

A STUDY OF SULPHUR ABUNDANCES IN IONISED GASEOUS NEBULAE

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SULPHUR IN GASEOUS NEBULAE

Metallicity (Z) is a key parameter in order to reach a complete understanding of gaseous nebulae and the objects where they are. Oxygen (O) is the main abundance tracer of Z.

Sulphur (S) is an α product of the last stages of stellar massive evolution ejected in type II SN and it's expected to track O abundance.

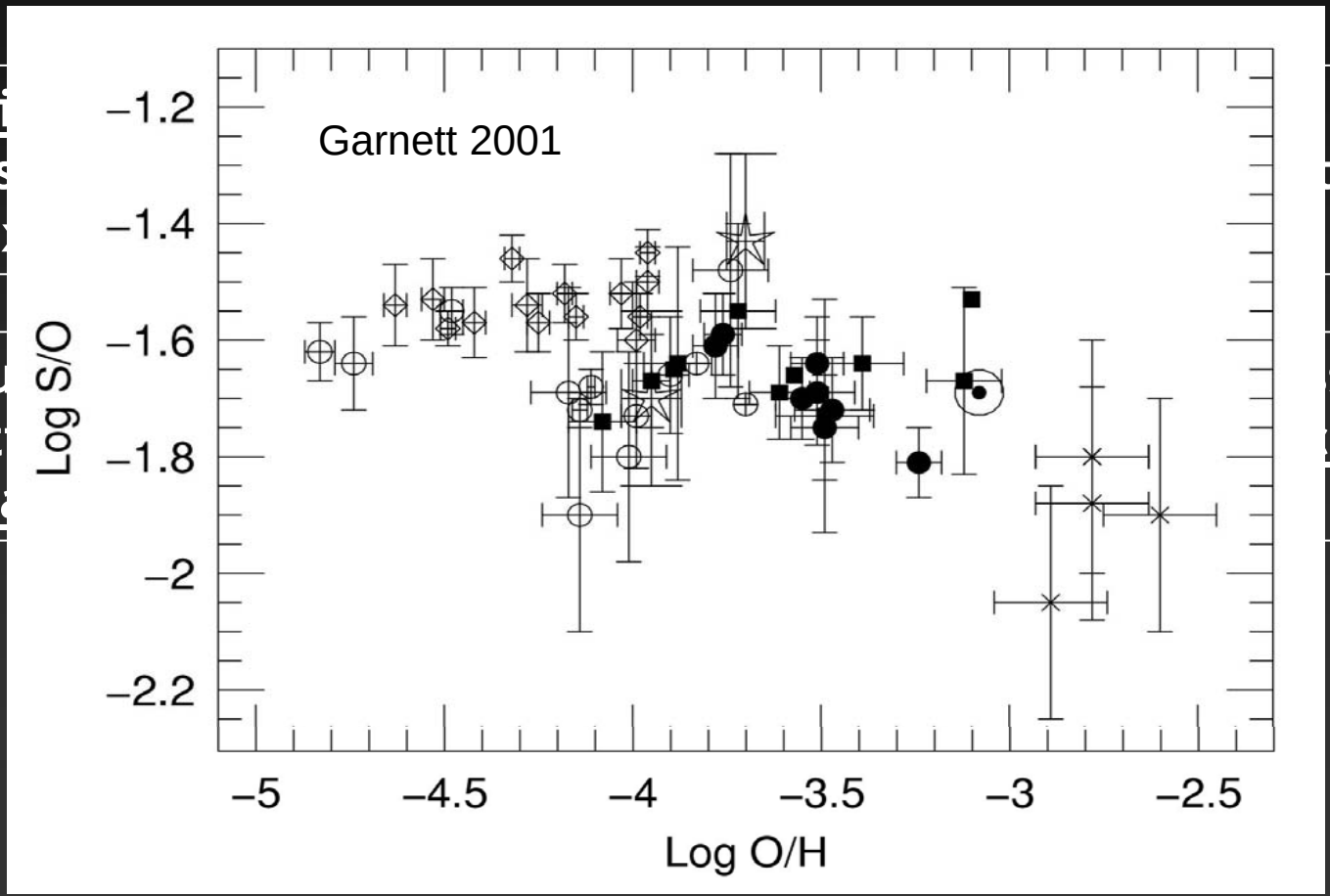
SULPHUR IN GASEOUS NEBULAE

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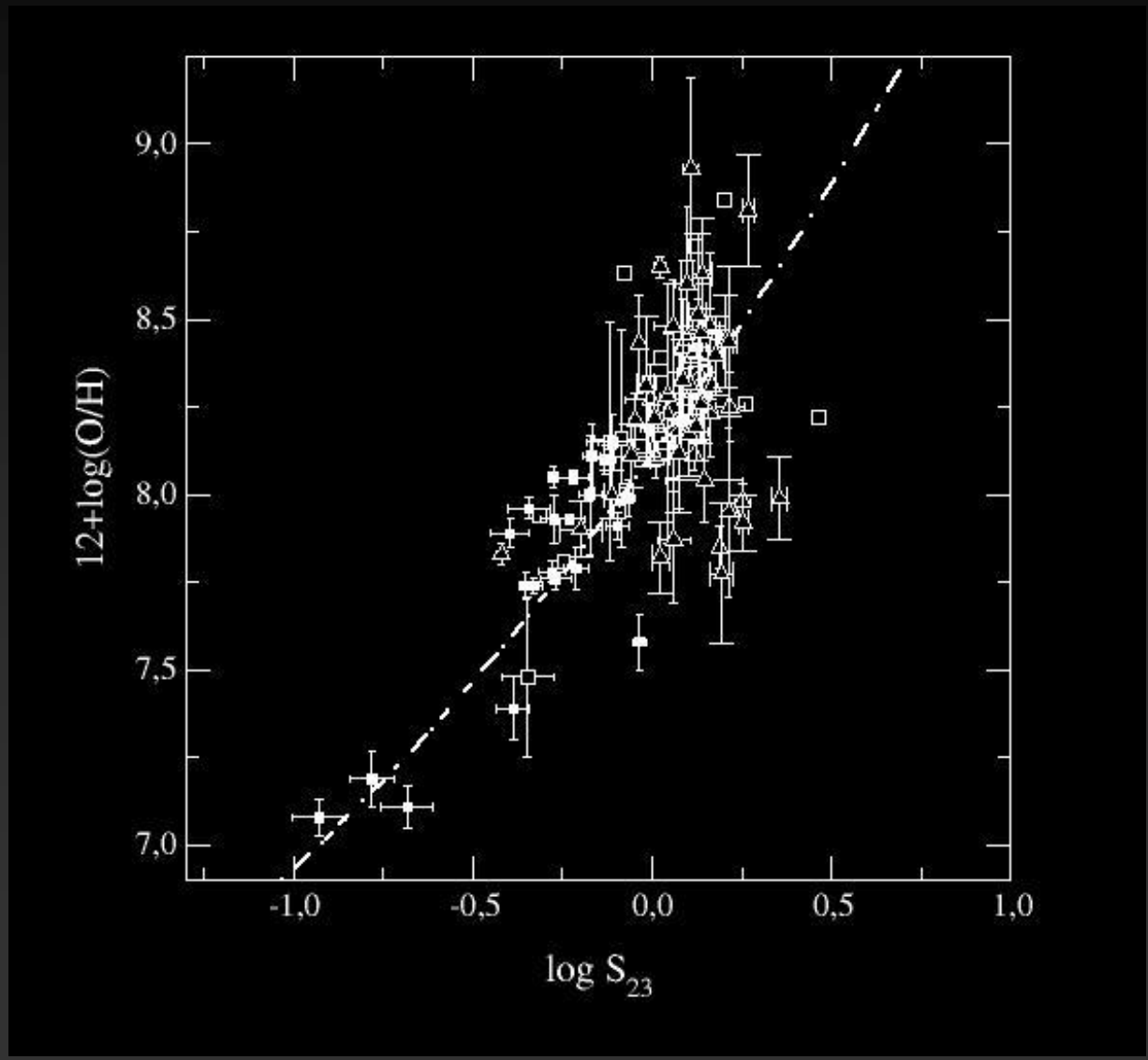


EMPIRICAL PARAMETERS

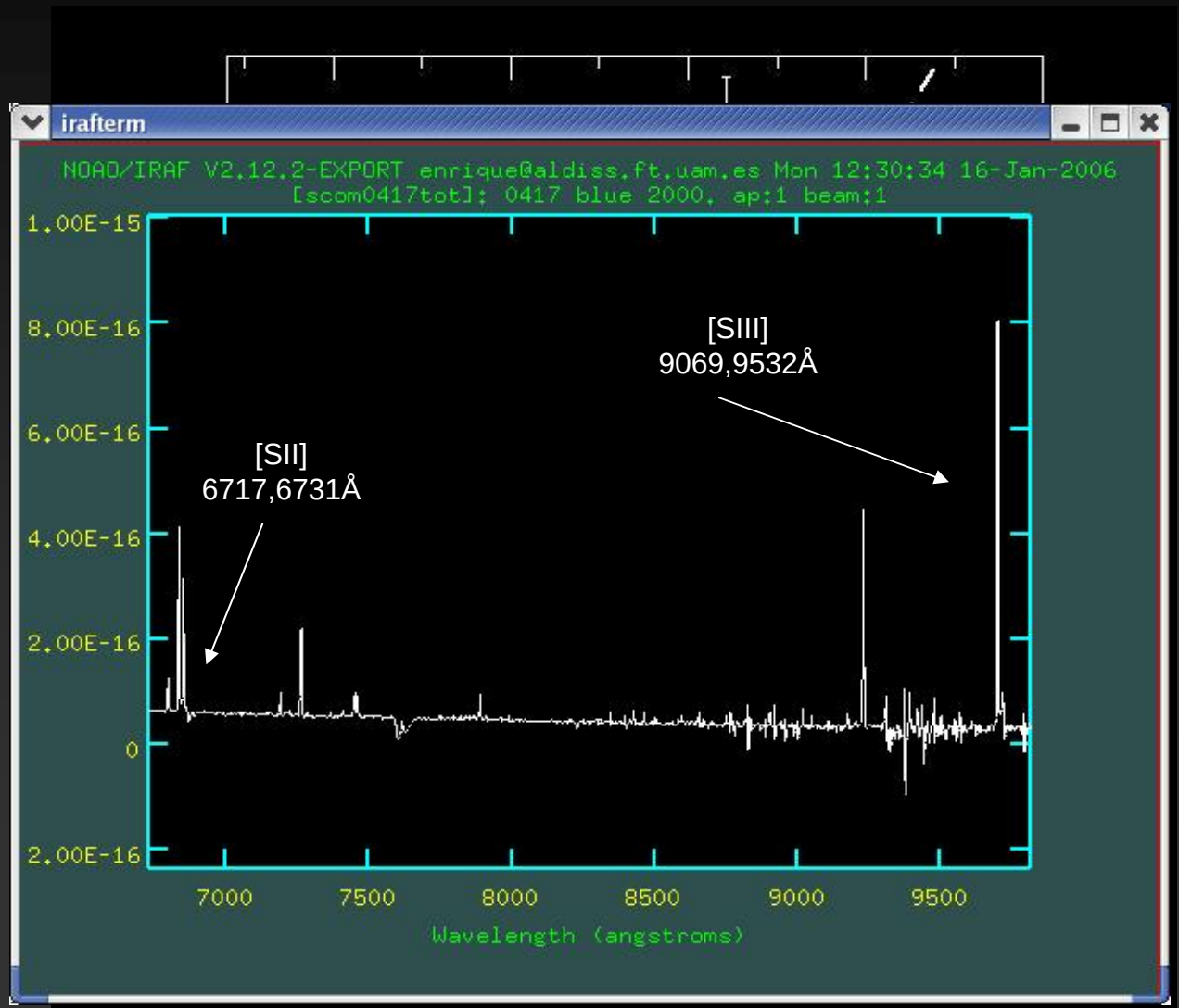
The chemical abundance of S is uncertain in those cases in which no direct determination of the electron gas temperature exists.

