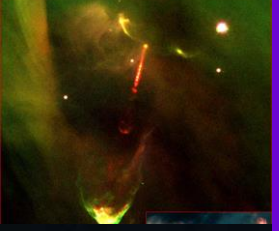
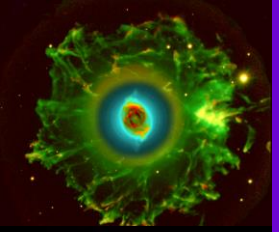




NEBULATOM
Emission line objects in the Universe

Hands-on session
Looking at nebular spectra

Grażyna Stasińska

Observatoire de Paris







The analysis of photoionized media
is mainly the analysis of their emission lines

The mere presence of emission lines indicates

- the existence of gas
  - eg emission line galaxies contain gas in large amount while galaxies emitting only a continuum with absorption features (such as elliptical galaxies) do not
- the existence of an ionizing agent (most emission lines come from ionized species)
  - hot star(s)
  - active nucleus
  - (shocks) …

Emission lines are easy to detect and relatively easy to interpret

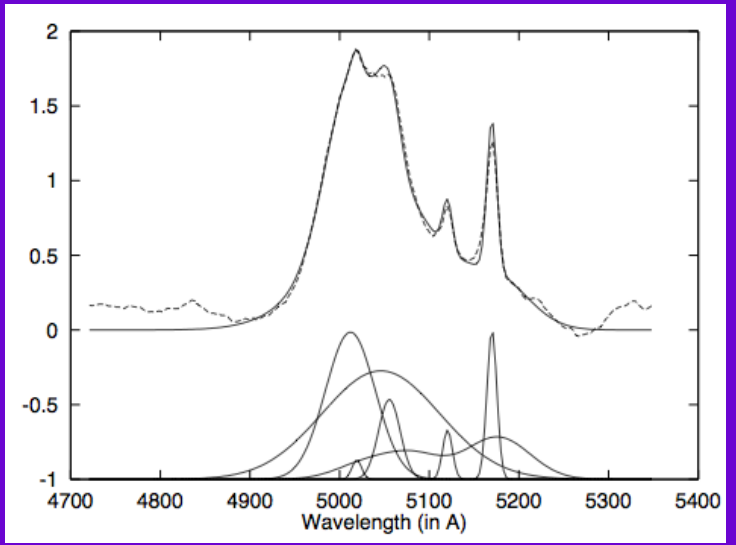
- chemical composition
- star formation rate
- velocities

line displacements tell about radial velocities

and allow one to measure

- internal motions

•in zones of line emission

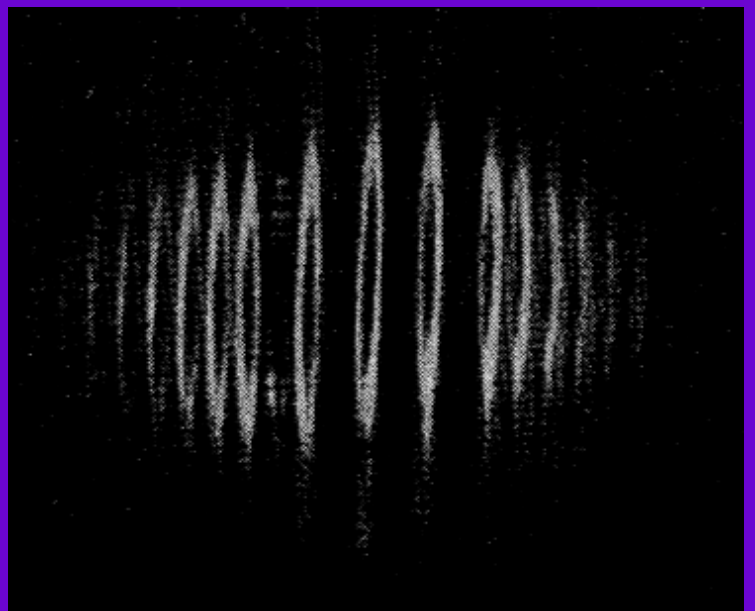


line broadening in the AGN Akn 120 Popovic+03

- expansion velocities

for example in PNe

high resolution multislit spectroscopy of the NGC 7009 in the [NeIII] line showing expansion of the envelope Wilson 58

