The discovery of oxygen in the Universe

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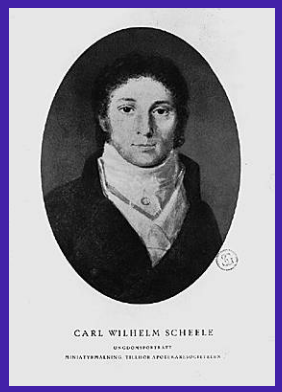
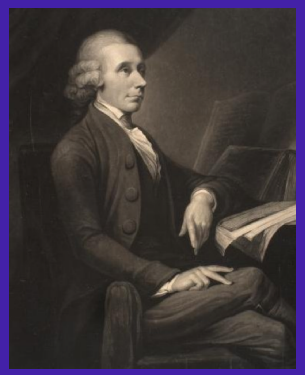
The discovery of oxygen

Carl Scheele (1742-1786)
is the first (**1773;1777**)
to isolate oxygen
by heating HgO he found
that it released a gas
which enhanced combustion.



Joseph Priestley (1733-1804)
was the first (1774)
to publish this result
(which he interpreted within
the phlogiston theory)



Georg Ernst Stahl
(1659-1734)
the father of the
phlogiston theory.
phlogiston is the fire
that escapes from matter
when it burns

Antoine de Lavoisier (1743-1794)
discovered that air contains about 20 % oxygen
and that when any substance burns,
it actually combines chemically with oxygen (1775)
he gave oxygen its present name (oxy-gen = acid-forming)
he stated the law of the conservation of matter

Before the “discovery” of oxygen

Leonardo da Vinci (1452-1519)

- air is a mixture of gases
- breathing ~ combustion

"Where flame cannot live no animal that draw breath can live."

Michael Sendivogius (1566-1636)
(Michał Sędziwój)

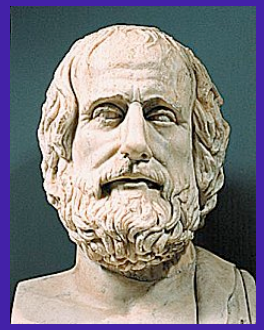
produced a gas he called “food of life”

by heating saltpeter (KNO_3)

Cornelius Drebbel (1572-1633)
constructed in 1621 the first submarine .

To “refresh” the air inside it, he generated oxygen by heating saltpeter as Sendivogius had tought him

“chemistry” before Lavoisier



Anaxagoras of Clazomenes (500 BC - 428 BC)
had already expressed “the law of Lavoisier”:
“Rien ne se perd, rien ne se crée, tout se transforme“

Robert Boyle (1627- 1691)

- noted that it was impossible to combine

the four Greek elements to form any substance

- he called element any substance

that cannot be decomposed into a simpler substance

From the molecule to the atom

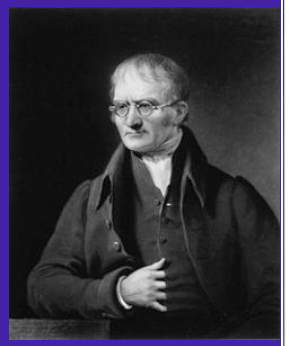
John Dalton (1766-1844)

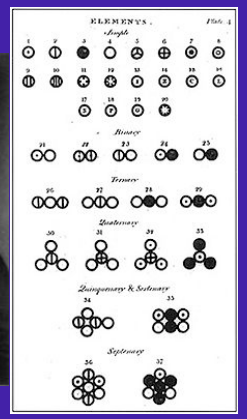
- Elements are made of very small particles:
- Atoms of a given element

are identical in size, mass, and other properties;

- Atoms of different elements combine

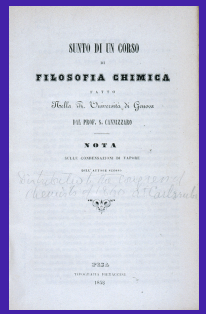
in simple whole-number ratios to form chemical compounds





