WILLIAM HENNEY, RIE MORELIA 2024-01

HOW I THOUGHT I HAD DISCOVERED 100 NEW OPTICAL EMISSION LINES…

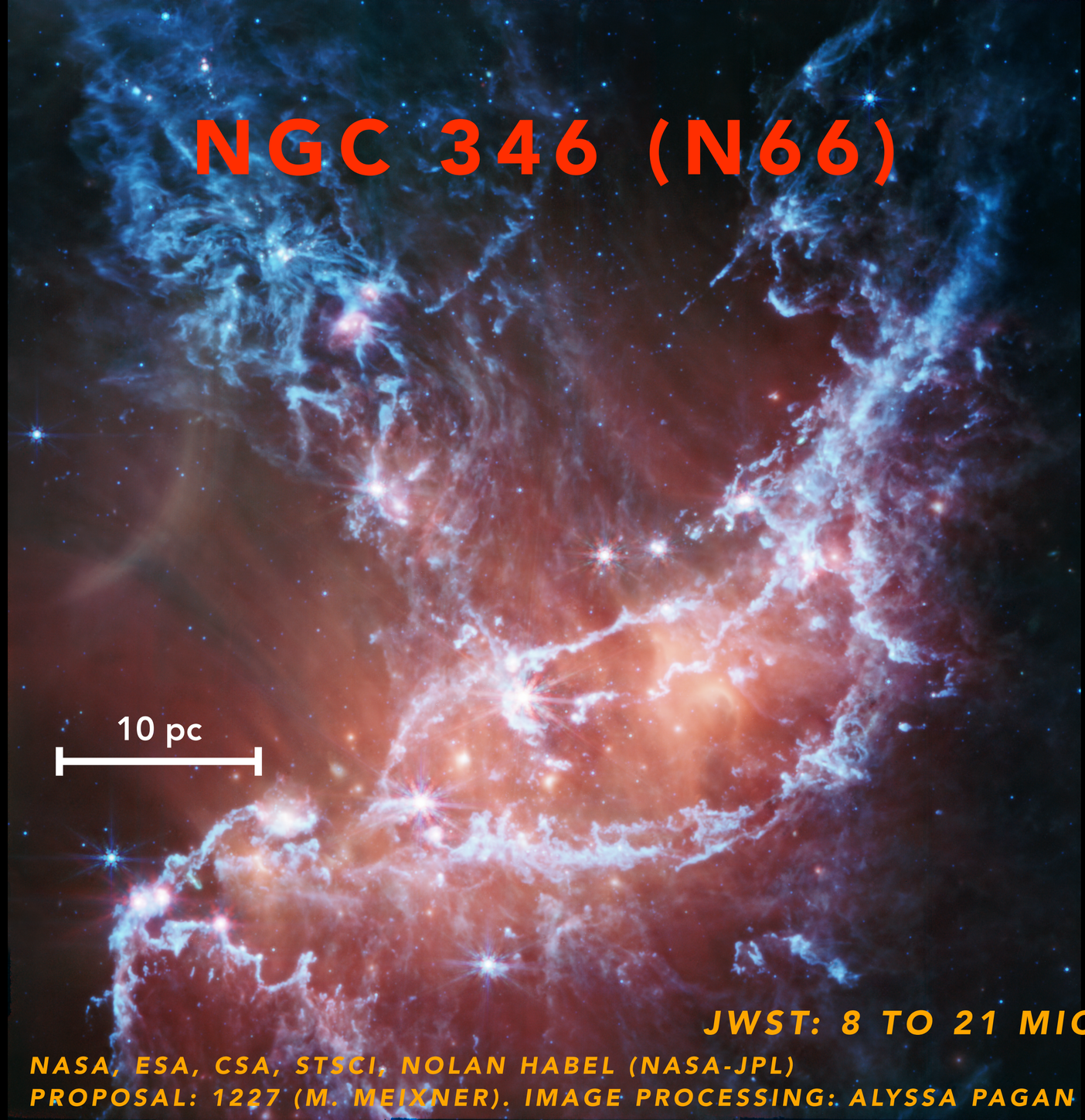
… AND HOW IT TURNED OUT THAT THEY WERE NOT SO NEW AFTER ALL

COLLABORATION WITH MABEL VALERDI, INAOE