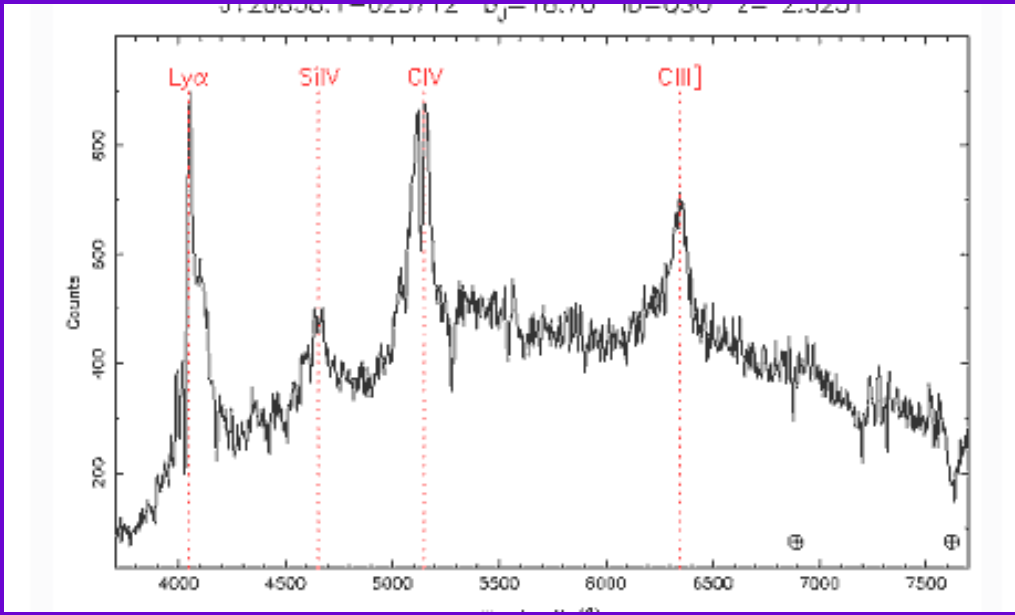


line displacements tell about radial velocities

and allow one to measure

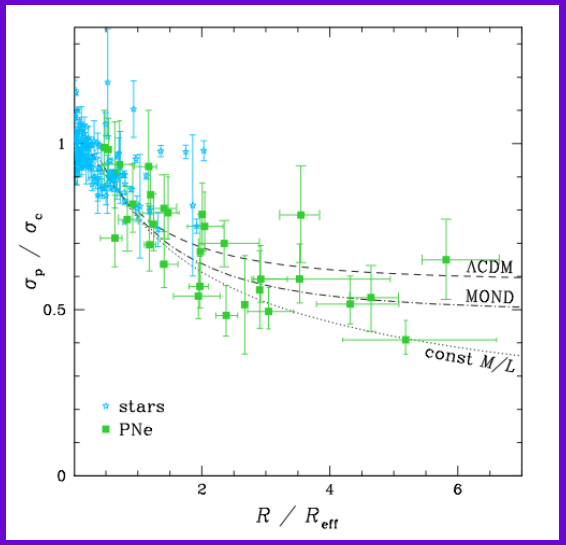
• redshifts of galaxies

a quasar at z=2.32
the UV lines
SIV, CIV, CIII]
are visible in
an optical spectrum



• dark matter mass in galaxies
using PNe as test particles
(eg Romanowsky 06)

PNe measurements
extend to much larger radii
than stellar measurements



main lines from C,N,O,Ne ions as a function of wavelength range

FUV (FUSE)	
1036	C II
1038	O VI
1084	N II
1134	N I
1214	[O V]
1239	N V

UV (STIS)	
1335	C II
1394	[O IV]
1483	[N IV]
1551	C IV
1658	[O III]
1744	[N III]
1907	[C III]
2137	[N II]
2322	[O III]
2323	[C II]
2471	[O II]

OPTICAL	
3427	[Ne V]
3730	[O II]
3969	[Ne III]
4364	[O III]
4715	[Ne IV]
5008	[O III]
5202	[N I]
5579	[O I]
5756	[N II]
6302	[O I]
6585	[N II]
7321	[O II]
10401	[N I]

IR	
76524	[Ne VI]
128135	[Ne II]
143217	[Ne V]
155551	[Ne III]
243175	[Ne V]
258903	[O IV]
360135	[Ne III]
518145	[O III]
573400	[N III]
631850	[O I]
883560	[O III]

the ionization chart

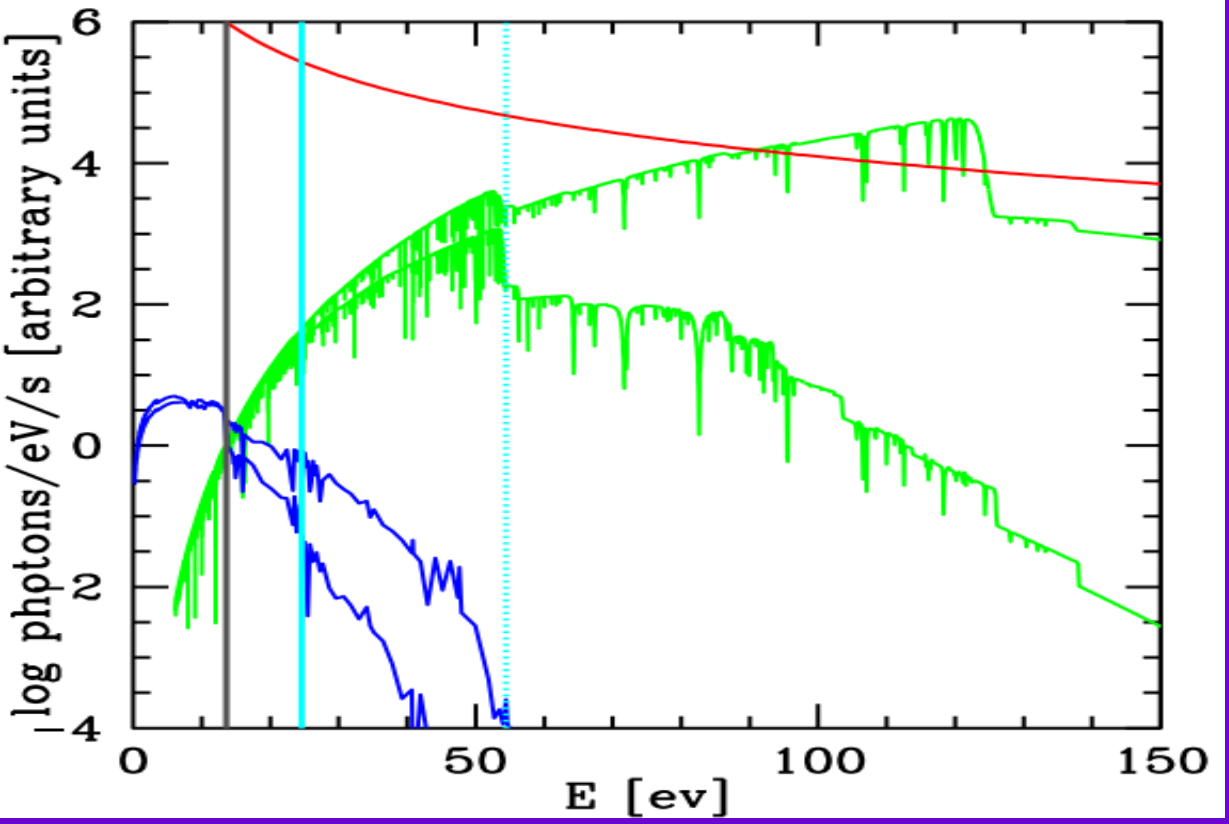
	I	II	III	IV	V	VI
H	13.60					
He	24.59	54.52				
C	11.26	24.38	47.89	64.49		
N	14.53	29.60	47.45	77.47	97.89	
O	13.62	35.11	54.94	77.71	113.90	138.12
Ne	21.56	40.96	63.45	97.12	126.11	157.17

the presence of ions with different ionization potentials in the spectra indicate the hardness of the ionizing radiation

