# The WSO-UV mission and the investigation of chemical abundances in the Milky Way

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# Summary

• The World Space – Ultraviolet (WSO-UV) telescope

  * Instruments

  * The role of the Spanish team

• Science with the WSO-UV

• Chemical element abundances in the UV

# Need for UV facilities

The investigation of astronomical objects has been allowed by the continuous improvements of the instrumentation from optical up to radio wavelengths

The study of several key problems cannot further progress without information in the **UV band**, which is accessible only from space (Gomez de Castro et al. 2006)

**The World Space Observatory-Ultraviolet (WSO-UV) is a space telescope built to guarantee access to the 1050-3200 Å range in the post-HST epoch**

ROSCOSMOS
Russian Federal Space Agency

Russia –
INASAN (scientific contractor) and
Lavochkin (industry contractor):
Telescope, Satellite,
Mission Integration,
Launcher,
Ground Station,
Science Mission Center, Spectrographs...

Spain –
UCM (scientific contractor);
SENER and GMV (industry contractors):
Ground Segment and field camera unit (ISSIS)

# The World Space Observatory-Ultraviolet

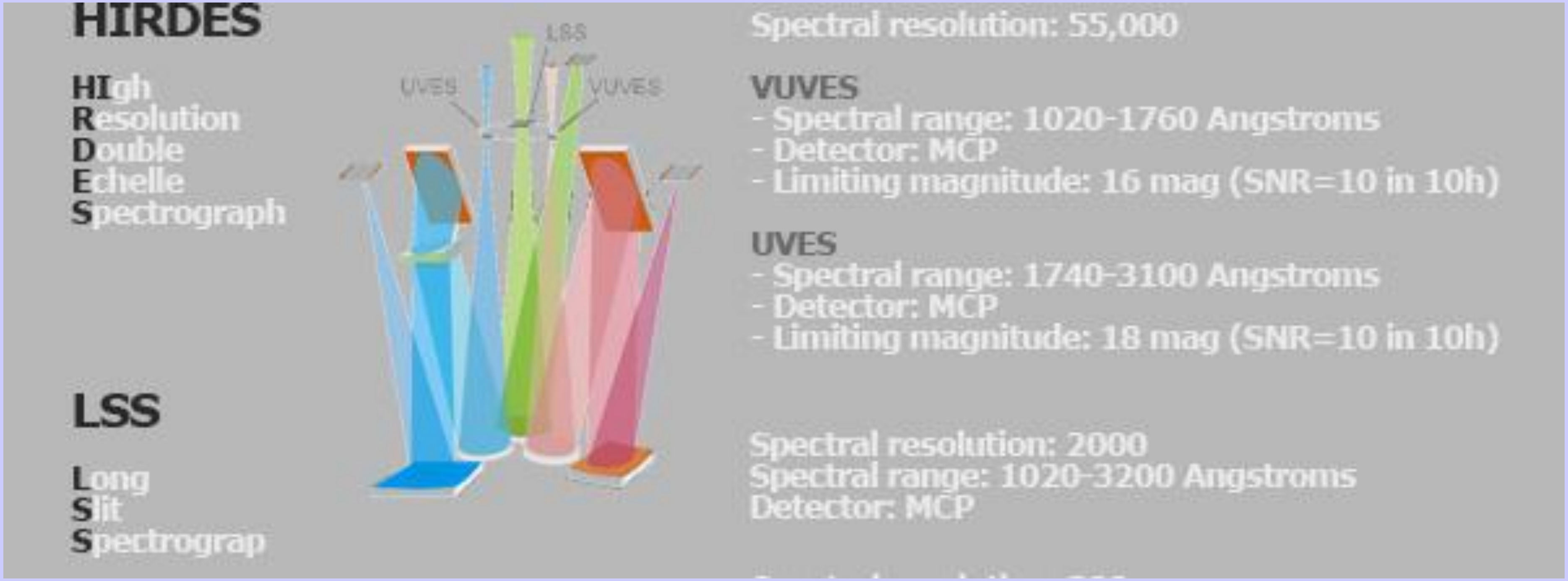
The WSO-UV mission is equipped with a 170 cm aperture telescope and its coatings and design are optimized for wavelengths around 2000 Å. It will be in a geosynchronous orbit, well above the Earthshine and geocoronal emission.

