Carbon stars in the Local Group

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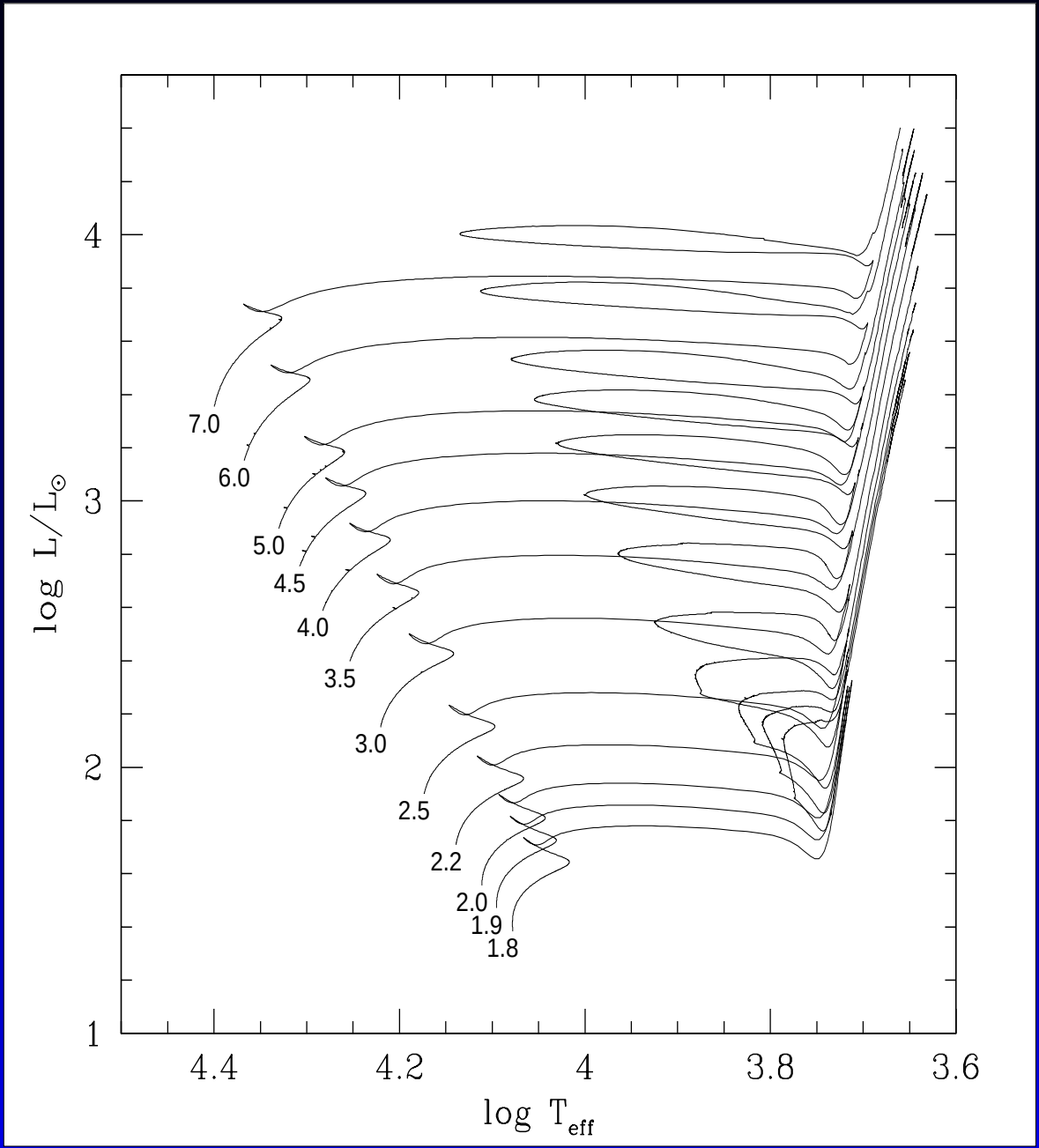
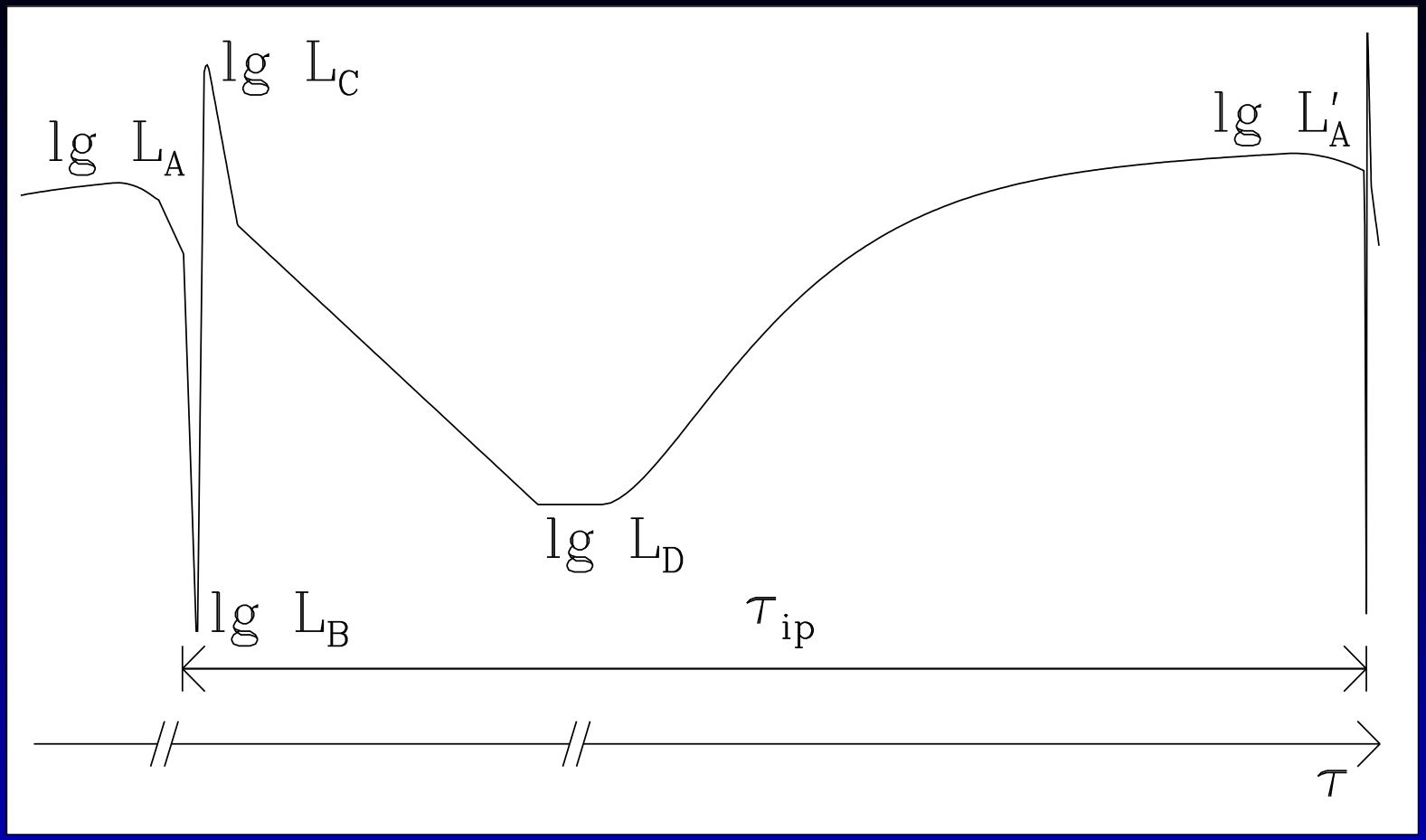
Overview

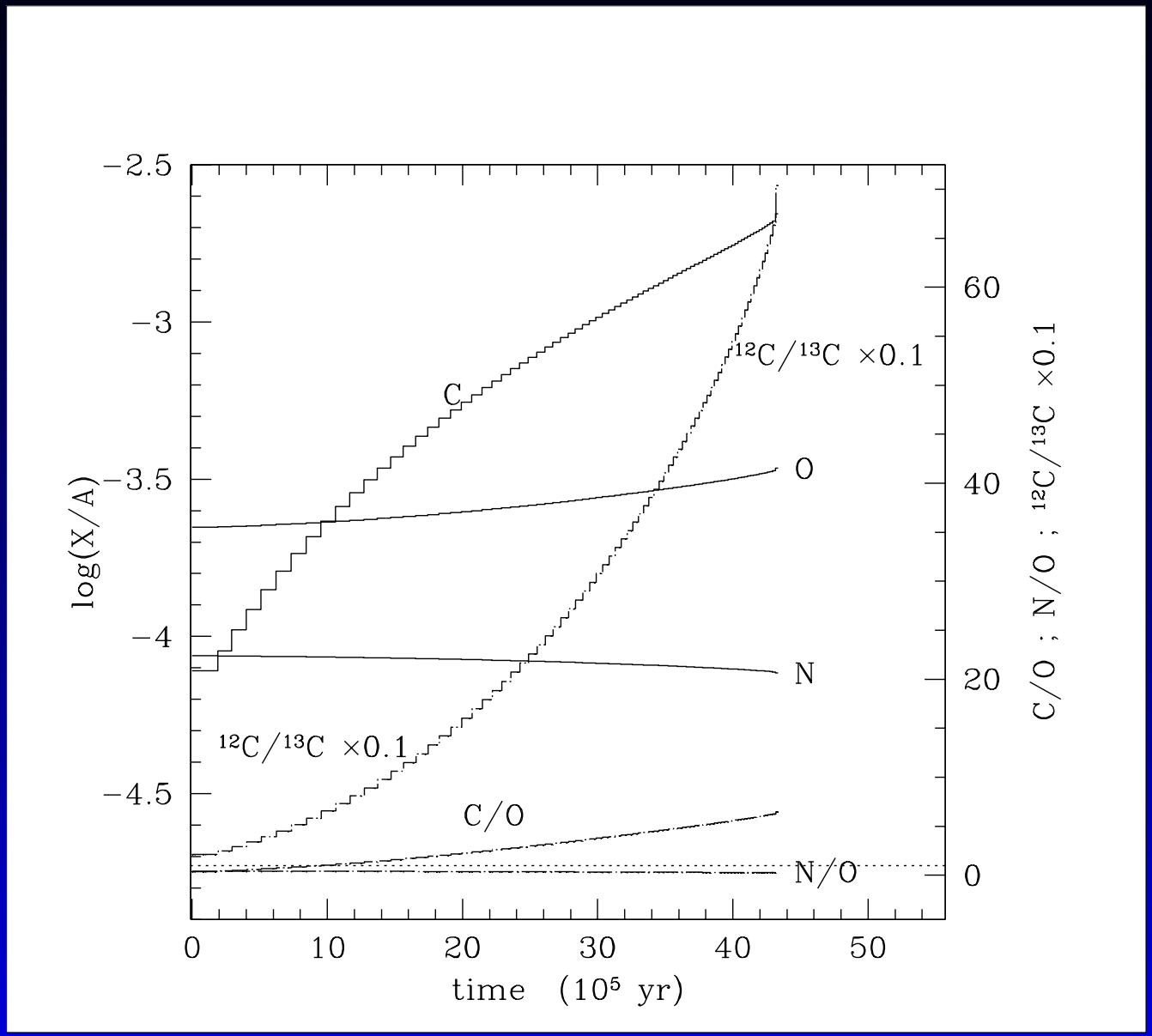
- Late-type stars
- How to find them?
- Inventory / Status report