In those cases, empirical parameters, based on the detection of strong nebular emission lines, are used.

S23



S23


irafterm
NOAO/IRAF V2.12.2-EXPORT enrique@aldiss.ft.uam.es Mon 12:30:34 16-Jan-2006
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1.00E-15
8.00E-16
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[SIII]
9069,9532Å
[SII]
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7000
7500
8000
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Wavelength (angstroms)

S23 FOR SULPHUR ABUNDANCES

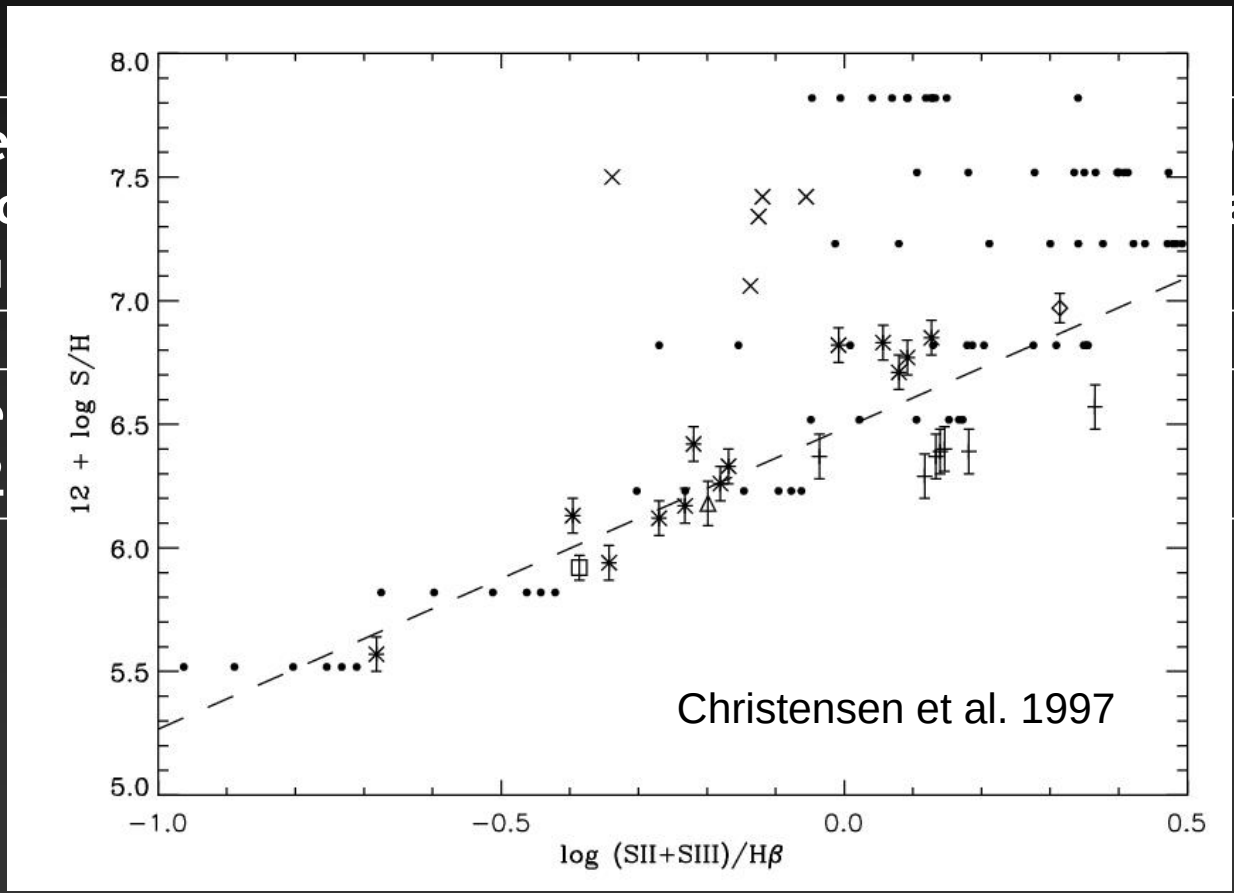
If the starting hypotheses S/O = constant is not completely correct, perhaps S23 is a more valuable empirical parameter for sulphur abundances.

Earlier works from Christensen et al. (1997) and Vermeij et al. (2002) have explored this calibration before.

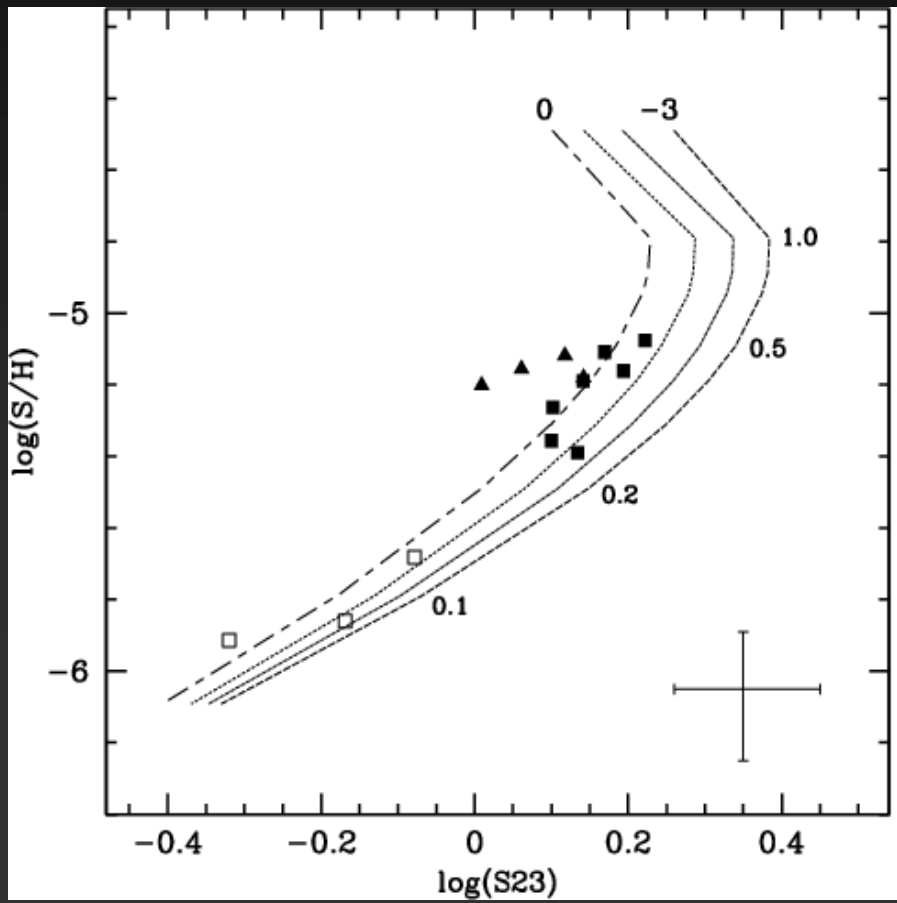
S23 FOR SULPHUR ABUNDANCES

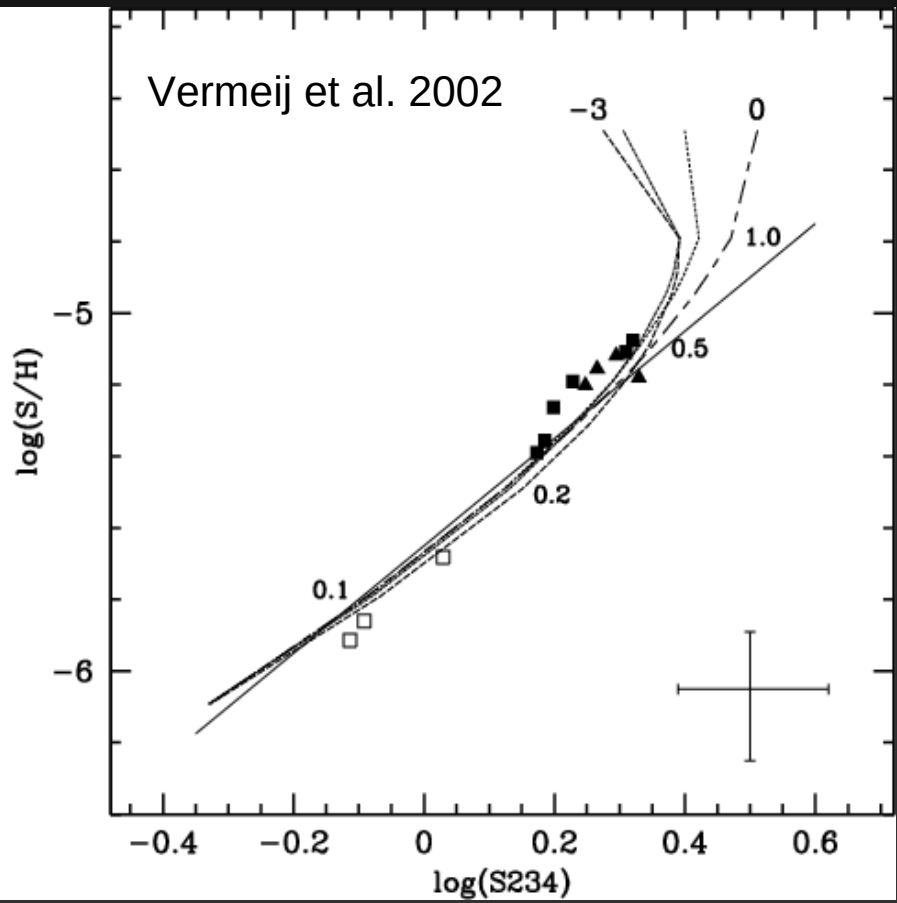
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(2002 …



S23 FOR SULPHUR ABUNDANCES





DIRECT DETERMINATION

Sulphur abundances have been calculated using strong nebular emission lines of [SII] and [SIII] in the red and near-infrared part of the spectrum. An electron temperature for each zone has been assumed.

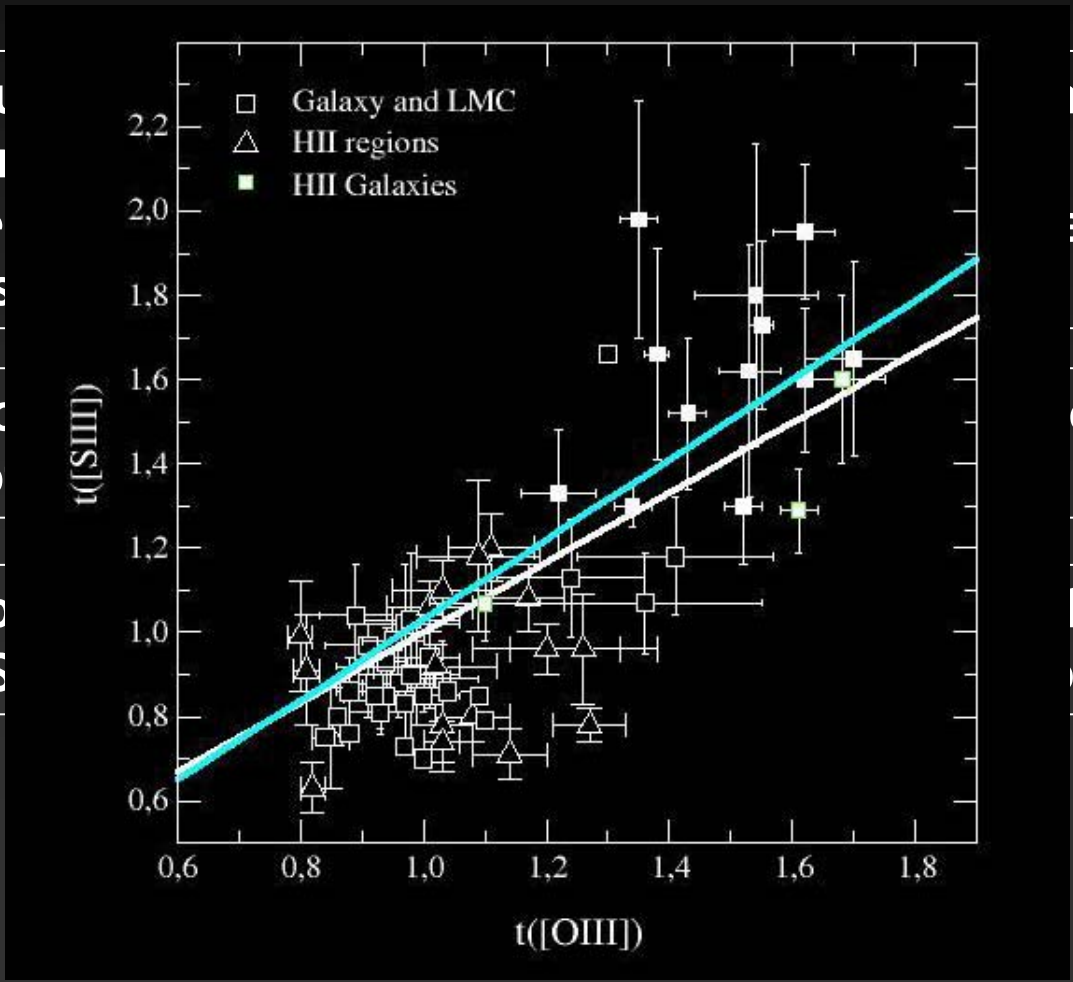
The electron temperature for S^{2+} has been measured directly by means of [SIII] 6312 Å in a 75% of the objects.