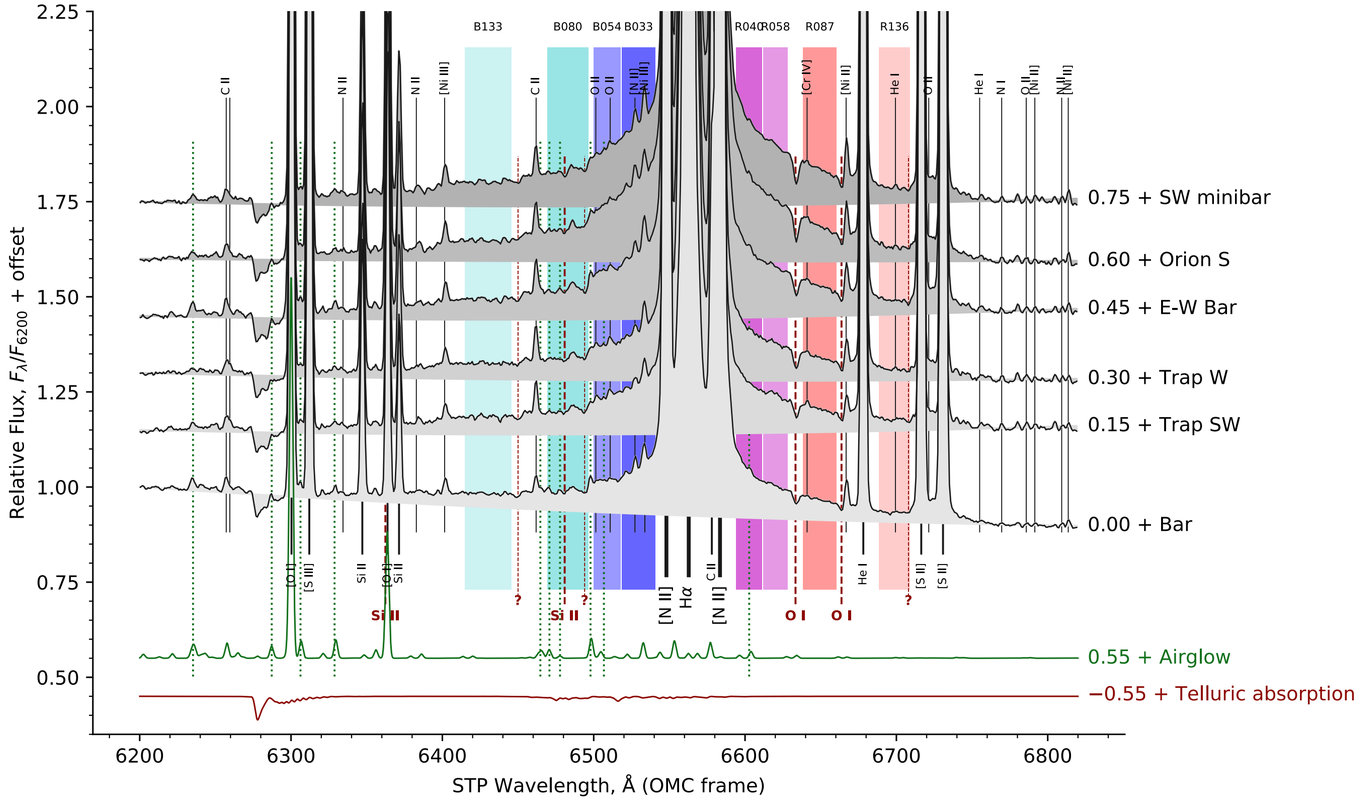
Young massive cluster and H II region

Most luminous star forming region in SMC

Local template for low-metallicity starbursts

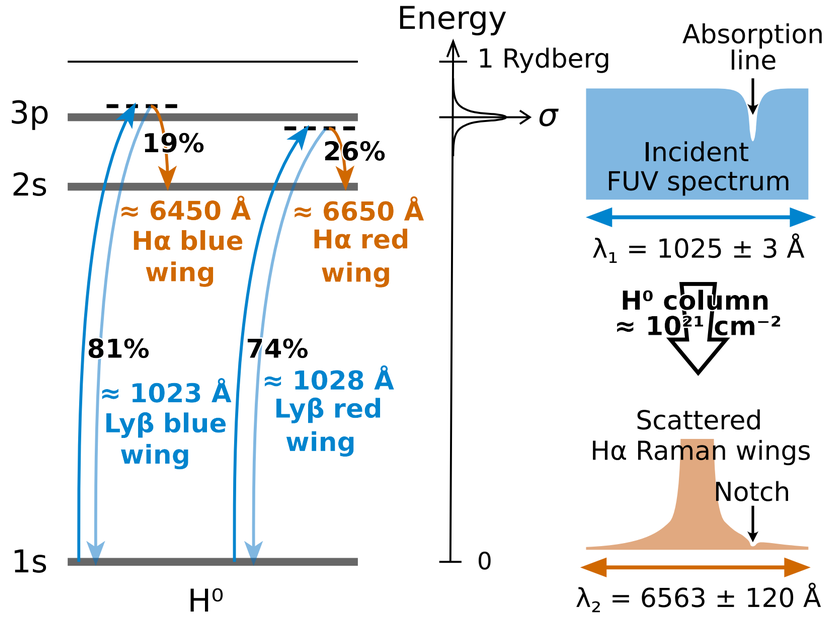


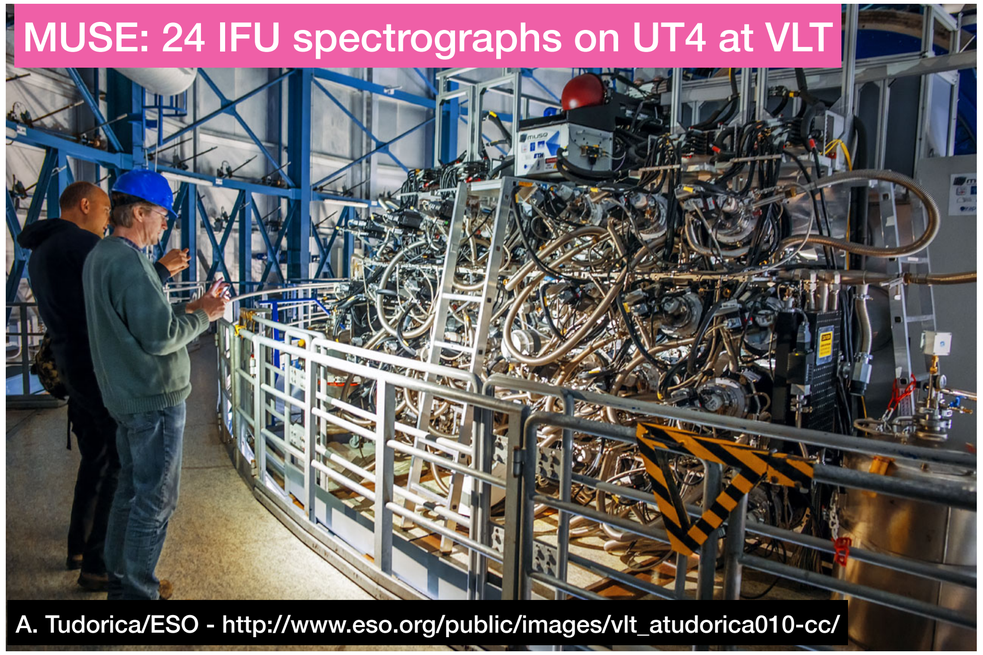