Evolutionary tracks



Thermal pulses or Helium shell flashes



Time evolution of some species

Late-type stars

- Carbon stars (C/O $\geq$ 1)

  N-type

  “infrared carbon stars”

  R-type

  CH-type

  carbon dwarfs

- S-stars (0.95 $\lesssim$ C/O < 1)

  “intrinsic”

  “extrinsic”

Late-type stars

- Oxygen-rich stars (C/O $\lesssim$ 0.95)

  Giants of spectral type M, MS

  OH/IR stars

  Barium stars

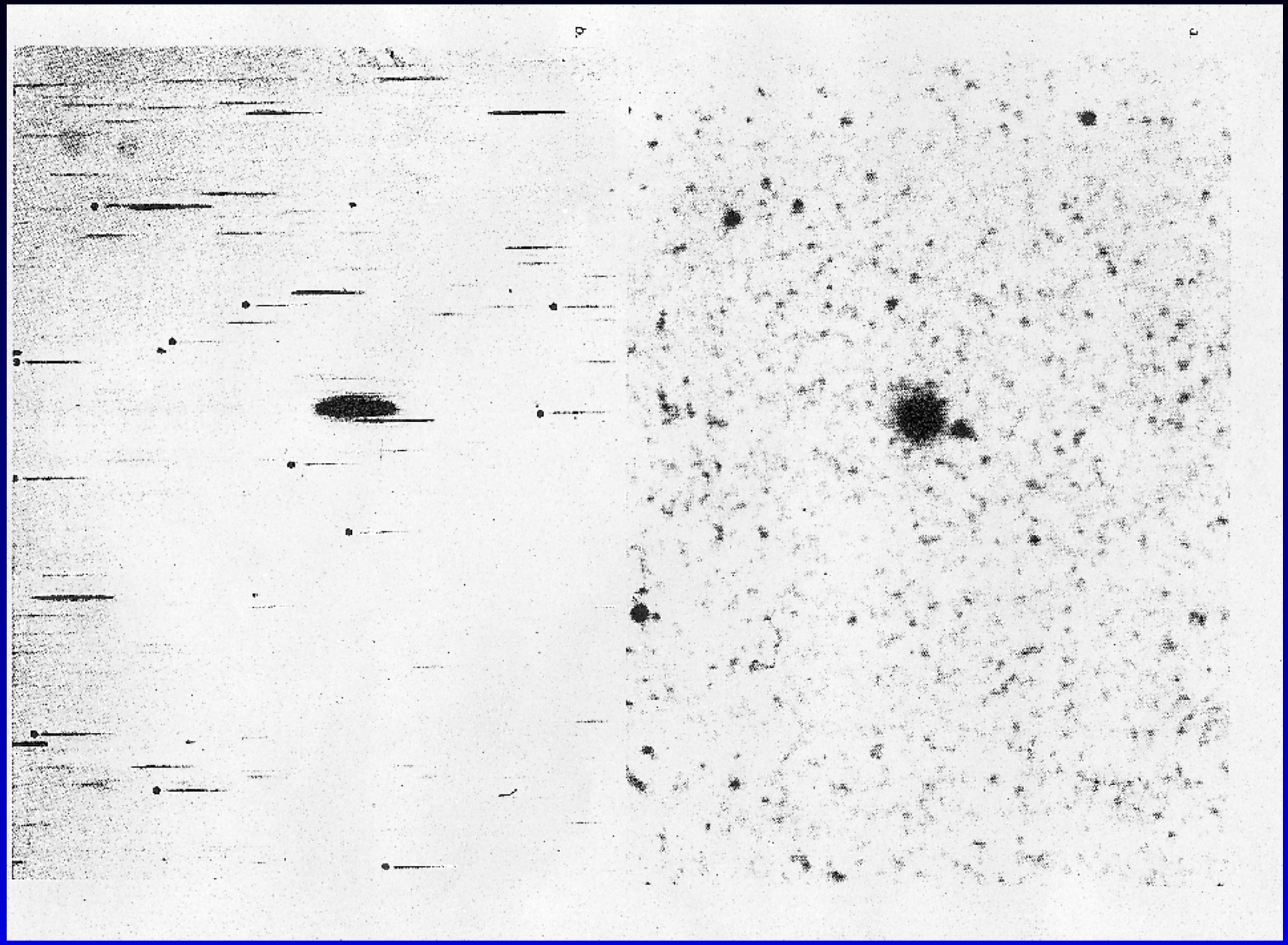
In general:
stars which show Tc are presently on the AGB

How to identify late-type stars ?

- Follow-up spectroscopy on red stars
- GRENS, GRISMS

Azzopardi and Westerlund

CN bands near 8000 Å
C_2 bands 4737, 5165 Å
disadvantage: crowding, sensitivity



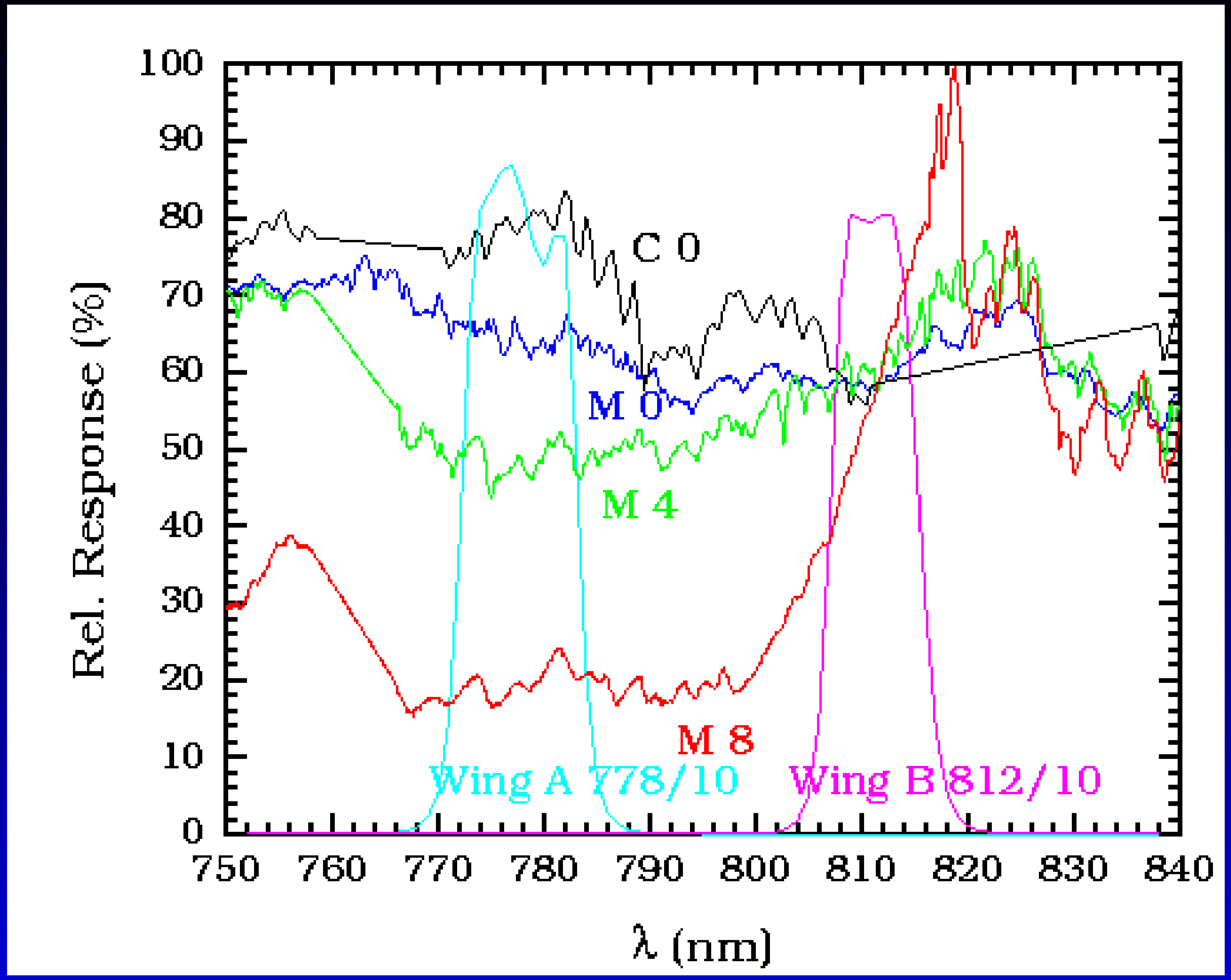
Westerlund 1978

How to identify late-type stars ?