Launch date is at the end of 2015 and mission lifetime is 5+5 years (Shustov et al. 2009, 2011)

# WSO-UV instrumentation (1, 2)

**HIRDES (High Resolution Double Echelle Spectrograph):** spectroscopy with R~55,000 of point sources in the range 1020-3100 Å with two echelle set-ups, and MCP detectors. Ten times the sensitivity of STIS at HST in a similar configuration

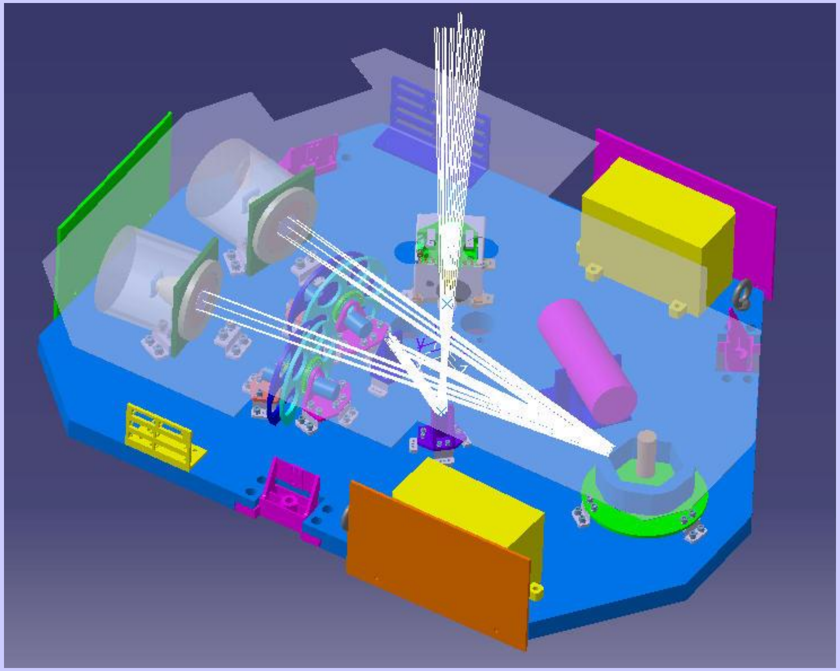
**LSS (Long Slit Spectrograph):** 1020-3200 Å, R~1500, MCP detector



# WSO-UV instrumentation (3)

**ISSIS (Image and Slitless Spectroscopy Instrument for Surveys):** Direct imaging and spectroscopy wirth R~500. Two optical systems, equipped with MCP detectors, a scale of 0.036 arcsec/equivalent pixel, and FoV~1.1'x1.1'

**FUV** channel: 1150-1750 Å (CsI MCP) / **NUV** channel: 1800-3200 Å (CsTe MCP)



Both channels contain a set of optical filters accomodated on a series of wheels along the optical path, and additional $MgF_2$ windows.

**First UV imager on a high altitude Earth orbit!**

**Developed at Universidad Complutense de Madrid (UCM) in collaboration with SENER as industry contractor (Gomez de Castro et al. 2011)**