LOOKING FOR RAMAN SCATTERING WITH MUSE



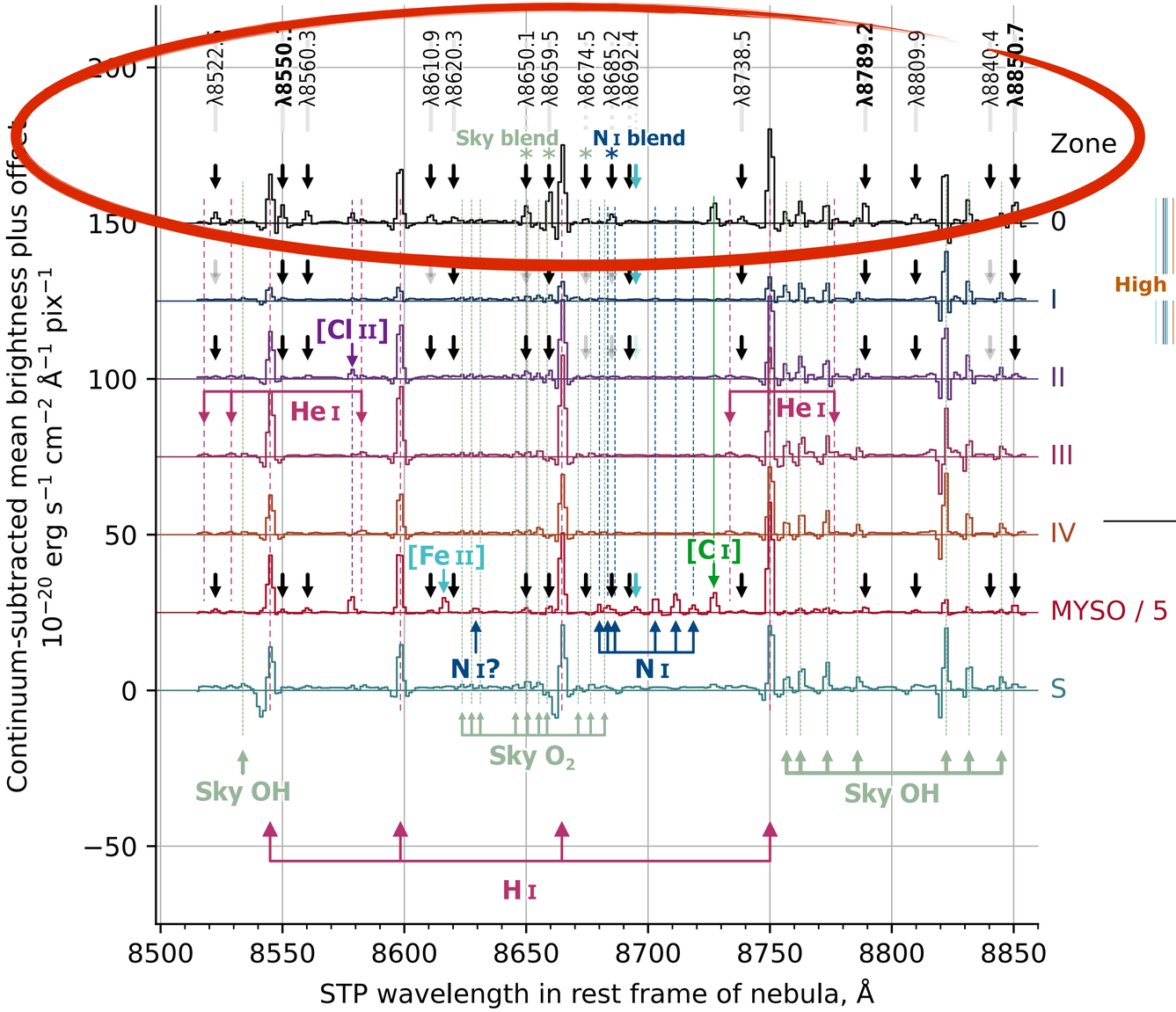
HENNEY 2021MNRAS.502.4597H

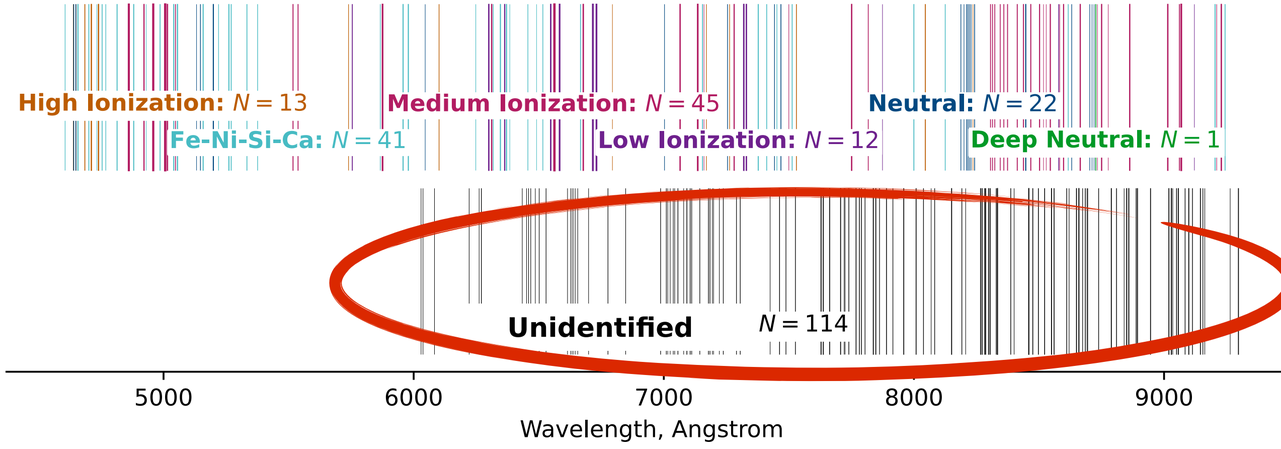
Medium resolution integral field spectroscopy at optical wavelengths