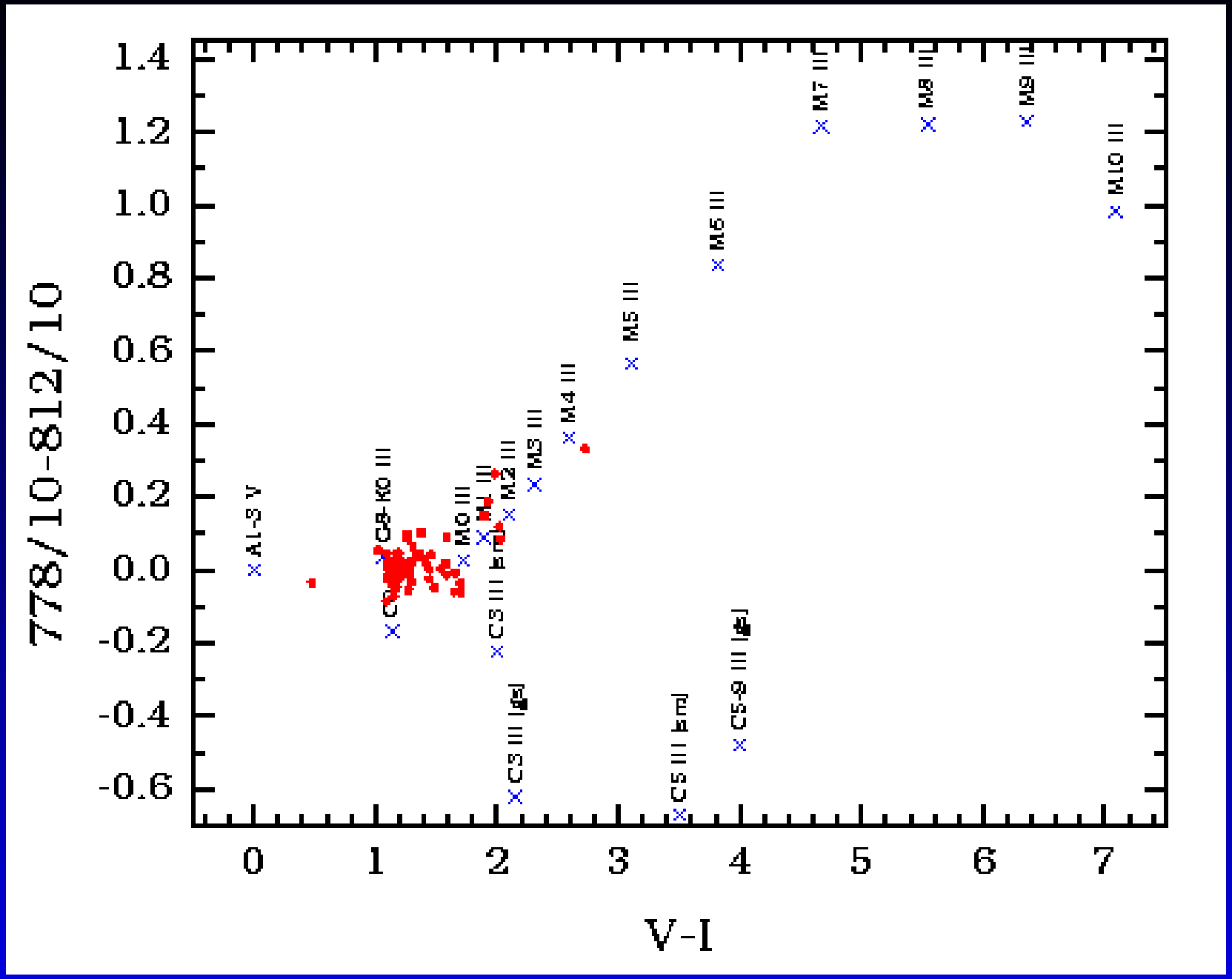
- Narrow-band filters

  Richer et al. (1984); Aaronson et al. (1984)

  broad-band V,R,I + narrow-band 78, 81



Kerschbaum et al. 1999



Kerschbaum et al. 1999

Other tracers

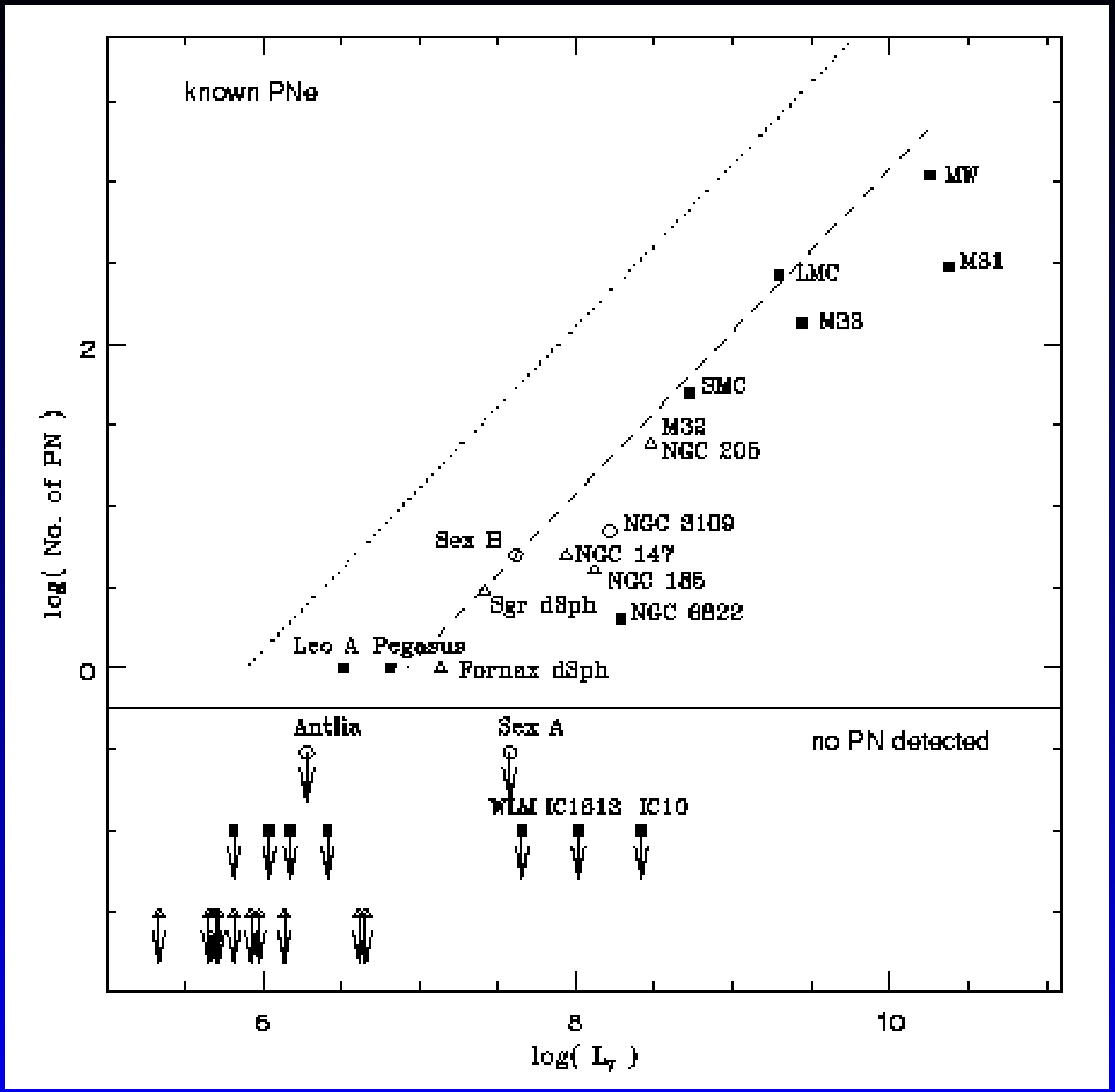
- Planetary Nebulae
- Long-Period variables

Mira PL-relation: distance indicator

Period distribution is a tracer of population

Whitelock et al. (1999): first confirmed Mira, in SagDSph

Bersier & Wood (2002): 85 LPV candidates in Fornax



Magrini et al. 2002

Other tracers

- Planetary Nebulae
- Long-Period variables

Mira PL-relation: distance indicator

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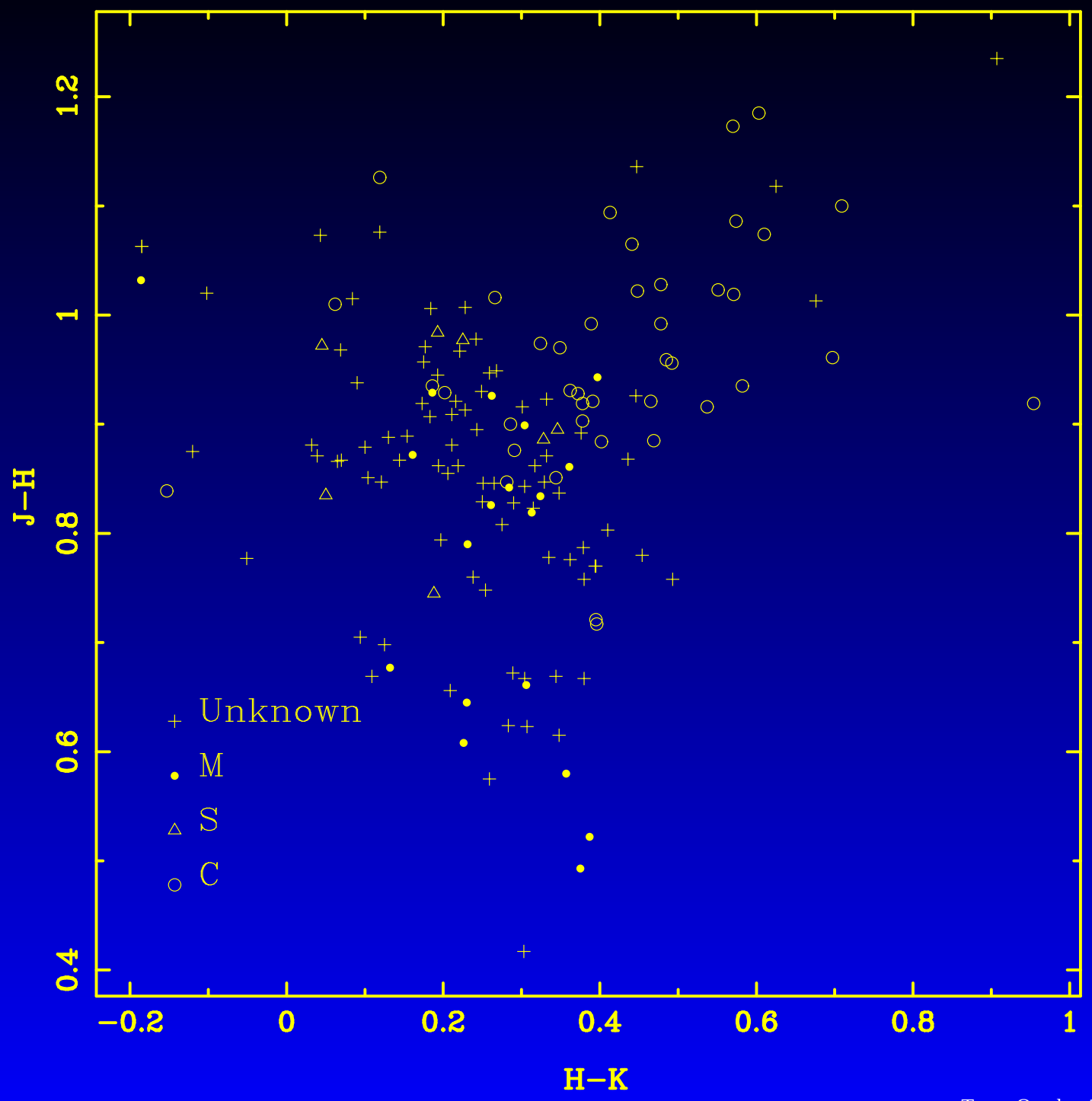
Some new results

