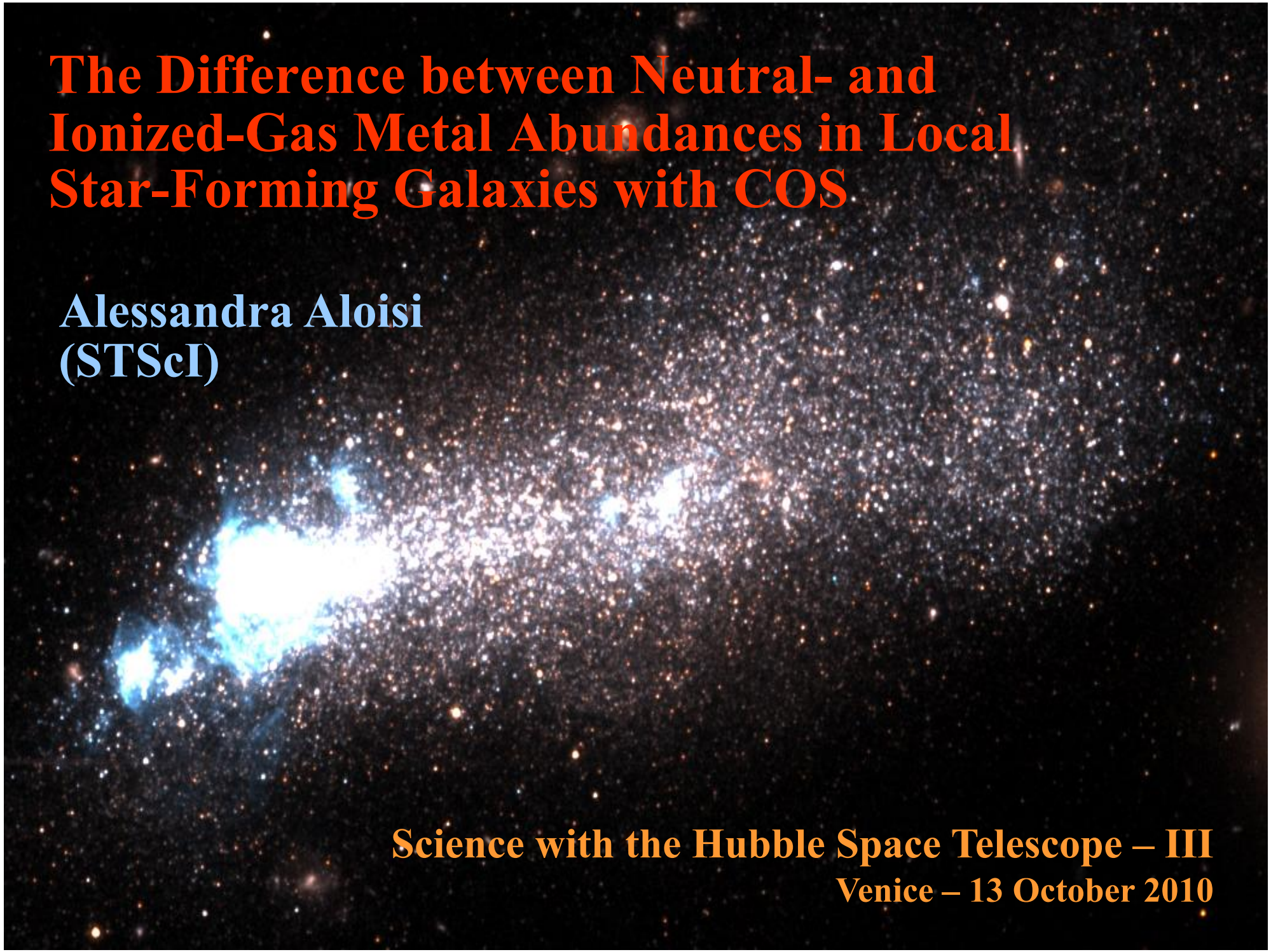
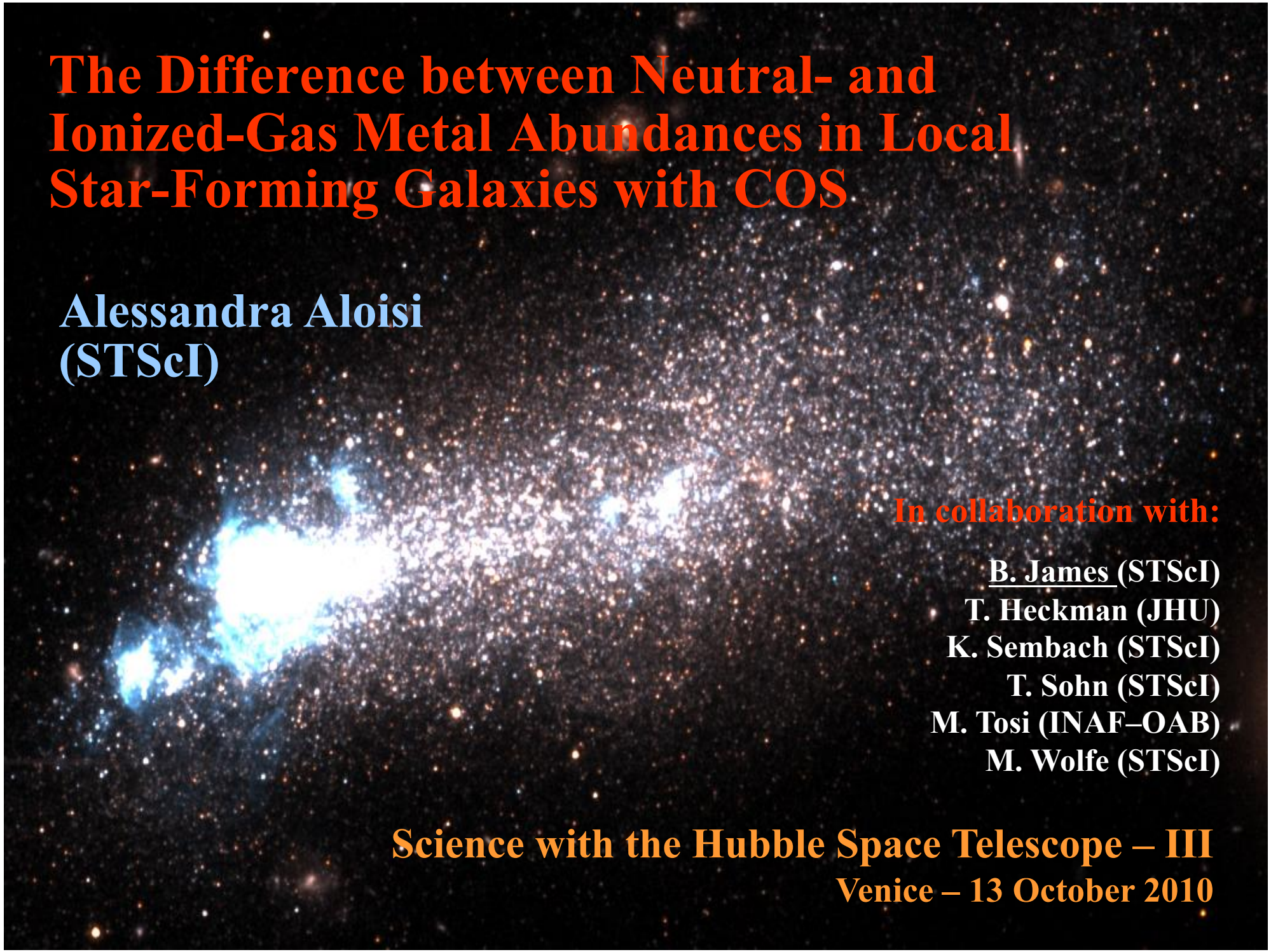
The Difference between Neutral- and Ionized-Gas Metal Abundances in Local Star-Forming Galaxies with COS