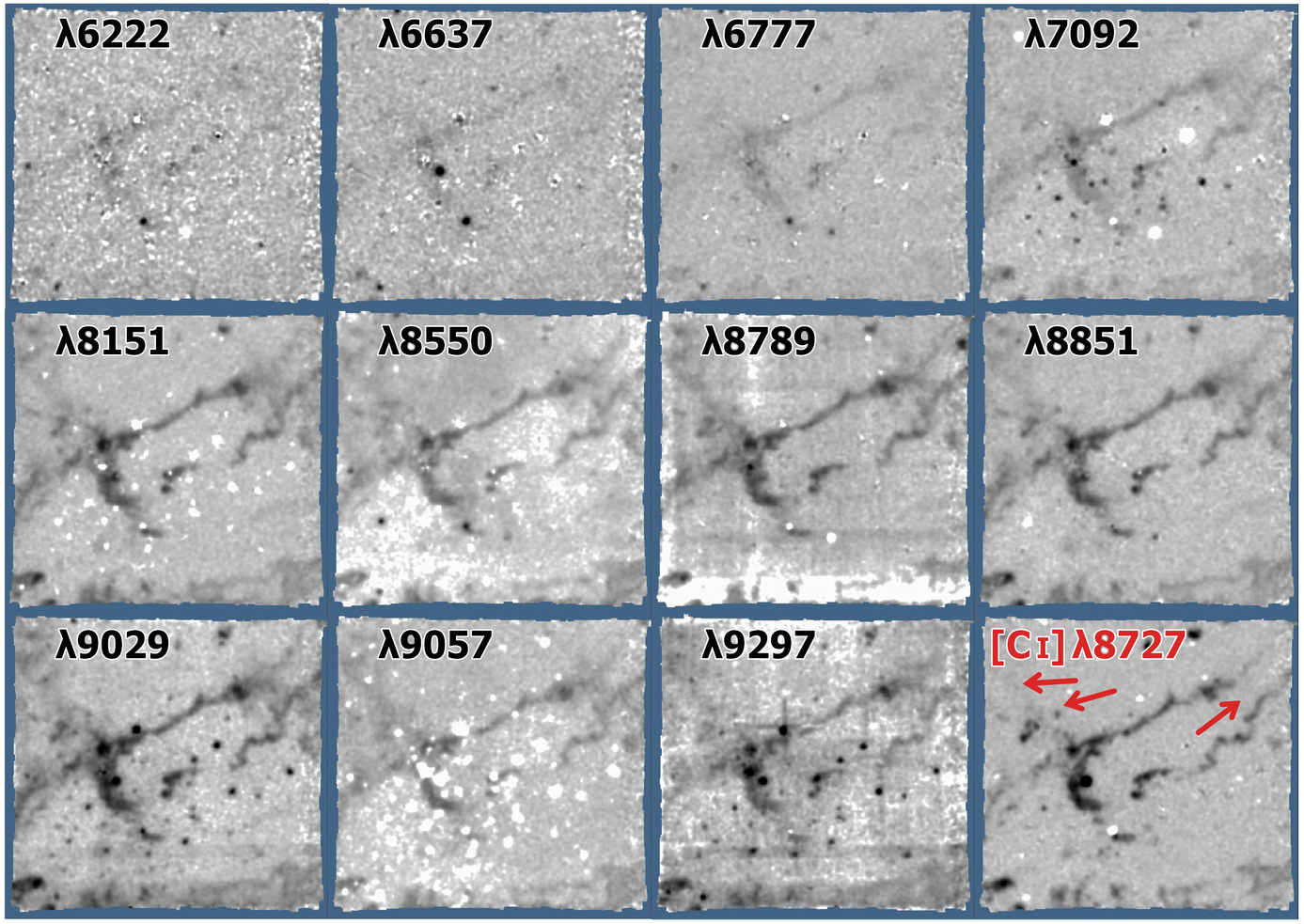
UNEXPECTED DISCOVERY: OVER 100 MYSTERIOUS UNIDENTIFIED EMISSION LINES





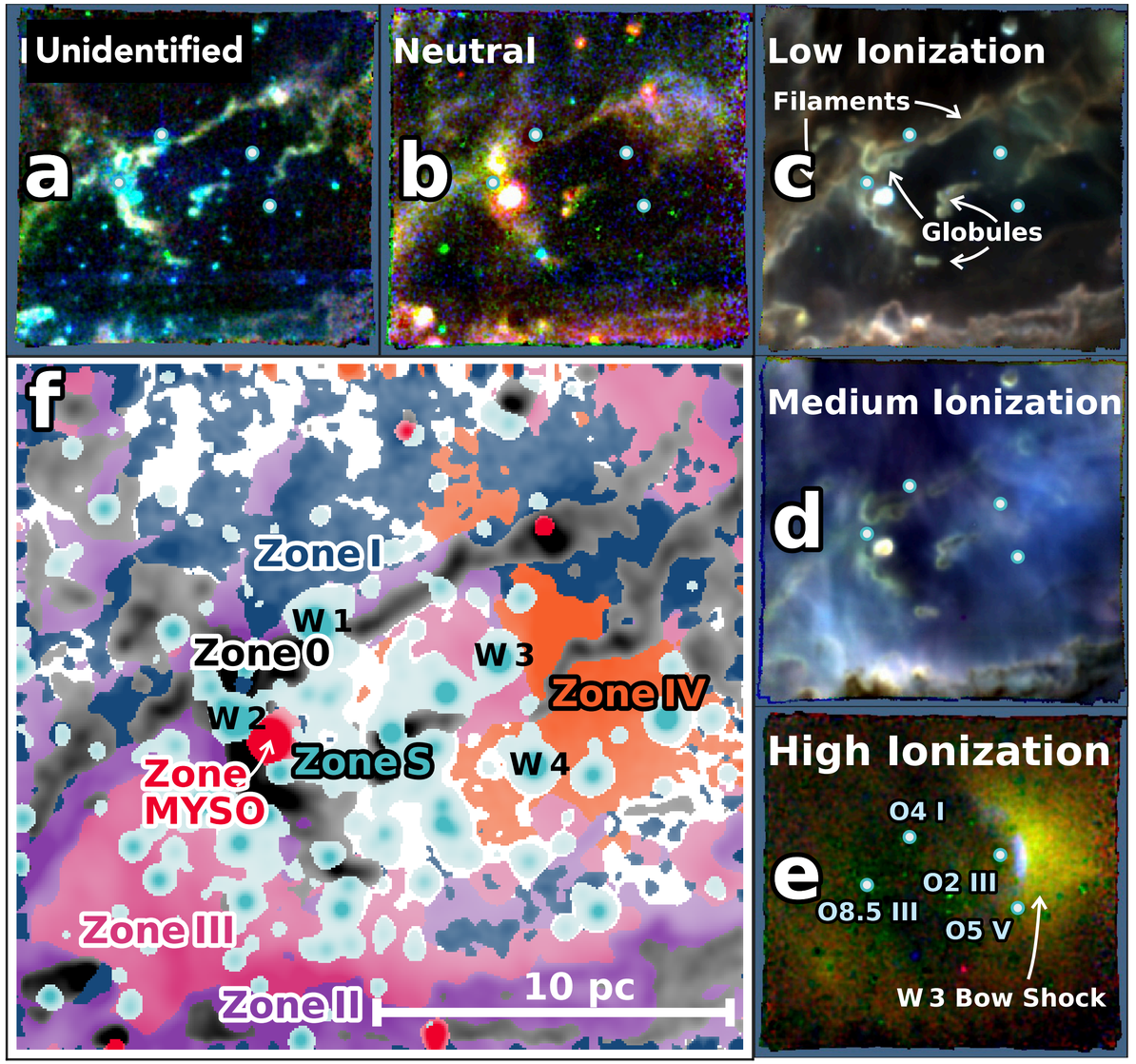
Wavelength range:
6000 – 9000 Å

SPATIAL DISTRIBUTION SIMILAR TO [C I] 8727 Å FAR-RED LINE



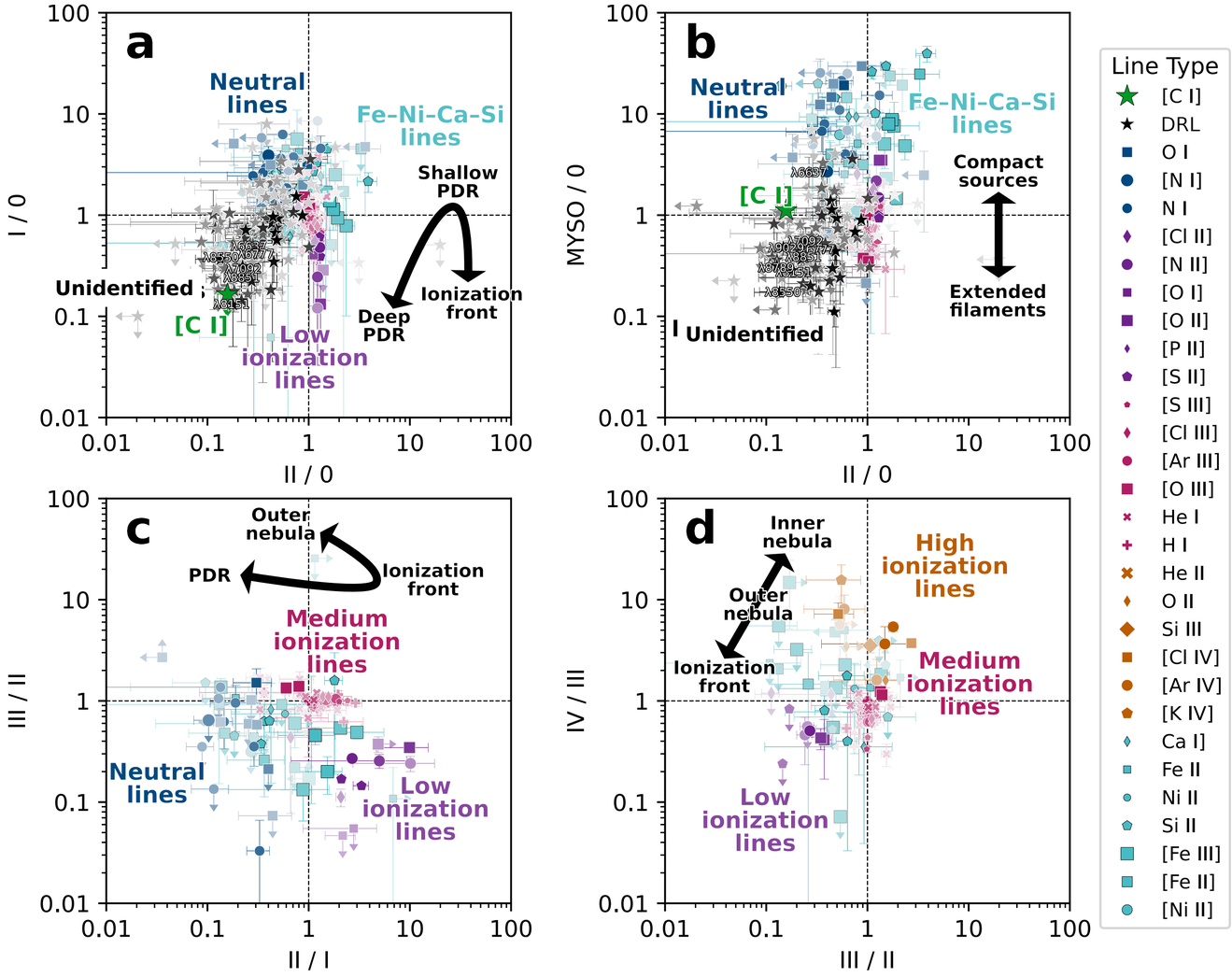
DIVIDE NEBULA INTO DIFFERENT IONIZATION ZONES

Compare spatial emission patterns for different lines

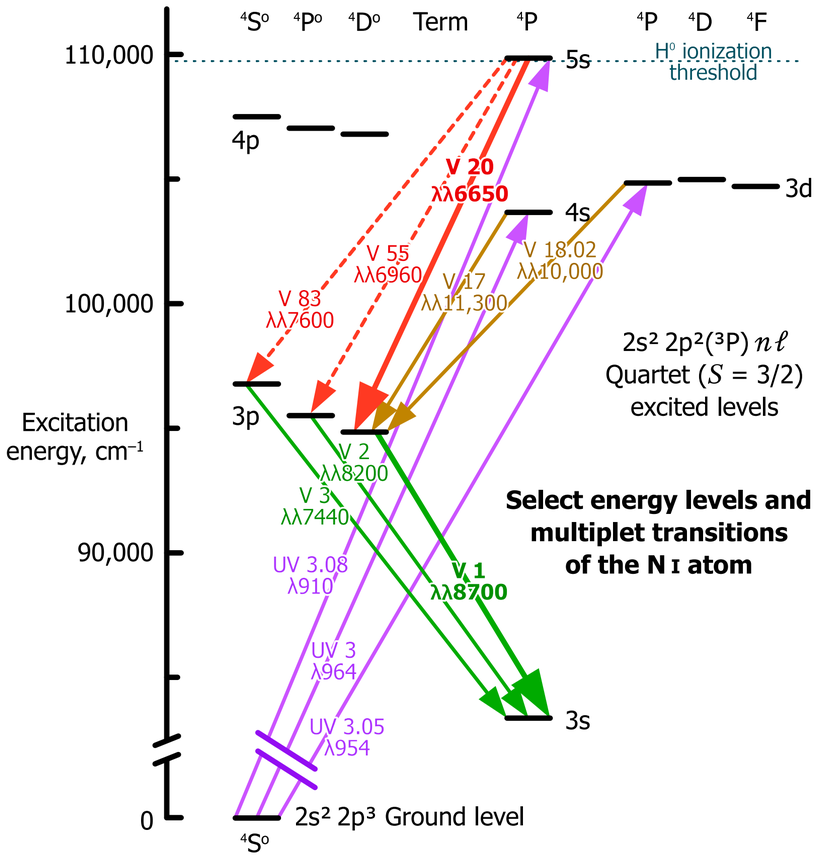


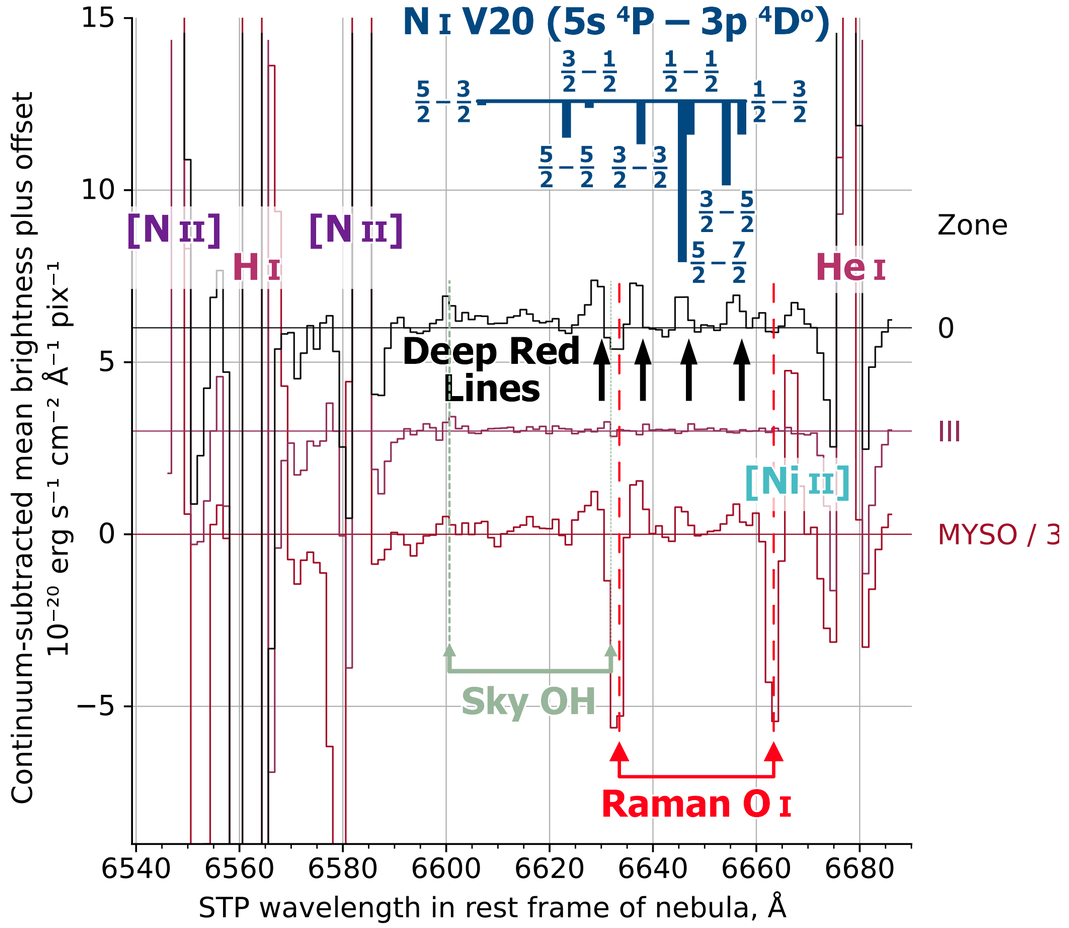
THEY SEEM TO FORM RELATIVELY DEEP IN THE PDR

Brightness ratios between spatial zones for different classes of emission line



COULD THEY BE FLUORESCENT LINES OF NEUTRAL METALS?





Some tantalizing coincidences but nothing pans out

SO WE SUBMITTED A PAPER

MNRAS **000**, 1–28 (2023) Preprint May 31, 2023 Compiled using MNRAS LATEX style file v3.0

One hundred new unidentified optical emission lines from a low-metallicity photodissociation region

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Accepted XXX. Received YYY; in original form ZZZ

ABSTRACT

We report the detection of a rich spectrum of more than one hundred optical emission lines from neutral/molecular gas in the photodissociation region (PDR) around the mini-starburst cluster NGC 346 in the Small Magellanic Cloud. We propose the term Deep Red Line (DRL) for these lines, which are concentrated in the spectral range 6000 Å to 9300 Å and have observed brightnesses