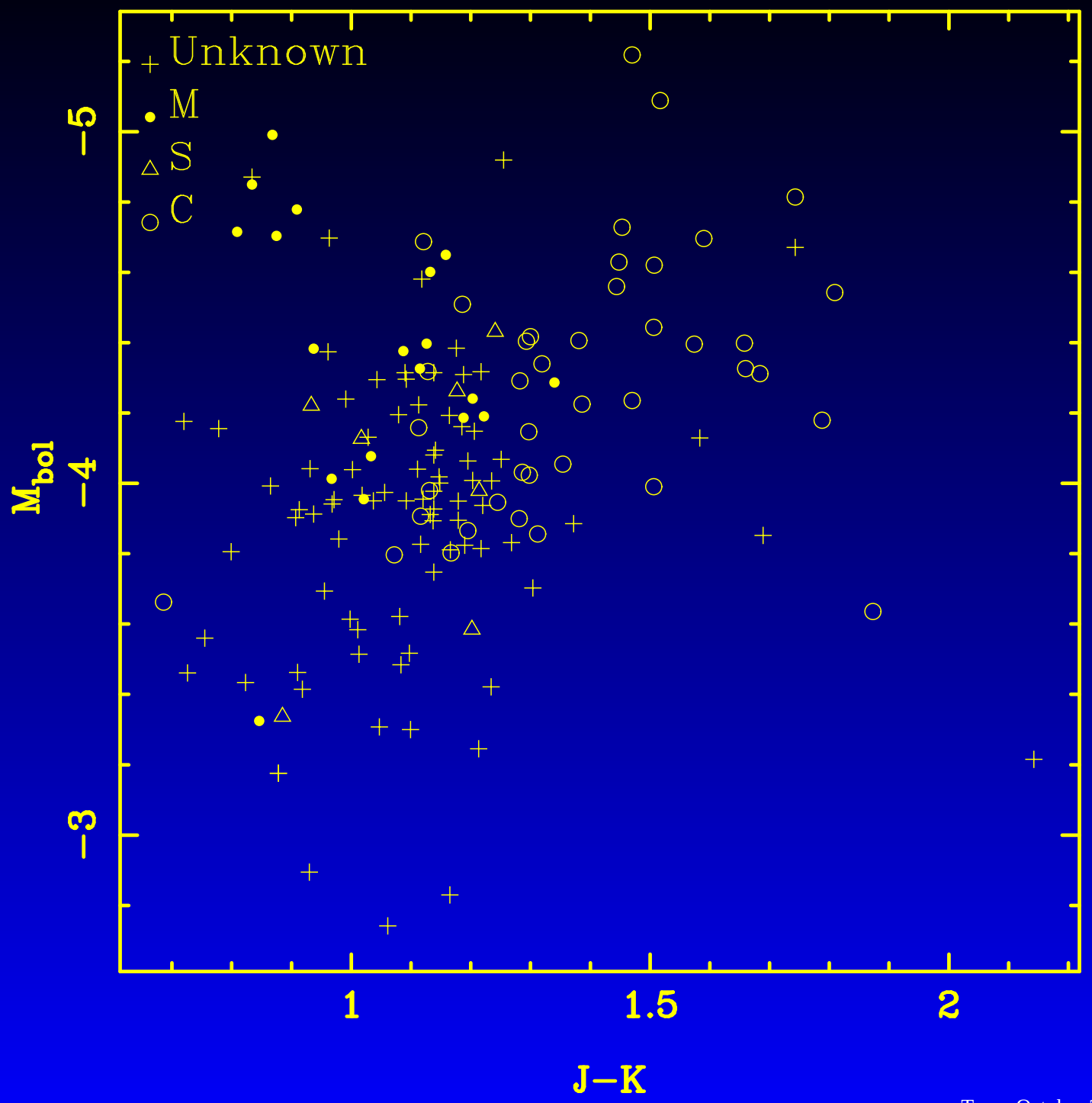
New surveys

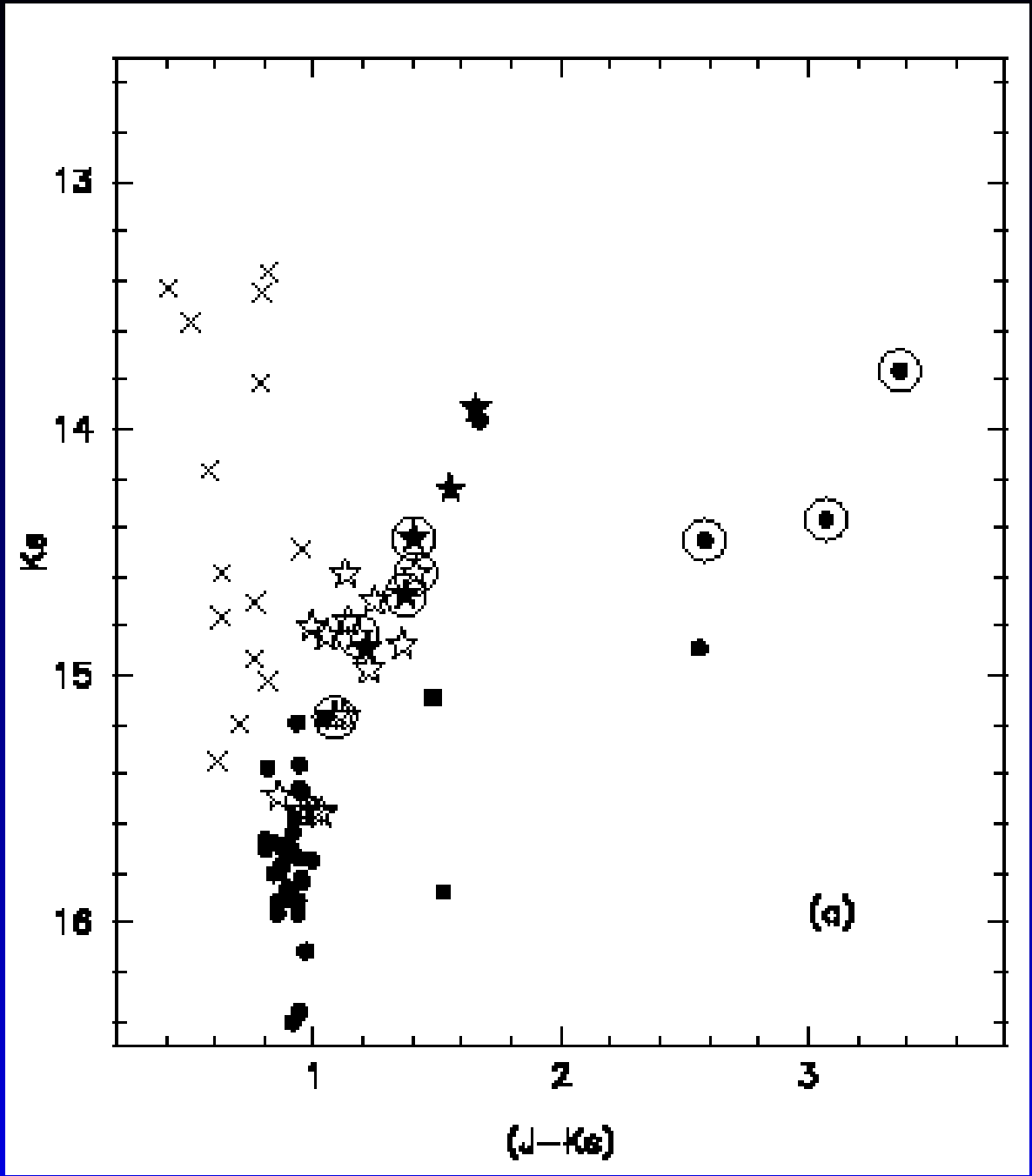
- Demers/Battinelli: SagDIG, Leo I, NGC 6822, Pegasus, Aquarius, Tucana, IC1613
- Nowotny et al.: M 31
- Kontizas et al.: LMC (7760 stars)