Alessandra Aloisi
(STScI)



Science with the Hubble Space Telescope – III
Venice – 13 October 2010



The Difference between Neutral- and Ionized-Gas Metal Abundances in Local Star-Forming Galaxies with COS

Alessandra Aloisi
(STScI)

In collaboration with:

B. James (STScI)
T. Heckman (JHU)
K. Sembach (STScI)
T. Sohn (STScI)
M. Tosi (INAF–OAB)
M. Wolfe (STScI)

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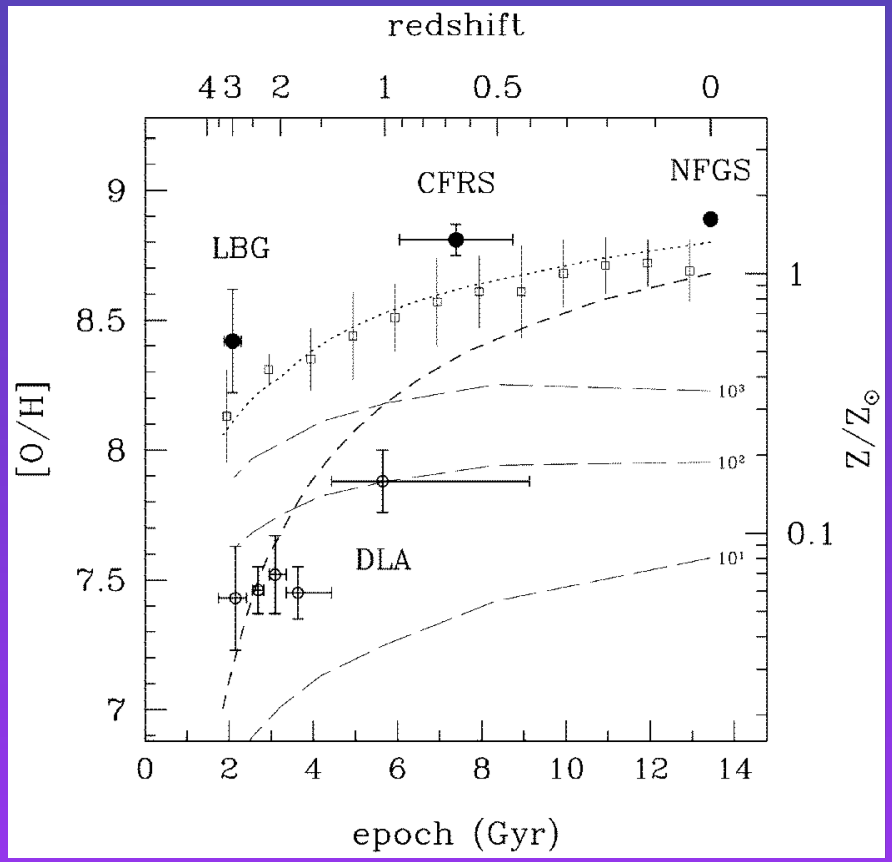
The Real Abundances of SFGs

Abundances in SFGs inferred from O in nebular (emission-line) spectra of HII regions. However:

- ✓ **HII regions may suffer from self-enrichment** *(Kunth & Sargent 1986)*
- ✓ **Bulk of metals in SFGs may be in neutral gas (up to 90-95%)**

Need to infer abundances in neutral ISM through absorption-line spectra !

Importance of this Kind of Studies



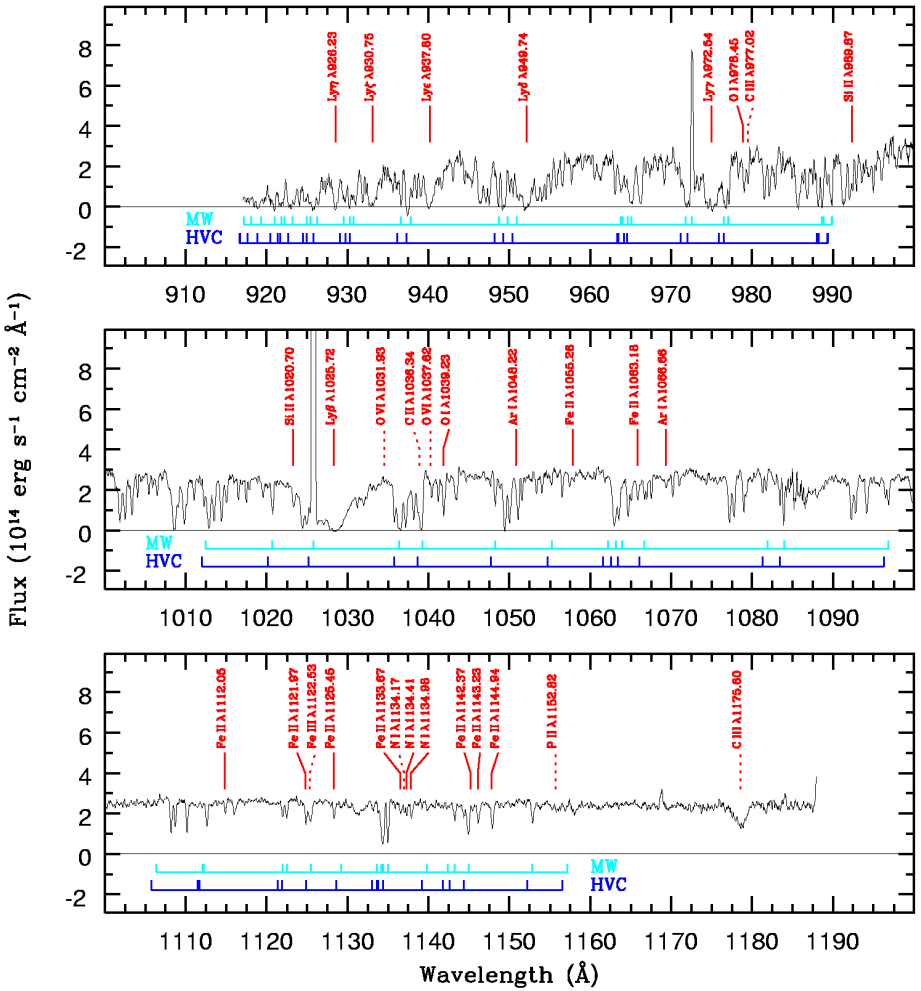
- Solid circles: [O/H] from em lines
- Open circles: [Fe/H] from abs lines
- Lines: various theoretical models

Clear Z offset at high-z between LBGs and DLAs

Lilly et al. (2003)

- High-z difference due to techniques or samples ?
- Similar offset at z = 0 ?