ranging from 0.01% to 0.4% times that of the Hβ λ4861 hydrogen recombination line. The vast majority of the DRLs have never previously been detected from astronomical nebulae. Some of them may be due to neutral atoms, but most have no credible identifications in databases of atomic line transitions, and it is possible that some may correspond to transitions in molecules or molecular ions. Analysis of the spatial distribution of the DRLs shows that they originate from a range of depths in the PDR, providing a missing link between the shallow layers probed by known fluorescent lines of neutral nitrogen and oxygen, and the more shielded layers probed by neutral carbon recombination lines. Comparison with other PDRs shows that the relative strength of the DRLs with respect to the [C I] λ8727 line increases rapidly with decreasing metallicity.

Key words: Atomic physics – ISM: individual objects (NGC 346) – Photodissociation regions

But then, while planning follow up observations, we made a **discovery** …

A CLUE FROM SAN PEDRO MÁRTIR

Enero 26/2005

Lista de equipo enviado por John Meaburn para SPM en calidad de Préstamo por tiempo indefinido.

2-4 lámparas de calibración de Th-Ar
-1 lámpara de Cu-Ar puesta en el espectrómetro.

✓-1 rejilla echelle se fue a Grecia
✓-1 grism B & L para MES se fué a Grecia
✓-2 espejos de repuesto para MES (uno es el doblador de haz a 45° y el otro el espejo grande que entra enfrente de la rejilla)