DIRECT DETERMINATION

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DIRECT DETERMINATION

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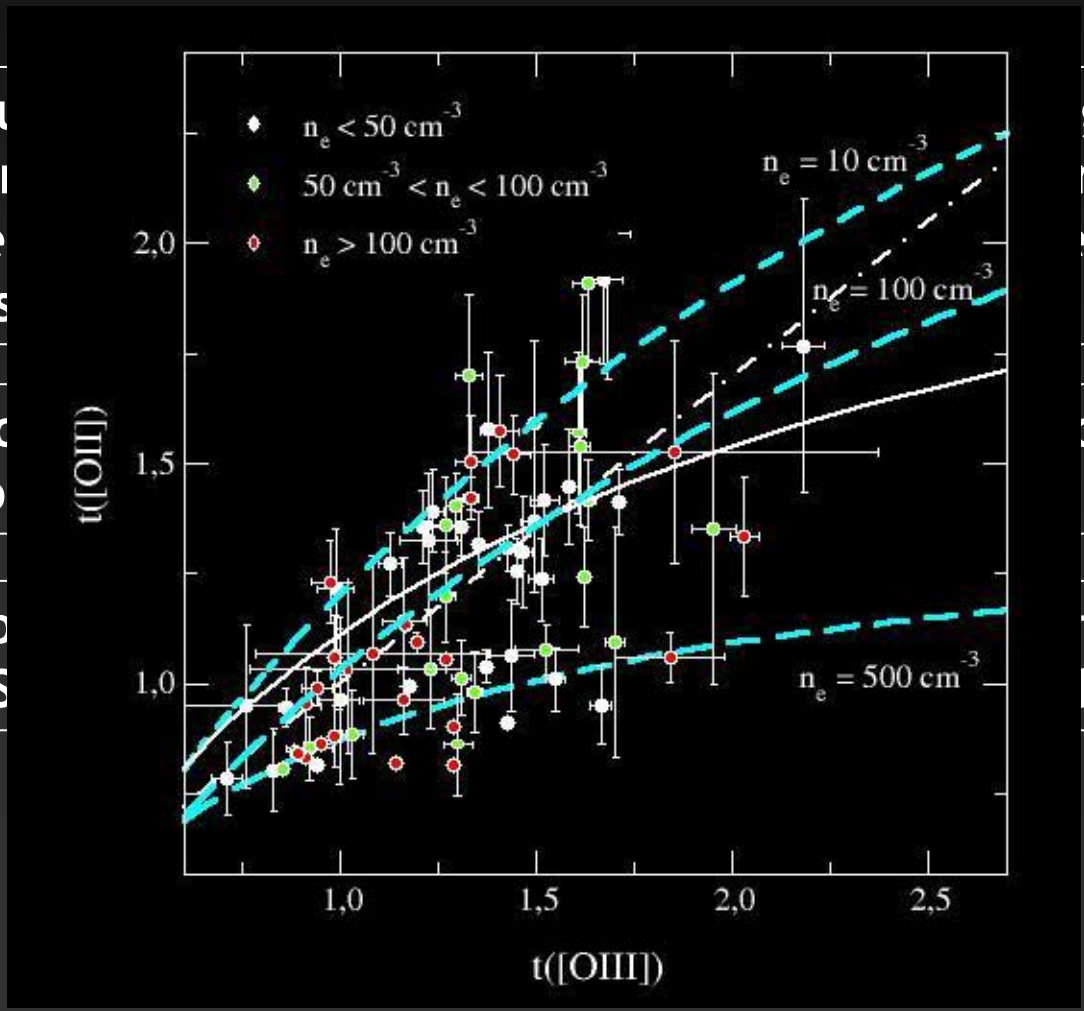
The electron temperature for S^{+} has been measured directly by means of [SII] 4072 Å or [OII] 7325 Å in a 60% of the objects.

DIRECT DETERMINATION

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Presentación

Actividad docente / Teaching activities

Actividad investigadora / Research activities

The S23 parameter

Electron temperatures

HII galaxies

Ionizing clusters



Enrique Pérez Montero (enrique.perez@uam.es)

Actividad investigadora / Research interests

My main interest in Astrophysics is related with the study of the ionized gas by very recent episodes of star formation (HII regions) and all about the information we can access through the study of their emission line spectra and the modelization of this gas. Here I describe some of the issues and some of the publications their study has caused, for instance the S23 parameter, the properties of the electron temperatures, HII galaxies and, more recently, the properties of their ionizing clusters.

To learn more about HII regions:
Las regiones HII. (spanish). Por Patricio T. Díaz Pazos
HII regions and planetary nebulae. By Chris Flynn (Tuorla Observatory)

and a brief tutorial about how to calculate electron density, temperature and ionic abundances in HII regions:

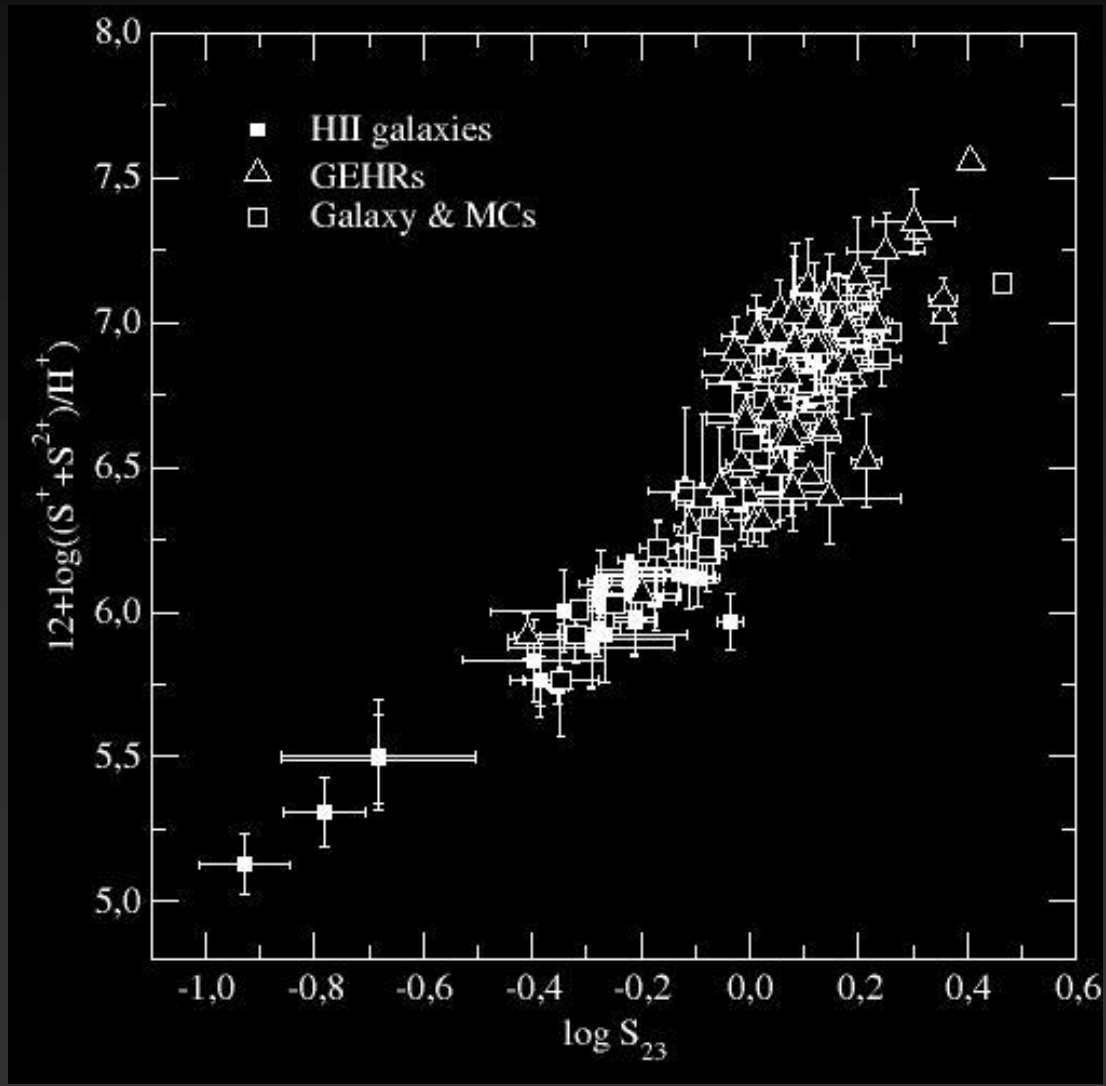
Ionized nebulae diagnostics
Enrique Pérez Montero
Internal report of the coordinated project "Estallidos de formación estelar en galaxias"

PDF (english) PDF (español)

http://pollux.ft.uam.es/enrique/research.htm

THE SAMPLE OF OBJECTS

We have calculated sulphur abundance for a sample of 171 objects.