# Role of the UCM

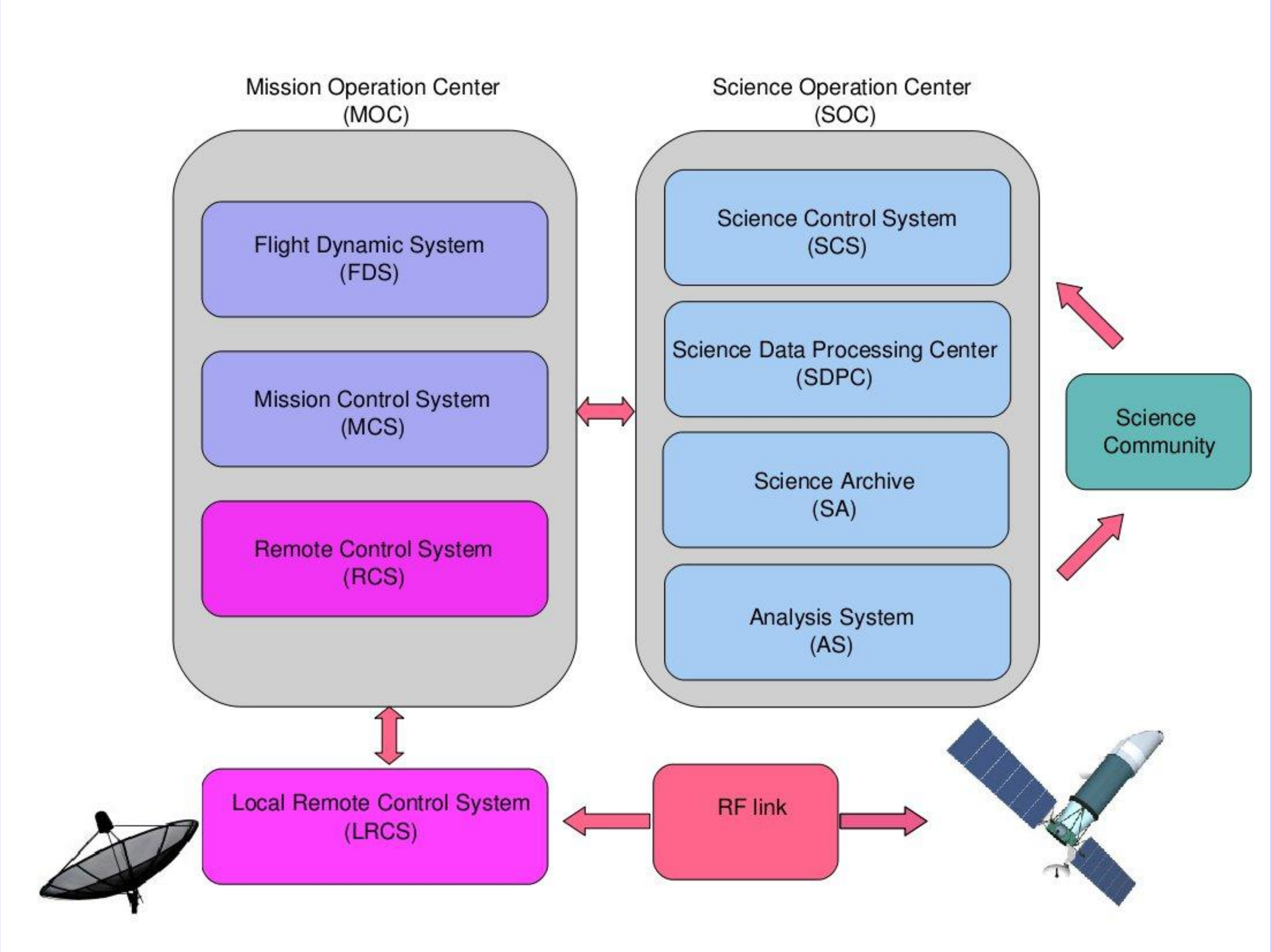
The **Universidad Complutense de Madrid is the science contractor** representative of **Spain**. The UCM Team within the WSO-UV project is leading the development of:

1) **the instrument ISSIS, attached to the telescope** – **Scientific supervision** of the instrument, selection of **scientific requirements** and interaction with the industry contractor (SENER) and with the Spanish astronomical community.