FILTROS Barr par MES:

✓-1- 4730 Å, 55 Å, → He II 4686 λc between orders 121 and 120
✓-2- 4690 Å, 55 Å, → He II 4686 (mejor que el anterior) λc between orders.

✓-3- 6572 Å, 15 Å, → Hα solamente
✓-4- 6576 Å, 20 Å, → Hα solamente (muy alta calidad)
✓-5- 6450 Å, 100 Å, → continuo para Hα (buena calidad) λc slightly off blaze

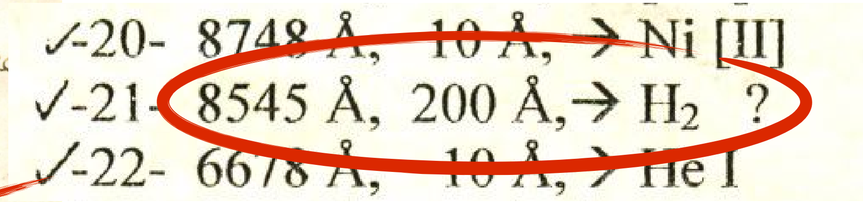
✓-6- 6300 Å, 90 Å, → [O I] 6300 λc better between orders, use RC
✓-7- 4366 Å, 20 Å, → [O III] 4363 λc between orders.
✓-8- 6740 Å, 100 Å, → [S II] 6717/6731 λc between orders, needs RC
✓-9- 5900 Å, 80 Å, → Na I o He I 5876 λc between orders, RC needed

✓-10- 4910 Å, 60 Å, → Hβ, doppler shifted λc on blaze!
✓-11- 5960 Å, 80 Å, → Na I, doppler shifted λc between orders, use RC
✓-12- 5100 Å, 75 Å, → [O III] 5007, doppler shifted λc off blaze, needs RC
✓-13- 5200 Å, 70 Å, → [O III] 5007, doppler shifted λc between orders, need RC

OTROS FILTROS (banda angosta)

✓-14- 6595 Å, 10 Å, → [N II] 6584, alta calidad
-15- 6585 Å, 10 Å, → [N II] 6584
✓-16- 6731 Å, 7 Å, → [S II] 6731
✓-17- 9071 Å, 10 Å, → [S III]
✓-18- 6304 Å, 8 Å, → [O I] 6300
✓-19- 6312 Å, 8 Å, → [O I] 6300
✓-20- 8748 Å, 10 Å, → Ni [II]
✓-21- 8545 Å, 200 Å, → H_2 ?
✓-22- 6678 Å, 10 Å, → He I
✓-23- 3433 Å, 30 Å, → Ne V (3425)

✓ 5050Å 60Å



List of narrow-band filters donated by John Meaburn for use with the MES spectrograph

Could molecular hydrogen be the answer?