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$$12 + \log\left(\frac{S^+ + S^{2+}}{H^+}\right) = 6.540 + 2.071 \log S_{23} + 0.348 (\log S_{23})^2$$

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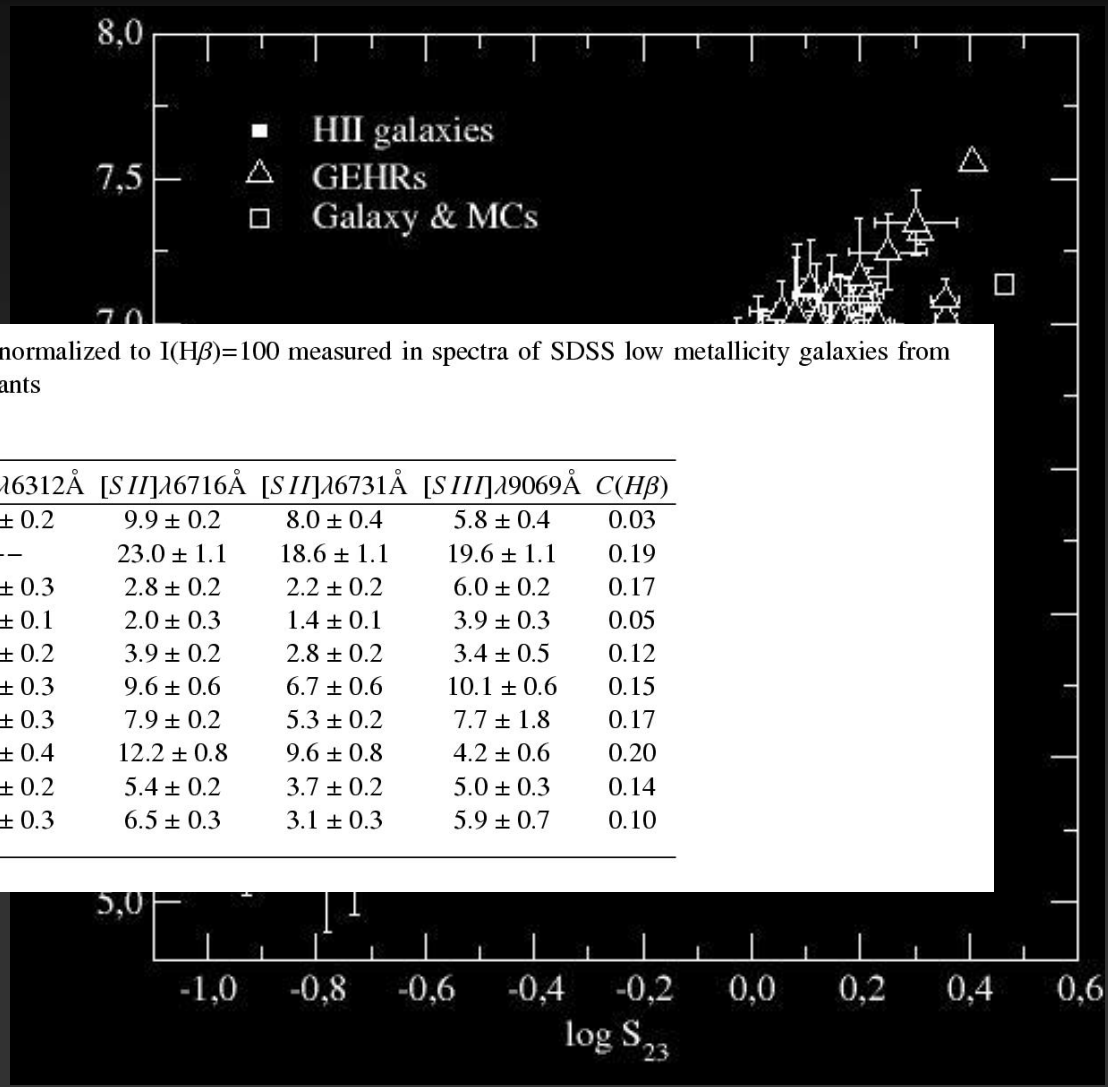


Table 1. Reddening corrected line fluxes for sulphur normalized to I(Hβ)=100 measured in spectra of SDSS low metallicity galaxies from Kniazev et al. (2003), along with their reddening constants

Object	[S III]λ6312Å	[S II]λ6716Å	[S II]λ6731Å	[S III]λ9069Å	C(Hβ)
	0.9 ± 0.2	9.9 ± 0.2	8.0 ± 0.4	5.8 ± 0.4	0.03
	−−	23.0 ± 1.1	18.6 ± 1.1	19.6 ± 1.1	0.19
[illegible]	1.4 ± 0.3	2.8 ± 0.2	2.2 ± 0.2	6.0 ± 0.2	0.17
*IZw*18 − *NW*	0.8 ± 0.1	2.0 ± 0.3	1.4 ± 0.1	3.9 ± 0.3	0.05
*IZw*18 − *SE*	0.5 ± 0.2	3.9 ± 0.2	2.8 ± 0.2	3.4 ± 0.5	0.12
SBS 1102 + 606	1.6 ± 0.3	9.6 ± 0.6	6.7 ± 0.6	10.1 ± 0.6	0.15
*A*1116 + 517	1.3 ± 0.3	7.9 ± 0.2	5.3 ± 0.2	7.7 ± 1.8	0.17
*SDSS J*1121 + 0324	1.3 ± 0.4	12.2 ± 0.8	9.6 ± 0.8	4.2 ± 0.6	0.20
*SDSS J*1201 + 0211	1.0 ± 0.2	5.4 ± 0.2	3.7 ± 0.2	5.0 ± 0.3	0.14
*CGCG*269 − 049	1.4 ± 0.3	6.5 ± 0.3	3.1 ± 0.3	5.9 ± 0.7	0.10

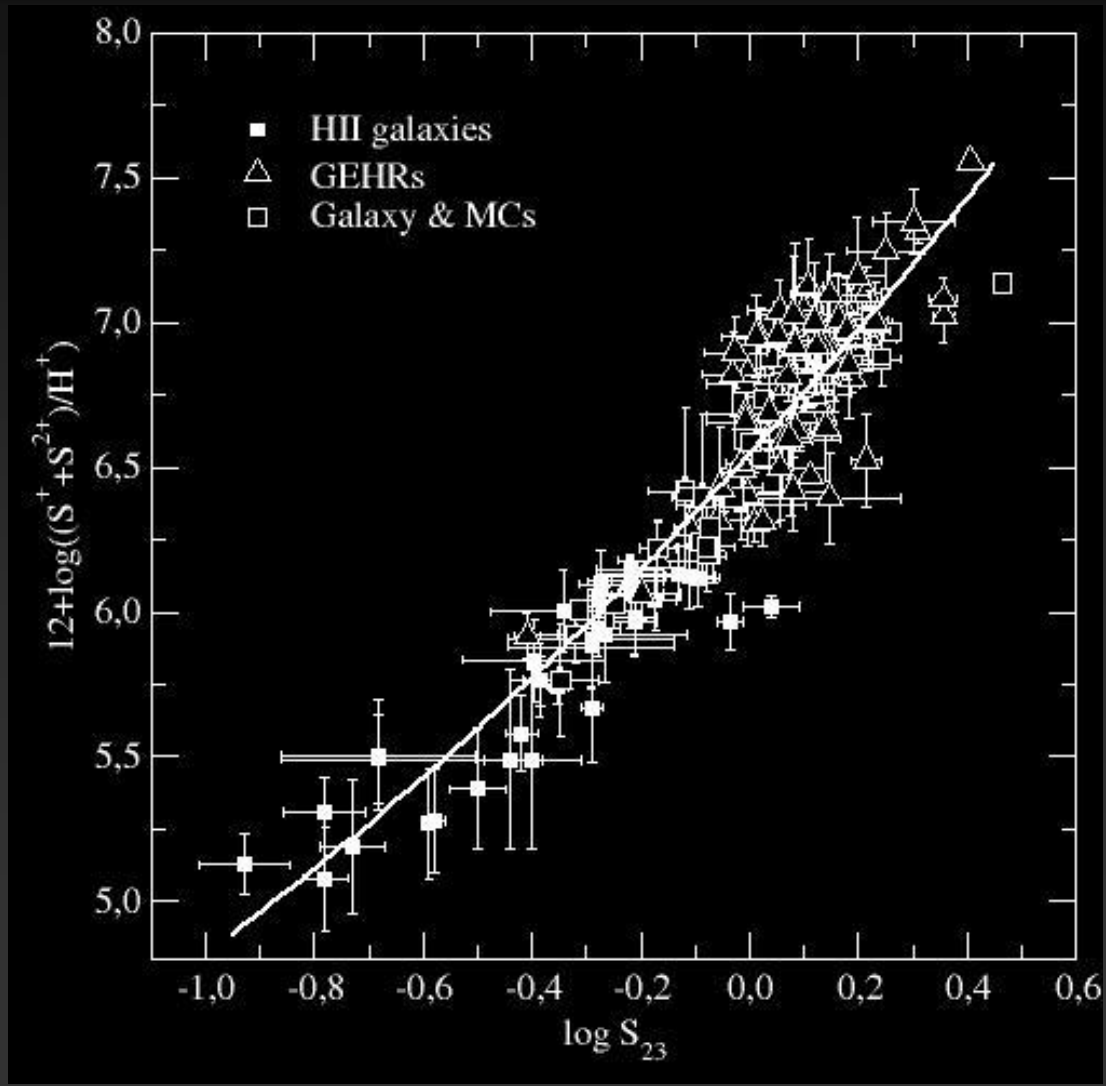
THE SAMPLE OF OBJECTS

We have calculated sulphur abundance for a sample of 171 objects.

The best fit for the sample yields:

$$12 + \log\left(\frac{S^+ + S^{2+}}{H^+}\right) = 6.540 + 2.071 \log S_{23} + 0.348 (\log S_{23})^2$$

With a dispersion of 0.17 dex



THE TOTAL ABUNDANCE

The total abundance of sulphur must be taken into the account by means of the abundance of S^{3+} through direct measurement in the mid-IR or the use of Ionisation Correction Factor (ICF).

$$\frac{N(S)}{N(H)} = ICF(S^+ + S^{2+}) \cdot \frac{N(S^+ + S^{2+})}{N(H^+)} =$$

$$= \frac{N(S^+ + S^{2+} + S^{3+})}{N(S^+ + S^{2+})} \cdot \frac{N(S^+ + S^{2+})}{N(H^+)}$$

THE ICF OF SULPHUR

The main efforts to calculate the ICF try to use the relation between the main stages of ionisation of oxygen.

The first proposed ICF scheme for sulphur (Peimbert & Costero, 1969) was based on the similarity of the ionisation potentials of O^+ (35.1 eV) and S^{2+} (34.8 eV)

$$ICF(S^+ + S^{2+}) = \frac{N(O)}{N(O^+)}$$

THE ICF OF SULPHUR

The main efforts to calculate the ICF try to use the relation between the main stages of ionisation of oxygen.

Nevertheless, some authors have pointed out that this relation has a strong correlation with the ionisation degree of the nebula (e.g. Barker 1978; Pagel 1978), thus implying an overestimation of the sulphur abundance in nebulae with low electron temperature. Barker (1980) proposed a new relation, based on the photoionisation models of Stasiǹska (1978):

$$ICF(S^+ + S^{2+}) = \left[1 - \left(1 - \frac{N(O^+)}{N(O)}\right)^{\alpha}\right]^{-1/\alpha}$$

THE ICF OF SULPHUR

We have compiled ISO data of the [SIV] line at 10.52μ in HII regions in the Galaxy and MCs (Vermeij et al., 2002) and one HII galaxy (Mrk 209; Nollenberg et al., 2001).

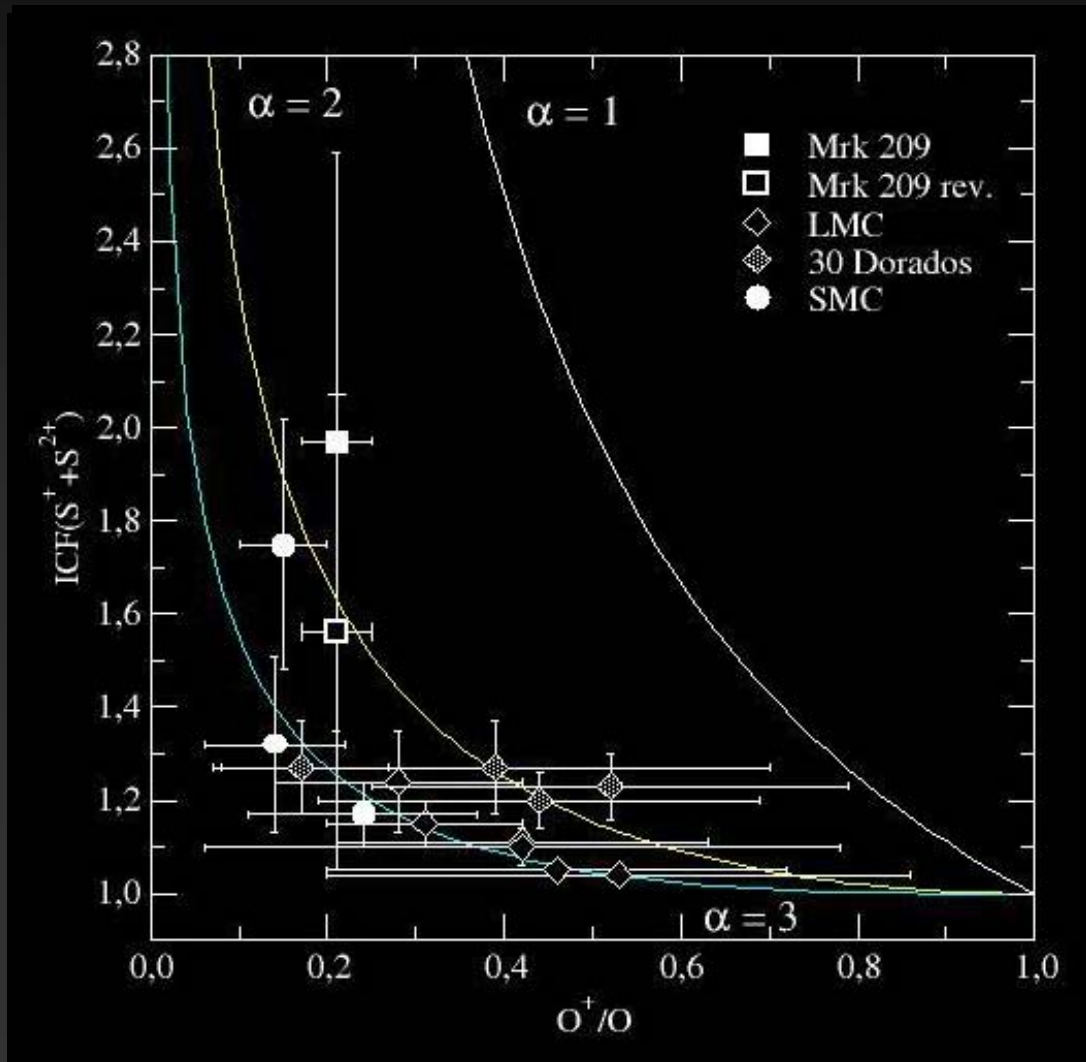
Table 3. Abundances of S^{3+} for the objects for which there are ISO observations of the [SIV] 10.52 μ emission line and the corresponding ICF(S^++S^{2+}).