=>

the nature of the ionizing source

- HeII cannot appear in HII regions
- HeII alone is not sufficient to estimate the T* of a PN central star



power law spectrum α = -1.2

PN central star **T* = 170kK**
T* = 100kK

O3 star **T* = 45kK**
O7 star **T* = 35kK**

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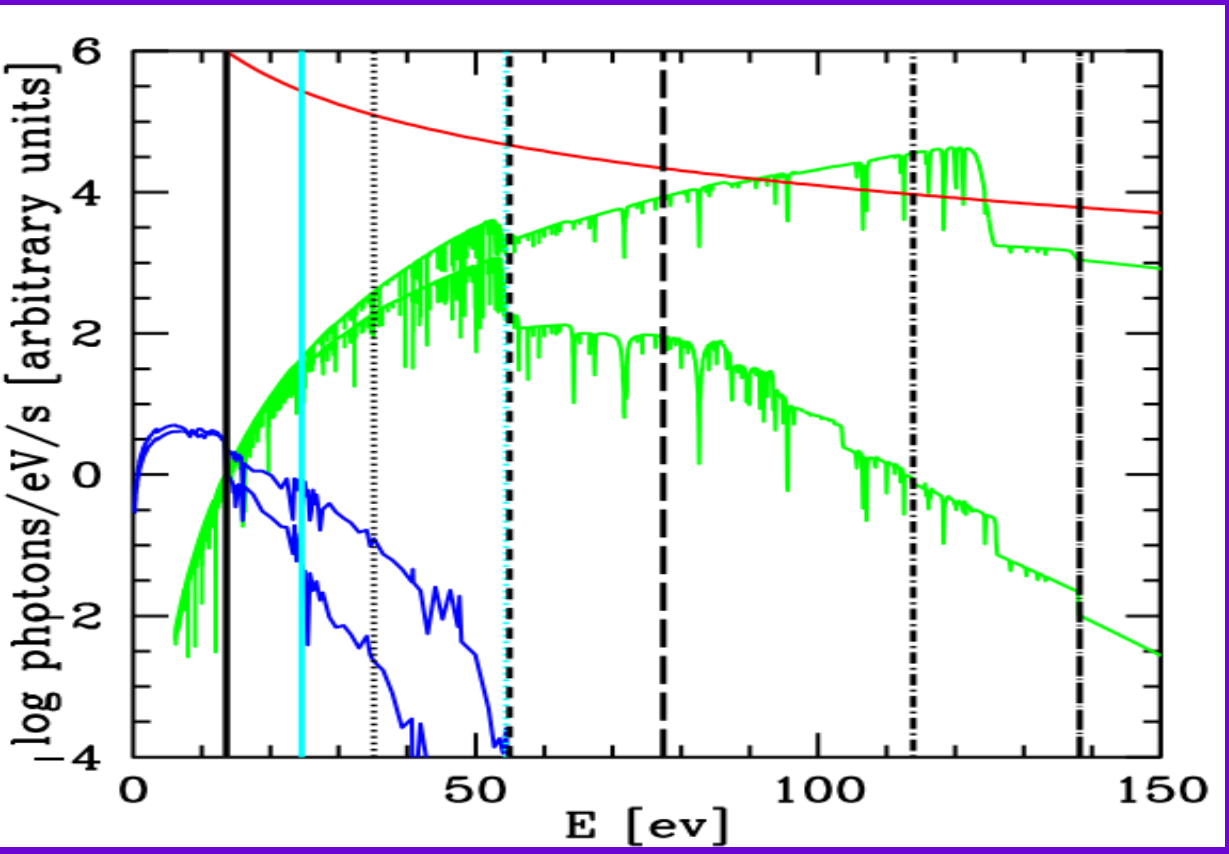

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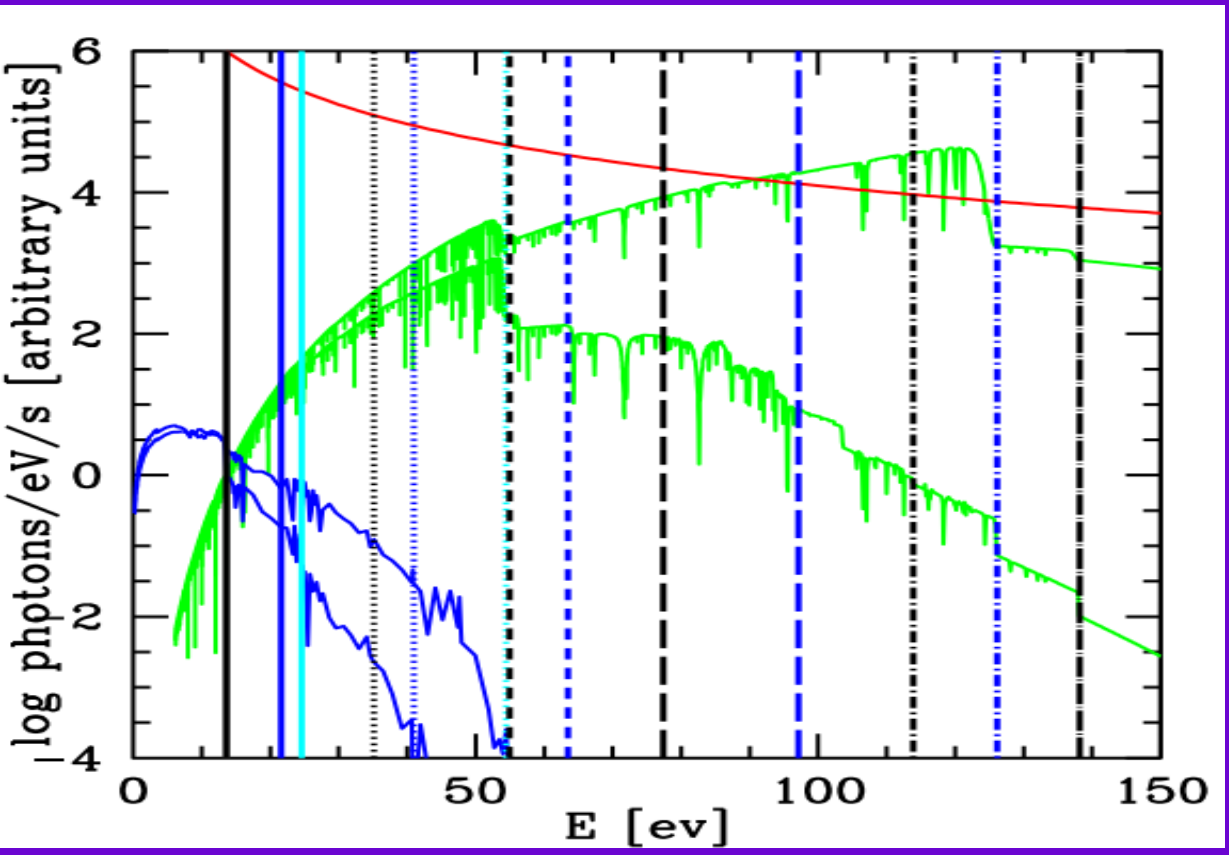