Stanislao Canizzarro (1826-1910)

At the first international chemical congress (Karlsruhe 1860)
he emphasized the difference
between atoms and molecules


SUNTO DI UN CORSO
DI
FILOSOFIA CHIMICA
NOTA

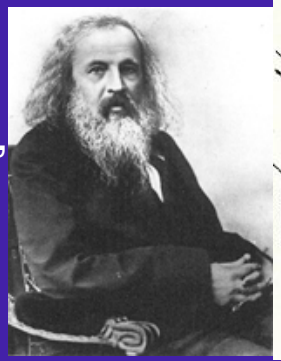
Dimitri Mendeleev (1834-1907)

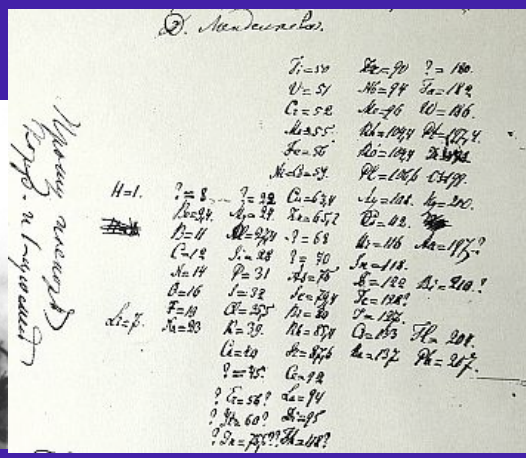
- classified the 63 elements known by their atomic weights,

organizing them them into groups with similar properties.

- predicted the properties of elements

yet to be discovered.





Oxygen on Earth

- Oxygen constitutes 49.2% of the Earth's crust by mass (Si O_2)
- Oxygen constitutes 88.2% of the mass of the Oceans (H_2O)
- Oxygen gas constitutes 23.1% of the Earth's atmosphere by mass (O_2)

Oxygen in meteorites

Jean-Baptiste Biot (1774-1862)

the origin of meteorites is extraterrestrial (1803)

meteories contain silicium, iron, megnesium .. and oxygen

météorite de l'Aigle

Les échantillons de pierres météoriques , dont il a été question dans ce mémoire, sont déposés au Muséum d'histoire naturelle. Le citoyen Thénard a bien voulu en analyser quelques-uns, et il a trouvé :

Silice	46
Fer oxidé	45
Magnésie	10
Nickel	2
Soufre, environ	5

108

Oxygen in the Sun ?

Wollaston 1802
first spectrum of the Sun

Fraunhofer 1814
first systematic study of the absorption lines

Kirchhoff & Bunsen 1860-1861
Fraunhofer lines have same wavelenghts as some heated metals

1863:
the Sun's atmosphere contains
hydrogen, sodium, iron, magnesium.

what about oxygen?

Oxygen in the Sun ?

1877Natur..16R.364. Discovery of Oxygen in the Sun by Photography, and a New Theory of the Solar Spectrum
1877Natur..17..161M Meldola, R.Oxygen in the Sun
1878Obs.....1..286D Draper, H. Discovery of oxygen in the sun
1878MNRAS..38..201D Draper, H.Prof. H. Draper's researches on the existence of oxygen in the Sun
1878Natur..17..339D Draper, Henry Oxygen in the Sun
1878Obs.....1..315S Schuster, A. On the presence of oxygen in the sun
1878Natur..18..654.On the Presence of Dark Lines in the Solar Spectrum which Correspond Closely to the Lines of the Spectrum of Oxygen
1879AReg...17..117D Draper, Henry. Correspondence - Oxygen in the Sun.
1879AReg...17..117R Ranyard, A. C. Correspondence - Oxygen in the Sun.
1879MNRAS..39..388S Schuster, A. on the probable presence of oxygen in the solar chromosphere
1879MNRAS..39..440D Draper, H. on the coincidence of the bright lines of the oxygen spectrum with bright lines in the solar spectrum
1879Obs.....3...46D Draper, J. C. On the dark lines of oxygen in the solar spectrum on the less refrangible side of G
1879Obs.....3..118M Maunder, E. W. Bright lines of oxygen in the solar spectrum
1879MNRAS..40...14D Draper, J. C. on a photograph of the solar spectrum, showing dark lines of oxygen

all these are false detections!

