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# Chemical abundance analysis of the red giants in the S-type symbiotic systems.

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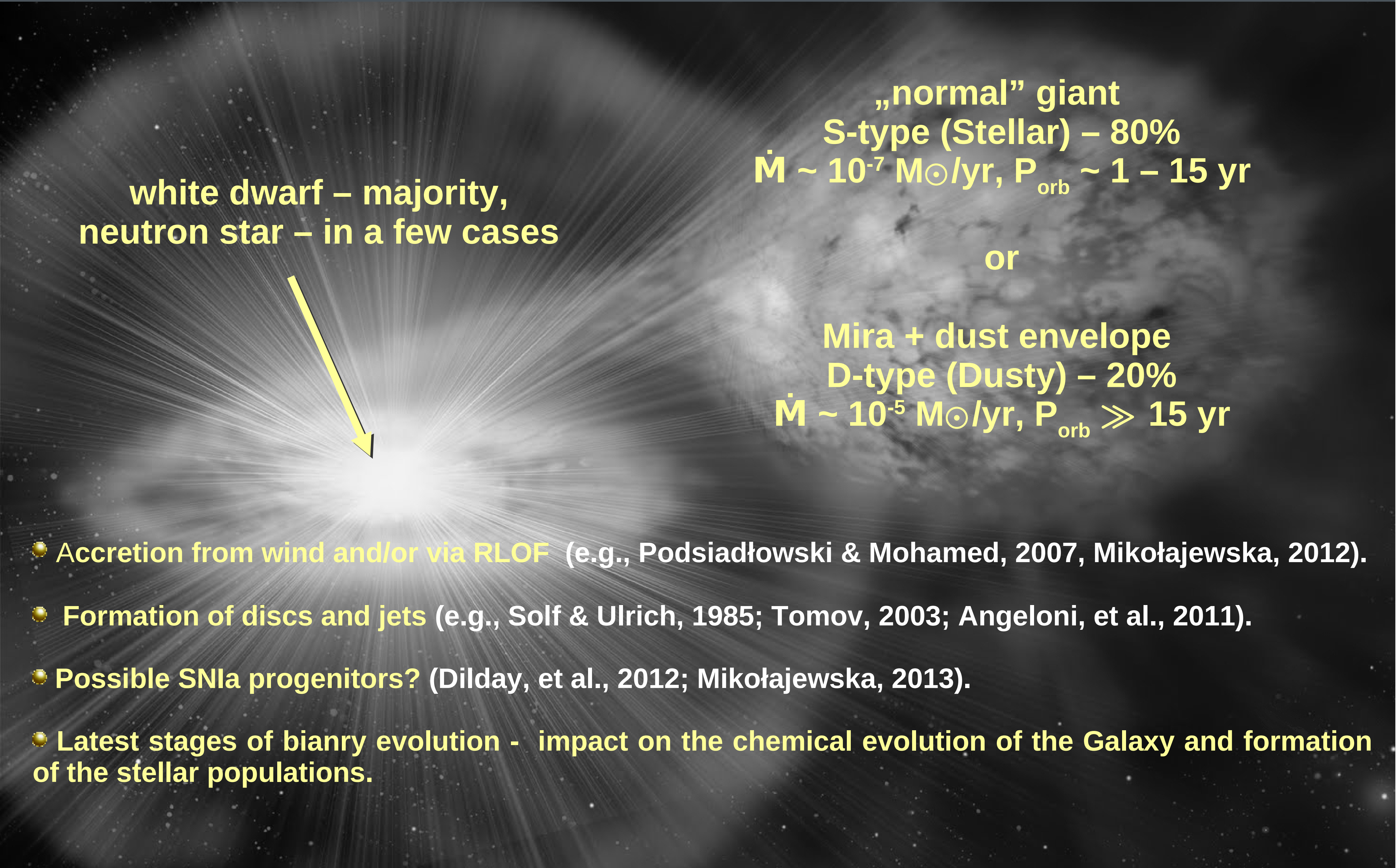
**Cooperation: J. Mikołajewska, K. H. Hinkle, M. Schmidt & M. Gromadzki**

**February 27, 2014**

# *Symbiotic systems*



**white dwarf – majority,**
**neutron star – in a few cases**

**„normal" giant**
**S-type (Stellar) – 80%**
$\dot{M} \sim 10^{-7}\ M_\odot/\mathrm{yr}$, $P_{orb} \sim 1 – 15$ yr

**or**

**Mira + dust envelope**
**D-type (Dusty) – 20%**
$\dot{M} \sim 10^{-5}\ M_\odot/\mathrm{yr}$, $P_{orb} \gg 15$ yr

- **Accretion from wind and/or via RLOF (e.g., Podsiadłowski & Mohamed, 2007, Mikołajewska, 2012).**
- **Formation of discs and jets (e.g., Solf & Ulrich, 1985; Tomov, 2003; Angeloni, et al., 2011).**
- **Possible SNIa progenitors? (Dilday, et al., 2012; Mikołajewska, 2013).**
- **Latest stages of bianry evolution - impact on the chemical evolution of the Galaxy and formation of the stellar populations.**

# *SySs with known abundances – a few*

## with normal giants in S-type systems:

**V2116 Oph** – SyS with neutron star (Hinkle et al,. 2006),

**T CrB** – recurrent nova (Wallerstein et al., 2008),

**RS Oph** – recurrent nova (Wallerstein et al., 2008; Pavlenko et al., 2008),

**CH Cyg** – the brightest SyS (Schmidt et al., 2006).

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## a dozen of yellow symbiotic systems:

**AG Dra, BD-21 3873 (Smith et al. 1996, 1997), Hen 2-467 (Pereira et al. 1998), CD-43 14304, Hen 3-1213, Hen 3-863, StHA 176 (Pereira & Roig 2009), – S-type SySs with giants of K/G spectral type**

**StHA 190 (Smith et al. 2001), HD 330036, AS 201 (Pereira et al. 2005), – D'-type SySs with fast rotating G-type giants**

# *SySs with known abundances – a few*

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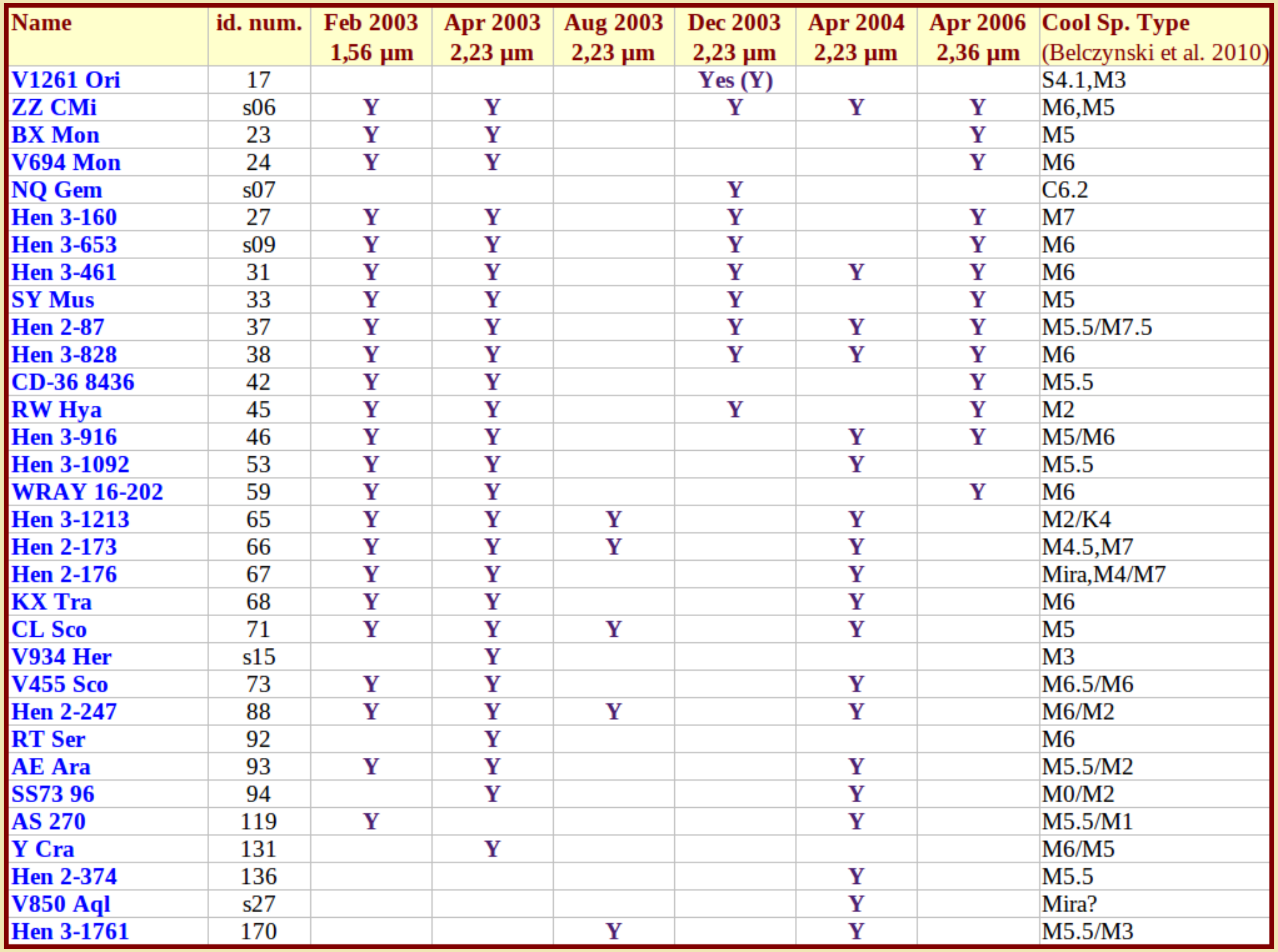
**Too small a number for statistical considerations!**