2) **the mission Ground Segment (GS)** – Two complete GS systems are being developed, one in Moscow and the other in Madrid, with shared satellite operations. UCM is developing the **Science Data Processing System**, the **Science Archive**, and the **Scheduling System**

**Lozano et al. 2010, Gomez de Castro et al. 2012 (submitted)**

# Ground Segment structure



# Science with the WSO-UV

**GENERAL OBJECTIVES OF THE WSO-UV MISSION:**

- Galaxy formation: determination of the diffuse baryonic content in the Universe and its chemical evolution – baryonic content of the warm/hot IGM, damped Ly-α systems, He II reionization, role of starbursts in IGM evolution, galaxy formation...

- The physics of accretion and outflows: the astronomical engines – stars, black holes, etc.: accretion flow mechanisms and their efficiency and time scales; role of the radiation pressure; disk instabilities

- The Milky Way formation and evolution – interaction between stars and gas, UV observations to measure energy inputs in the gas; role of magnetic fields on star formation; tracking of Galactic history through GC observations (complementar with GAIA)...

- Extrasolar planetary atmospheres and astrochemistry in the presence of strong UV radiation fields – T Tauri stars to study the environment where planetary systems grow; chemical proterties of the atmospheres

# Science with the WSO-UV (ISSIS)

**SOME OF THE KEY SCIENCE DRIVERS TO ISSIS DESIGN (proposed by the Spanish Working Group)**

▷ Absoprtion of stellar radiation by **transiting planets** (e.g. Gomez de Castro et al. 2009)

▷ **Stellar clusters: UV atlas** and contribution to evolution and proper motion studies

▷ σ Orionis in the UV: from massive O stars to **T tauri brown dwarfs** and beyond. Better knowledge of substellar objects (e.g. Caballero et al. 2006)

▷ **Protostellar jets**: fundamental information about the mechanisms at work in these objects and about ISM (e.g. Gomez de Castro & Robles 1999)

▷ **Planetary Nebulae:** investigation of **chemical abundances** (the carbon issue), UV imaging to detect proper motions, expansion and shocks, search for companions in IR bright AGB stars and proto-PNe (e.g. Guerrero et al. 2010, 2012)

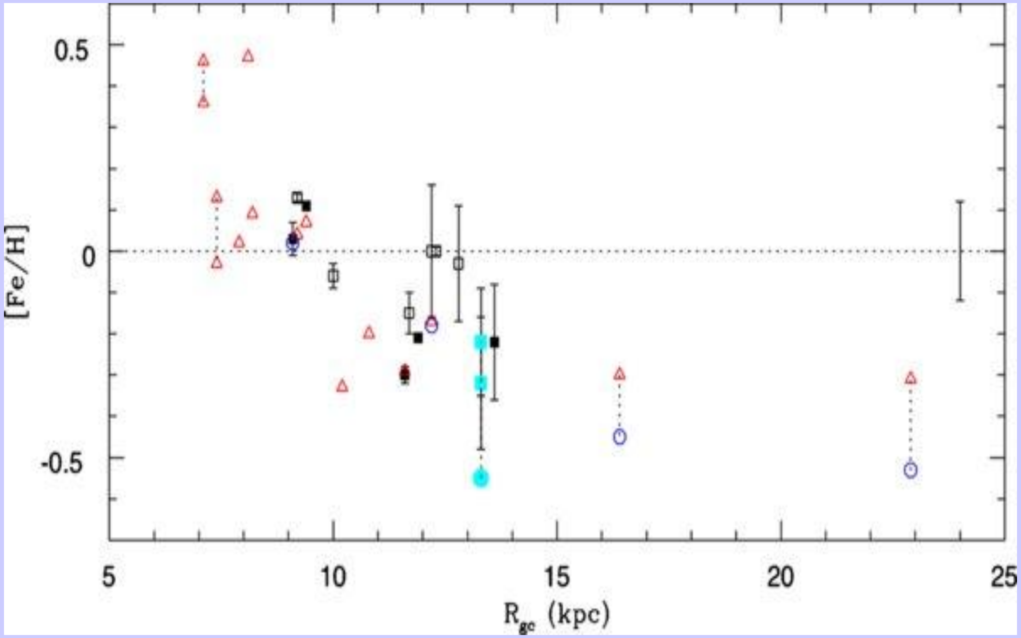
*"The Imaging and Slitless Spectroscopy Instrument for Surveys (ISSIS) for the World Space Observatory-Ultraviolet (WSO-UV)"* (2012)