The first detection of oxygen in the Sun

ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME IV DECEMBER 1896 NUMBER 5

OXYGEN IN THE SUN.

By C. RUNGE and F. PASCHEN.

IN the spectrum of a vacuum tube filled with oxygen Piazzi Smyth discovered a line of wave-length about 7775.[1] This line we have lately found to consist of three components, of which the strongest is the most refrangible and the weakest the least refrangible. They seem to coincide with three lines of the same relative intensities in the solar spectrum.

the thickness of the layers traversed by the rays. A conclusive test of the true solar origin of the lines can only consist in a determination of their displacement on the Sun's limb. We hope that some one better equipped for this kind of work than we are will undertake to settle the question.

Runge & Paschen 1896

The O I 7777 lines are weak and in a spectral zone not much studied before

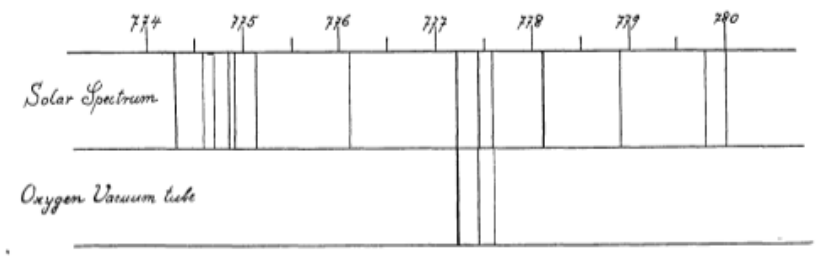


FIG. 1.

The detection of oxygen in stars

Solar-like stars
only a few other OI lines were later identified
in the Sun and solar-like stars.

hot stars
McClean 1897, Gill 1899
detection of lines of ionized oxygen

ON THE PRESENCE OF OXYGEN IN THE ATMOSPHERES OF CERTAIN FIXED STARS.[1]

By DAVID GILL.

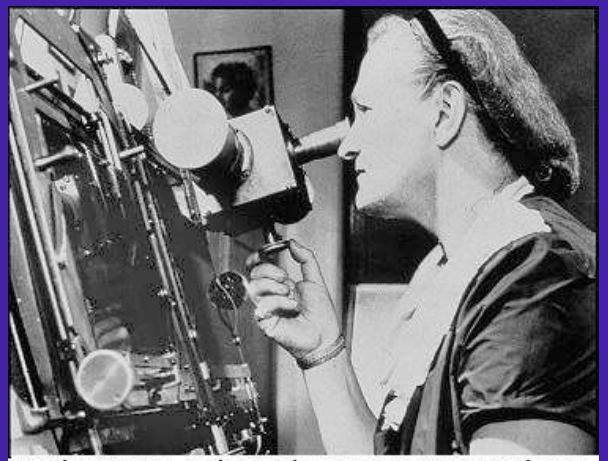
IN a paper read before the Society on April 8, 1897, and in a subsequent paper,[2] Mr. Frank McClean draws attention to the grouping of lines other than those of helium and hydrogen in the spectra of β Scorpii, β Canis Majoris, β Centauri and β Crucis, suggesting that the close correspondence between the grouping of these extra lines and the known lines of oxygen, points to the probable presence of that gas in the atmosphere of these stars.