# *Soon chemical abundances for 32 symbiotic giants*

**Near-IR spectra obtained at ~1.56, ~2.23, ~2.36 μm in the narrow spectral range ~100 Å.**
**Phoenix spectrometer/Gemini-South (S/N ~ 100, R = Δλ/λ ~ 50000).**

**Useful to search for C, N, O, and elements around iron peak Sc, Ti, Fe, Ni, and $^{12}C/^{13}C$.**



| Name | id. num. | Feb 2003 1,56 μm | Apr 2003 2,23 μm | Aug 2003 2,23 μm | Dec 2003 2,23 μm | Apr 2004 2,23 μm | Apr 2006 2,36 μm | Cool Sp. Type (Belczynski et al. 2010) |
|---|---|---|---|---|---|---|---|---|
| **V1261 Ori** | 17 | | | | Yes (Y) | | | S4.1,M3 |
| **ZZ CMi** | s06 | Y | Y | | Y | Y | Y | M6,M5 |
| **BX Mon** | 23 | Y | Y | | | | Y | M5 |
| **V694 Mon** | 24 | Y | Y | | | | Y | M6 |
| **NQ Gem** | s07 | | | | Y | | | C6.2 |
| **Hen 3-160** | 27 | Y | Y | | Y | | Y | M7 |
| **Hen 3-653** | s09 | Y | Y | | Y | | Y | M6 |
| **Hen 3-461** | 31 | Y | Y | | Y | Y | Y | M6 |
| **SY Mus** | 33 | Y | Y | | Y | | Y | M5 |
| **Hen 2-87** | 37 | Y | Y | | Y | Y | Y | M5.5/M7.5 |
| **Hen 3-828** | 38 | Y | Y | | Y | Y | Y | M6 |
| **CD-36 8436** | 42 | Y | Y | | | | Y | M5.5 |
| **RW Hya** | 45 | Y | Y | | Y | | Y | M2 |
| **Hen 3-916** | 46 | Y | Y | | | Y | Y | M5/M6 |
| **Hen 3-1092** | 53 | Y | Y | | | Y | | M5.5 |
| **WRAY 16-202** | 59 | Y | Y | | | | Y | M6 |
| **Hen 3-1213** | 65 | Y | Y | Y | | Y | | M2/K4 |
| **Hen 2-173** | 66 | Y | Y | Y | | Y | | M4.5,M7 |
| **Hen 2-176** | 67 | Y | Y | | | Y | | Mira,M4/M7 |
| **KX Tra** | 68 | Y | Y | | | Y | | M6 |
| **CL Sco** | 71 | Y | Y | Y | | Y | | M5 |
| **V934 Her** | s15 | | Y | | | | | M3 |
| **V455 Sco** | 73 | Y | Y | | | Y | | M6.5/M6 |
| **Hen 2-247** | 88 | Y | Y | Y | | Y | | M6/M2 |
| **RT Ser** | 92 | | Y | | | | | M6 |
| **AE Ara** | 93 | Y | Y | | | Y | | M5.5/M2 |
| **SS73 96** | 94 | | Y | | | Y | | M0/M2 |
| **AS 270** | 119 | Y | | | | Y | | M5.5/M1 |
| **Y Cra** | 131 | | Y | | | | | M6/M5 |
| **Hen 2-374** | 136 | | | | | Y | | M5.5 |
| **V850 Aql** | s27 | | | | | Y | | Mira? |
| **Hen 3-1761** | 170 | | | Y | | Y | | M5.5/M3 |

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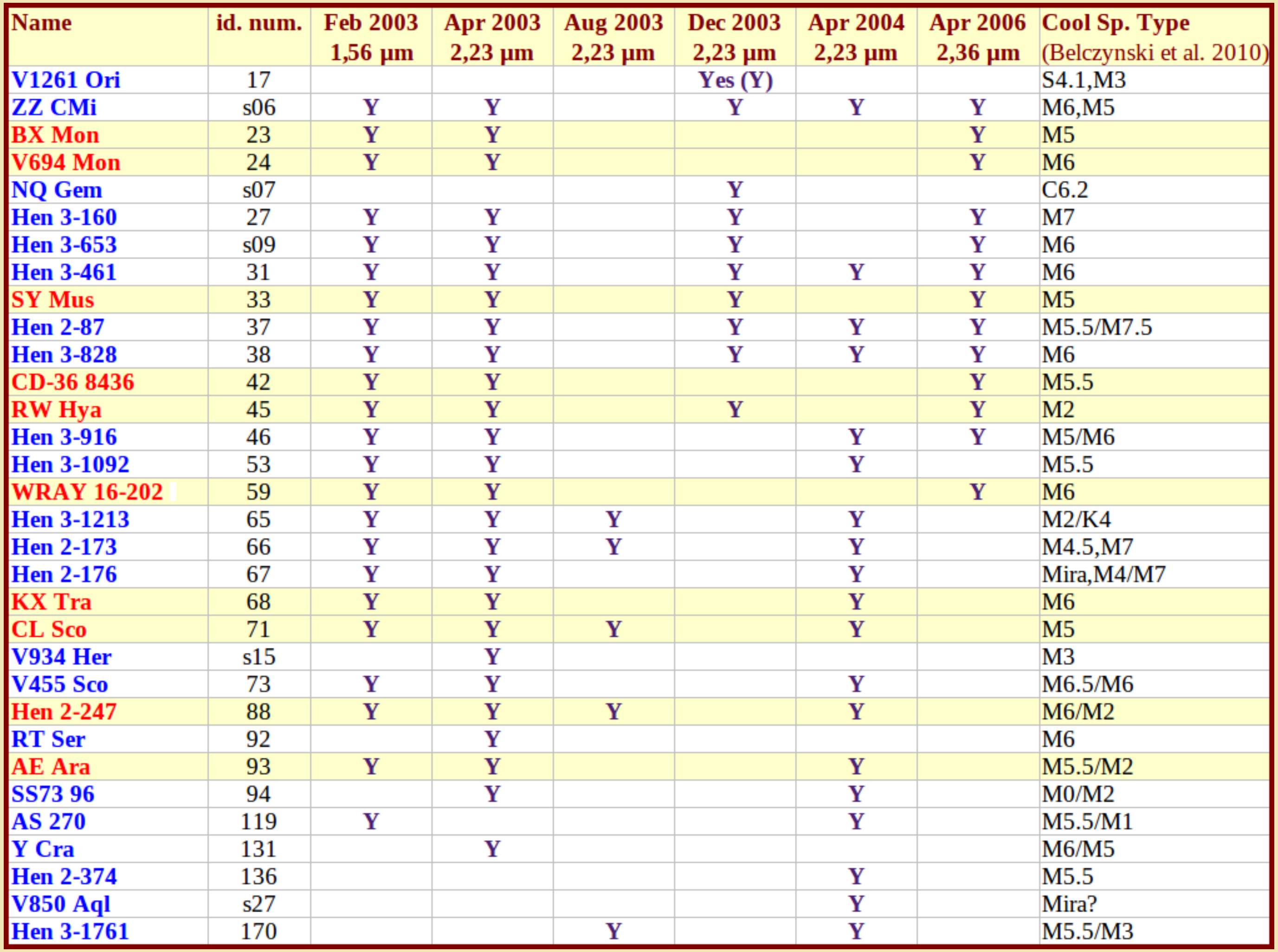