# Chemical abundances in the Milky Way

**Metallicity gradients and abundance trends –** the investigation of detailed chemical abundances (Fe and other elements) in all the Milky Way components is fundamental to understand our galaxy's evolution

Old open clusters are suitable natural laboratories for tracing the Galactic disk history; high resolution spectroscopy is mandatory

Several investigations have been carried out during the last decades by various research groups (Friel et al. 2003, 2010, Carretta et al. 2004, 2007, Yong et al. 2005, Sestito et al. 2006, 2008, the talks by E. Friel, R. Carrera, G. Tautvaisiene., D. Romano...and references therein!)




Radial [Fe/H] gradient from OCs

(Friel et al. 2010)

# Heavy elements

The **elements mostly investigated**, besides Fe, are the light elements (Na, Al, Mg), α-elements (O, Si, N, Ca, Ti...), Fe-peak elements (V, Cr, Mn, Co, Ni...), s-process and r-process elements (Ba, La, Eu, Pb...) (talk by E. Maiorca)

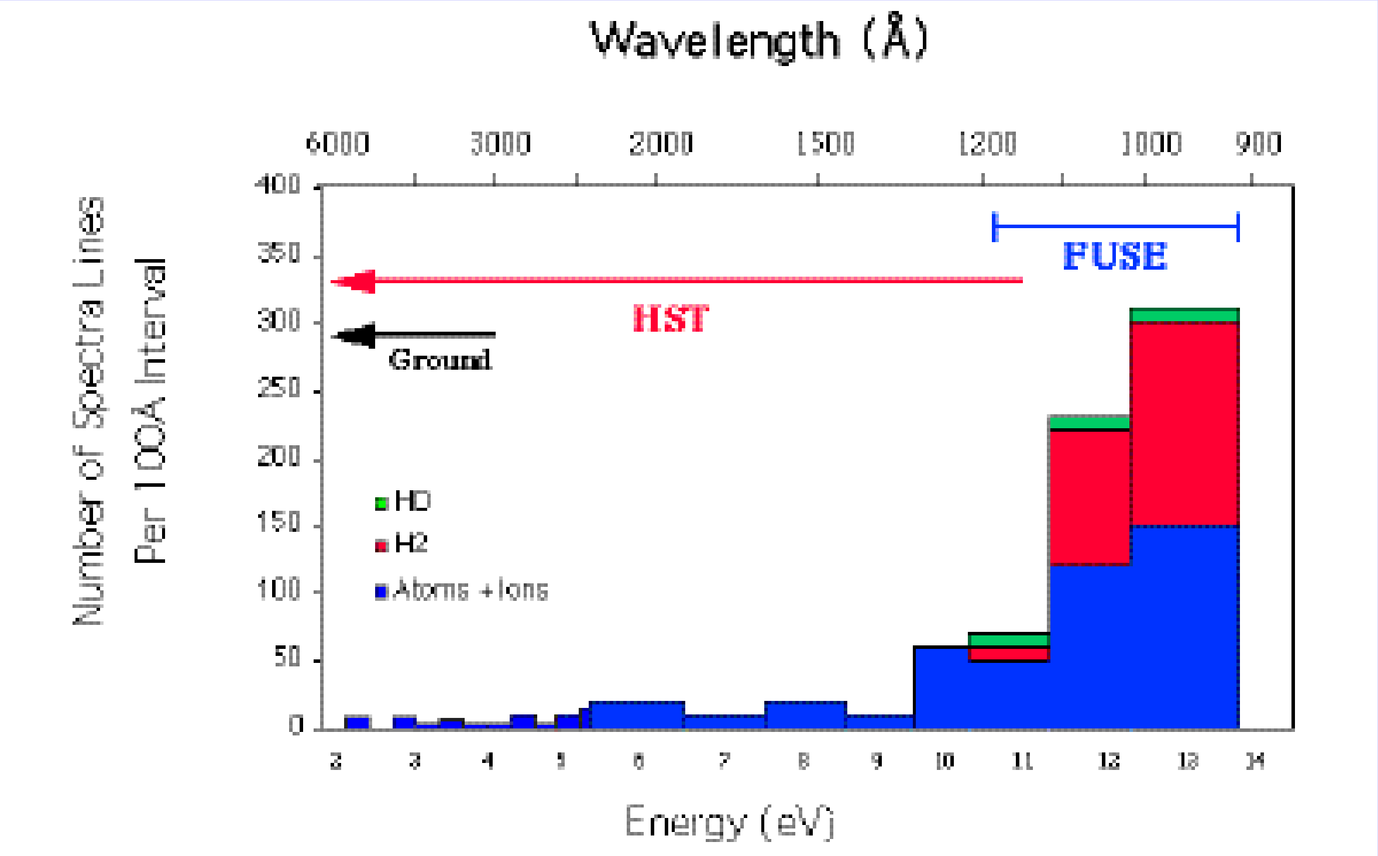
The **GAIA-ESO** spectroscopy survey and the advent of the **GAIA mission** will significantly enhance our knowledge of MW evolution (see, e.g., talks by C. Jordi, S. Randich)