The first determination of elemental abundances in stars

Cecilia Payne (1900-1979)

- her thesis (**1925**) lays the basis of quantitative analysis of stellar spectra:
- intensities of abssorption lines are complicated function of temperature, pressure and atomic data.
- weak lines do not necessarily indicate small abundances

Element	Abundance of atoms	
	Stellar	Terrestrial
Oxygen	45	54
Silicon	16	6
Aluminum	5	4
Sodium	6	2
Calcium	3	1.5
Iron	2.5	1



Cecilia Payne, trabajando en espectros estelares

The derived "relative abundance" for the stellar atmosphere places oxygen at the head of the elements, with about thirty times as many atoms as calcium.

The first determination of elemental abundances in stars

What about hydrogen?

Hydrogen and helium are omitted from the table. The stellar abundance deduced for these elements is improbably high, and is almost certainly not real. Russell and Compton[17] have suggested that the anomalous astrophysical behavior of the Balmer lines may be attributed to metastability, an interpretation which would also explain the great apparent abundance of the element in stellar atmospheres. The abundance of

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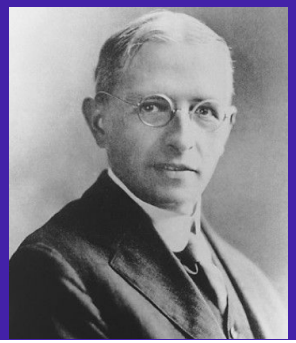
The first solar oxygen abundance

Henry Norris Russell
(1877-1957)

1929

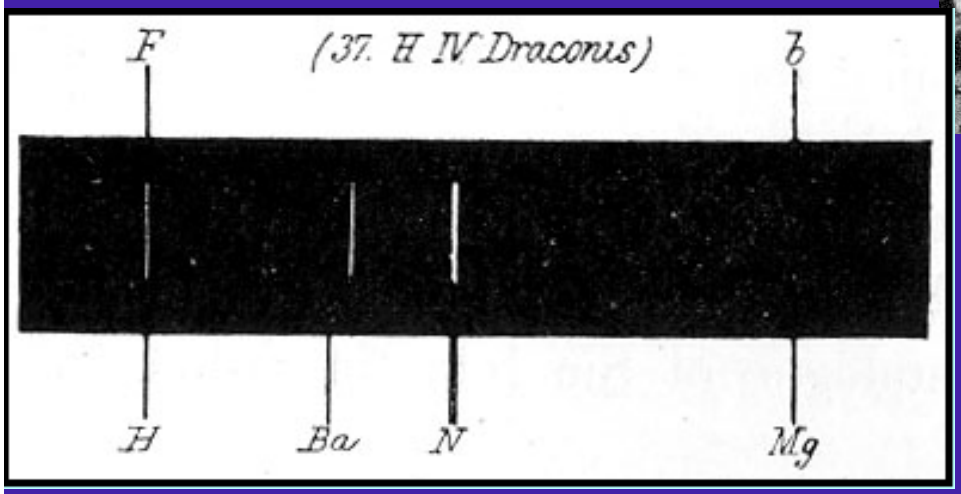


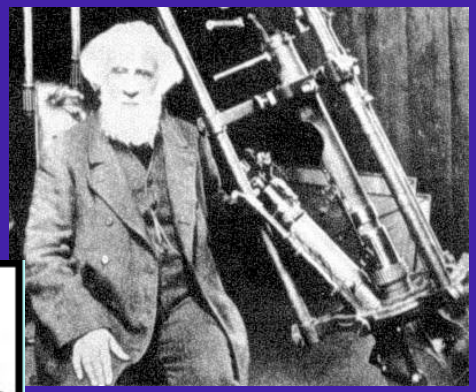
PROBABLE COMPOSITION OF THE SUN'S ATMOSPHERE

Element	By Volume	By Weight	log T	log Q
Hydrogen	60 parts	60	9.9	9.9
Helium	2 ?	8?	8.4?	9.0?
Oxygen	2	32	8.4	9.6
Metals	1	32	8.1	9.6
Free electrons	0.8	0	8.0	.....
Total	65.8	132	.....	.....