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# *Journal of spectroscopic observations*

## Spectra at 1.56 μm (*H*), 2.23 μm (*K*), 2.36 μm (*K'*)

| Object | Sp. Region Band (λ[μm]) | Date | HJD | Orb. Phase | Object | Sp. Region Band (λ[μm]) | Date | HJD | Orb. Phase |
|---|---|---|---|---|---|---|---|---|---|
| **RW Hya** | H (~1.56) | 16.02.2003 | 2452686.8380 | 0.57 | **CL Sco** | H (~1.56) | 17.02.2003 | 2452687.8341 | 0.07 |
| | K (~2.23) | 20.04.2003 | 2452749.6295 | 0.74 | | K (~2.23) | 20.04.2003 | 2452749.7780 | 0.17 |
| | K (~2.23) | 13.12.2003 | 2452986.8656 | 0.38 | | K (~2.23) | 15.08.2003 | 2452866.5367 | 0.36 |
| | K' (~2.36) | 3.04.2006 | 2453828.6308 | 0.65 | | K (~2.23) | 3.04.2004 | 2453098.7794 | 0.73 |
| **SY Mus** | H (~1.56) | 17.02.2003 | 2452687.7566 | 0.02 | **Hen 2-247** | H (~1.56) | 17.02.2003 | 2452687.8745 | 0.05 |
| | K (~2.23) | 20.04.2003 | 2452749.5817 | 0.12 | | K (~2.23) | 20.04.2003 | 2452749.8453 | 0.12 |
| | K (~2.23) | 13.12.2003 | 2452986.8250 | 0.50 | | K (~2.23) | 15.08.2003 | 2452866.5144 | 0.25 |
| | K' (~2.36) | 3.04.2006 | 2453828.5767 | 0.84 | | K (~2.23) | 3.04.2004 | 2453098.8329 | 0.51 |
| **BX Mon** | H (~1.56) | 16.02.2003 | 2452686.7409 | 0.30 | **MWC 560** | H (~1.56) | 16.02.2003 | 2452686.7491 | ? |
| | K (~2.23) | 20.04.2003 | 2452749.5231 | 0.35 | | K (~2.23) | 20.04.2003 | 2452749.5326 | ? |
| | K' (~2.36) | 3.04.2006 | 2453828.5095 | 0.20 | | K' (~2.36) | 3.04.2006 | 2453828.5187 | ? |
| **AE Ara** | H (~1.56) | 17.02.2003 | 2452687.8830 | 0.05 | **CD-36 8436** | H (~1.56) | 16.02.2003 | 2452686.8181 | ? |
| | K (~2.23) | 20.04.2003 | 2452749.8669 | 0.13 | | K (~2.23) | 20.04.2003 | 2452749.6156 | ? |
| | K (~2.23) | 3.04.2004 | 2453098.8487 | 0.56 | | K' (~2.36) | 3.04.2006 | 2453828.6211 | ? |
| **KX TrA** | H (~1.56) | 17.02.2003 | 2452687.8230 | 0.73 | **WRAY 16-202** | H (~1.56) | 17.02.2003 | 2452687.7936 | ? |
| | K (~2.23) | 20.04.2003 | 2452749.7670 | 0.78 | | K (~2.23) | 20.04.2003 | 2452749.7301 | ? |
| | K (~2.23) | 3.04.2004 | 2453098.7314 | 0.03 | | K' (~2.36) | 3.04.2006 | 2453828.6812 | ? |

# *Methods*

## The standard LTE analysis

**Synthetic models of atmosfer MARCS** (Gustafsson et al., 2008)

**WIDMO code** – to calculate synthetic spectra (Schmidt et al., 2006)

**Simplex algorithm** (Brandt 1998, Kallrath & Milone 1999) in C/tcsh
– for authomatic minimization in the parameter space

**Atomic data:**

- VALD (Kupka et al. 1999) – *K*-band region,
- list by Mlendez & Barbuy (1999) for *H*-band region

**Molecular data:**

- the vibration rotation lines of $^{12}$CO, $^{13}$CO, isotopes (Goorvitch 1994),
- $^{12}$CN, and OH molecular lines from Kurucz (1999)

# *Methods*

## Input stellar parameters

### $T_{\mathrm{eff}}$ and log $g$

| Object | Spectral Type | $T_{\mathrm{eff}}$ [K] | $T_{\mathrm{eff}}$ [K] | $J$-$K$ | $E(B$-$V)$ | $(J$-$K)_0$ | $T_{\mathrm{eff}}$ [K] | log $g$ | $T_{\mathrm{eff}}$ [K] |
|---|---|---|---|---|---|---|---|---|---|
| | Murset & Schmid, 1999 | Richichi et al., 1999 | van Belle et al., 1999 | | | | Kucinskas et al., 2005 | | adopted |
| RW Hya | M2 | 3655 ± 80 | 3750 ± 22 | 1.15 | 0.02-0.10 | ~1.1 | 3600–3700 | 0.5 | 3700 |
| SY Mus | M4.5 | 3410 ± 75 | 3424 ± 30 | 1.40 | 0.40-0.50 | ~1.2 | ≲3500 | 0.5 | 3400 |
| BX Mon | M5.5 | 3325 ± 75 | 3410 ± 30 | 1.37 | 0.12-0.16 | ~1.29 | ~3270 | 0.0 | 3400 |
| AE Ara | M5.5 | 3300 ± 75 | 3400 ± 30 | 1.36 | 0.19-0.25 | ~1.25 | ~3350 | 0.0 | 3400 |
| KX Tra | M6 | 3240 ± 75 | 3375 ± 34 | 1.39 | 0.13-0.23 | ~1.3 | ~3250 | 0.0 | 3300 |
| CL Sco | M5 | 3355 ± 75 | 3424 ± 30 | 1.29 | 0.26-0.34 | ~1.15 | ~3560 | 0.5 | 3400 |
| MWC 560 | M5.5-M6 | 3270 ± 75 | 3390 ± 30 | 1.42 | 0.19-0.24 | ~1.31 | ~3230 | 0.0 | 3300 |
| CD-36 8436 | M5.5 | 3300 ± 75 | 3400 ± 30 | 1.27 | 0.04-0.06 | ~1.25 | ~3350 | 0.0 | 3400 |
| WRAY 16-202 | M6 | 3240 ± 75 | 3375 ± 34 | 2.09 | >1.00 | ? | ? | 0.0 | 3200 |
| Hen 2-247 | M6 | 3240 ± 75 | 3375 ± 34 | 1.61 | 0.60-0.70 | ~1.29 | ~3270 | 0.0 | 3300 |