Object	*Ref.*[a]	$12+\log\left(\frac{S^{3+}}{H^+}\right)$	$ICF(S^+ + S^{2+})$
*Mrk*209	1	5.93 ± 0.20	1.97 ± 0.62
*Mrk*209[b]	1	5.68 ± 0.23	1.56 ± 0.76
*N*160 − *A*1	2	6.08 ± 0.11	1.15 ± 0.05
*N*160 − *A*2	2	5.90 ± 0.10	1.11 ± 0.03
*N*159 − 5	2	6.03 ± 0.10	1.10 ± 0.04
*N*157 − *B*	2	5.54 ± 0.12	1.05 ± 0.02
30*Dor* − 1	2	6.16 ± 0.11	1.27 ± 0.10
30*Dor* − 2	2	6.24 ± 0.11	1.27 ± 0.10
30*Dor* − 3	2	6.16 ± 0.10	1.20 ± 0.06
30*Dor* − 4	2	6.15 ± 0.10	1.23 ± 0.07
*N*83 − *B*	2	5.45 ± 0.12	1.04 ± 0.02
*N*4 − *A*	2	6.17 ± 0.15	1.24 ± 0.11
*N*88 − *A*	2	5.80 ± 0.10	1.75 ± 0.27
*N*66	2	5.73 ± 0.15	1.32 ± 0.19
*N*81	2	5.45 ± 0.11	1.17 ± 0.07

THE ICF OF SULPHUR

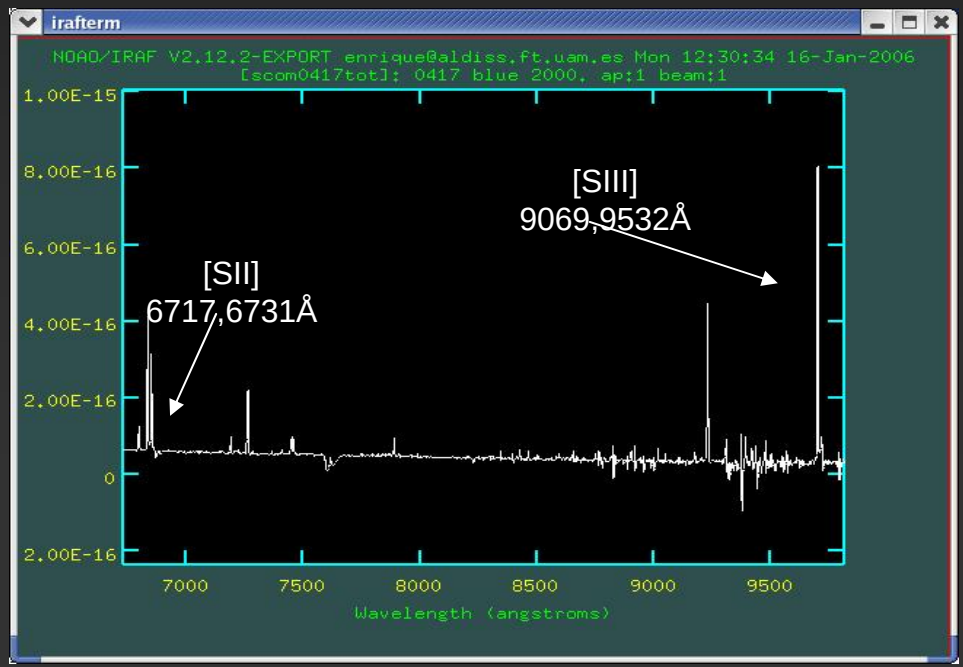
We have recalculated the S^{3+} abundance of Mrk209 assumming a constant S^{3+}/S^{2+} ratio for the near IR.

The best fit is obtained thus for $\alpha = 2.5$



A RED ICF FOR SULPHUR

Since oxygen abundances depend on optical observations, we consider the calculation of a new ICF based only on emission lines in the red and near-IR part of the spectrum, e.g. [SII]/[SIII], indeed an estimator of ionisation parameter (e,g, Díaz et al. 1991)



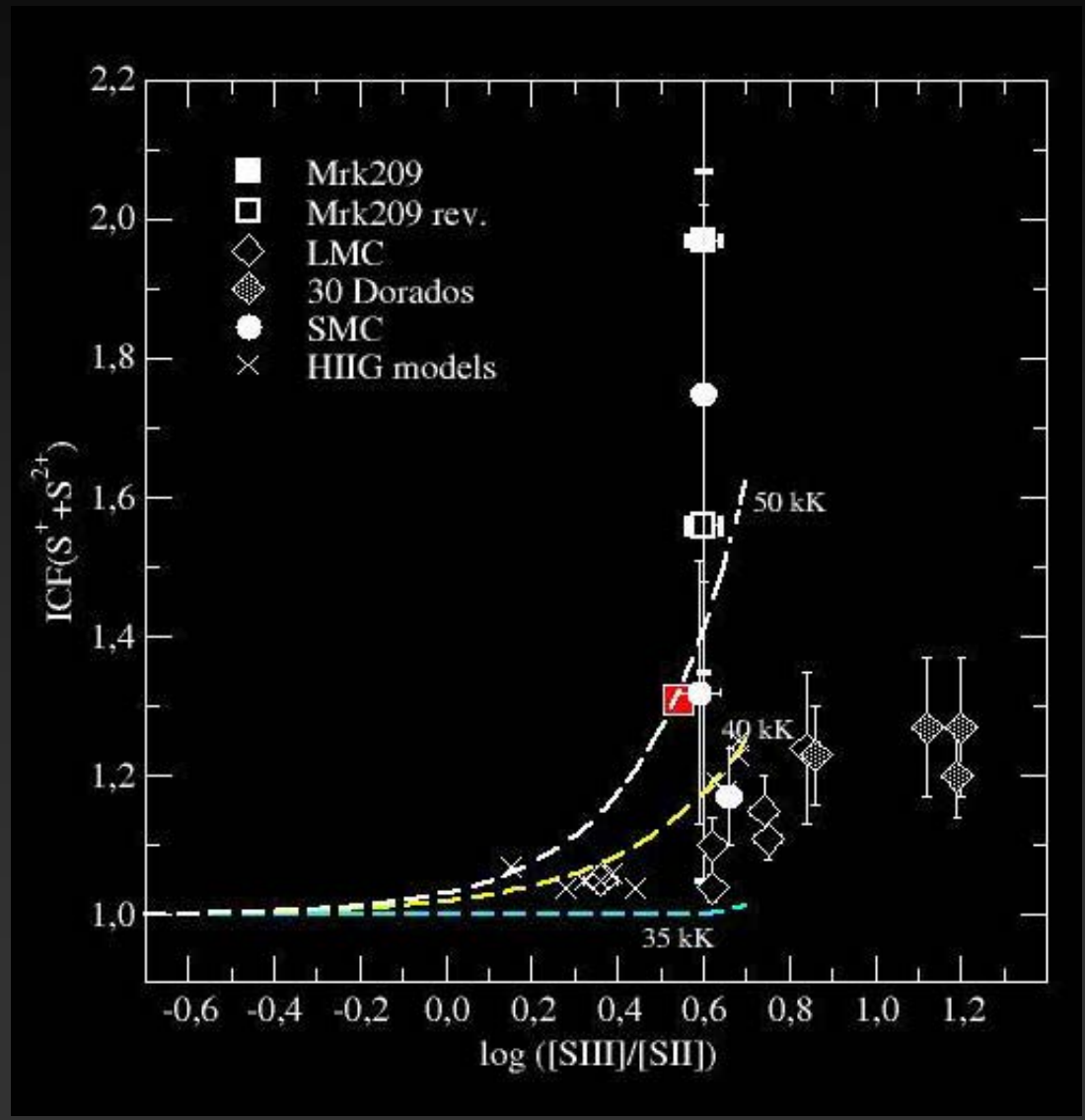
A STUDY OF SULPHUR ABUNDANCES IN IONISED GASEOUS NEBULAE. Enrique Pérez Montero

Taylored models of HII galaxies (Pérez-Montero & Díaz, 2004) show that there is a sequence for HII galaxies.

Synthesis models show that it's evolutionary and not very sensible to metallicity.

However these models do not predict the observed effective equivalent T.

A new taylored model for Mrk209 (in prep.) predicts the correct T assumming a reliable geometry and the presence of dust.