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- HeII alone is not sufficient to estimate the T* of a PN central star
- O would be helpful (but no lines of OIV and higher in the optical)
- Ne is useful [NeV] 3426 A

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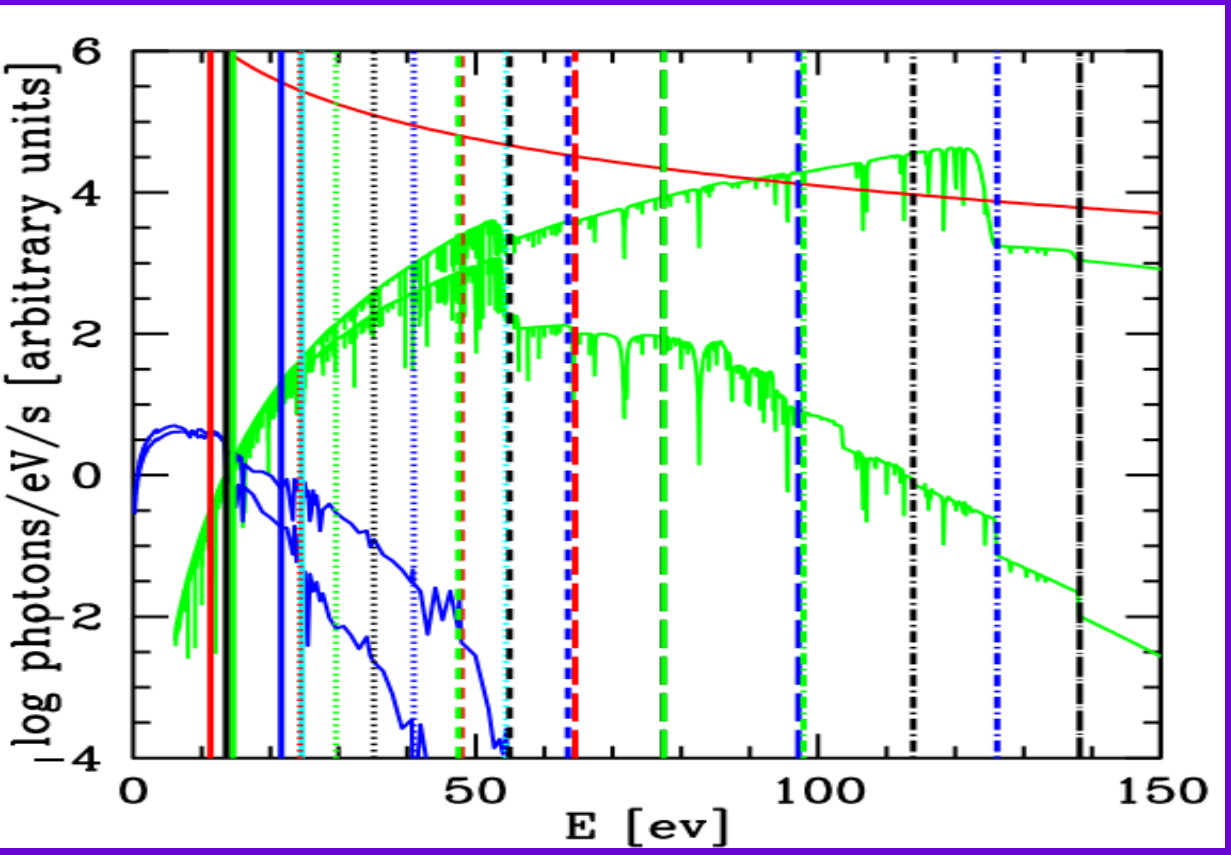
note that some ions have very similar ionization potentials:

- HI and OI
- CIII and NIII
- NIV and OIV



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The important lines of C,N,O,Ne in various wavelengths ranges

C	
1335	C II
2323	[C II]
1907	[C III]
1551	C IV

N	
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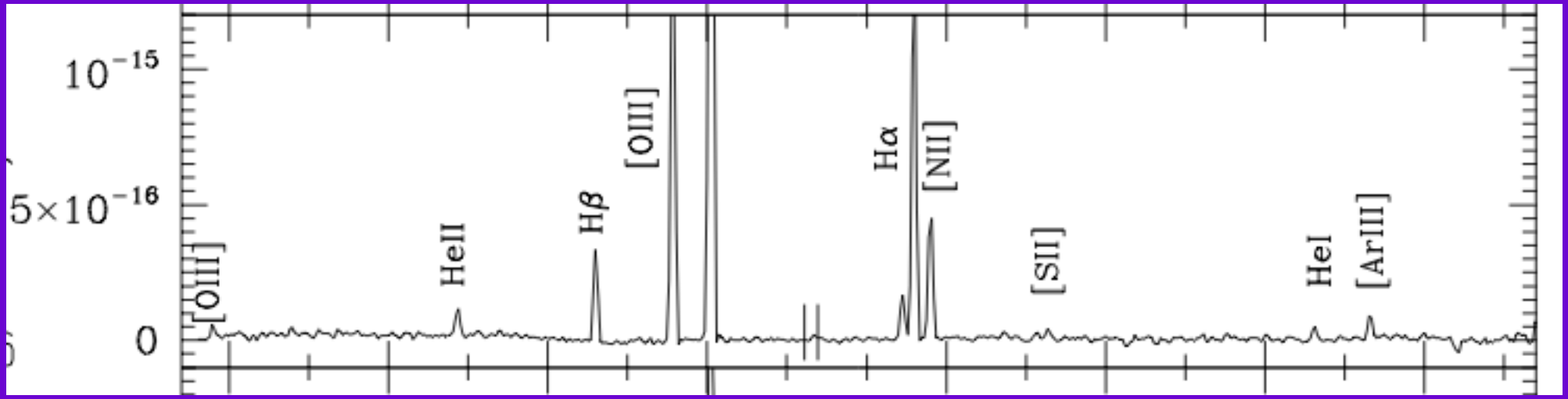
	IR
	optical
	UV
	FUV