**$\zeta_t$ = 3 km/s – macroturbulence**

## Free parameters

**C, N, O, Sc, Ti, Fe, Ni and $^{12}C/^{13}C$ – parameters of the chemical composition**

**$V_{\mathrm{rot}}$ sin $i$ – rotational velocity**

**$\xi_t$ – microturbulence**

# *Methods*

## Rotational and radial velocities

**1. Cross-correlation technique in the way similar to adopted by Carlberg et al. (2011)**

**- synthetic spectra used as the templates**

**- measured FWHMs of cross-correlation peak $\mu_*$ and auto-correlation peak $\mu_t$ (IRAF *fxcor*)**

**- widths of spectral lines from stellar processes:**

$$\omega_\star = (\mu_\star^2 - 0.5\mu_t^2 - \omega_i^2)^{0.5}$$

**- $\omega_*$ was converted to total stellar broadening $\beta_{Gray}$:**

$$\omega_\star(\mathrm{kms}^{-1}) = 1.89582 + 1.16526\beta_{\mathrm{Gray}} + 0.0065\beta_{\mathrm{Gray}}^2$$

**Quadrature sum of projected $V_{rot}$ sin $i$ and $\xi_t$:**

$$(V_{\mathrm{rot}}^2 \sin^2 i + \xi_{\mathrm{t}}^2)^{0.5} = (\beta_{\mathrm{Gray}}^2 - \zeta_{\mathrm{t}}^2)^{0.5}$$

**2. By direct measure of FWHMs of 6 atomic lines (Ti I: 22217 Å, 22239 Å, 22280 Å; Fe I: 22263 Å, 22266 Å; Sc I: 22273 Å) at *K*-band spectra (Fekel et al. 2003)**

# *Methods*

## Procedure to derive abundances

**Estimation of the initial values of the abundance parameters:**

**- at first approach the solar composition adopted from Asplund et al. (2009)**

**- fitting by eye alternately to the OH, CO, CN and atomic lines**

**Building of the n+1, n dimensional sets of free parameters – the so called simplex.**

**Minimisation with the simplex algorithm:**

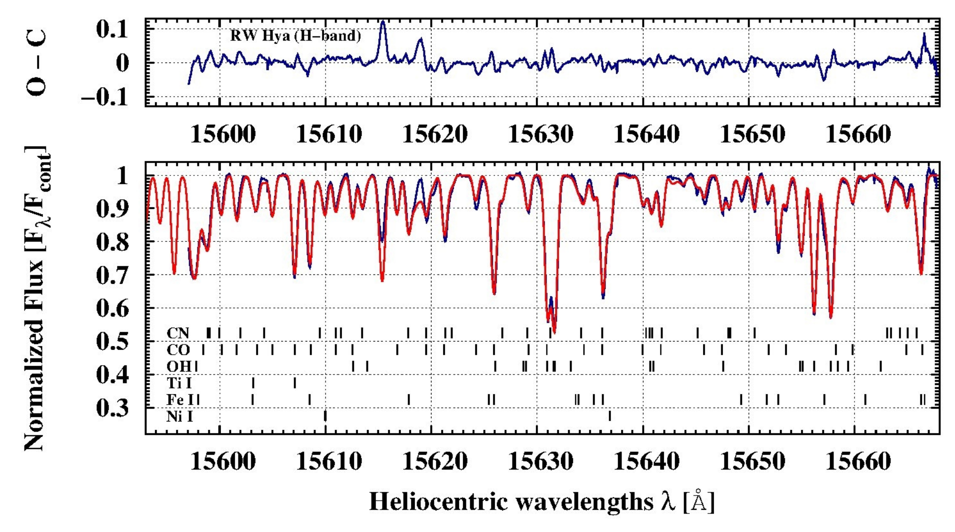
**- 9 different simplexes were used to calculation with different $\xi_t$ values sampled in the range 1.2 – 2.6 km/s to obtain optimal fit to *H*- and *K*-band spectra**

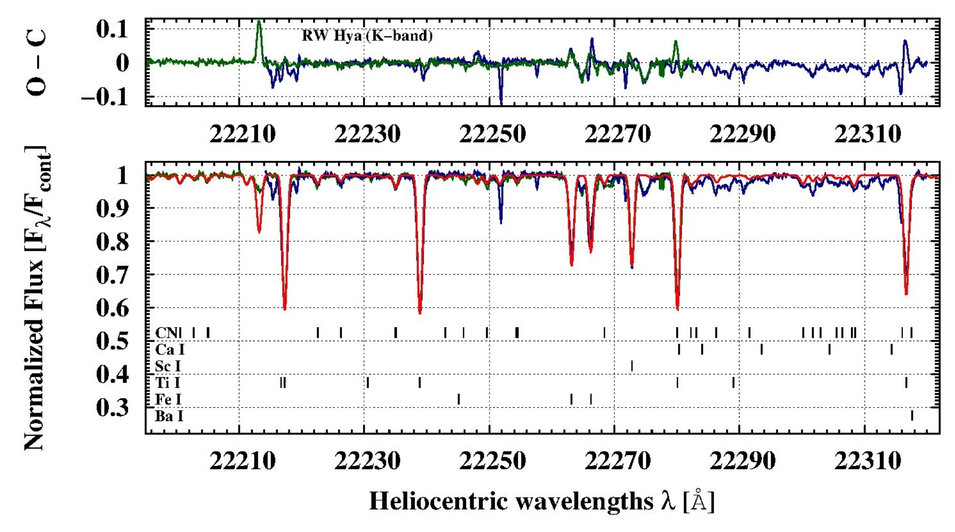
**- searching for $^{12}C/^{13}C$ by fitting to *K*'-band spectrum**

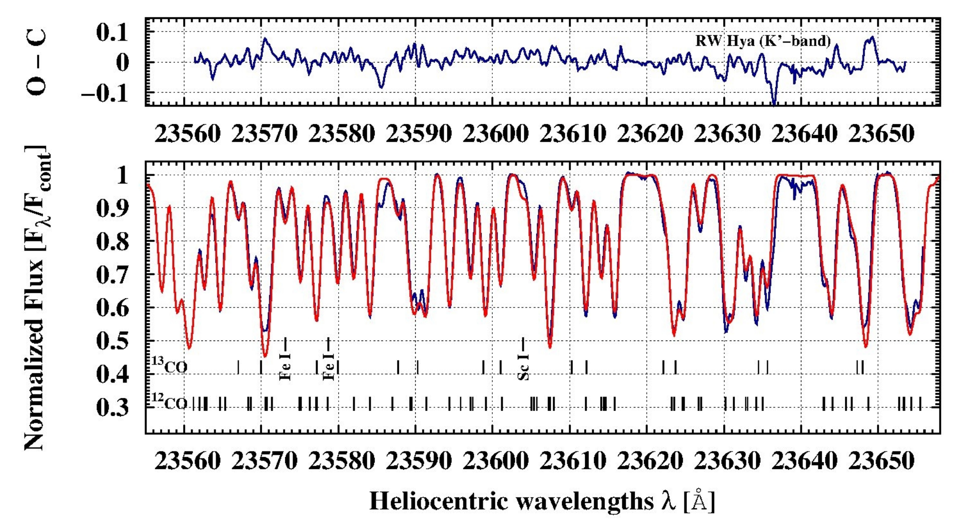
**- reconciliation of $^{12}C$ and $^{12}C/^{13}C$ within $\leq 4$ iterations**