I Zw 18: an Example of Neutral Gas Abundances with FUSE



Aloisi et al. (2003)

FUSE suitable for most abundant species – HI, OI, Ar I, Si II, P II, C II, NI, Fe II

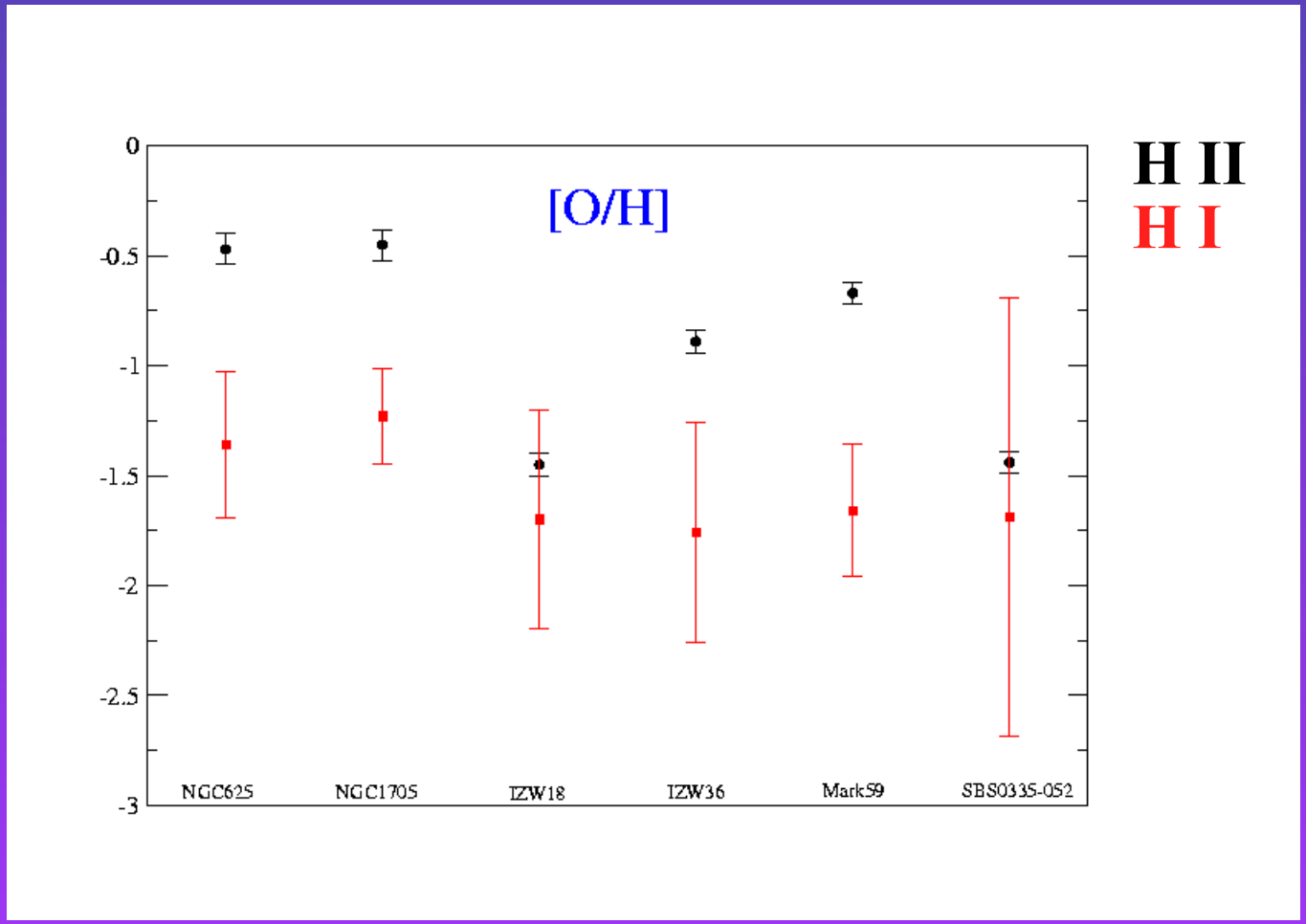
HI already enriched in heavy elements, i.e. not primordial

Existence of a metallicity offset between neutral and ionized gas, except for Fe

SF at least ~ 1 Gyr old required to explain Fe in ISM

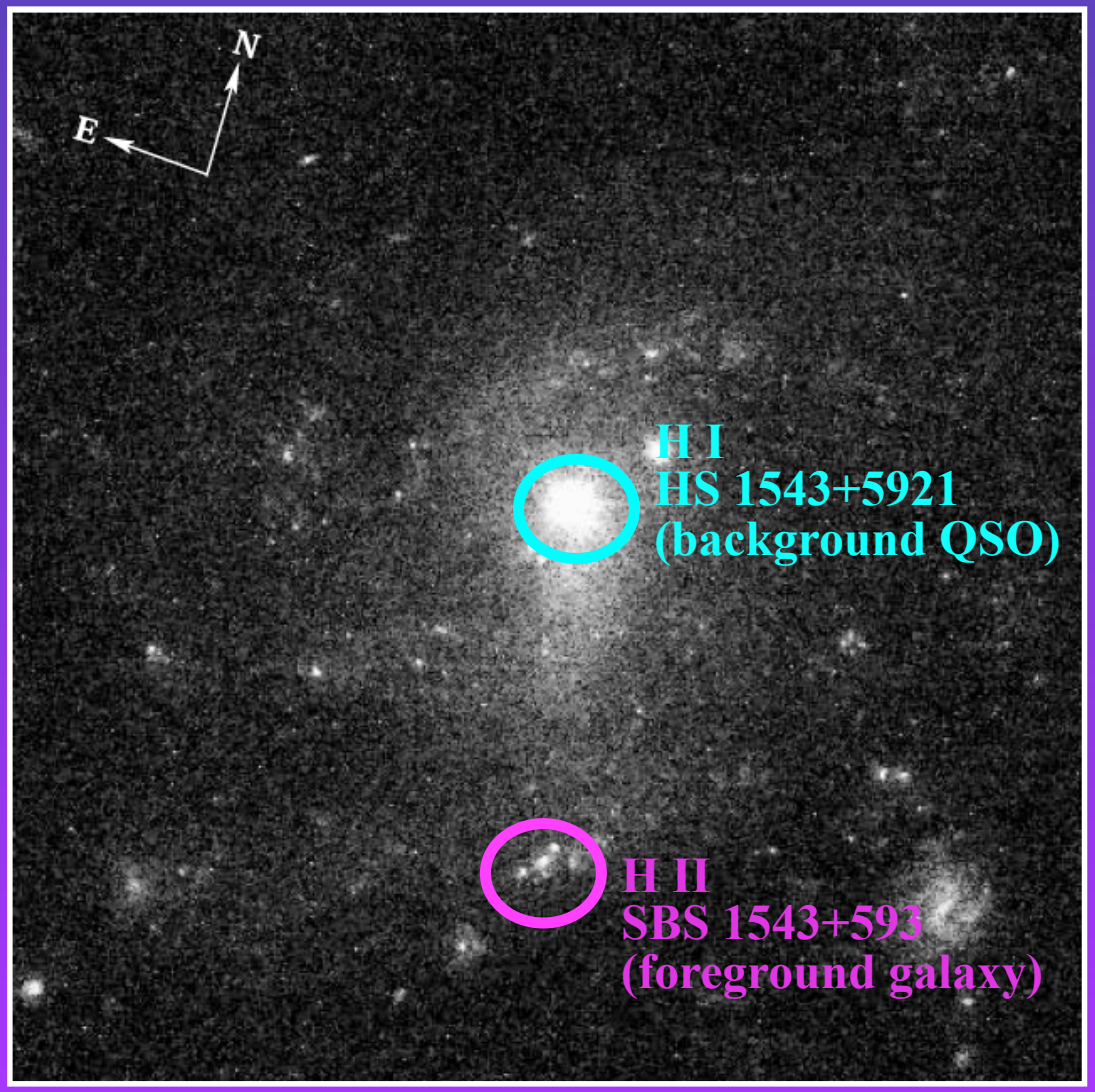
Constraints to chemical evolution models

FUSE Results on Neutral Gas Abundances in Local SFGs



➡ **H I more metal-poor than H II ?**
H II regions not fair tracer of the ISM metallicity ?