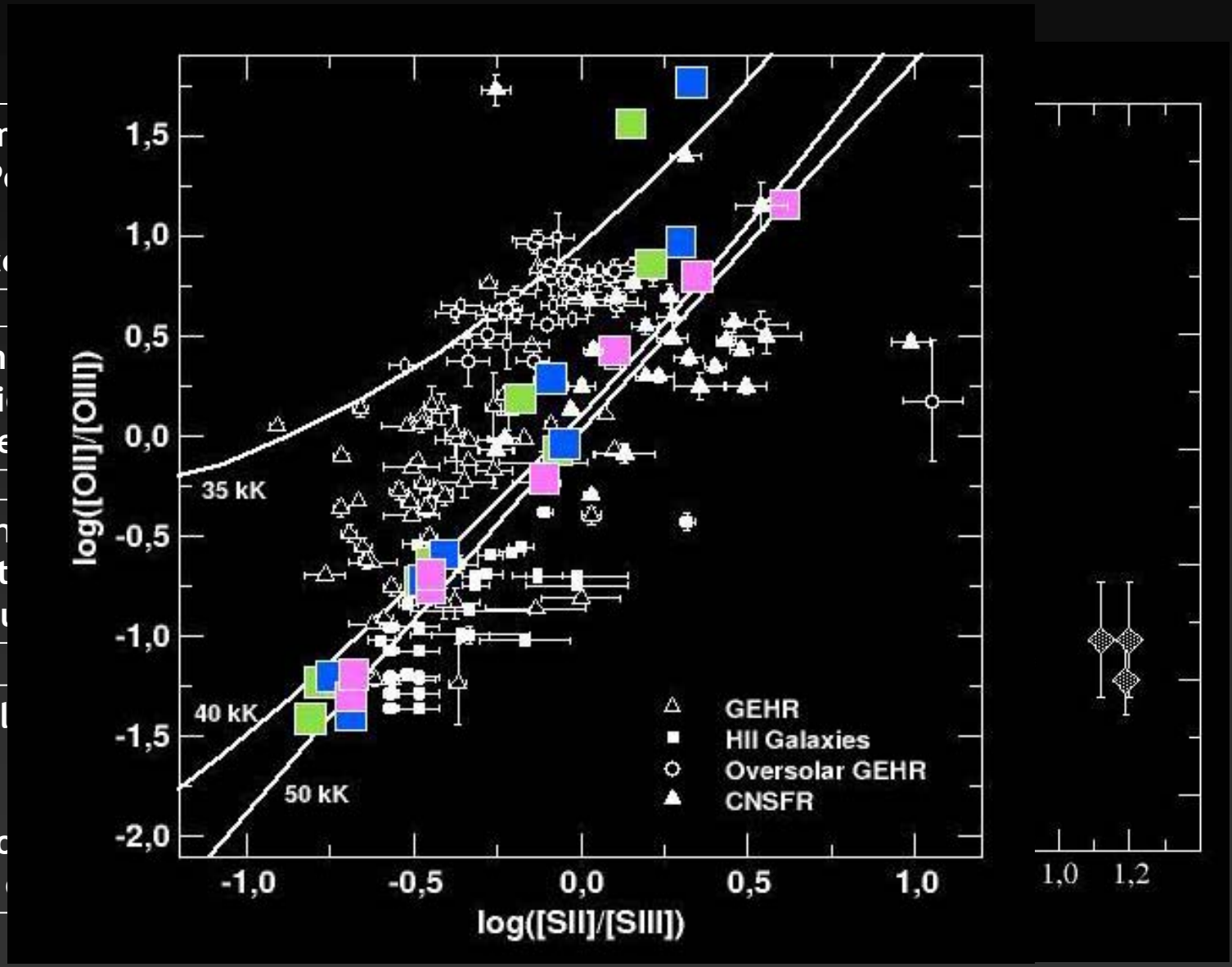
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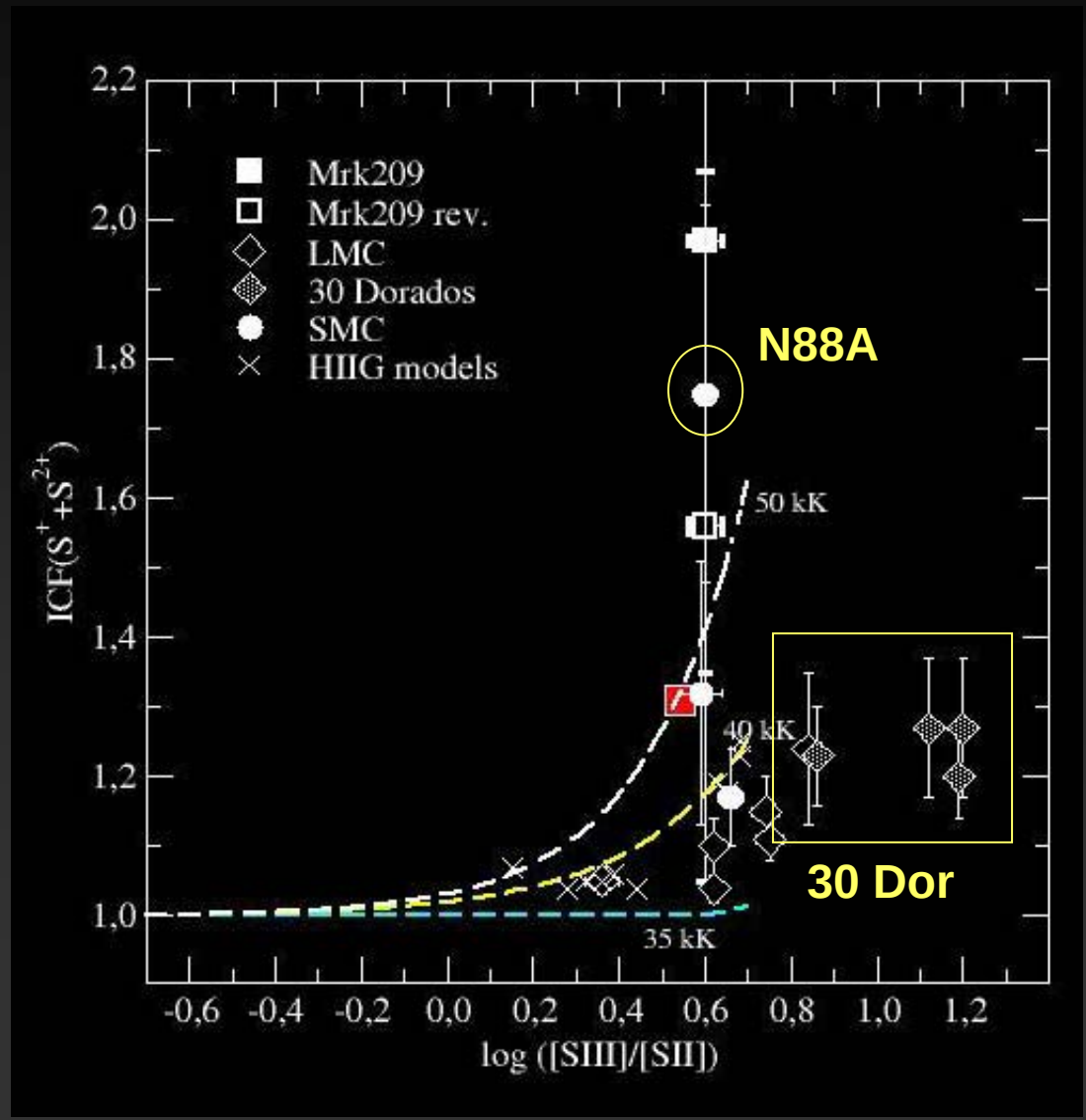


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N88A results to be a very young HII region breaking out its natal cloud (Heydari-Malayeri et al. 1999)

30 Dorados do not lie near of any model prediction and it's probably due to its geometry (matter-bounded?)

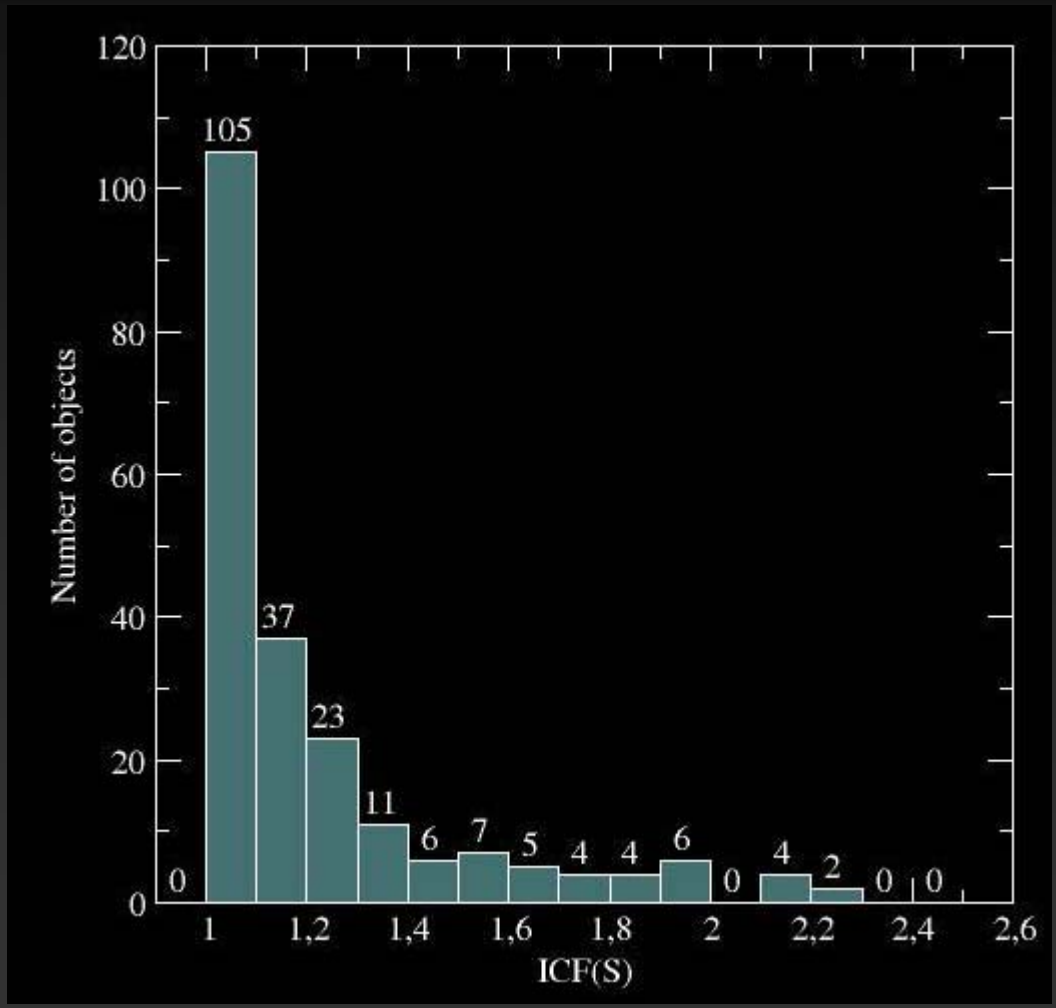
Therefore, we can probably use this schema only for HII galaxies, assumming the CoStar models for T between 40kK and 50 kK



ICF FOR SULPHUR

With the Barker's ICF for α = 2.5 only a 34% have ICF > 1.2.

The results are quite similar for HII galaxies using the red ICF.



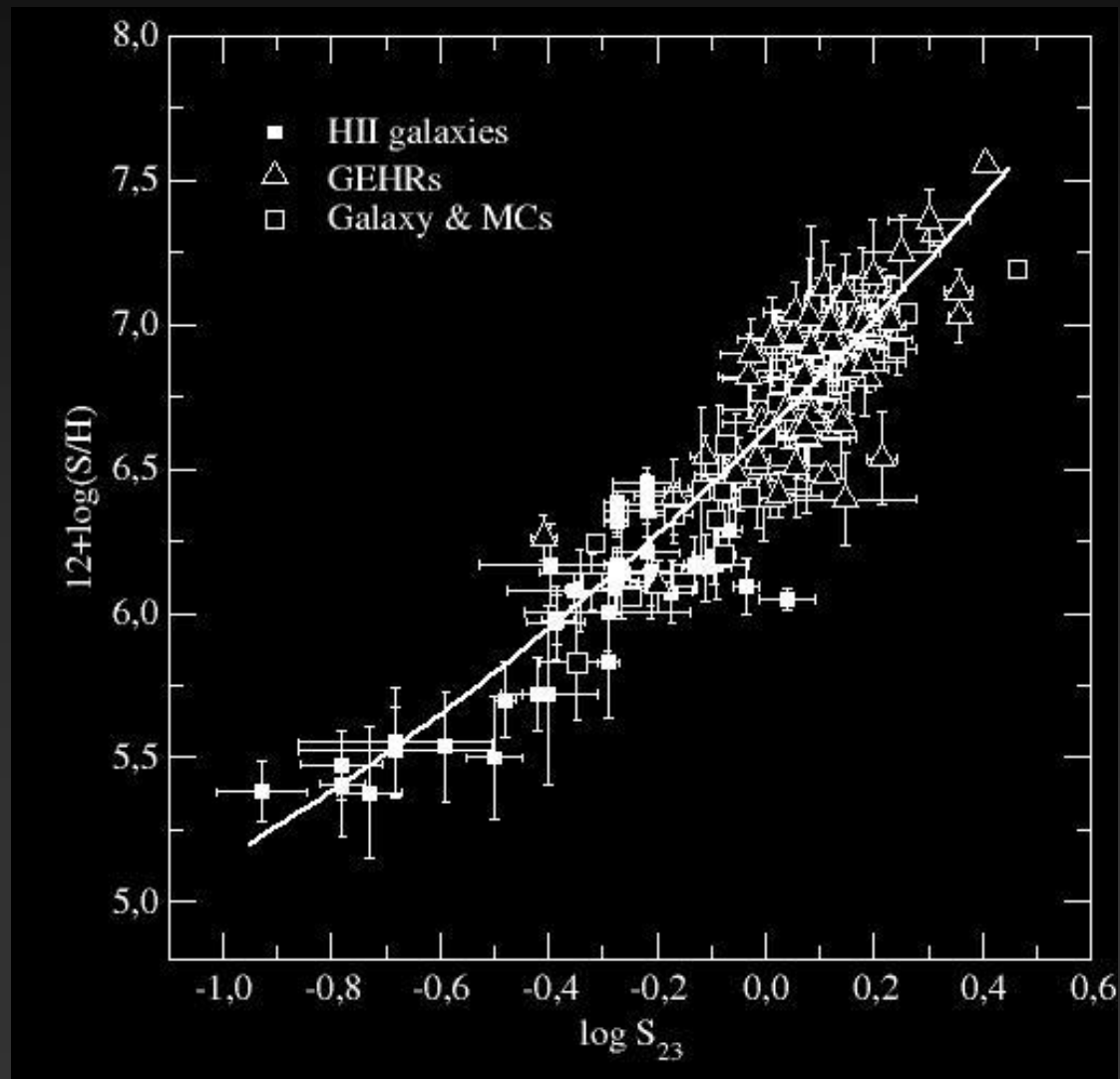
S23 vs. S/H

Now we can calculate the calibration of S23 for the total abundance.