# *Exemplary synthetic fits for RW Hya*

**$T_{\rm eff}$ = 3700 K,**
**log $g$ = 0.5**

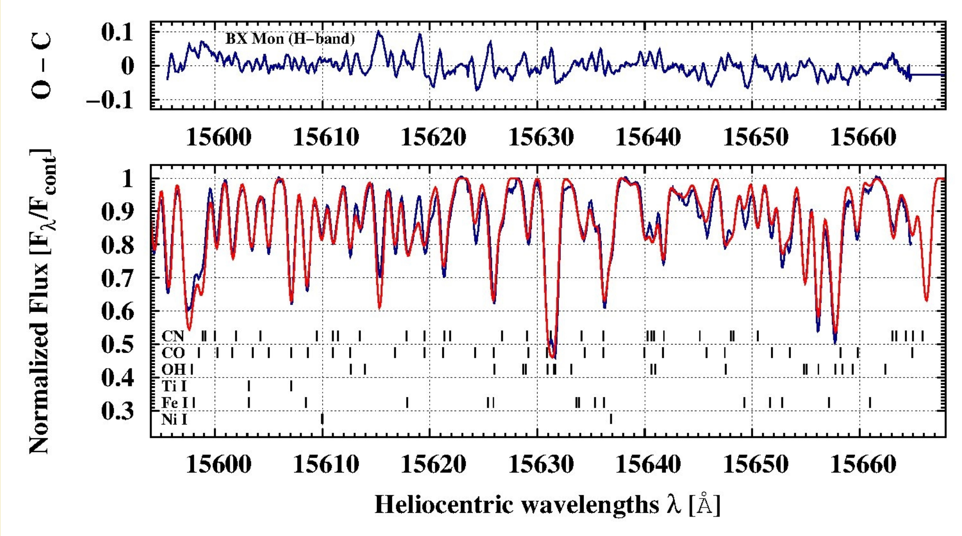


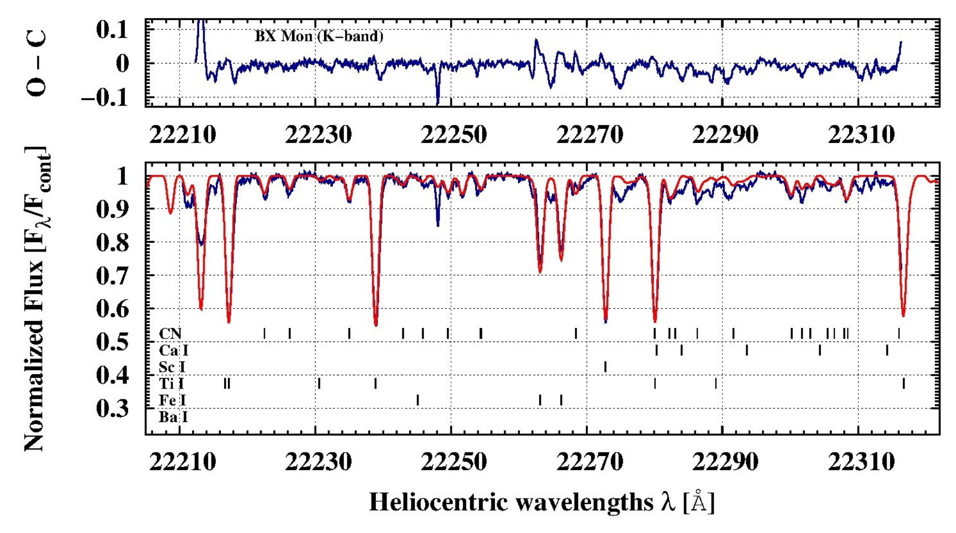


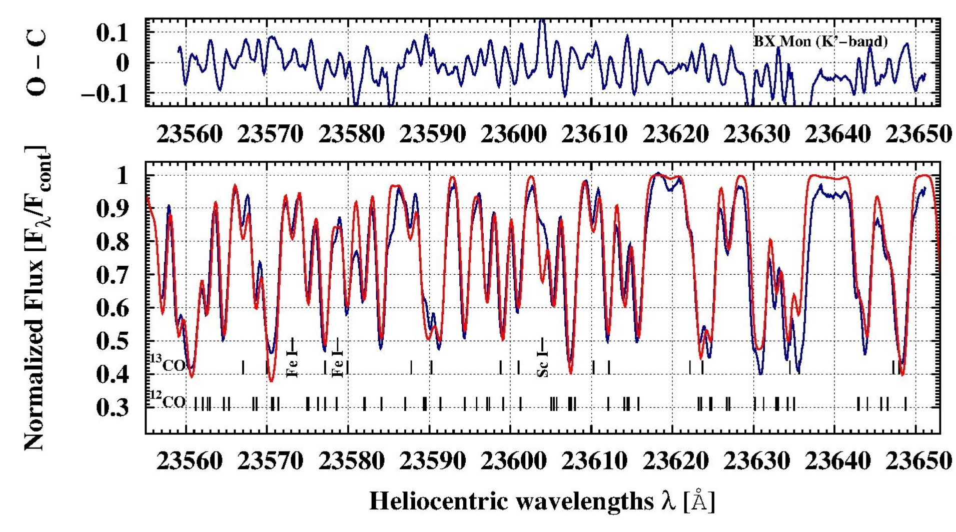


# *Exemplary synthetic fits for BX Mon*

**$T_{\text{eff}}$ = 3400 K,**
**log $g$ = 0.0**

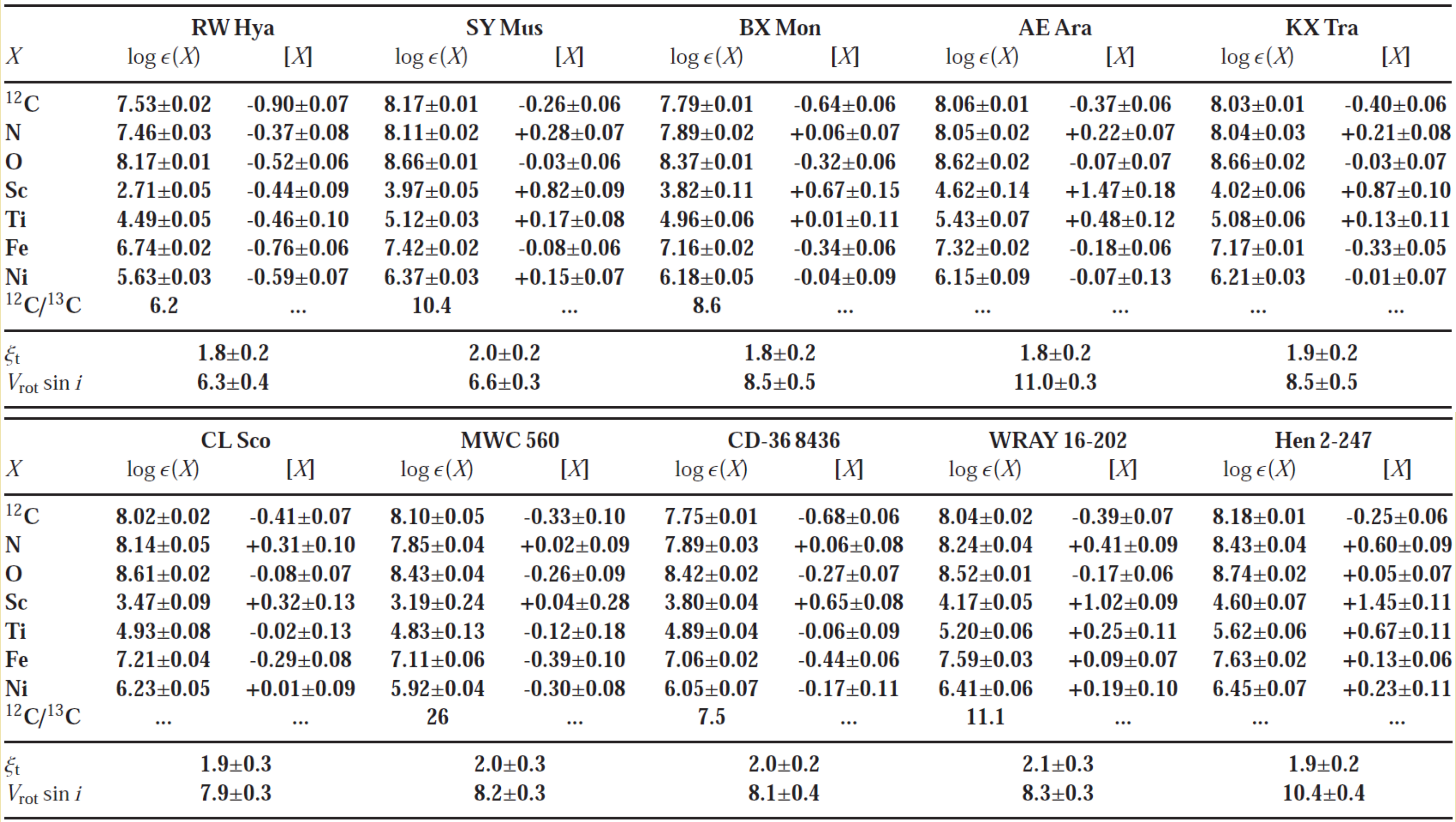






# *Resulted chemical compositions*

**Final chemical abundances $\log \varepsilon(X) = \log(N(X)\,N(H)^{-1}) + 12$, [$X$] relative to Asplund et al. (2009), isotopic ratio $^{12}C/^{13}C$, microturbulences $\xi_t$, and rotational velocities $V_{rot}\sin i$**