A Counterexample: SBS 1543+593/HS 1543+5921



Schulte-Ladbeck et al. (2004, 2005)

- **STIS abundances of the damped Lyα system toward QSO HS 1543+5921**

- **Emission-line abundances of the HII region in SBS 1543+593**

→

Neutral & ionized gas abundances agree

However, measurements where not along the same sightline !

Caveats on Neutral Gas Abundances from FUSE Studies

Saturation

- strong lines (e.g., O)
- unresolved multiple components due to large FUSE aperture used

Ionization

- ionization corrections (only some ions may be present)
- intervening ionized gas (S, Si, Mg, P, C, Fe, Al)
- partially ionized gas (N & Ar)

Depletion

- alpha-elements Si & Mg more than O, Ar & S
- Fe-peak element Fe (Cr, Co, Ni) more than Zn or Mn

Need to move to COS/STIS wavelengths !

COS Survey of Local SFGs

34 HST orbits in Cycle 17 to target 9 galaxies (program 11579, PI: Aloisi)

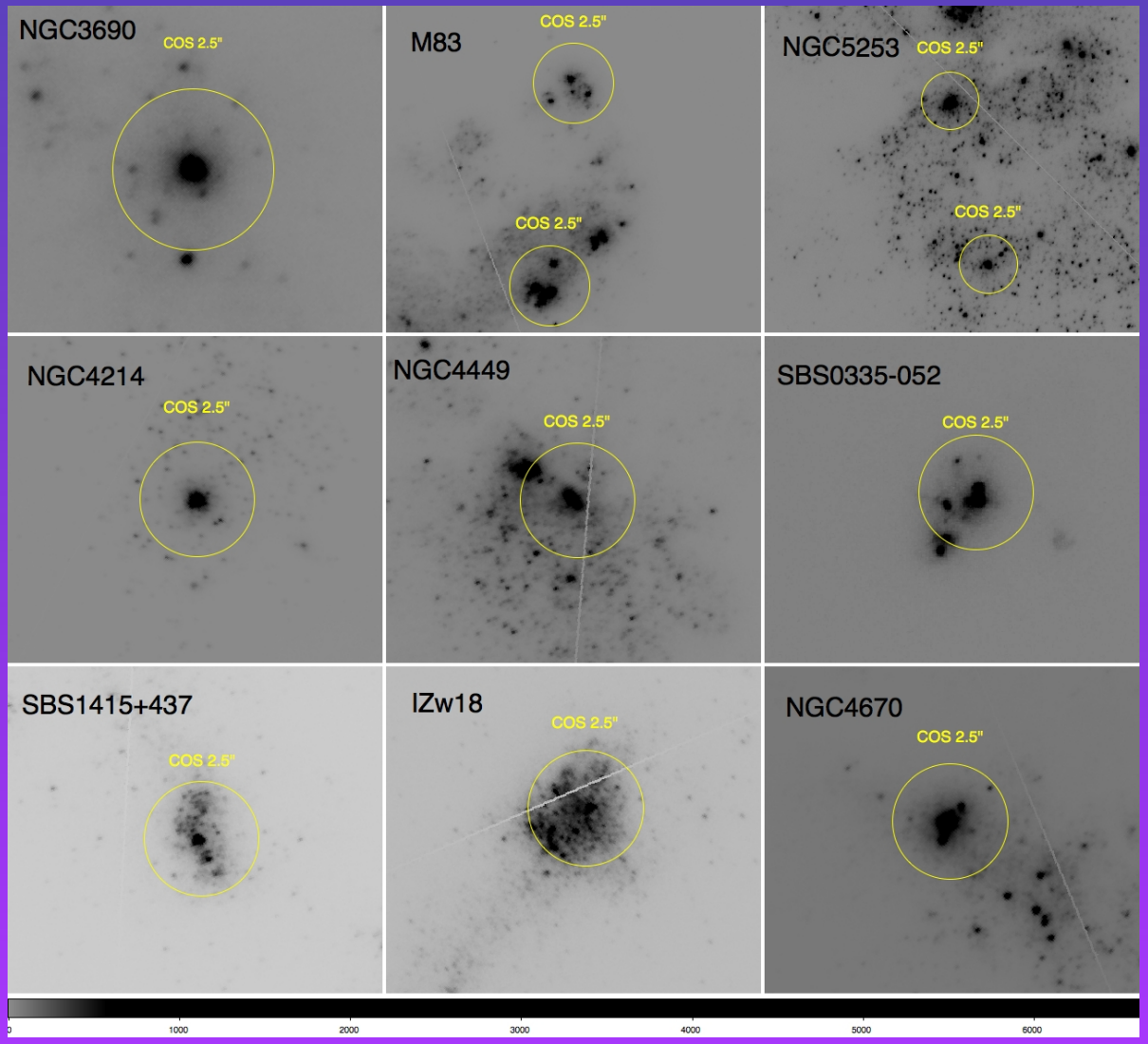
- **8 orbits of ACS/SBC pre-imaging (archival data for SBS0335-052)**
  - ✓ F125LP filter used (longwards of Lyα)
  - ✓ Data taken Jan-Mar 2009 (before SM4)
  - ✓ Additional ACS/WFC, ACS/HRC, WFPC2 archival data used for read leak
- **26 orbits of COS/FUV spectroscopy**
  - ✓ one sightline in each galaxy of the sample
  - ✓ second sightline in M83 and NGC5253
  - ✓ COS spectra of 8/9 targets acquired Nov 2009 – Sep 2010
    - Observations of NGC 4214 to be repeated due to a failure during TA
    - Observations of IZw18 still to be executed (Jan 2011)

Properties of the COS SFG Sample

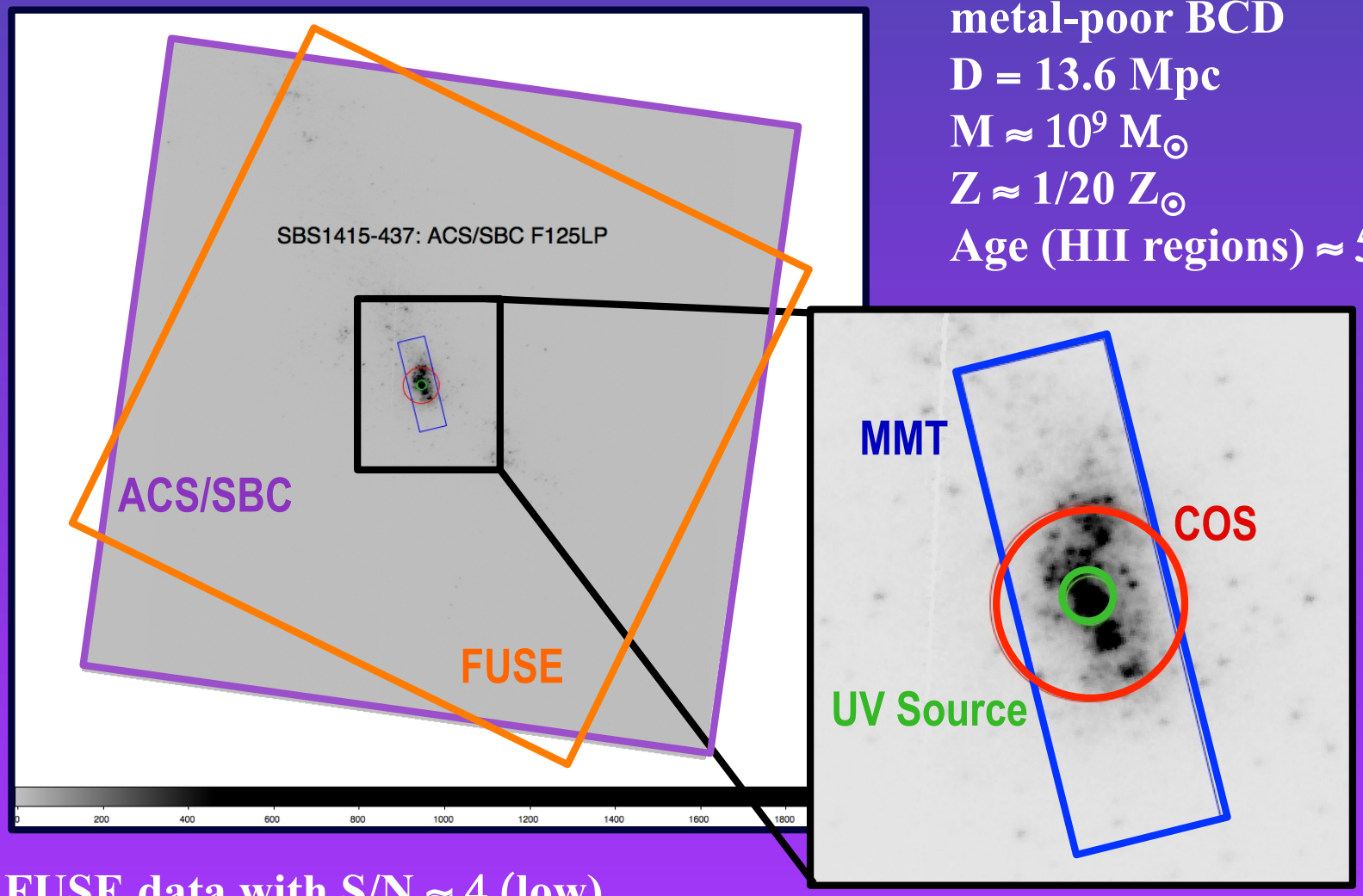
COS Sample of SFGs spans a wide range in Z, SFR, and type of galaxy, allowing to investigate the metallicity behavior of the neutral ISM as a function of the galaxy properties at z = 0