The best fit for the sample yields:

$$12 + \log\left(\frac{S}{H}\right) = 6.622 + 1.860 \log S_{23} + 0.382 \, (\log S_{23})^2$$

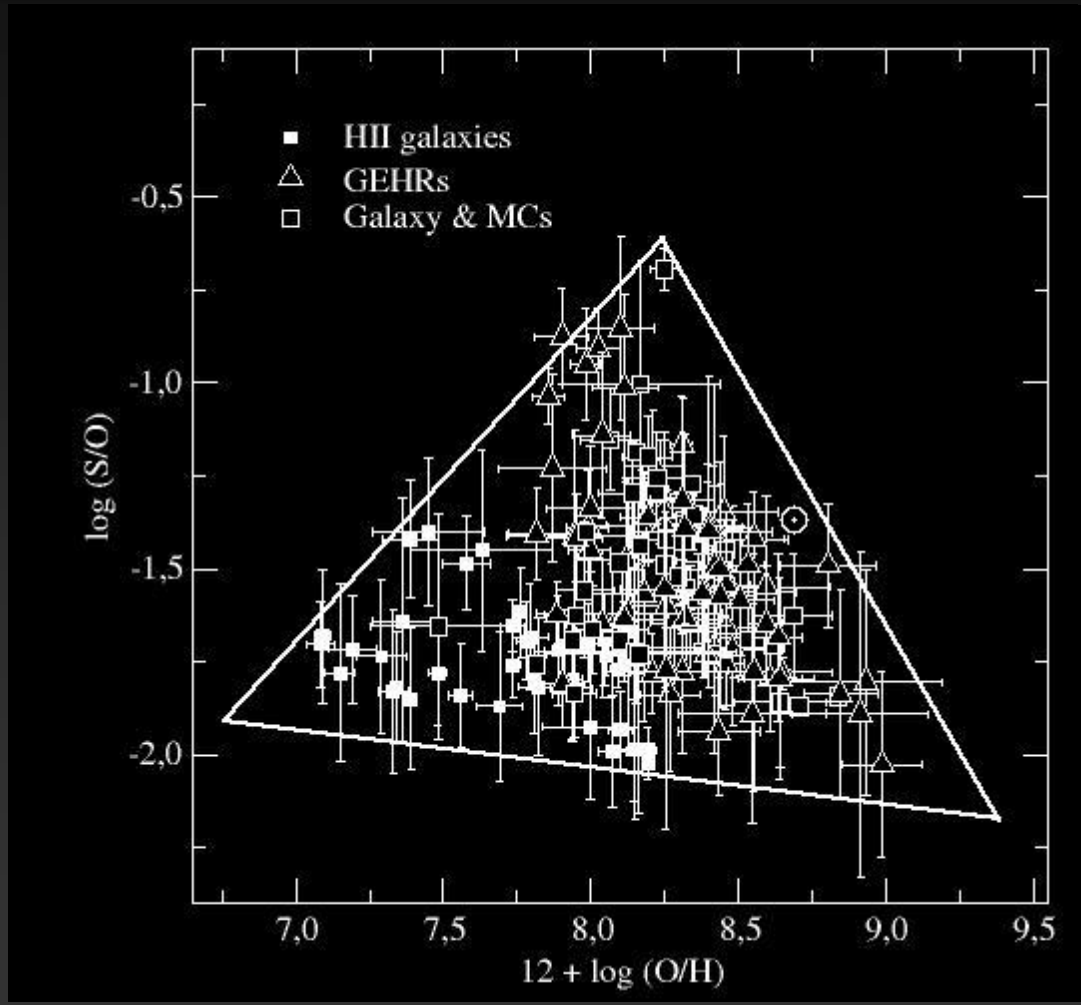
With a dispersion of 0.185 dex



S/O vs. O/H

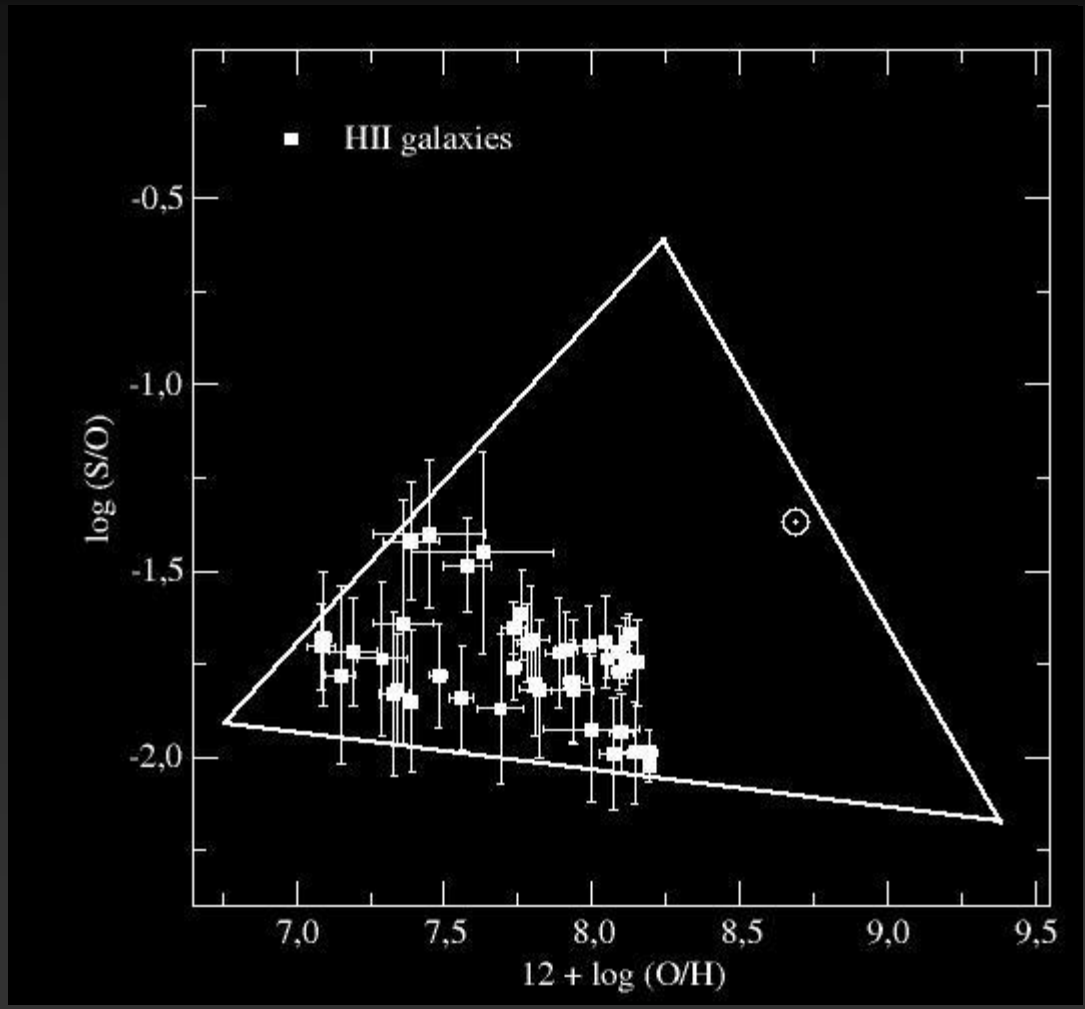
Using these S abundances to study their relation with O, they apper not to follow any constant value.

In fact, we can plot an envolving triangle whose maximum would be at $1/2Z_{\odot}$.



S/O vs. O/H

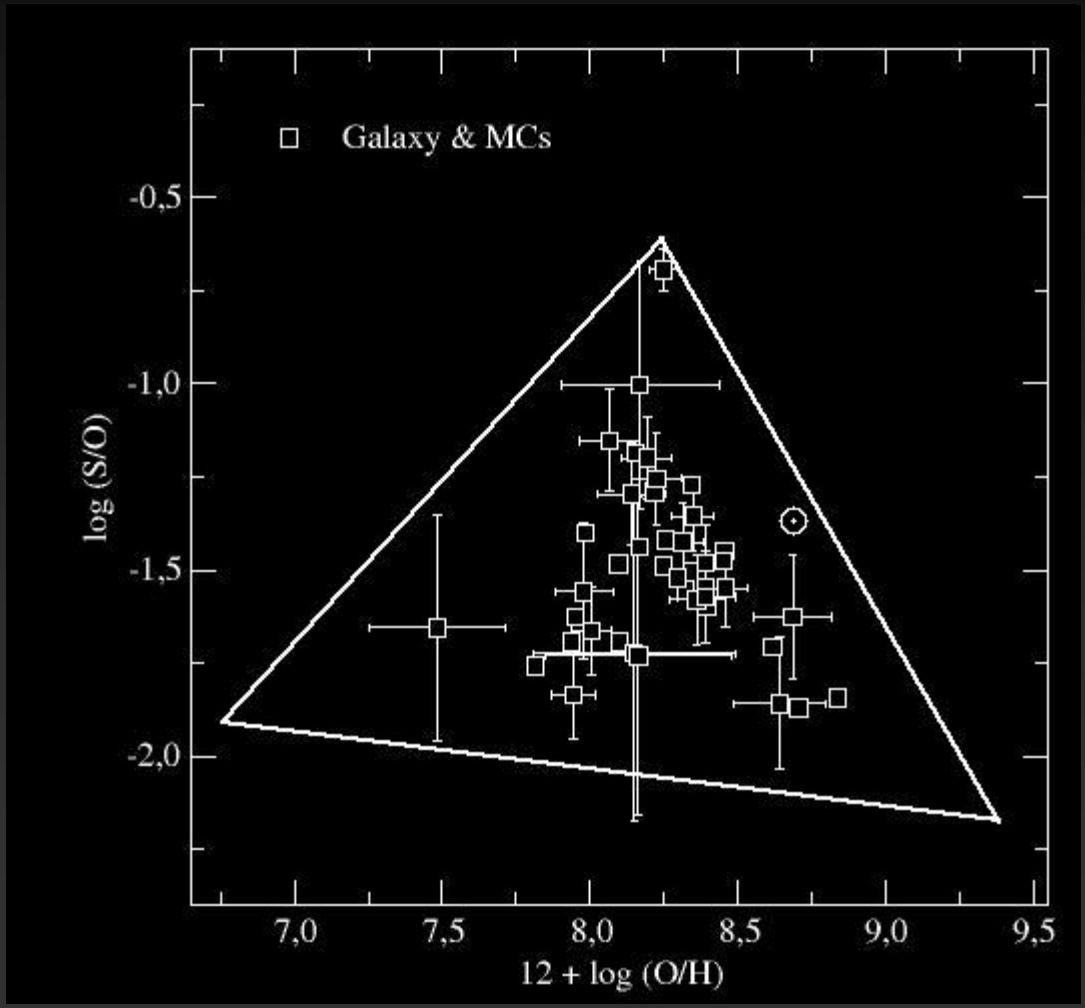
Inspecting the plot for object type, we see HII galaxies in a constant value around solar value.