| $X$ | RW Hya log $\epsilon(X)$ | RW Hya [$X$] | SY Mus log $\epsilon(X)$ | SY Mus [$X$] | BX Mon log $\epsilon(X)$ | BX Mon [$X$] | AE Ara log $\epsilon(X)$ | AE Ara [$X$] | KX Tra log $\epsilon(X)$ | KX Tra [$X$] |
|---|---|---|---|---|---|---|---|---|---|---|
| $^{12}$C | 7.53±0.02 | -0.90±0.07 | 8.17±0.01 | -0.26±0.06 | 7.79±0.01 | -0.64±0.06 | 8.06±0.01 | -0.37±0.06 | 8.03±0.01 | -0.40±0.06 |
| N | 7.46±0.03 | -0.37±0.08 | 8.11±0.02 | +0.28±0.07 | 7.89±0.02 | +0.06±0.07 | 8.05±0.02 | +0.22±0.07 | 8.04±0.03 | +0.21±0.08 |
| O | 8.17±0.01 | -0.52±0.06 | 8.66±0.01 | -0.03±0.06 | 8.37±0.01 | -0.32±0.06 | 8.62±0.02 | -0.07±0.07 | 8.66±0.02 | -0.03±0.07 |
| Sc | 2.71±0.05 | -0.44±0.09 | 3.97±0.05 | +0.82±0.09 | 3.82±0.11 | +0.67±0.15 | 4.62±0.14 | +1.47±0.18 | 4.02±0.06 | +0.87±0.10 |
| Ti | 4.49±0.05 | -0.46±0.10 | 5.12±0.03 | +0.17±0.08 | 4.96±0.06 | +0.01±0.11 | 5.43±0.07 | +0.48±0.12 | 5.08±0.06 | +0.13±0.11 |
| Fe | 6.74±0.02 | -0.76±0.06 | 7.42±0.02 | -0.08±0.06 | 7.16±0.02 | -0.34±0.06 | 7.32±0.02 | -0.18±0.06 | 7.17±0.01 | -0.33±0.05 |
| Ni | 5.63±0.03 | -0.59±0.07 | 6.37±0.03 | +0.15±0.07 | 6.18±0.05 | -0.04±0.09 | 6.15±0.09 | -0.07±0.13 | 6.21±0.03 | -0.01±0.07 |
| $^{12}$C/$^{13}$C | 6.2 | ... | 10.4 | ... | 8.6 | ... | ... | ... | ... | ... |
| $\xi_t$ | 1.8±0.2 | | 2.0±0.2 | | 1.8±0.2 | | 1.8±0.2 | | 1.9±0.2 | |
| $V_{rot}\sin i$ | 6.3±0.4 | | 6.6±0.3 | | 8.5±0.5 | | 11.0±0.3 | | 8.5±0.5 | |

| $X$ | CL Sco log $\epsilon(X)$ | CL Sco [$X$] | MWC 560 log $\epsilon(X)$ | MWC 560 [$X$] | CD-36 8436 log $\epsilon(X)$ | CD-36 8436 [$X$] | WRAY 16-202 log $\epsilon(X)$ | WRAY 16-202 [$X$] | Hen 2-247 log $\epsilon(X)$ | Hen 2-247 [$X$] |
|---|---|---|---|---|---|---|---|---|---|---|
| $^{12}$C | 8.02±0.02 | -0.41±0.07 | 8.10±0.05 | -0.33±0.10 | 7.75±0.01 | -0.68±0.06 | 8.04±0.02 | -0.39±0.07 | 8.18±0.01 | -0.25±0.06 |
| N | 8.14±0.05 | +0.31±0.10 | 7.85±0.04 | +0.02±0.09 | 7.89±0.03 | +0.06±0.08 | 8.24±0.04 | +0.41±0.09 | 8.43±0.04 | +0.60±0.09 |
| O | 8.61±0.02 | -0.08±0.07 | 8.43±0.04 | -0.26±0.09 | 8.42±0.02 | -0.27±0.07 | 8.52±0.01 | -0.17±0.06 | 8.74±0.02 | +0.05±0.07 |
| Sc | 3.47±0.09 | +0.32±0.13 | 3.19±0.24 | +0.04±0.28 | 3.80±0.04 | +0.65±0.08 | 4.17±0.05 | +1.02±0.09 | 4.60±0.07 | +1.45±0.11 |
| Ti | 4.93±0.08 | -0.02±0.13 | 4.83±0.13 | -0.12±0.18 | 4.89±0.04 | -0.06±0.09 | 5.20±0.06 | +0.25±0.11 | 5.62±0.06 | +0.67±0.11 |
| Fe | 7.21±0.04 | -0.29±0.08 | 7.11±0.06 | -0.39±0.10 | 7.06±0.02 | -0.44±0.06 | 7.59±0.03 | +0.09±0.07 | 7.63±0.02 | +0.13±0.06 |
| Ni | 6.23±0.05 | +0.01±0.09 | 5.92±0.04 | -0.30±0.08 | 6.05±0.07 | -0.17±0.11 | 6.41±0.06 | +0.19±0.10 | 6.45±0.07 | +0.23±0.11 |
| $^{12}$C/$^{13}$C | ... | ... | 26 | ... | 7.5 | ... | 11.1 | ... | ... | ... |
| $\xi_t$ | 1.9±0.3 | | 2.0±0.3 | | 2.0±0.2 | | 2.1±0.3 | | 1.9±0.2 | |
| $V_{rot}\sin i$ | 7.9±0.3 | | 8.2±0.3 | | 8.1±0.4 | | 8.3±0.3 | | 10.4±0.4 | |