2MASS

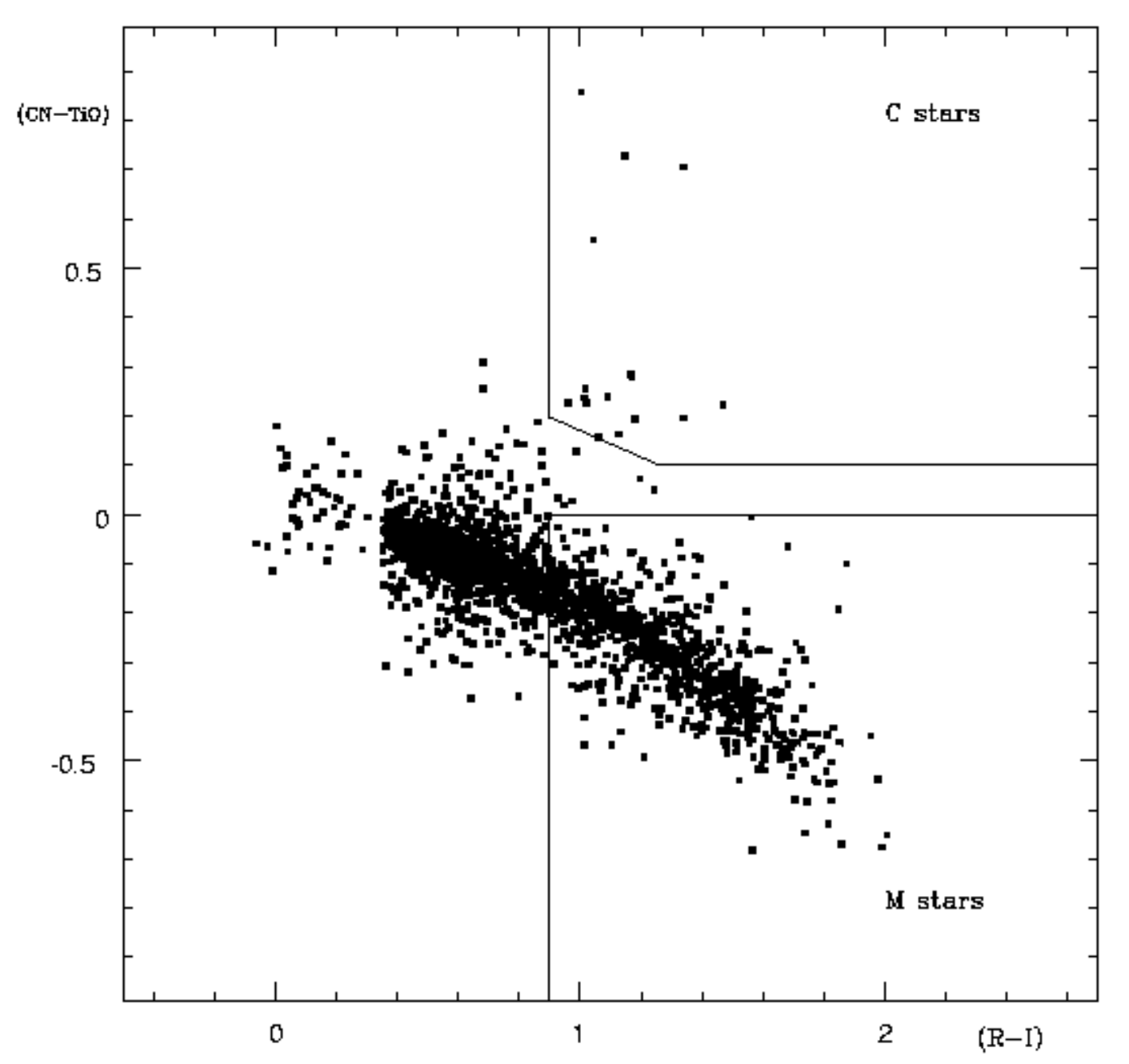
- Demers et al. (2002) on Fornax and LMC
- Correlated known carbon stars in Sculptor, Sagittarius DSph, Leo II, Ursa Minor, red stars in Fornax from Stetson et al. (1998)