examples of nebular spectra



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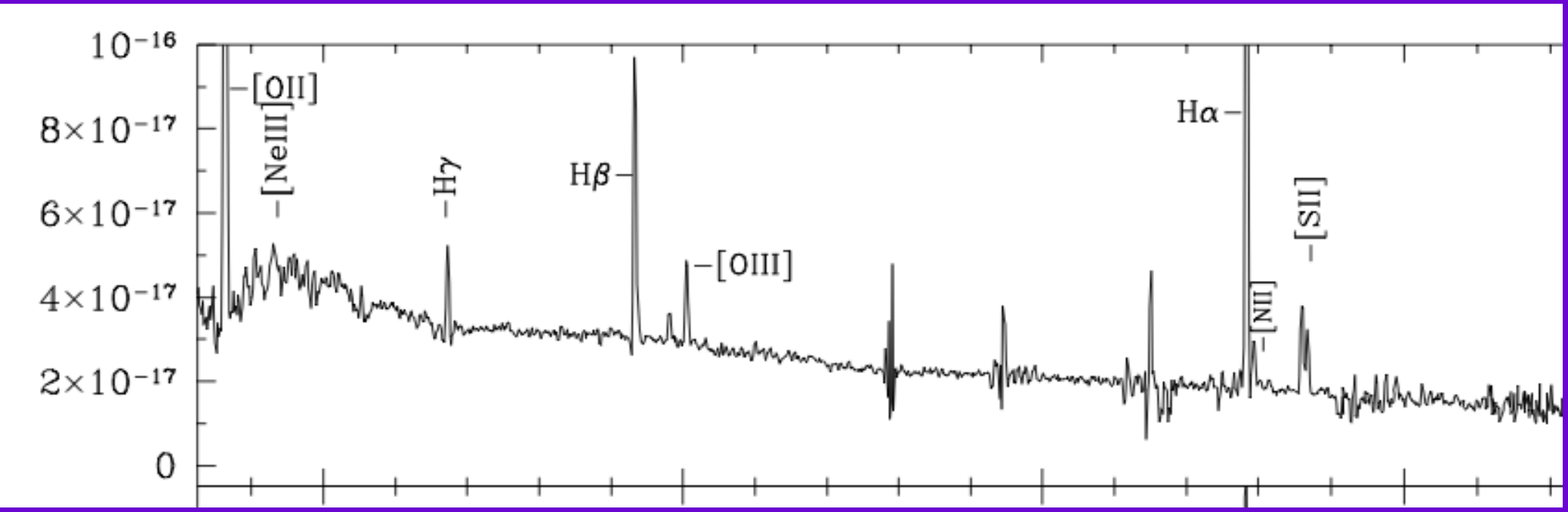