**Mostly low $^{12}C/^{13}C$ - giants are after first dredge-up (eg. Keller et al. 2001)**

**$\xi_t$ typical for Galactic M giants (eg. Smith & Lambert 1986, 1990)**

# *Symbiotic stars in galactic populations*

## Abundances and their ratios from our analysis:

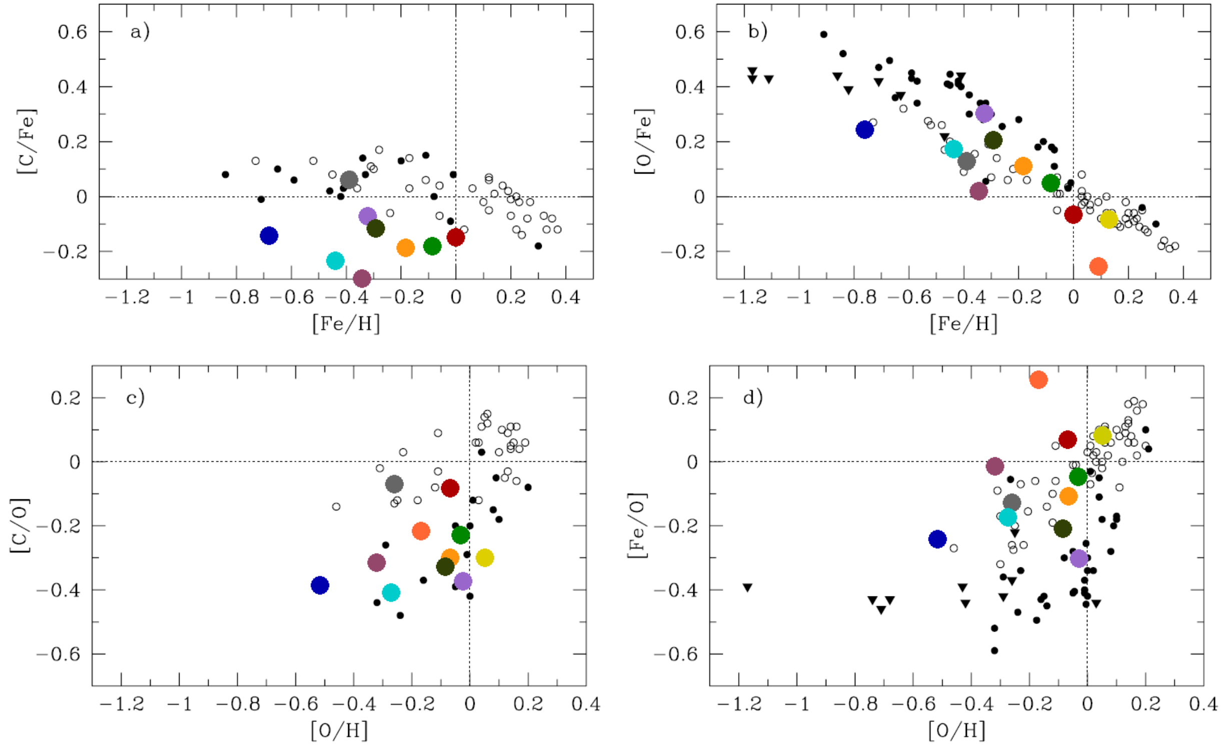
| | $A(^{12}C)$ | $A(^{14}N)$ | $^{12}C/^{14}N$ | [C/N] | [C/O] | [C/Fe] | [O/H] | [O/Fe] | [Fe/H] | [Ti/O] | [Ti/Fe] | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RW Hya** | 7.53 | 7.46 | 1.17 | -0.53 | -0.38 | -0.14 | -0.52 | +0.24 | -0.76 | +0.06 | +0.30 | this work |
| **SY Mus** | 8.17 | 8.11 | 1.15 | -0.54 | -0.23 | -0.18 | -0.03 | +0.05 | -0.08 | +0.20 | +0.25 | this work |
| **BX Mon** | 7.79 | 7.89 | 0.79 | -0.70 | -0.32 | -0.30 | -0.32 | +0.02 | -0.34 | +0.33 | +0.35 | this work |
| **AE Ara** | 8.06 | 8.05 | 1.02 | -0.59 | -0.30 | -0.19 | -0.07 | +0.11 | -0.18 | +0.55 | +0.66 | this work |
| **KX TrA** | 8.03 | 8.04 | 0.98 | -0.61 | -0.37 | -0.07 | -0.03 | +0.30 | -0.33 | +0.16 | +0.46 | this work |
| **CL Sco** | 8.02 | 8.14 | 0.76 | -0.72 | -0.33 | -0.12 | -0.08 | +0.21 | -0.29 | +0.06 | +0.27 | this work |
| **MWC 560** | 8.10 | 7.85 | 1.78 | -0.35 | -0.07 | +0.06 | -0.26 | +0.13 | -0.39 | +0.14 | +0.27 | this work |
| **CD-36 8436** | 7.75 | 7.89 | 0.72 | -0.74 | -0.41 | -0.24 | -0.27 | +0.17 | -0.44 | +0.21 | +0.38 | this work |
| **WRAY 16-202** | 8.04 | 8.24 | 0.63 | -0.80 | -0.22 | -0.48 | -0.17 | -0.26 | +0.09 | +0.42 | +0.16 | this work |
| **Hen 2-247** | 8.18 | 8.43 | 0.56 | -0.85 | -0.30 | -0.38 | +0.05 | -0.08 | +0.13 | +0.62 | +0.54 | this work |
| **CH Cyg** | 8.37 | 8.08 | 1.95 | -0.31 | -0.08 | -0.15 | -0.07 | -0.07 | +0.00 | +0.29 | +0.22 | Schmidt et al. (2006) |