J−H
H−K
0.4
0.6
0.8
1
1.2
−0.2
0
0.2
0.4
0.6
0.8
1
Unknown
M
S
C

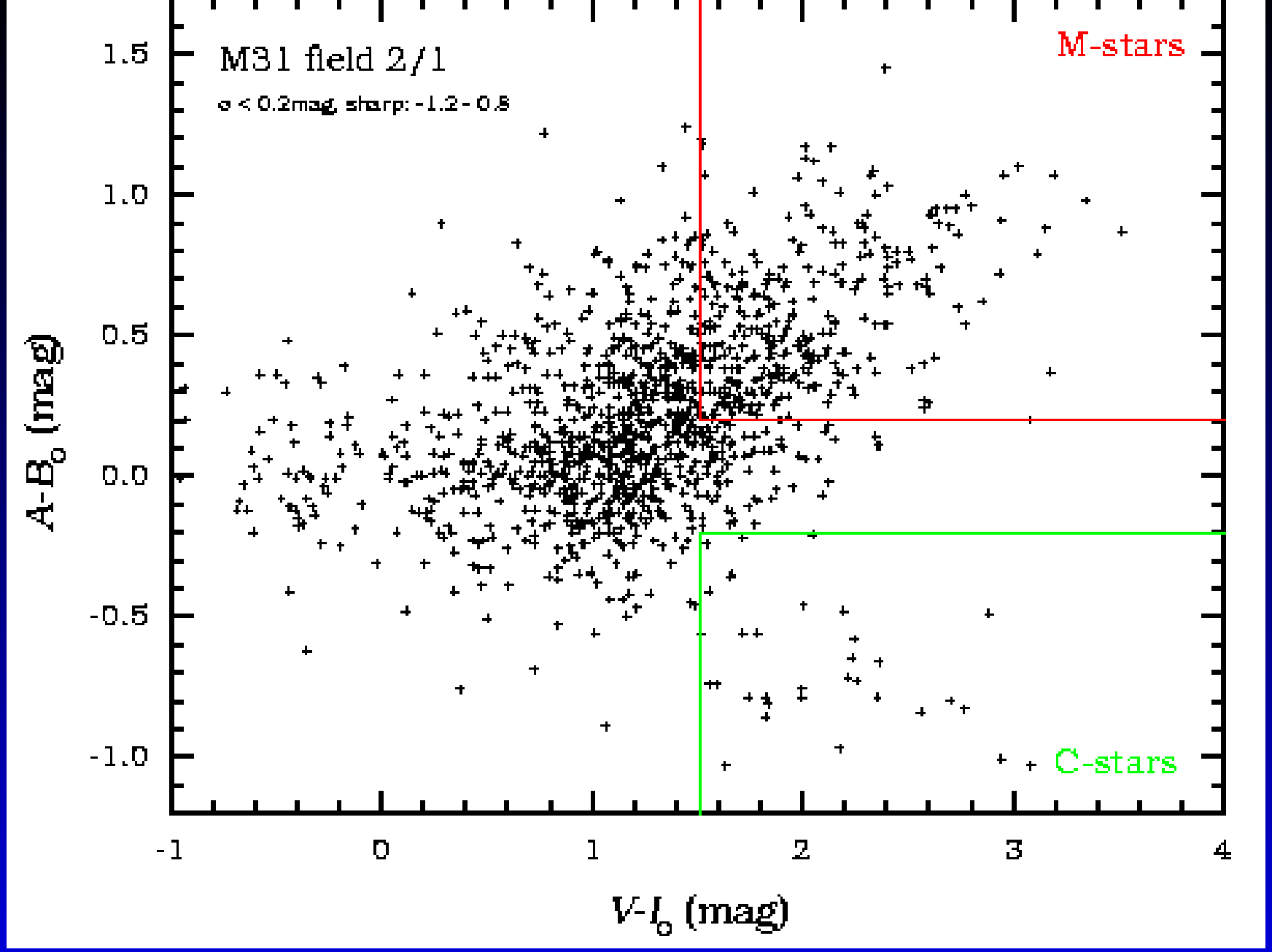

Unknown
M
S
C
−5
−4
−3
M_{bol}
1
1.5
2
J−K



Menzies et al. 2002 on Leo I



Demers et al. 2002 on Leo I

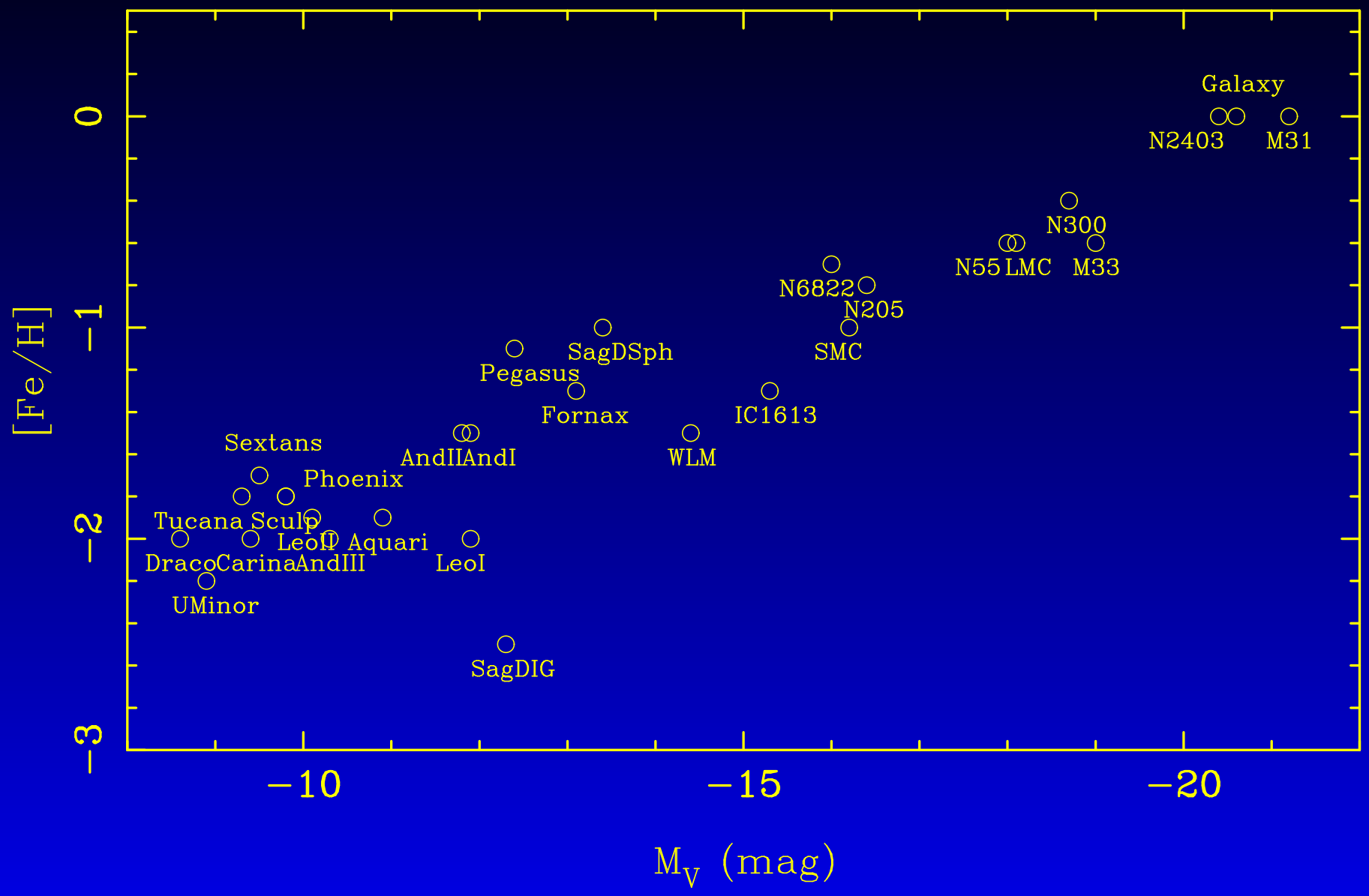


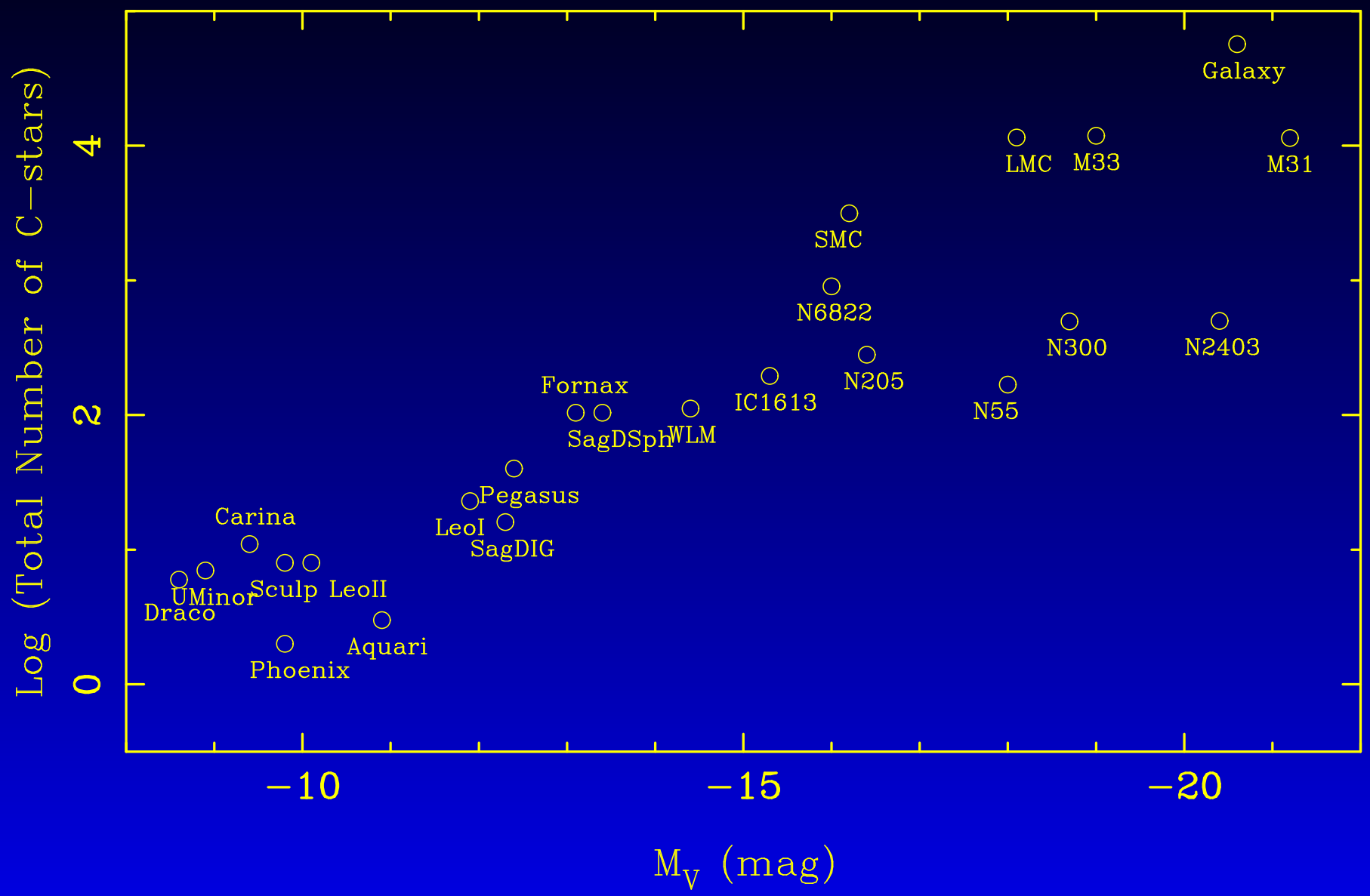
Nowotny et al. 2001

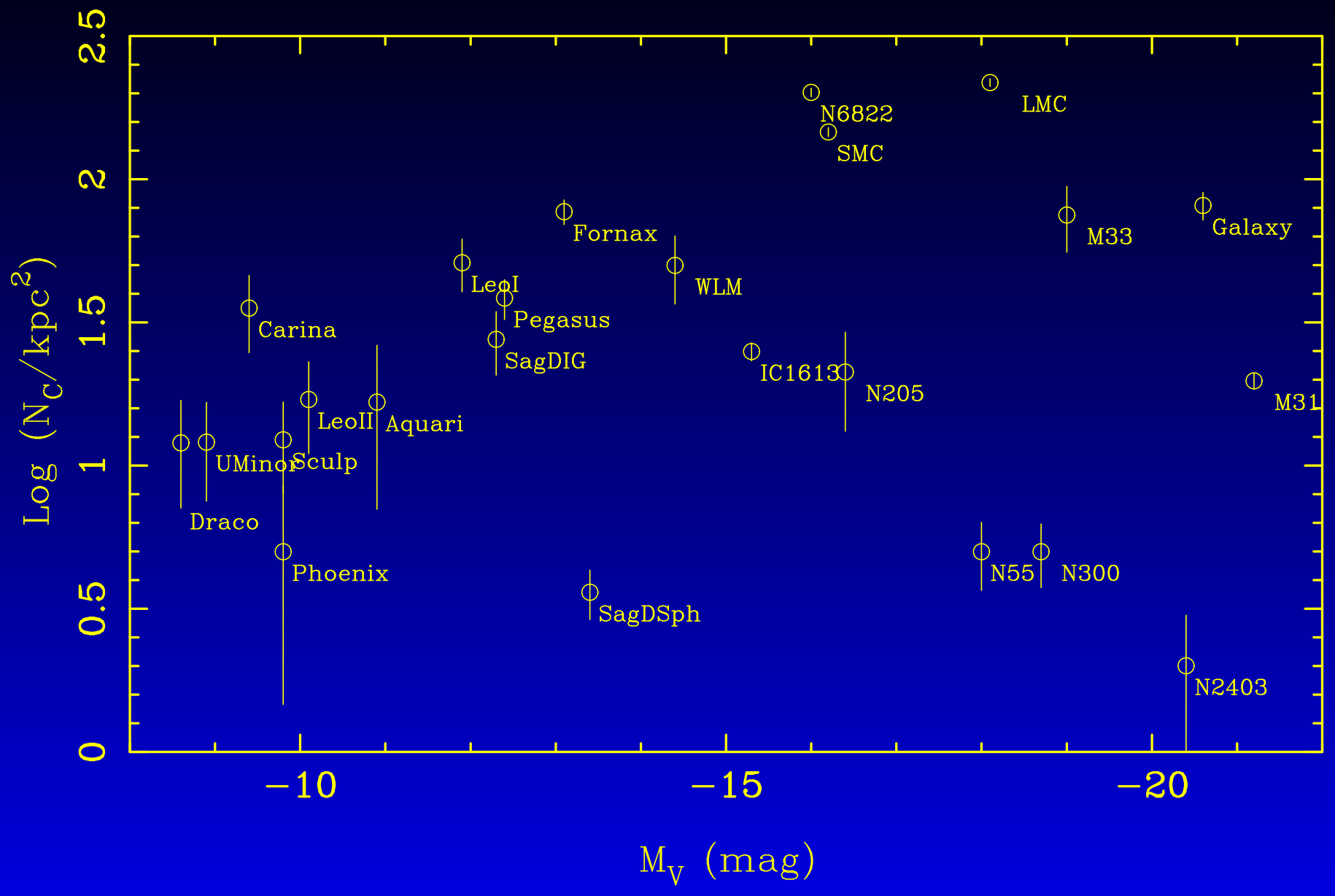
Name	D (kpc)	M_V (mag)	[Fe/H]	N_C	Area (kpc^2)	N_M
M31	770	–21.2	0.0	243	12.3	789 (5+)
Galaxy		–20.6	0.0	81	1.00	C/M $\approx$ 0.2
M33	840	–19.0	–0.6	15	0.20	5 (5+), 60 (0+)
LMC	50	–18.1	–0.6	1045	4.8	1300 (5+)
				7750	220.	
NGC 205	815	–16.4	–0.8	7	0.33	4 (5+), 17 (0+)
SMC	63	–16.2	–1.0	789	5.4	180 (5+)
				1707	12.2	
NGC 6822	490	–16.0	–0.7	904	4.5	941 (0+)
IC 1613	720	–15.3	–1.3	195	7.8	35 (5+), 300 (0+)
WLM	930	–14.4	–1.5	14	0.28	0 (5+), 6 (0+)