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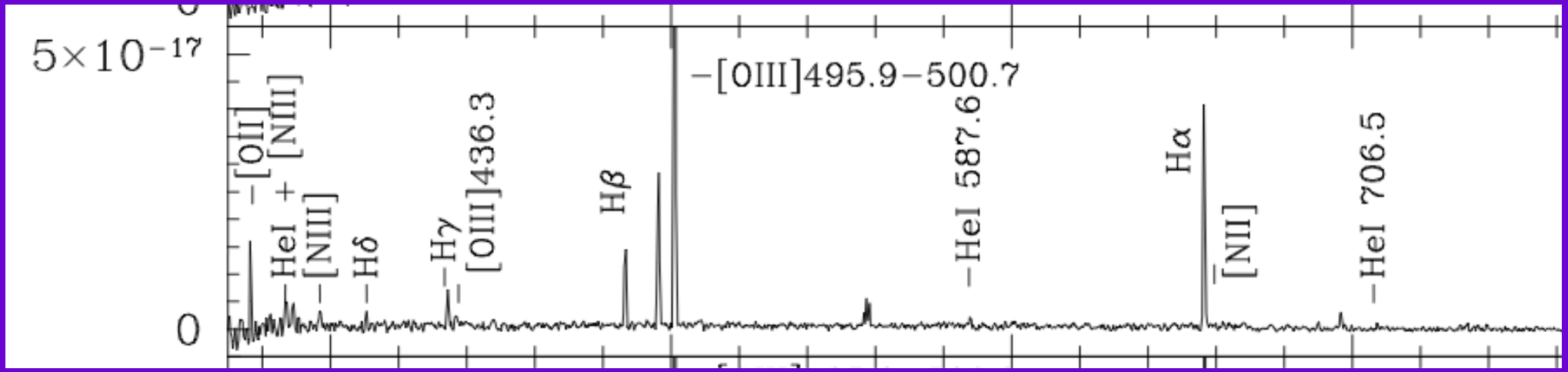
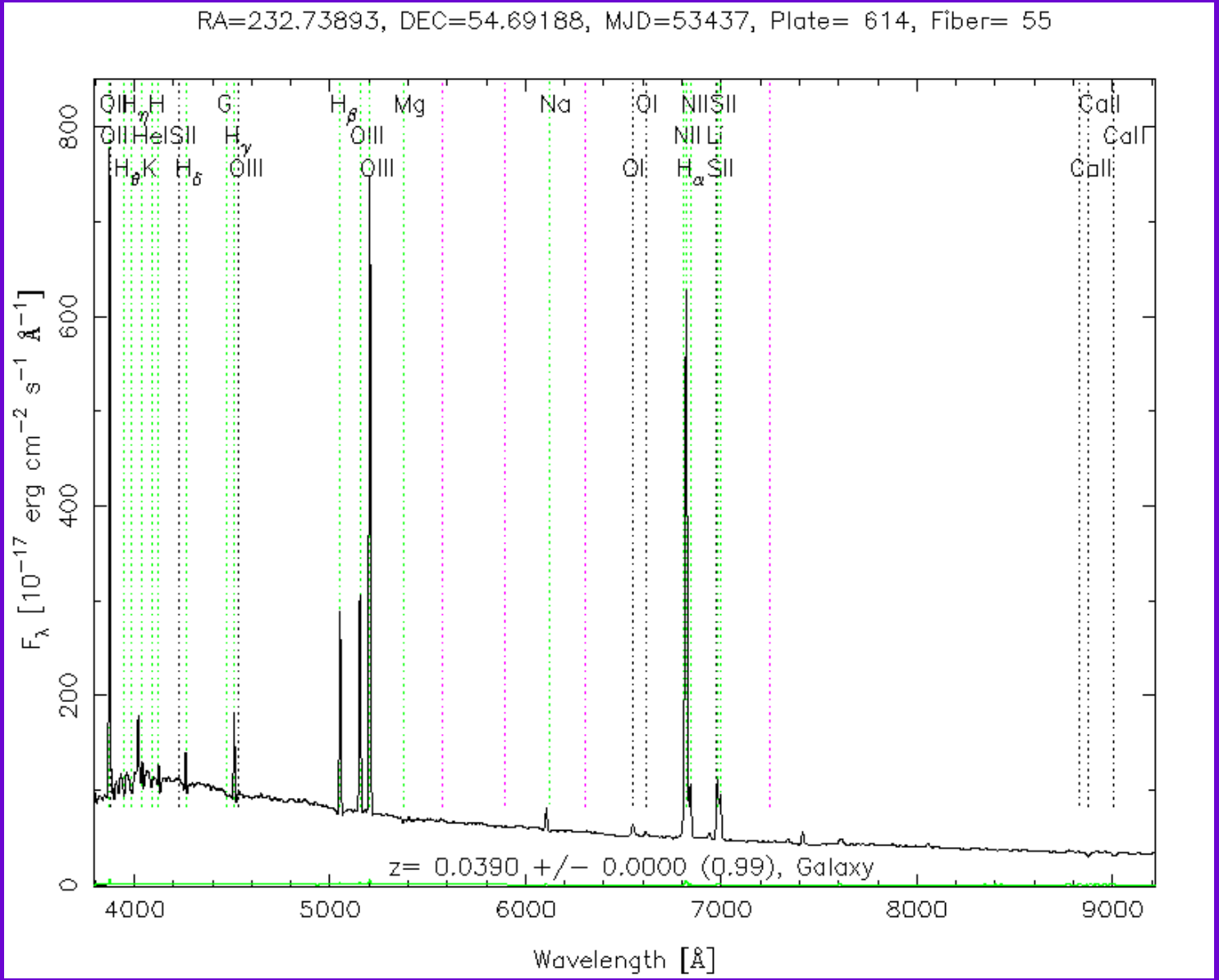


another spectrum obtained in the same galaxy

examples of nebular spectra



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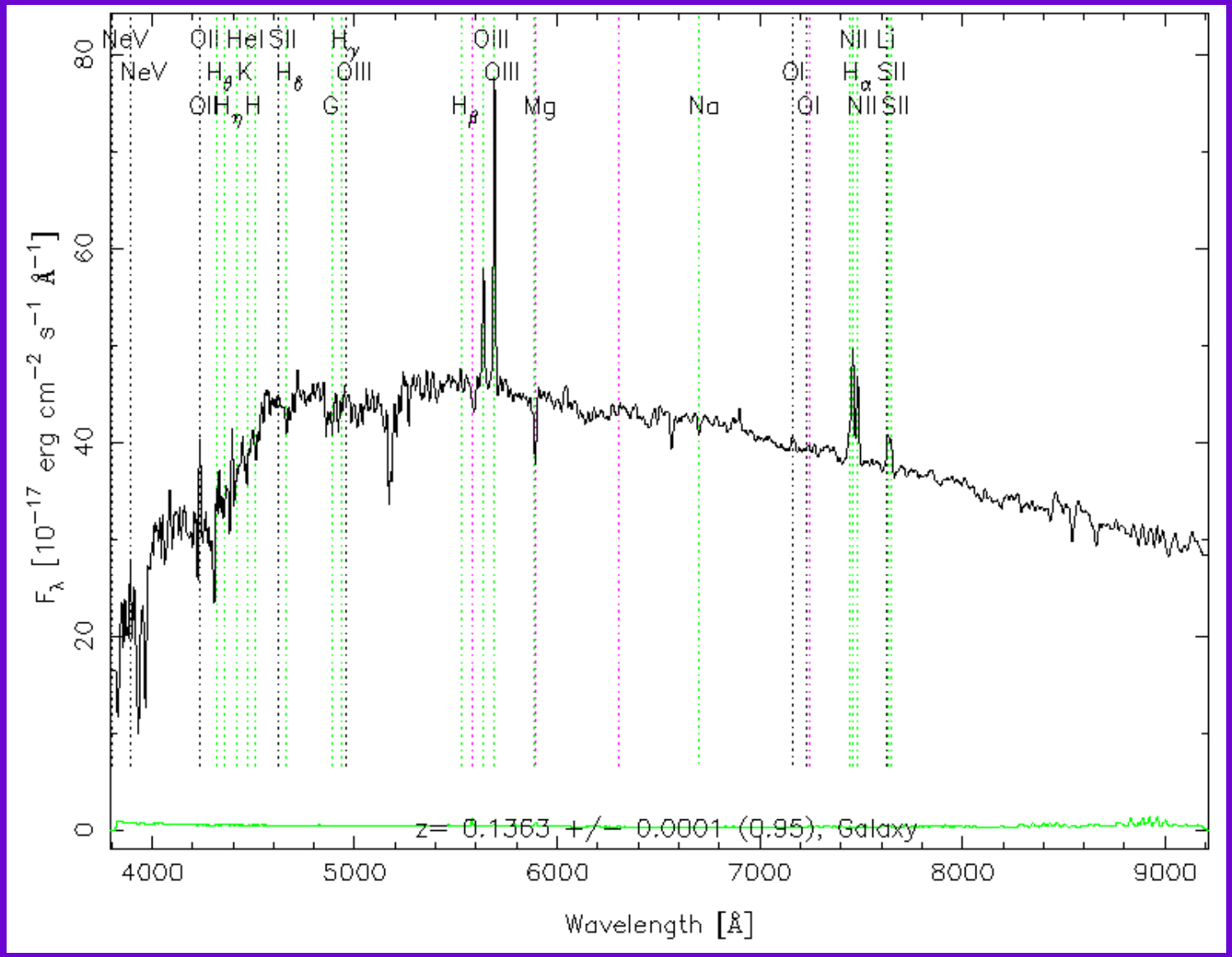