Name	Type	V (mag)	vel (km/s)	E(B-V) (mag)	12+log(O/H)	log(L_{UV}+L_{FIR}) (ergs/s)
M83	SBc	7.5	513	0.066	9.3	43.06
NGC 3690	Merger	12.0	3,119	0.017	8.8	45.06
NGC 4214	Irr	9.8	291	0.022	8.2	41.84
NGC 4449 NUC	Irr	9.6	203	0.019	8.4	42.38
NGC 4670	BCD	13.1	1,069	0.015	8.3	42.95
NGC 5253	Irr	10.4	403	0.056	8.2	41.77
SBS 0335-052	BCD	17.7	4,043	0.047	7.3	...
SBS 1415+437	BCD	15.6	609	0.009	7.6	41.83
I Zw 18	BCD	15.6	753	0.032	7.2	<41.82

ACS/SBC Pre-Imaging of COS SFG Sample



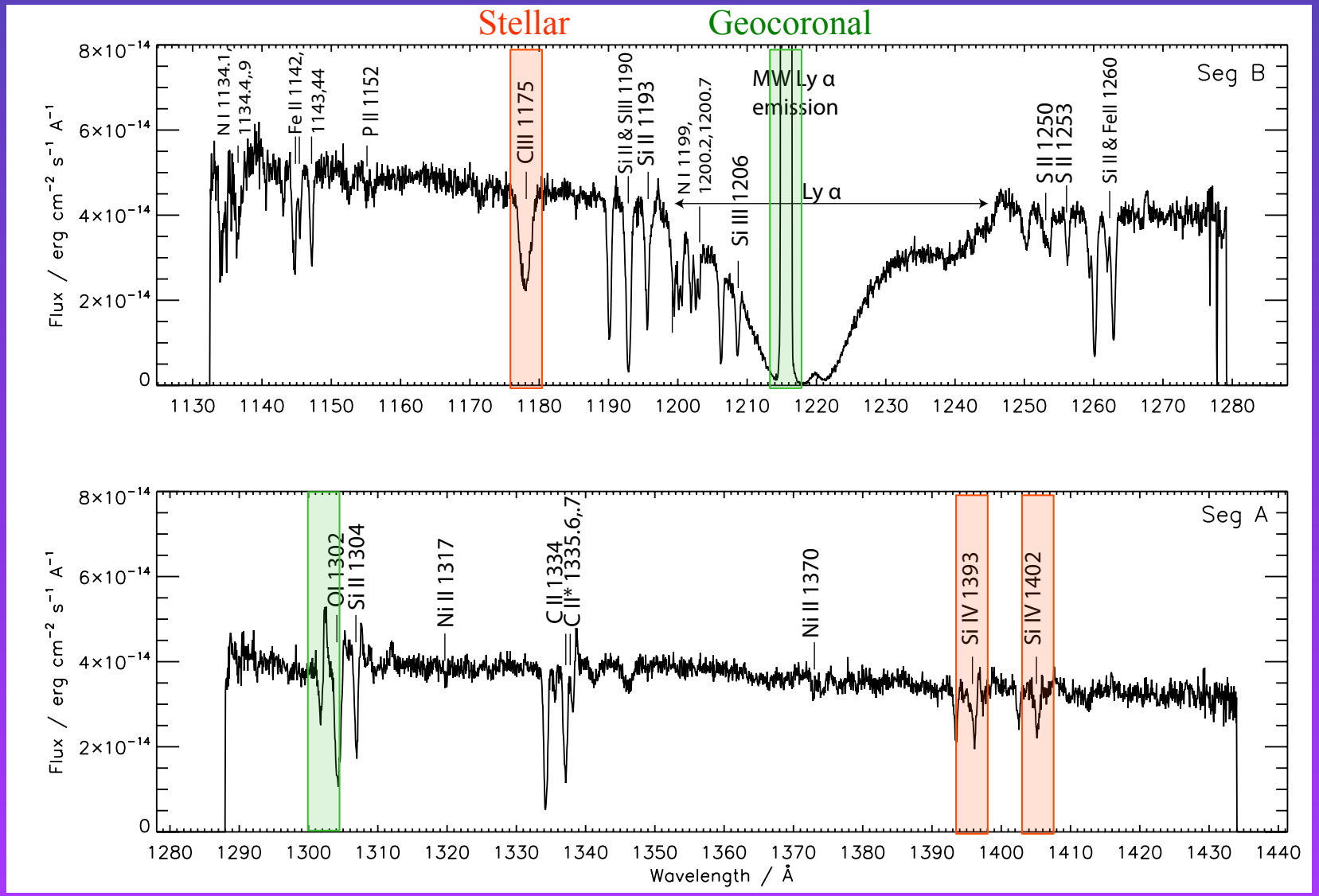
COS Observations of SBS 1415+437



metal-poor BCD
D = 13.6 Mpc
$M \approx 10^9 M_\odot$
$Z \approx 1/20 Z_\odot$
Age (HII regions) ≈ 5 Myr