COURTESY OF MICHAEL RICHER & BETO LÓPEZ

FIRST OBSERVED 30 YEARS AGO!

Mon. Not. R. astr. Soc. (1992) **257**, *Short Communication*, 1P–6P

Fluorescent molecular hydrogen line emission in the far-red

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[2] *Department of Mathematics, University of Tasmania, Hobart, TAS 7001, Australia*
[3] *Dublin Institute of Advanced Studies, 5 Merrion Square, Dublin 2, Ireland*
[4] *Joint Astronomy Centre, 665 Komohana Street, Hilo, HI 96720, USA*
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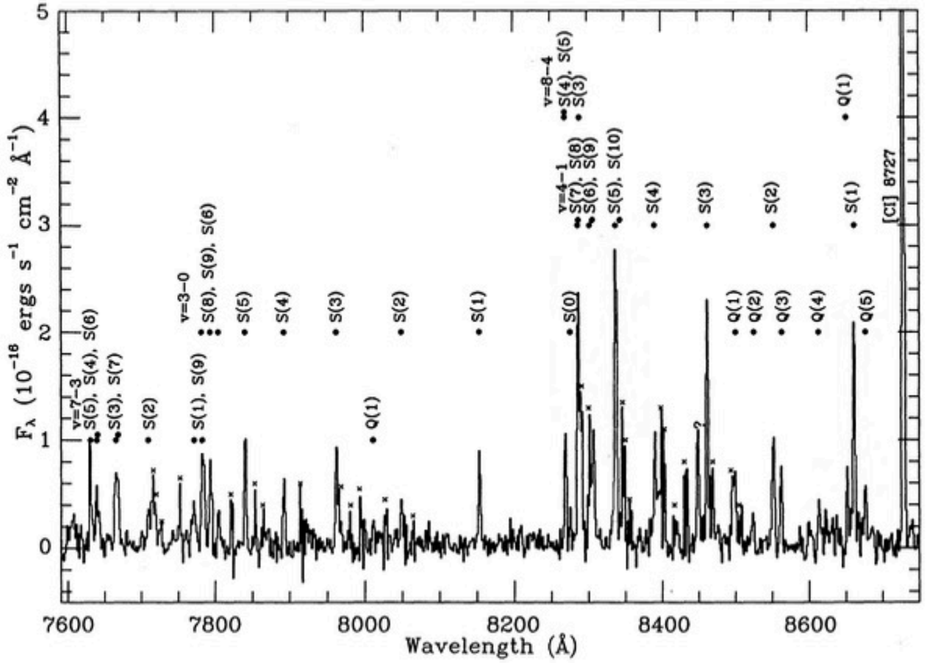
Accepted 1992 April 8. Rece ed 1992 April 7; in original form 1992 February 21

SUMMARY

Over 30 lines from the $v = 3–0$, 4–1, 7–3 and 8–4 vibrational series of the hydrogen molecule have been observed from $\lambda = 7600–8800$ Å in the reflection nebula NGC 2023, originating from levels up to 41 000 K above ground. This is the first time that H_2 has been observed in the optical CCD regime and these are the highest excitation lines from the ground electronic state that have yet been detected. The spectrum shows the characteristics expected of UV fluorescence, although in detail there are some differences from model predictions. Emission from newly formed molecules in $v = 4$ may have been detected. Strong [C I] 8727-Å forbidden line emission is also observed, coincident with the H_2 emission, and arising from the same photodissociation region gas.



Relatively forgotten since 1992:

published observations exist for just 3 objects (NGC 2023, HH 1, HH 91A)

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One hundred optical emission lines of molecular hydrogen from a low-metallicity photodissociation region

TIME TO CHANGE THE TITLE!

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[2]Instituto Nacional de Astrofísica, Óptica y Electrónica, (INAOE), Luis E. Erro No. 1, Sta. Ma. Tonantzintla, Puebla, C.P. 72840, México.

Accepted XXX. Received YYY; in original form ZZZ

ABSTRACT

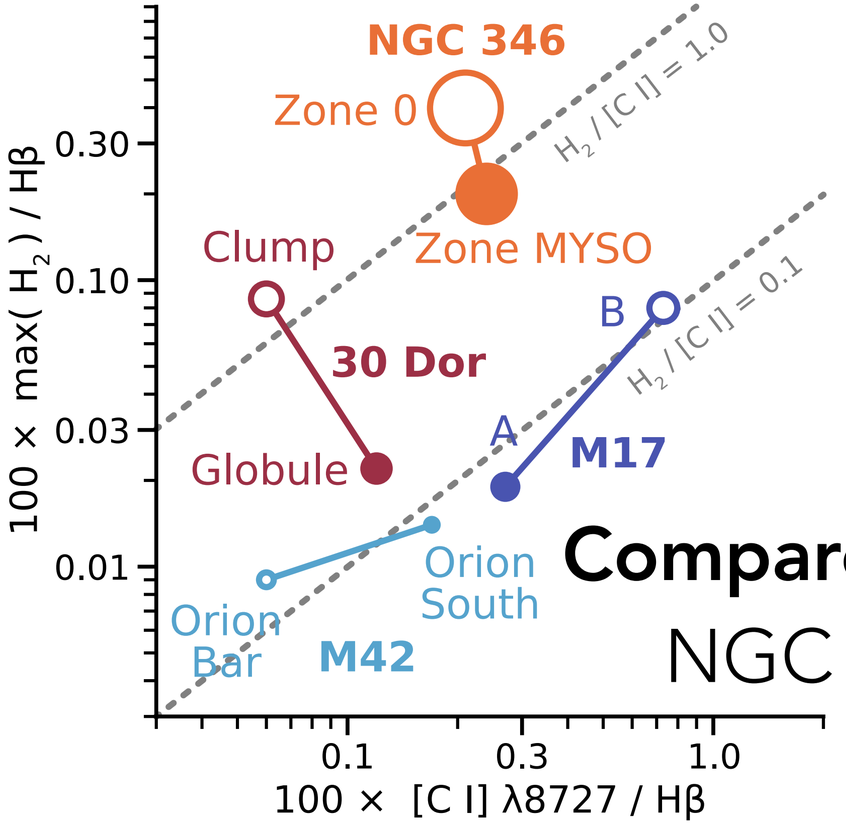
We report the detection of a rich spectrum of more than one hundred optical emission lines of vibrationally hot molecular hydrogen (H_2) from the photodissociation region (PDR) around the mini-starburst cluster NGC 346 in the Small Magellanic Cloud. The lines are concentrated in the spectral range 6000 Å to 9300 Å and have observed brightnesses ranging from 0.01% to 0.4% times that of the Hβ λ4861 hydrogen recombination line. Analysis of the spatial distribution of the H_2 lines shows that they originate from a range of depths in the PDR, intermediate between the shallow layers probed by fluorescent lines of neutral nitrogen and oxygen, and the more shielded layers probed by neutral carbon recombination lines. Comparison with other PDRs shows that the relative strength of the H_2 lines with respect to the [C I] λ8727 line increases rapidly with decreasing metallicity, being at least 40 times larger in NGC 346 than in the prototypical PDR of the Orion Bar. The internal PDR dust extinction is also found to be anomalously low in NGC 346. A separate result is the discovery of a high-ionization bow shock around the O2 star Walborn 3.