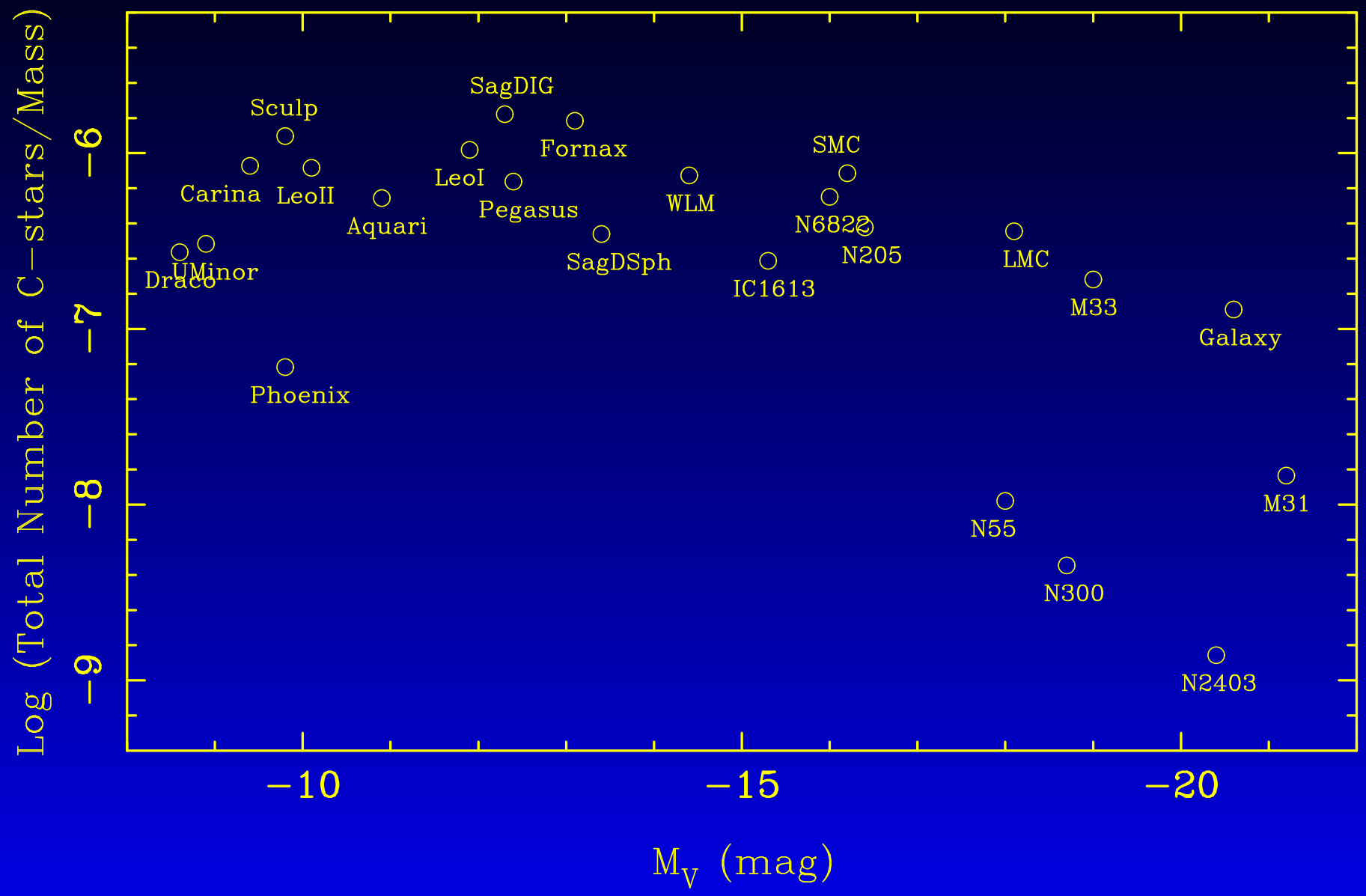
Name	D (kpc)	M_V (mag)	[Fe/H]	N_C	Area (kpc^2)	N_M
SagDSph	24	–13.4	–1.0	26	7.2	
Fornax	138	–13.1	–1.3	104	1.35	4 (5+), 25 (2+)
Pegasus	955	–12.4	–1.1	40	1.04	77 (0+)
SagDIG	1060	–12.3	–2.5	16	0.58	1 (0+)
Leo I	250	–11.9	–2.0	23	0.45	1 (5+), 15 (0+)
And I	790	–11.9	–1.5	0		
And II	680	–11.8	–1.5	8		1 (0+)
Aquarius	950	–10.9	–1.9	3	0.18	1 (0+)
And III	760	–10.3	–2.0	0		
Leo II	205	–10.1	–1.9	8	0.47	
Sculptor	79	–9.8	–1.8	8	0.65	40 (2+), 0 (5+)

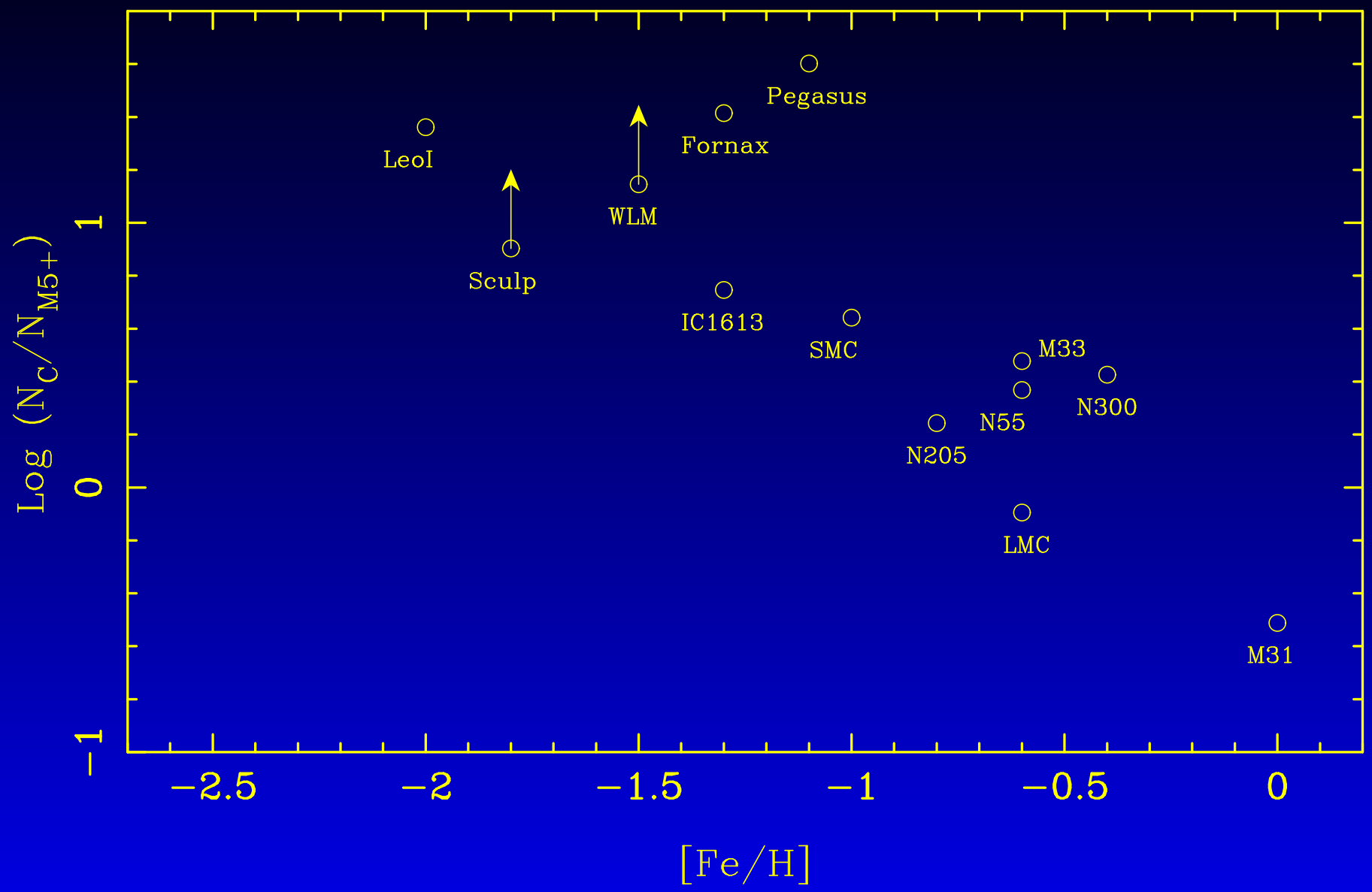
Name	D (kpc)	M_V (mag)	[Fe/H]	N_C	Area (kpc^2)	N_M
Phoenix	400	–9.8	–1.8	2	0.40	
Sextans	86	–9.5	–1.7	(0)		
Carina	100	–9.4	–2.0	11	0.31	
Tucana	870	–9.3	–1.8	0	0.22	
Ursa Minor	69	–8.9	–2.2	7	0.58	
Draco	82	–8.6	–2.0	6	0.50	
NGC 2403	3390	–20.4	0.0	4	2.0	7 (0+)
NGC 300	2170	–18.7	–0.4	16	3.2	23 (0+), 6 (5+)
NGC 55	1480	–18.0	–0.6	14	2.8	6 (5+)

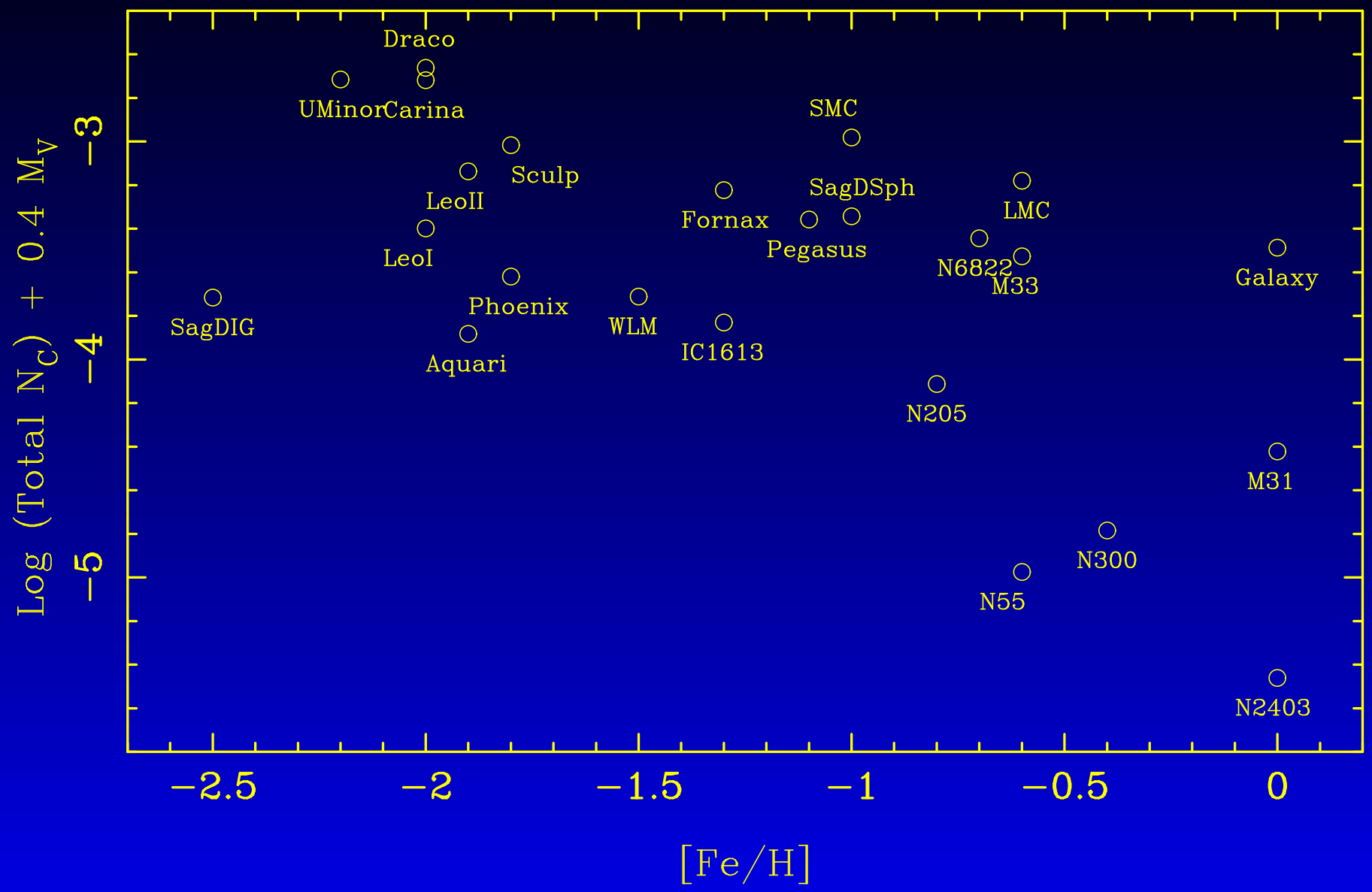

Galaxy
N2403
M31
N300
N55
LMC
M33
N6822
N205
SMC
SagDSph
Pegasus
Fornax
IC1613
WLM
Sextans
AndII
AndI
Phoenix
Tucana
Sculp
LeoII
Aquari
Draco
Carina
AndIII
LeoI
UMinor
SagDIG
0
−1
−2
−3
[Fe/H]
−10
−15
−20
M_V (mag)