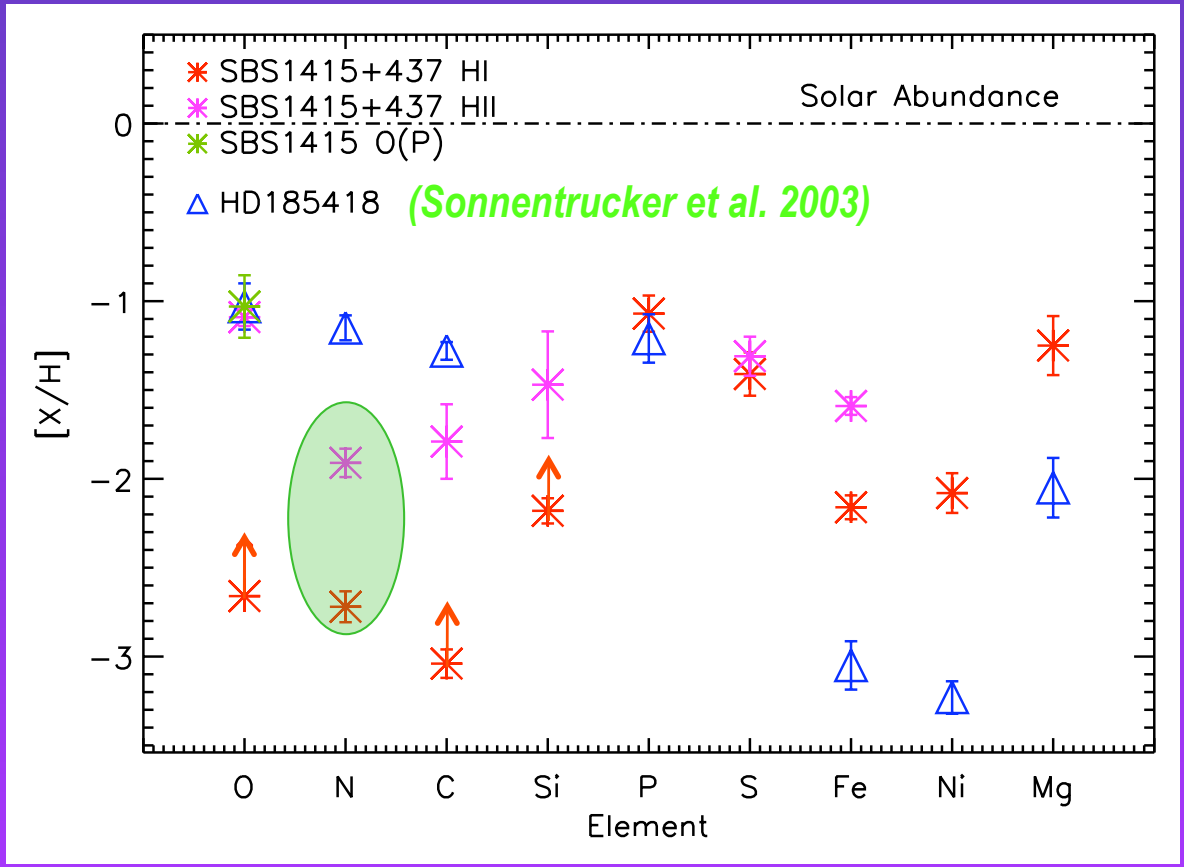
FUSE data with S/N ≈ 4 (low)
Nebular emission-line long-slit (1.5”x5”) spectra from MMT *(Thuan et al. 1999)*

COS/FUV Spectra of SBS 1415+437



Abundances in SBS 1415+437

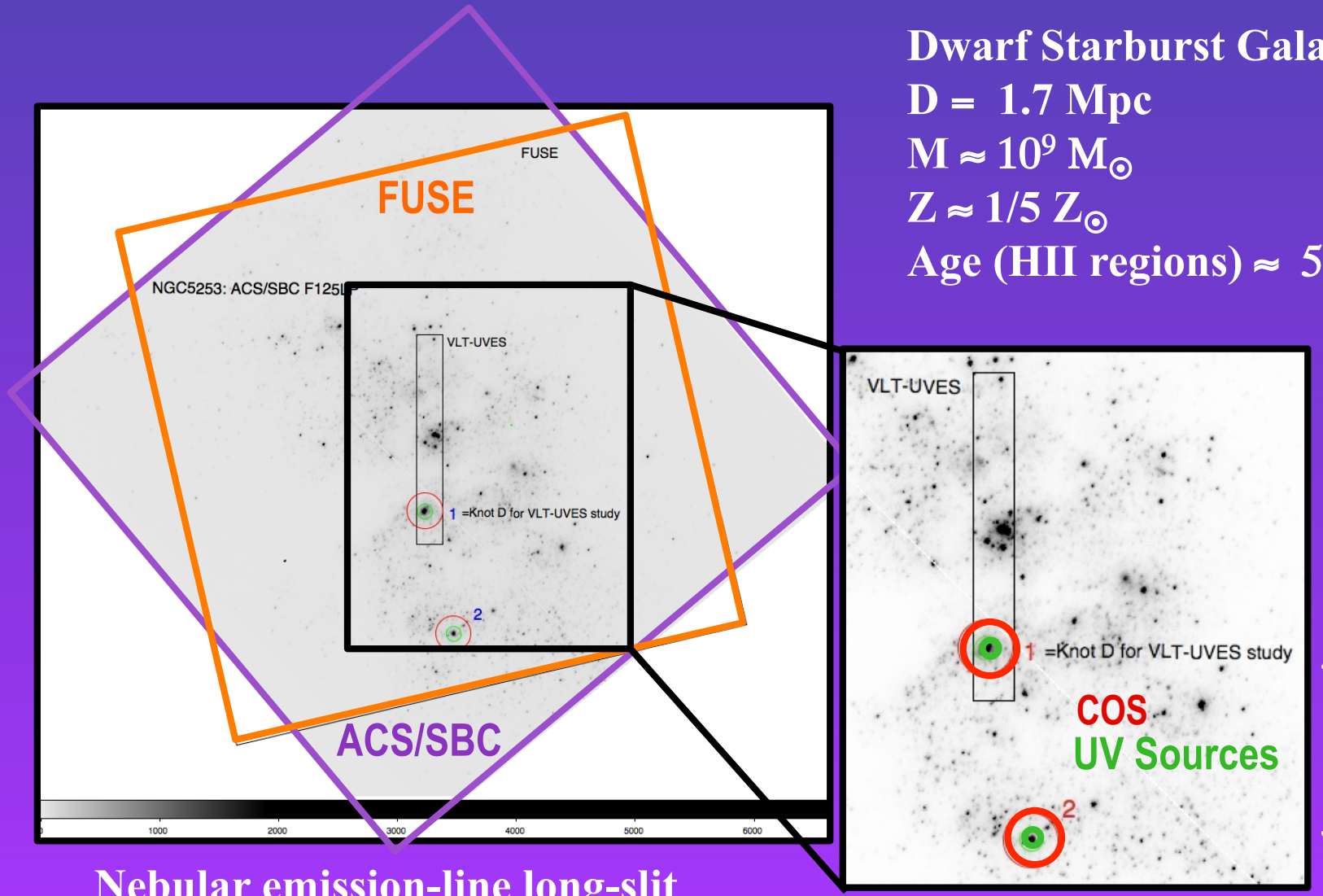
- α elements O as traced by P *(Lebouteiller et al. 2005)*, S, Mg consistent with each other and with values in HII region



- Fe slightly lower in HI than in HII (but HII has large ionization corrections)
- N lower in HI than in HII: N enrichment of HII regions or NI ionization effects in neutral ISM ?
- Fe, Ni, Mg less depleted than in sightline towards local star HD 185418 (similar N(H)): Z effect ?