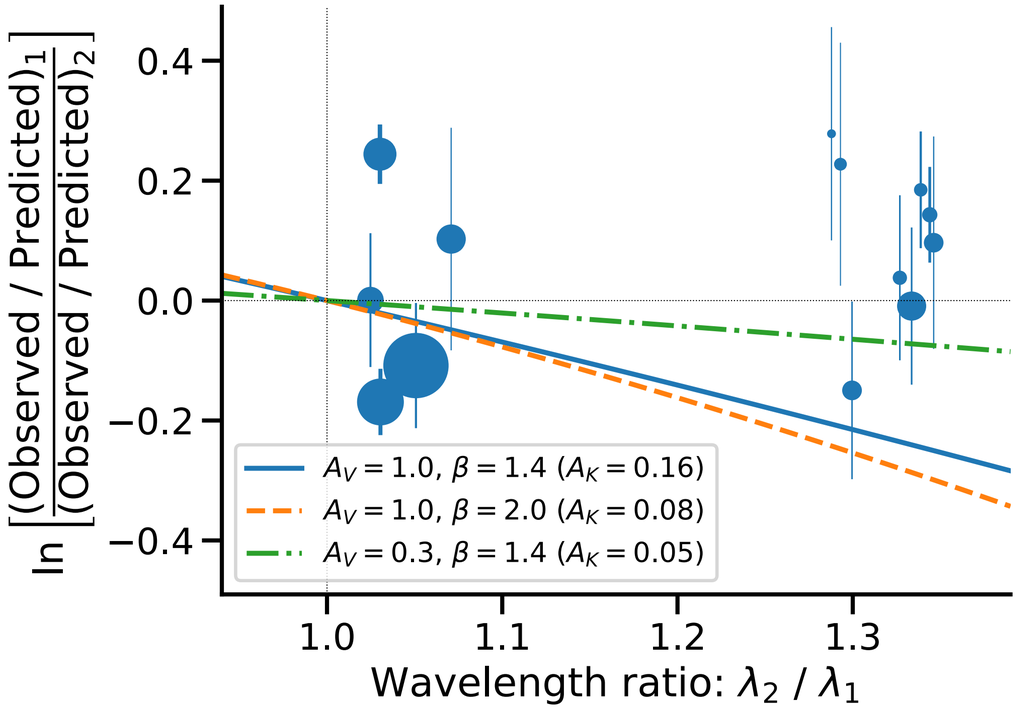
Key words: ISM: individual objects (NGC 346) – photodissociation region (PDR) – H II regions – ISM: lines and bands – Magellanic Clouds – ISM: molecules

WHAT USE ARE THE H_2 LINES?

Measure extinction through PDR:

very low value $A_V \ll 1$





Compare with other high-mass star forming regions:

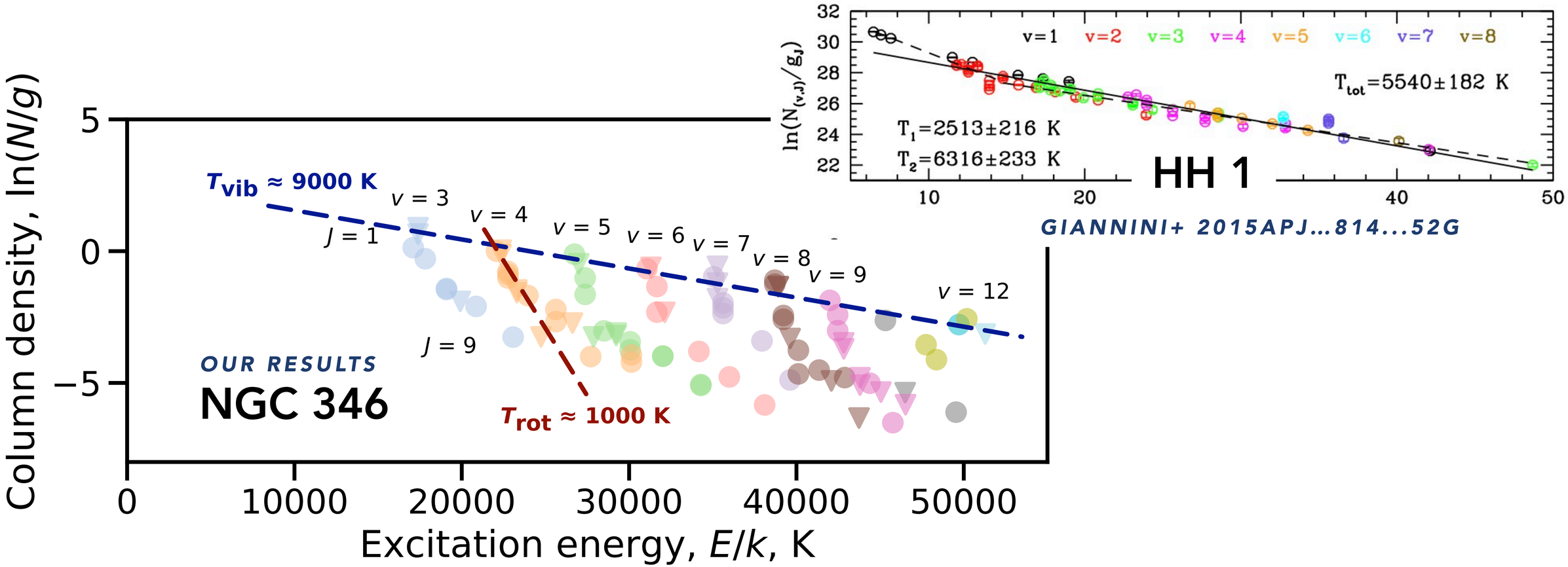
NGC 346 has very high relative brightness of H_2 – evidence for trend with metallicity

WHAT USE ARE THE H_2 LINES?

Diagnostics of excitation mechanism:

highly non-thermal distribution, $T_{rot} \ll T_{vib}$,

consistent with fluorescence (contrast with HH 1)



CONCLUSIONS

1. Molecular hydrogen emission can be observed at optical wavelengths (why should IR have all the fun?)

2. Brightest in low-metallicity regions

3. When you see a novel spectral feature, never bet against hydrogen

4. There is nothing new under the sun

THANK YOU