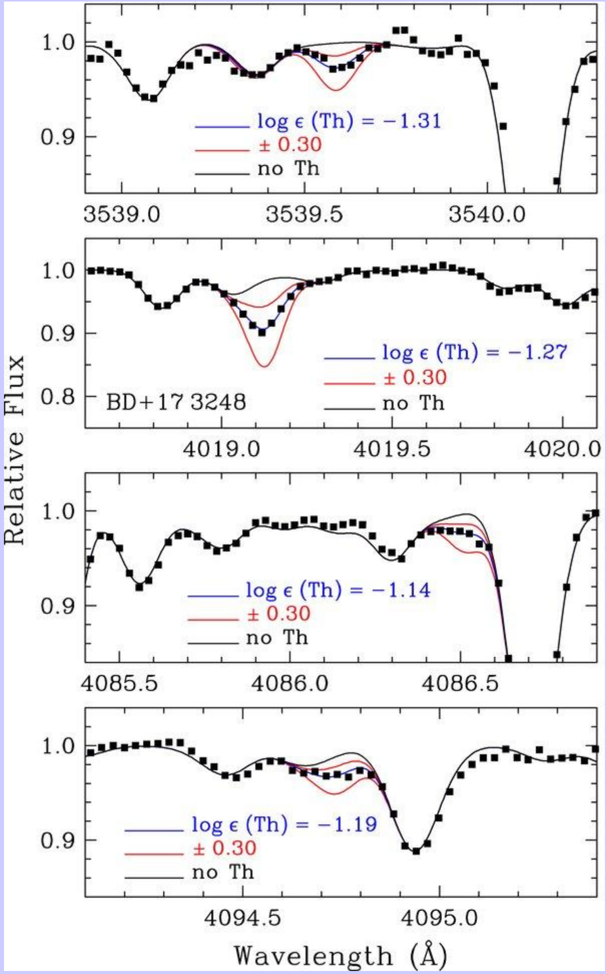
However...