The detection of nebulium

William Huggins
obtains the first spectrum of a PN (1863)





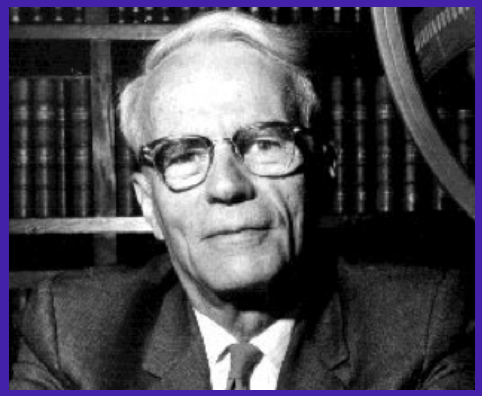
Padre Angelo Secchi,
obtains the first spectum
of the Orion nebula (1864)

oxygen lines were very strong in both

but they were attributed to nebulium

Oxygen in nebulae

Bowen (1898-1973)

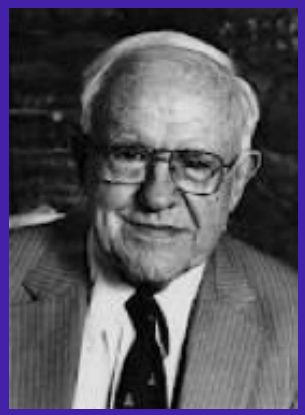


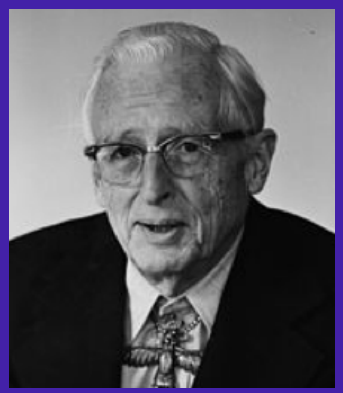
1927: the lines attributed to « nebulium » are due to forbidden transitions of oxygen, not observable on earth.

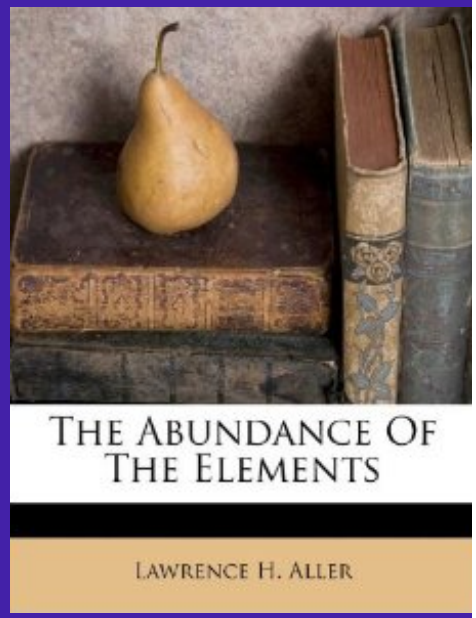
1934: oxygen lines in nebulae have intensities similar to hydrogen lines not because the abundances of the two elements are similar but because oxygen possesses energy levels that are easily attained by collisions with electrons

Lawrence Aller (1913-2003)
Donald Menzel (1901-1976)

1945: method
to compute nebular abundances







The abundances of oxygen in the Sun

in units of 12 + log O/H

Payne 1925	8
Russell 1929	9.5:
Hunaerts 1947	9.23
Bowen 1948	8.2
Unsold 1948	8.73
Class 1950	8.65
Goldberg 1960	8.96
Lambert 1968	8.77
Nikolaides 1973	8.93
Lambert 1978	8.92
Anders Grevesse 1989	8.93
Grevesse Sauval 1998	8.83
Allende Prieto 2001	8.69
Asplund 2009	8.69
Caffau Ludwig 2011	8.76

The present day estimate of the solar metalicity is $Z = 0.0134$
(much lower than the canonical value of $Z = 0.02$
and lower than the widely used $Z = 0.0189$ of Anders & Grevesse 1989)


CARL WILHELM SCHEELE
G. E.