S/O vs. O/H

Inspecting the plot for object type, we see HII galaxies in a constant value around solar value.

In galactic and Magellanic HII regions there is a higher dispersion of S/O in a narrower range of Z.

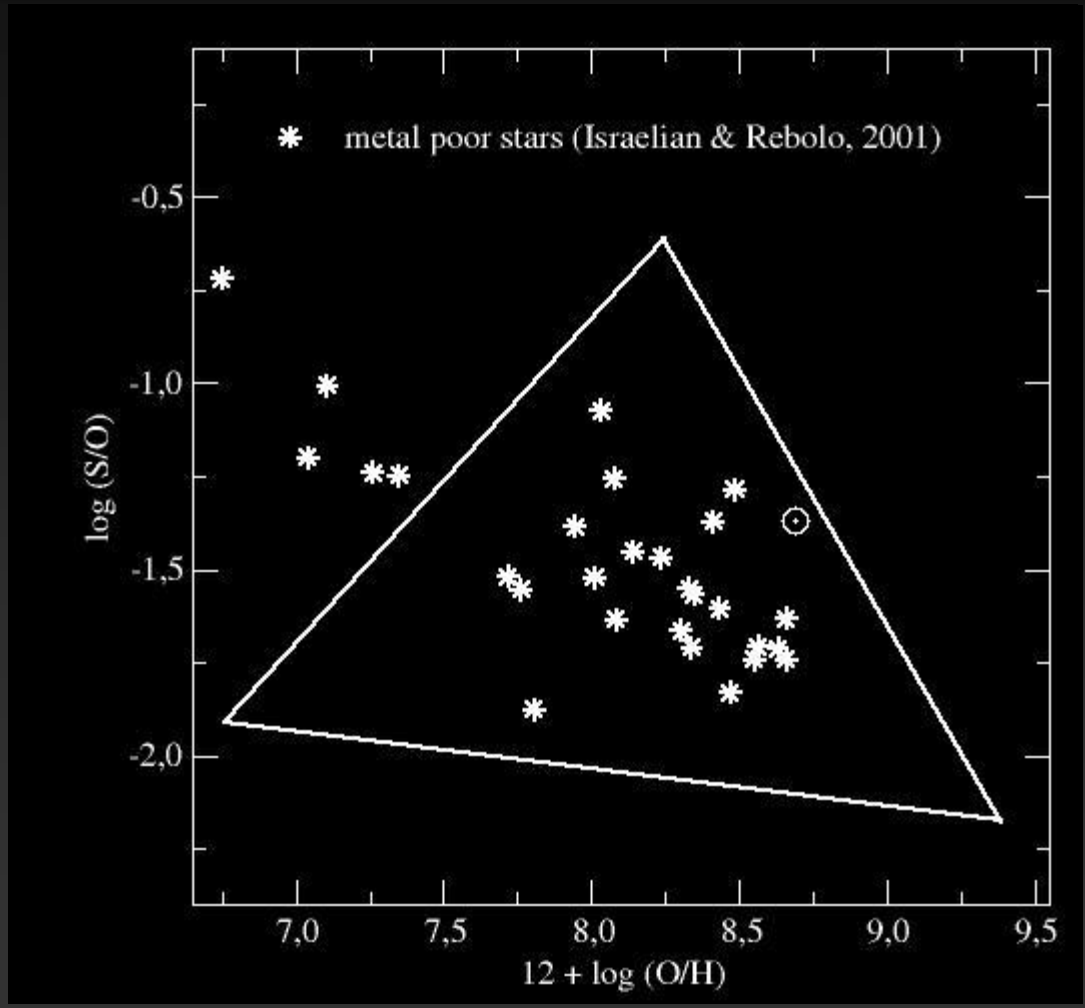


S/O vs. O/H

Inspecting the plot for object type, we see HII galaxies in a constant value around solar value.

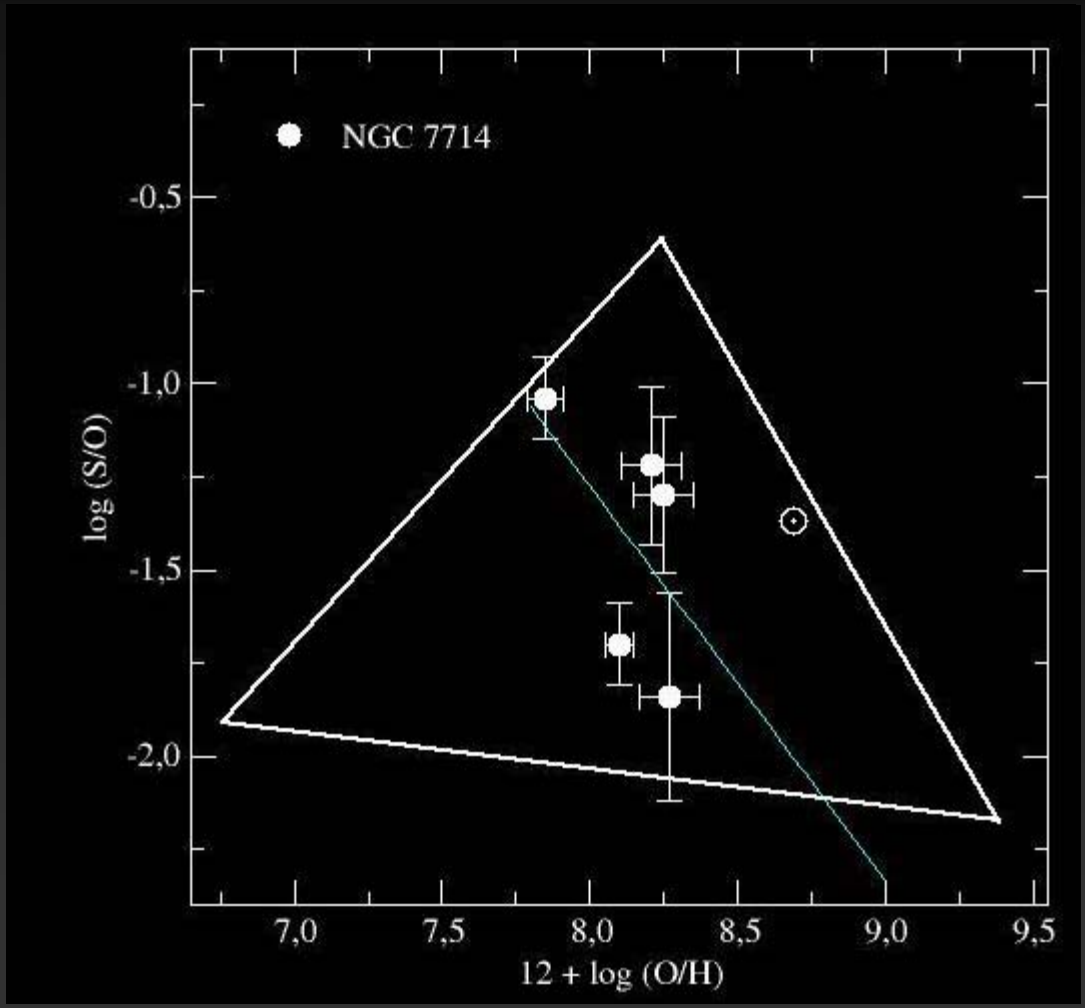
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Halo stars of the Galaxy present a variation of S/O with metallicity.



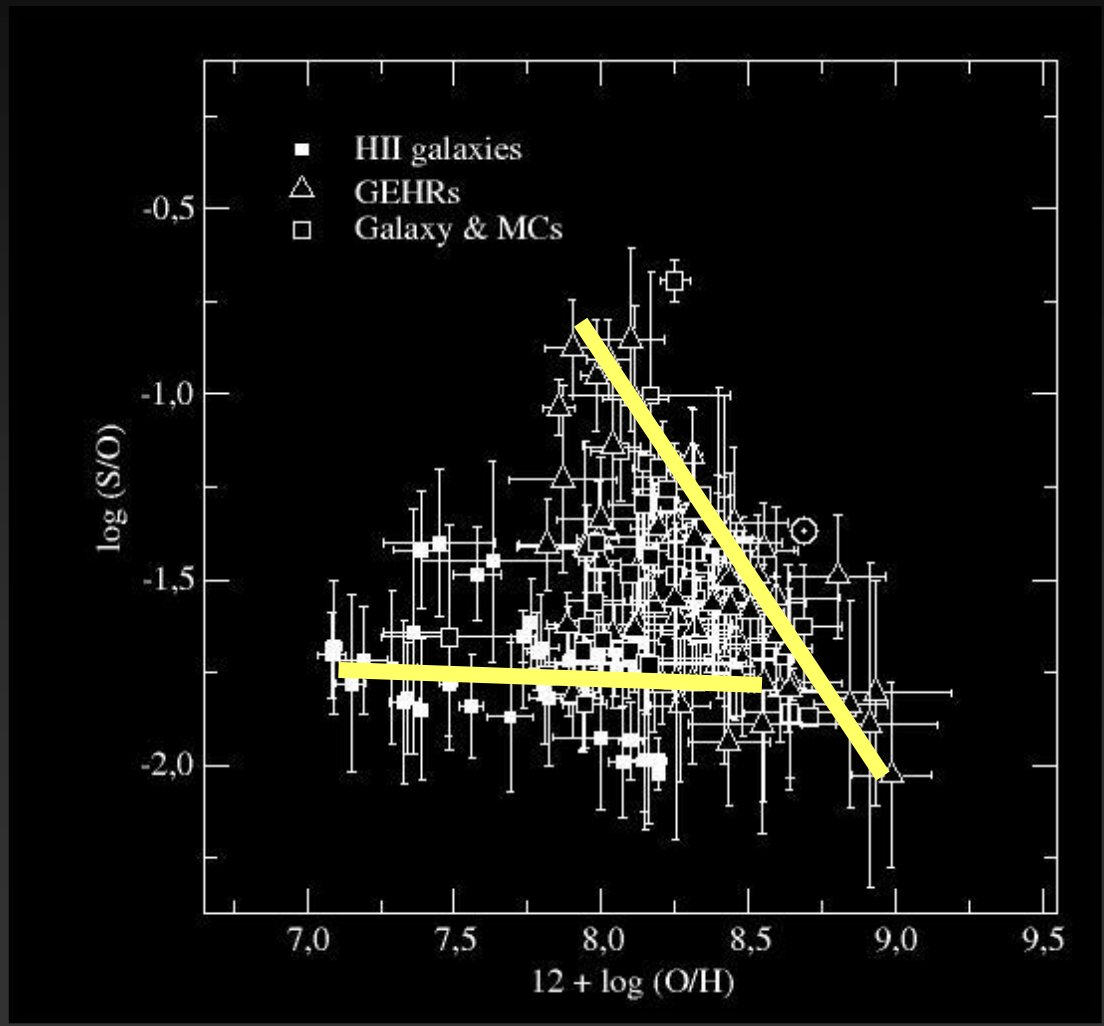
S/O vs. O/H

Regarding GEHRs in disks of spiral galaxies this trend is quite clear.



S/O vs. O/H

Both HII galaxy and GEHR patterns lead to the triangle shape.



SUMMARY AND CONCLUSIONS

Sulphur can be used to trace Z using only the red and near-IR spectral range in HII galaxies.

From ISO observations (very scarce), ICF do not affect much to the S23 calibration and conclusions about S/O plot.

A great deal of work has to be done to understand this plot, there are different and opposite behaviours for HII galaxies and GEHRs. In this last case, far away from a constant S/O ratio.

This work has been accepted for publication in A&A. Available in astro-ph(0511188) and *pollux.ft.uam.es/enrique*