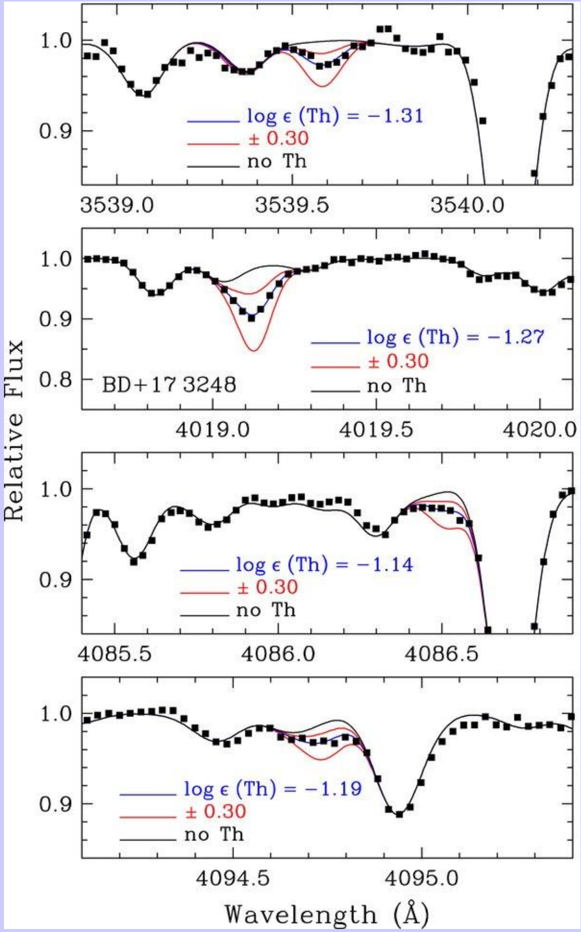
(i) in stellar atmospheres, the **ionized elements** are overabundants with respect to the neutral species

(ii) the spectral lines of ionized elements are stronger and better defined in the **UV range** than in the visible

(iii) several s- and r-process el. have a small (if any) number of lines in the optical: e.g., **lead (Pb I), iridium (Ir I) and erbium (Er II) show only UV lines; Dy, Th, La, Eu, Tl have stronger lines in UV**


Wavelength (Å)
6000
3000
2000
1500
1200
1000
900
Number of Spectra Lines
Per 100Å Interval
400
350
300
250
200
150
100
50
0
FUSE
HST
Ground
HD
H2
Atoms + Ions
2
3
4
5
6
7
8
9
10
11
12
13
14
Energy (eV)




Examples of heavy elements lines in the UV

(Roederer et al. 2009)

# UV observations

**Metal poor stars with HST/STIS and VLT/UVES**

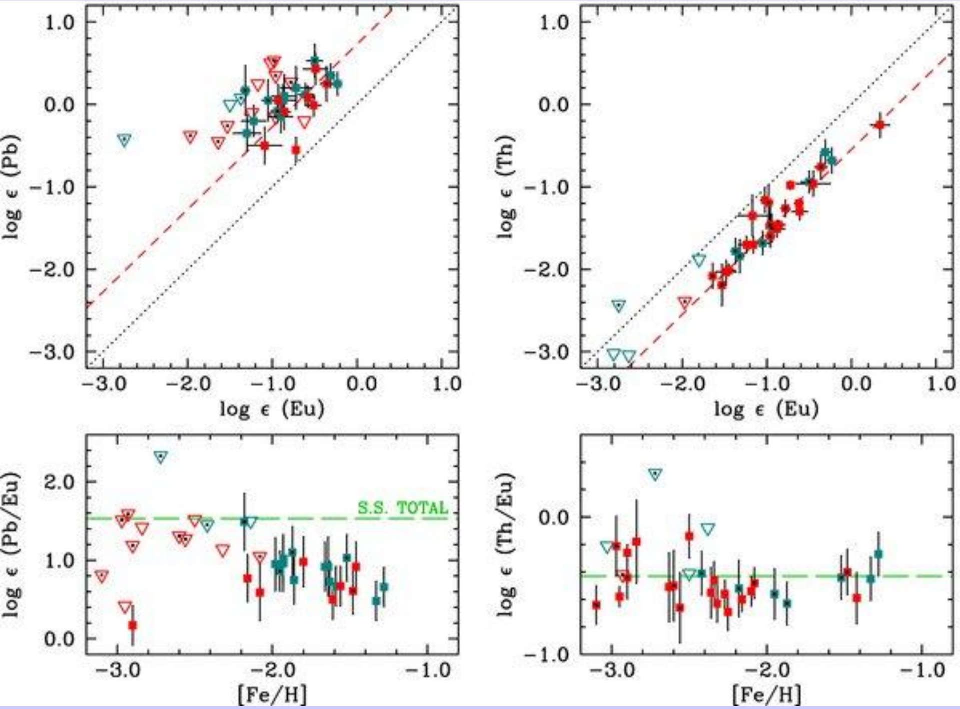
*Sneden et al. 2009:* abundances of **Pr, Dy, Tm, Yb, and Lu** for the solar photosphere and for five very metal-poor, r-process-rich giant stars. Very accurate solar/stellar abundances for the entire suite of **stable Rare Earth elements** are derived