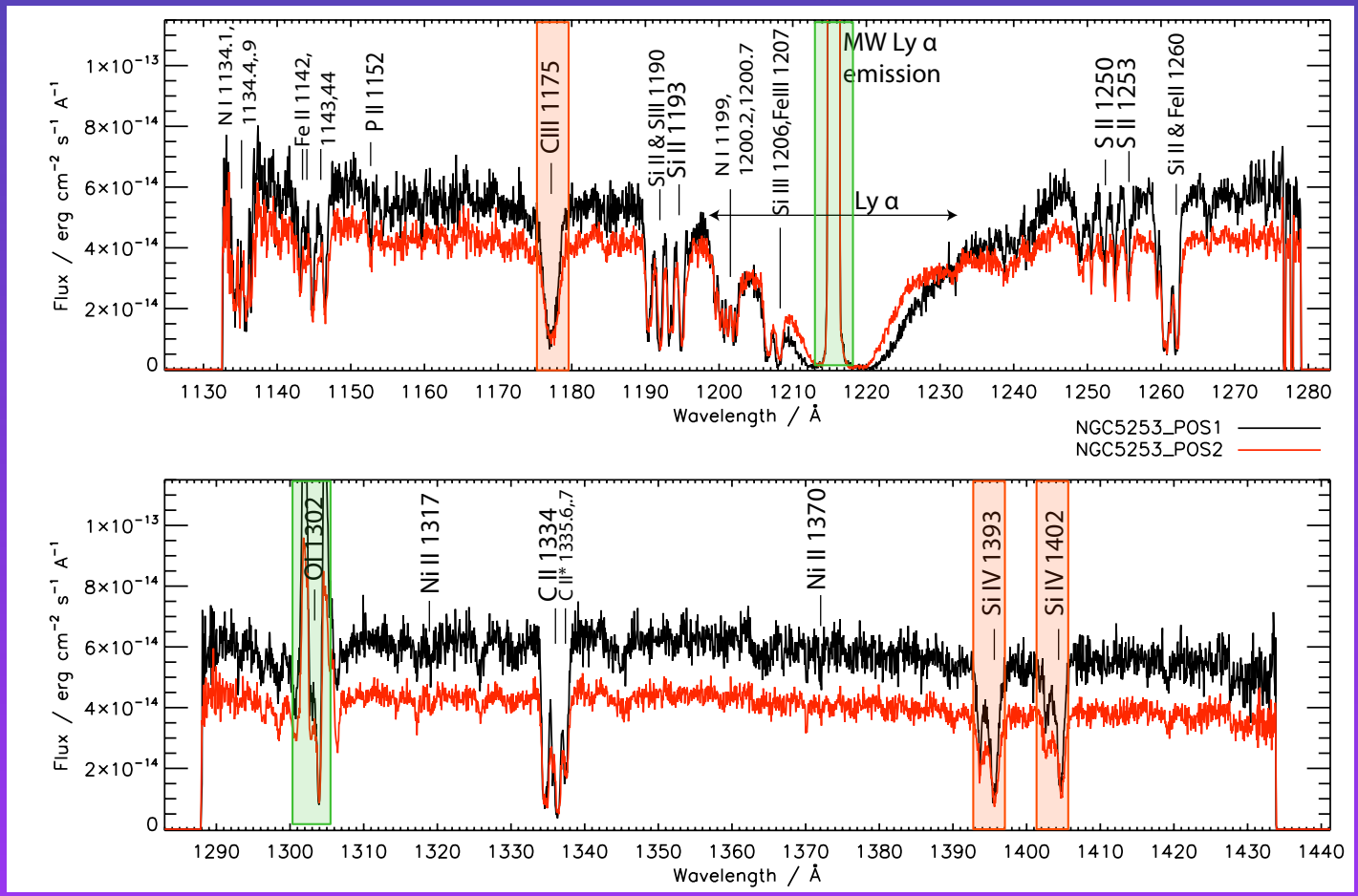
COS Observations of NGC 5253

Dwarf Starburst Galaxy
D = 1.7 Mpc
M ≈ 10^9 $M_\odot$
Z ≈ 1/5 $Z_\odot$
Age (HII regions) ≈ 5 Myr



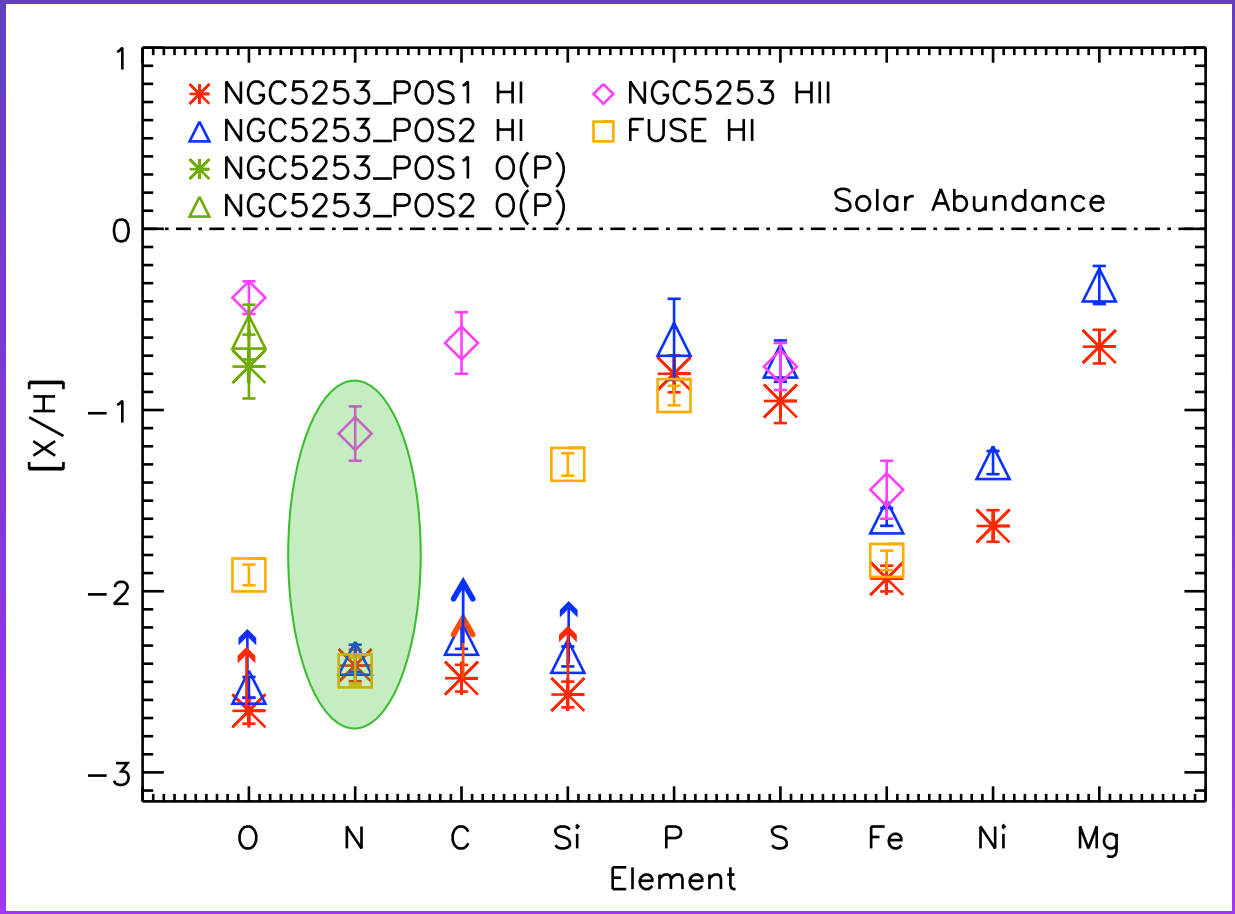
Nebular emission-line long-slit (knot D) spectra from VLT-UVES *(Lopez-Sanchez et al. 2007)*