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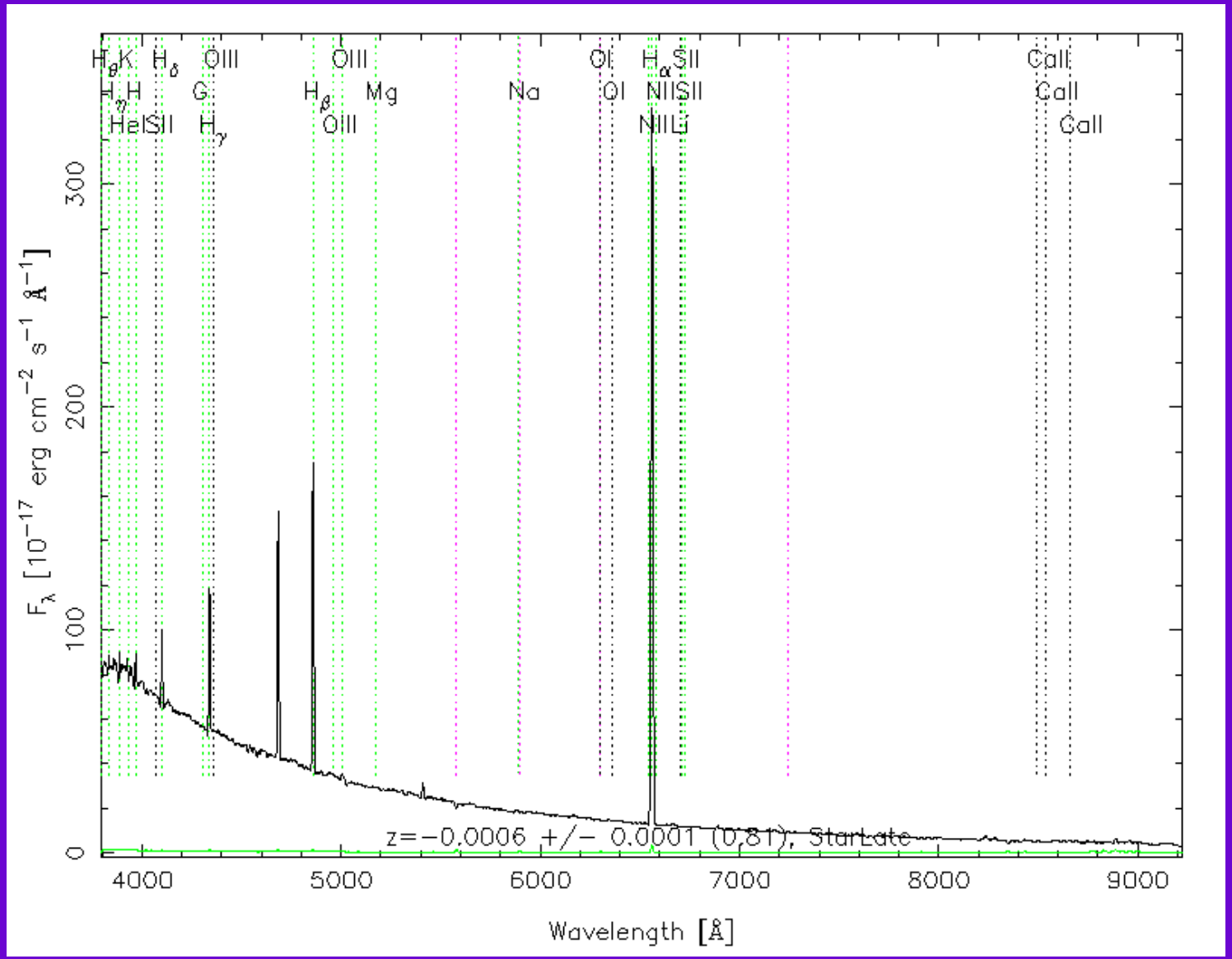