*Roederer et al. 2009:* **Pb and Th** abundances in metal-poor stars, to investigate **the abundance ratios among the Rare Earth elements and the third r-process peak elements** La, Eu, Er, Hf, and Ir

*Roederer et al. 2012:* STIS NUV spectra to detect **Te** in metal-poor stars and determine its production mechanisms

*Roederer & Lawler 2012:* **First detection of As and Se (UV)**

*Mashonkina et al. 2009:* **NLTE effects for Th and Pb lines in the UV**

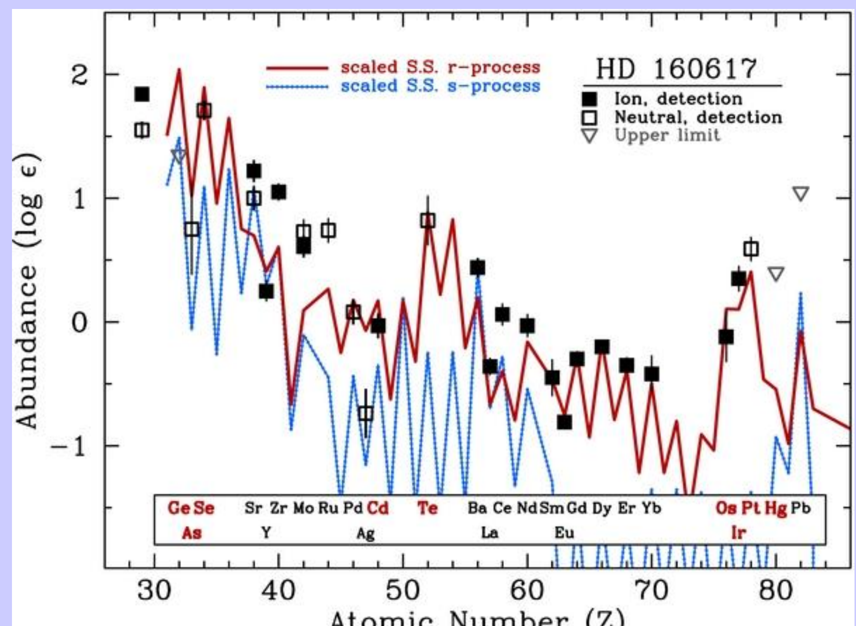



Pb/Eu and Th/Eu ratios

(Roederer et al. 2009)

Log abundances as a function of atomic number for a metal-poor star

(Roederer & Lawler 2012)



# With the WSO-UV

We propose to use the high resolution instrument **HIRDES @WSO-UV** to observe **giant stars in OCs** (ages>1 Gyr) to investigate the **chemical content by using UV lines**

The information will be complementar to data obtained so far in the optical range, and to the **Gaia-ESO survey**. Investigation of abundance gradients and MW evolution, and test of abundance analysis on a different ground

Feasibility:

the limiting magnitude for **HIRDES/UVES (1740-3100 Å) is V=18 to obtain S/N=10 in 10 hrs**. **Clump stars in old OCs** have typically V=12-16 for which S/N would be 10-$10^3$ times higher in the same exposure time.

**In the worst case of V=16, a S/N=10 in 1 hr would be obtained; for V=14, S/N=100 in 1 hr.**