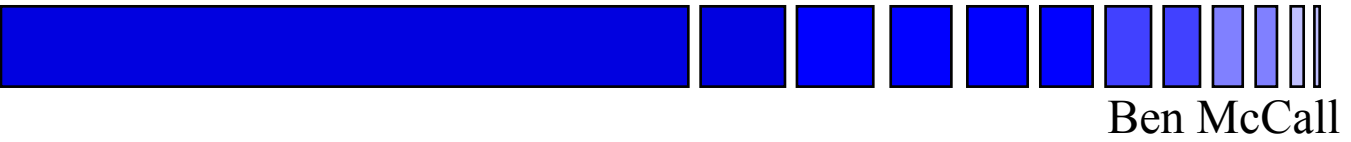


$\lambda\lambda$ 4963 & Doublets

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B ← X Bands



Conclusions



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- ★ Better astronomical data seem to have confirmed the C_7^- hypothesis
 - ★ Five lines seen
 - ★ Two doublets not seen
 - ★ Good wavelength agreement
 - ★ Good intensity agreement

- ★ Better laboratory data desirable

- ★ Important to understand rotational structure of C_7^- to better simulate astronomical spectra

- ★ $B \leftarrow X$ transitions not yet observable



After over 70 years, we now have the first convincing identification of DIBs!