COS Spectra of NGC5253



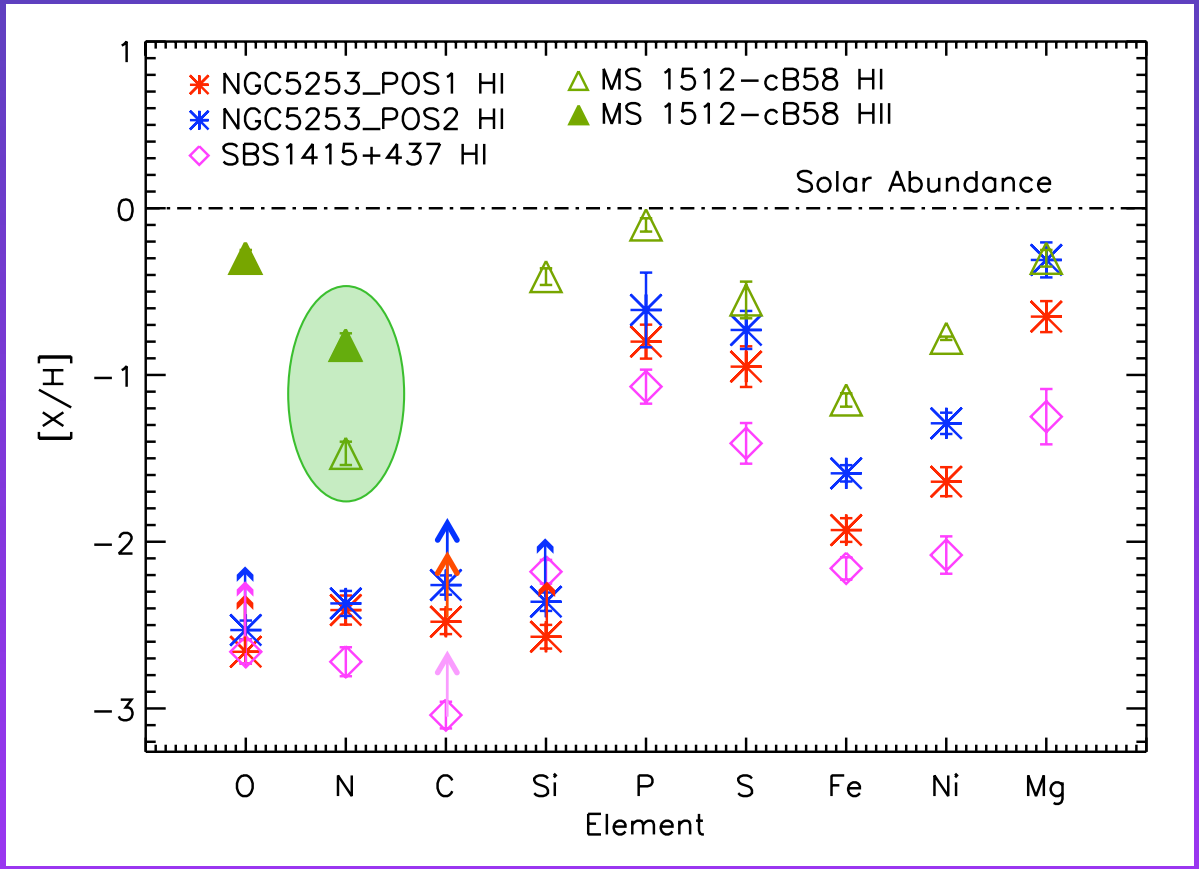
- Spectra in POS1 & POS2 with slightly different fluxes, otherwise similar to each other
- HI column density in POS1 higher by ~ 0.35 dex compared to POS2

Abundances in NGC 5253



- Trends in 2 COS positions similar, despite different (~ 0.35 dex) HI column densities
- For both COS positions, same trends as observed for SBS 1451+437 for α elements and Fe-peak elements
- In particular, N lower in HI than in HII
- FUSE data mainly consistent with COS

Comparison with LBG MS 1512-cB58

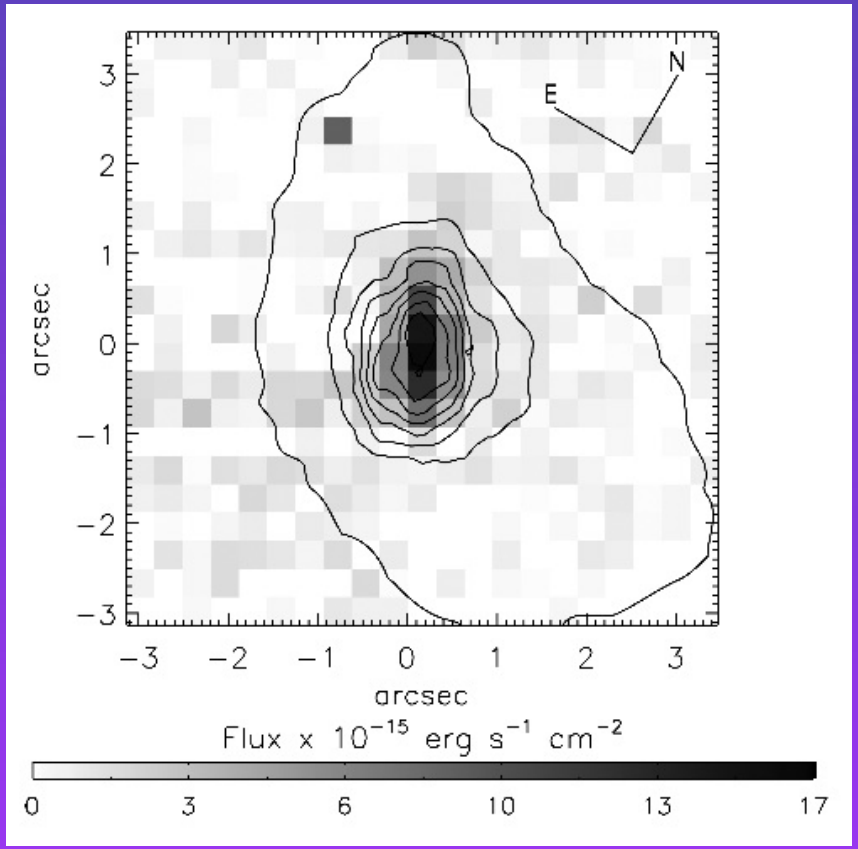


Teplitz et al. 2000, Pettini et al. 2002

- **Same N abundance offset between HI and HII in LBG cB58**
- **Relative trends in neutral ISM of z = 2.7 LBG cB58 quite similar to NGC 5253, except for N**
- **Neutral- and ionized-gas abundances in L* LBG at z = 2.7 (a galactic bulge or an elliptical in formation?) just ~ 0.5 dex higher than NGC 5253**

N Enrichment in HII Regions with IFU

James et al. 2009



- **Mkr 966 is BCD with anomalously high N/O**
- **IFU data show evidence of broad & narrow components**

  Broad component associated with high N_e (10^7 cm^{-3})

- **Emission map of WR feature at λ 4658 in the inner core region of Mrk 966 correlates with broad component that only shows elevated N/O**

Gemini/GMOS proposal submitted in Sep 2010 to obtain IFU data of COS SFG sample !

Summary and Conclusions

1. Sample of local SFGs observed with COS to address biases of FUSE observations (multiple sightlines, availability of ions, etc.)
2. The α element S, in addition to P used as tracer of O, is key to perform a direct comparison of the α-element abundances in the neutral and ionized gas.
3. The two cases studies so far show that all the α elements measured in HI with COS give consistent abundance values compared to each other.
4. HI abundances are similar to what found in the HII regions associated with the COS absorption-line spectra, except for N:
   - ✓ N enrichment in the HII regions by WNL stars ?
   - ✓ Same O metallicity in HI and HII ?
     - O offset identified by FUSE due to observational biases ?
5. Two different sightlines in NGC 5253 have different HI column densities, but very similar abundances: homogeneity of the HI on physical scales of the order of few 100 pc ?