**a) and b)**

**Carbon and Oxygen relative to Iron**

**c) and d)**

**Carbon and Iron relative to Oxygen**



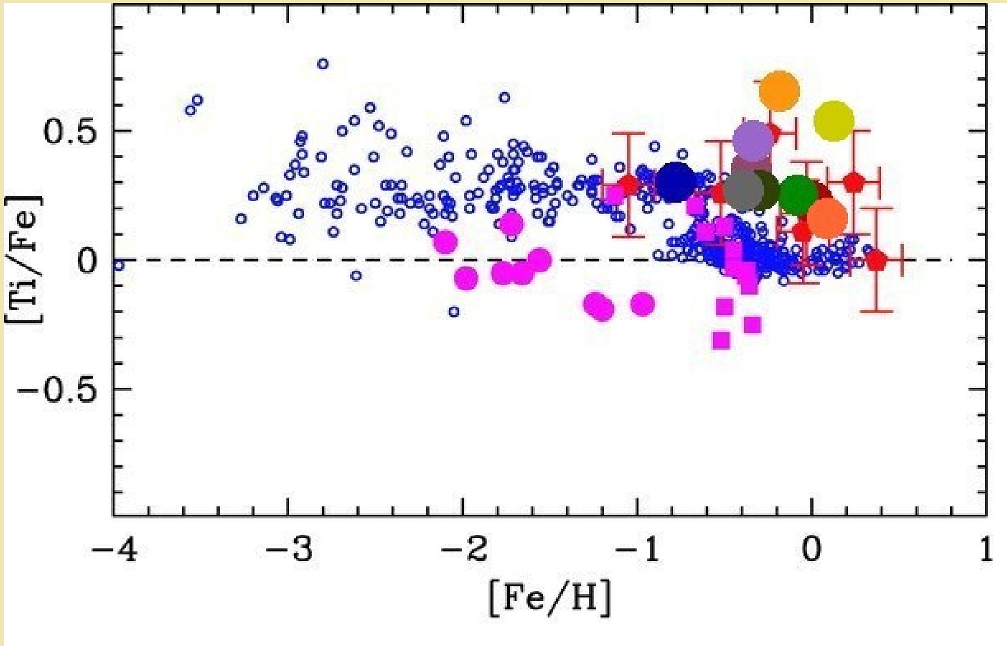
**Bensby & Feltzing (2006) [Fig. 11]**

# *Symbiotic stars in galactic populations*

## Relations [Ti/Fe]–[Fe/H], $^{14}$N/$^{12}$C

**Cunha & Smith, 2006, ApJ, 651, 491**

### Tithanium relative to Iron



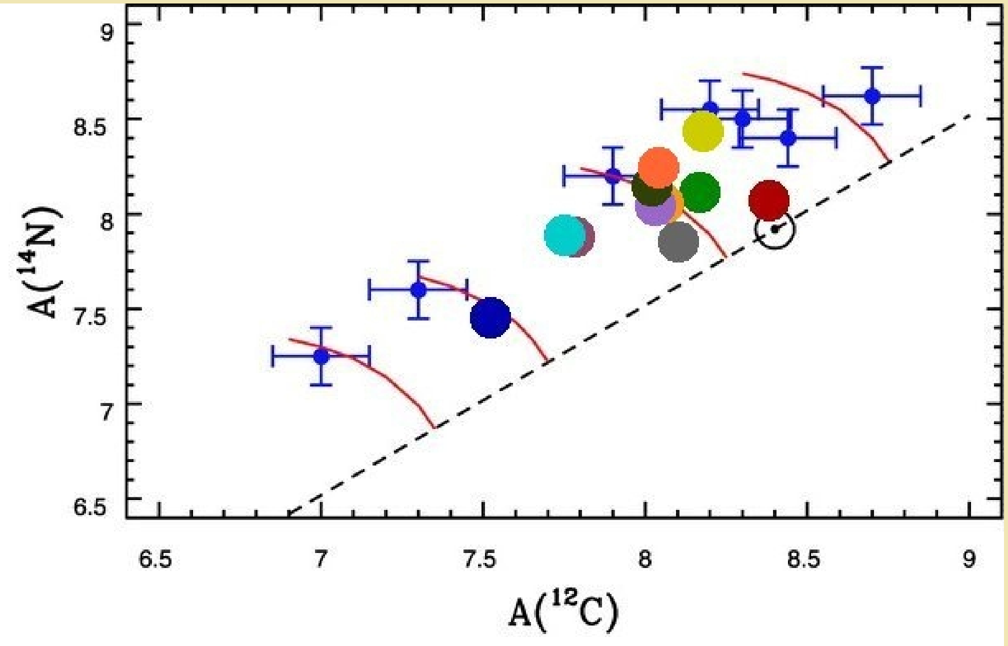
**Open, blue circles –** disc stars

**Red pentagons with errorbars –** Galactic bulge

**Magenta squares –** LMC

**Magenta circles –** Sculptor

### Evidence of the first dredge-up in the bulge red giants



**Filled circles with error-bars –** bulge red giant that fall in the $^{14}$N-rich region

**Solid curves –** lines of constant $^{12}$C+$^{14}$N

**Dashed line –** the scaled solar line

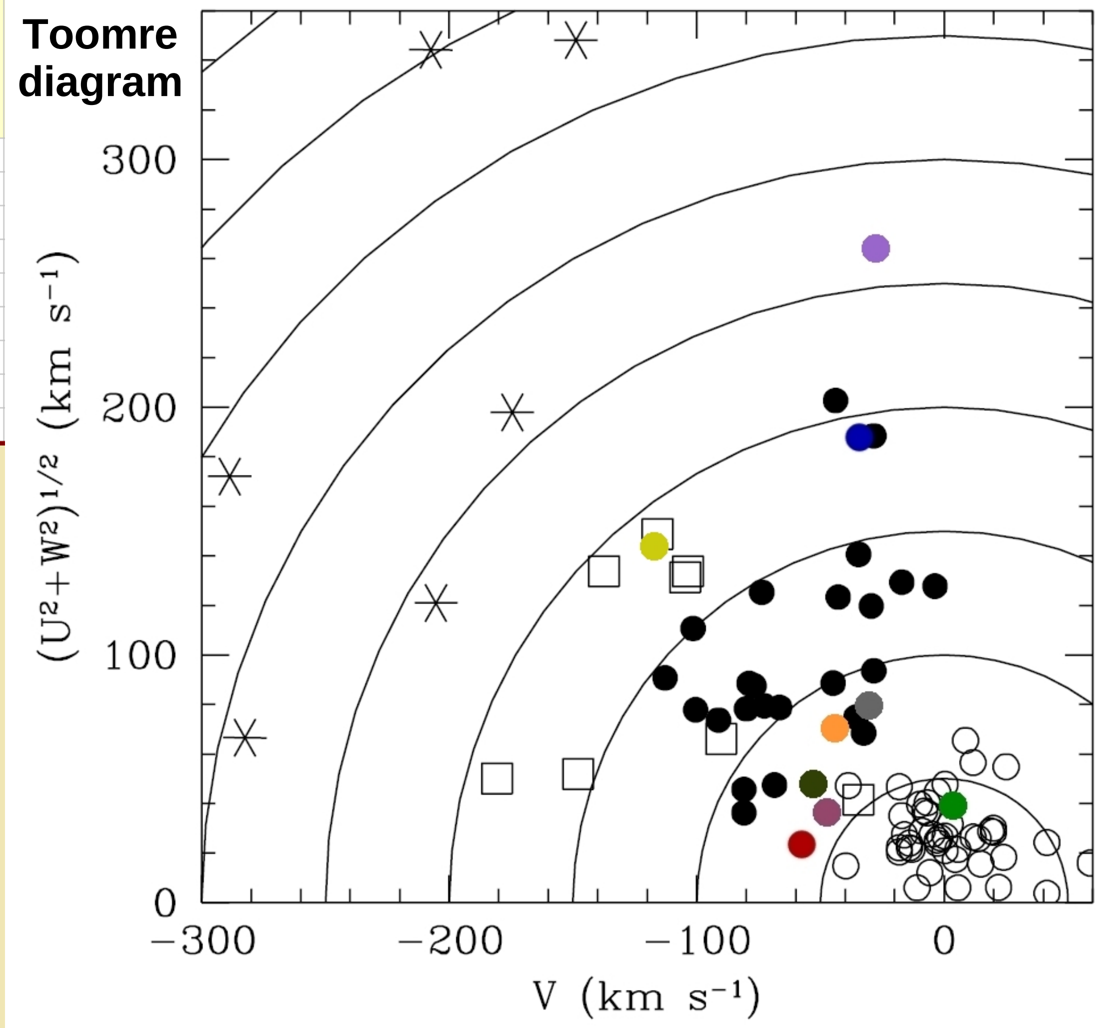
# *Symbiotic stars in galactic populations*

## Velocities in the Galaxy:

| | Galactic coordinates [degrees] | | Distance [pc] | References for distance | Proper motion [mas/yr] | | Systemic velocity [km/s] | Galactic velocities (U,V,W) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | [km/s] | [km/s] | [km/s] |
| | l | b | d | | $\mu_l$ cos b | $\mu_b$ | $\gamma$ | U | V | W |
| RW Hya | 315.0 | 36.5 | 1700 | this work | -15.3 | 17.6 | 12.4 | -142.2 | -34.5 | 121.6 |
| SY Mus | 294.8 | 3.8 | 1600 | this work | 4.8 | -0.7 | 12.9 | 39.2 | 3.4 | -4.2 |
| BX Mon | 220.0 | 5.9 | 2500 | this work | 2.9 | -3.3 | 29.1 | -3.8 | -47.4 | -36.2 |
| AE Ara | 344.0 | -8.7 | 4500 | this work | -2.4 | -3.0 | -10.7 | -35.1 | -44.1 | -60.9 |
| KX TrA | 326.4 | -10.9 | 3000 | this work | -9.6 | -13.1 | -125.9 | -211.5 | -26.2 | -159.6 |
| CL Sco | 352.3 | 8.1 | 3000 | Fekel et al. (2007) | -4.1 | -0.6 | -37.9 | -45.6 | -53.3 | -13.5 |
| MWC 560 | 223.8 | 4.0 | 2500 | Schmid et al. (2001) | 1.1 | 6.5 | 37.0 | -14.2 | -31.0 | 78.9 |
| Hen2-247 | 7.0 | 7.4 | 4700 | Fekel et al. (2008) | -5.7 | 4.6 | 89.5 | 90.5 | -116.9 | 112.4 |
| CH Cyg | 81.9 | 15.6 | 243 | Van Leeuwen (2007) | -21.1 | -1.6 | -57.7 | 16.2 | -58.0 | -17.3 |

# *Symbiotic stars in galactic populations*

## Velocities in the Galaxy:



**Toomre diagram**

| | stemic<br>elocity<br>km/s] | Galactic velocities (U,V,W) | | |
|---|---|---|---|---|
| | | [km/s] | [km/s] | [km/s] |
| | γ | U | V | W |
| **RW Hya** | 12.4 | -142.2 | -34.5 | 121.6 |
| **SY Mus** | 12.9 | 39.2 | 3.4 | -4.2 |
| **BX Mon** | 29.1 | -3.8 | -47.4 | -36.2 |
| **AE Ara** | -10.7 | -35.1 | -44.1 | -60.9 |
| **KX TrA** | 125.9 | -211.5 | -26.2 | -159.6 |
| **CL Sco** | -37.9 | -45.6 | -53.3 | -13.5 |
| **MWC 560** | 37.0 | -14.2 | -31.0 | 78.9 |
| **Hen2-247** | 89.5 | 90.5 | -116.9 | 112.4 |
| **CH Cyg** | -57.7 | 16.2 | -58.0 | -17.3 |

**Open circles – thin-disc stars**

**Filled circles and open squares – thick-disc stars**

**Asterisks – halo stars**

**Feltzing et al., 2003, A&A, 397, 1**

**Thank you**