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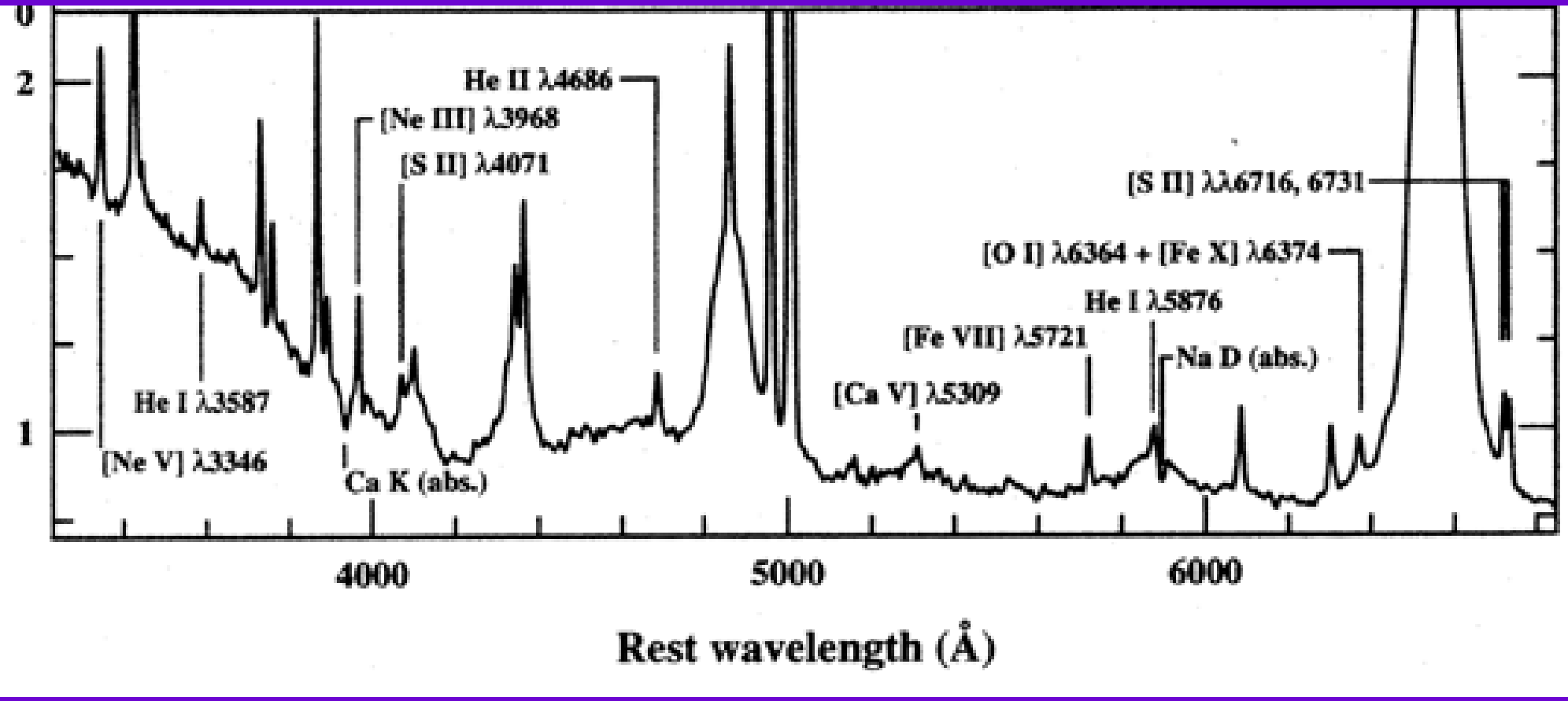

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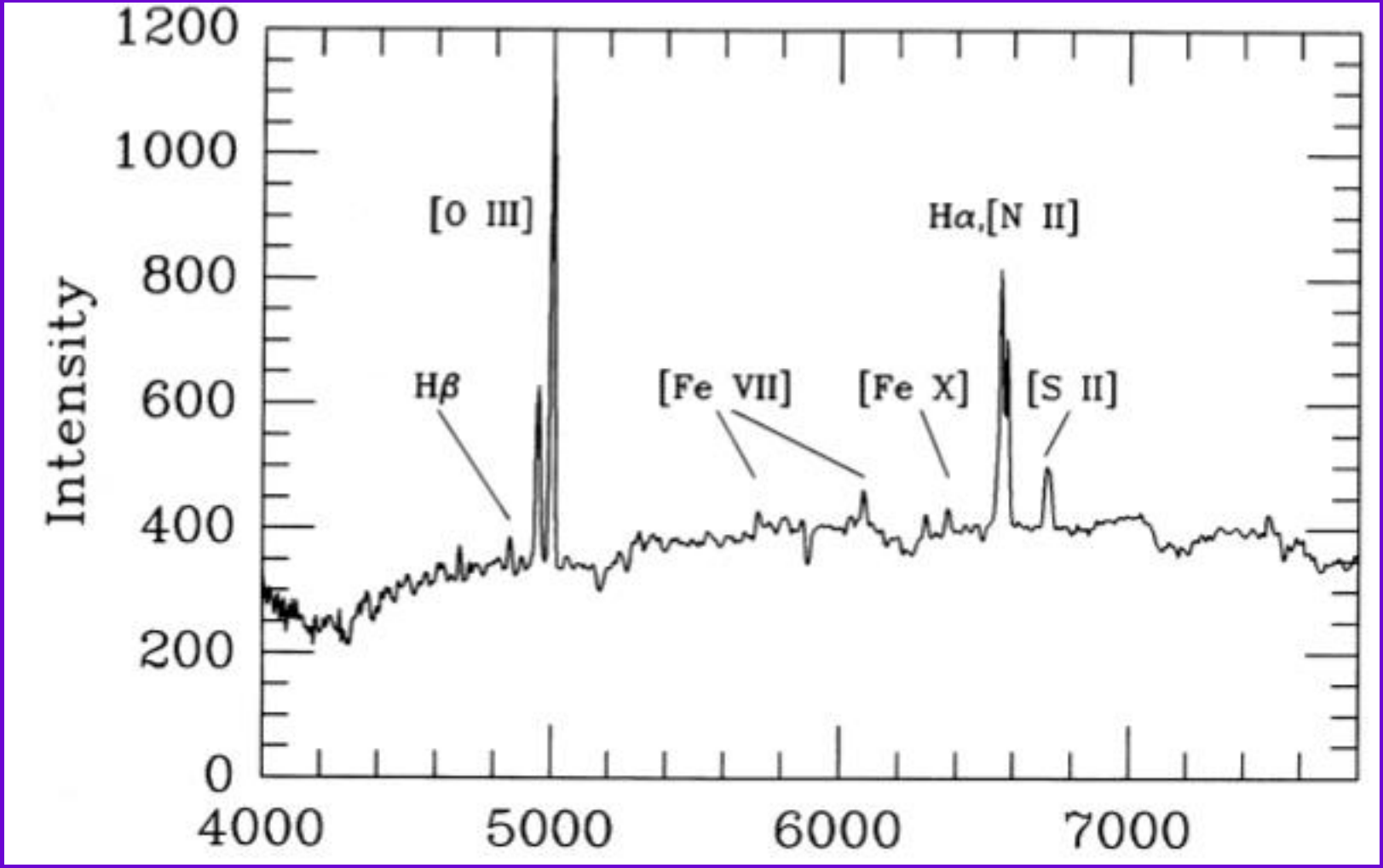

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