Log (Total Number of C−stars)
0
2
4
−10
−15
−20
M_V (mag)
Galaxy
LMC
M33
M31
SMC
N6822
N300
N2403
N205
IC1613
N55
Fornax
SagDSph
WLM
Pegasus
LeoI
SagDIG
Carina
UMinor
Draco
Sculp
LeoII
Aquari
Phoenix


Log (N_C/kpc^2)
2.5
2
1.5
1
0.5
0
−10
−15
−20
M_V (mag)
N6822
LMC
SMC
Fornax
M33
Galaxy
LeoI
WLM
Pegasus
Carina
SagDIG
IC1613
N205
M31
LeoII
Aquari
UMinor
Sculp
Draco
Phoenix
N55
N300
SagDSph
N2403

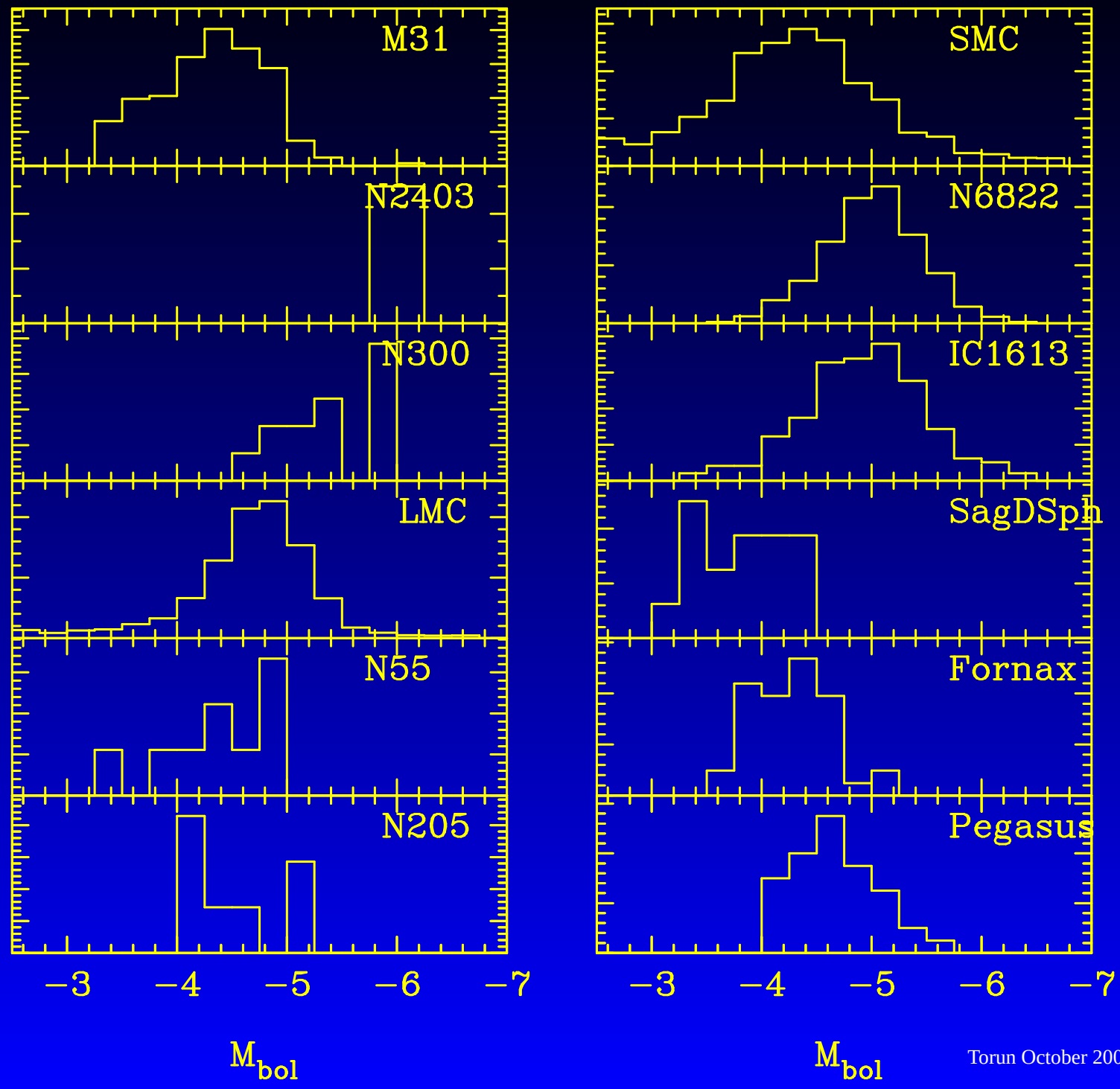

Log (Total Number of C−stars/Mass)
−6
−7
−8
−9
−10
−15
−20
M_V (mag)
SagDIG
Sculp
Fornax
SMC
LeoI
Carina
LeoII
Pegasus
WLM
Aquari
N6822
N205
SagDSph
LMC
UMinor
Draco
IC1613
M33
Galaxy
Phoenix
M31
N55
N300
N2403

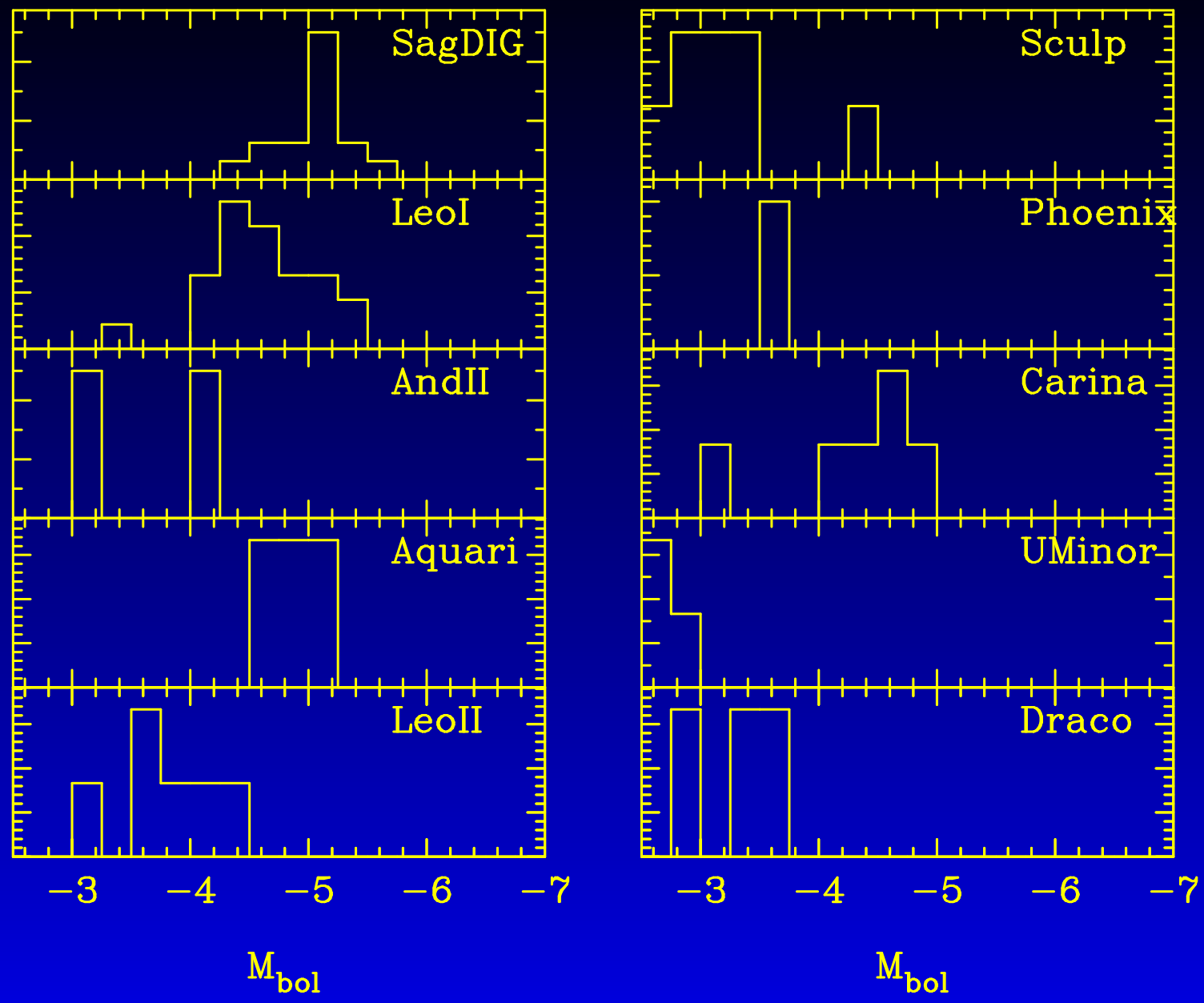

Pegasus
Fornax
LeoI
WLM
Sculp
IC1613
SMC
M33
N300
N55
N205
LMC
M31
Log (N_C/N_M5+)
[Fe/H]
−2.5
−2
−1.5
−1
−0.5
0
1
0
−1

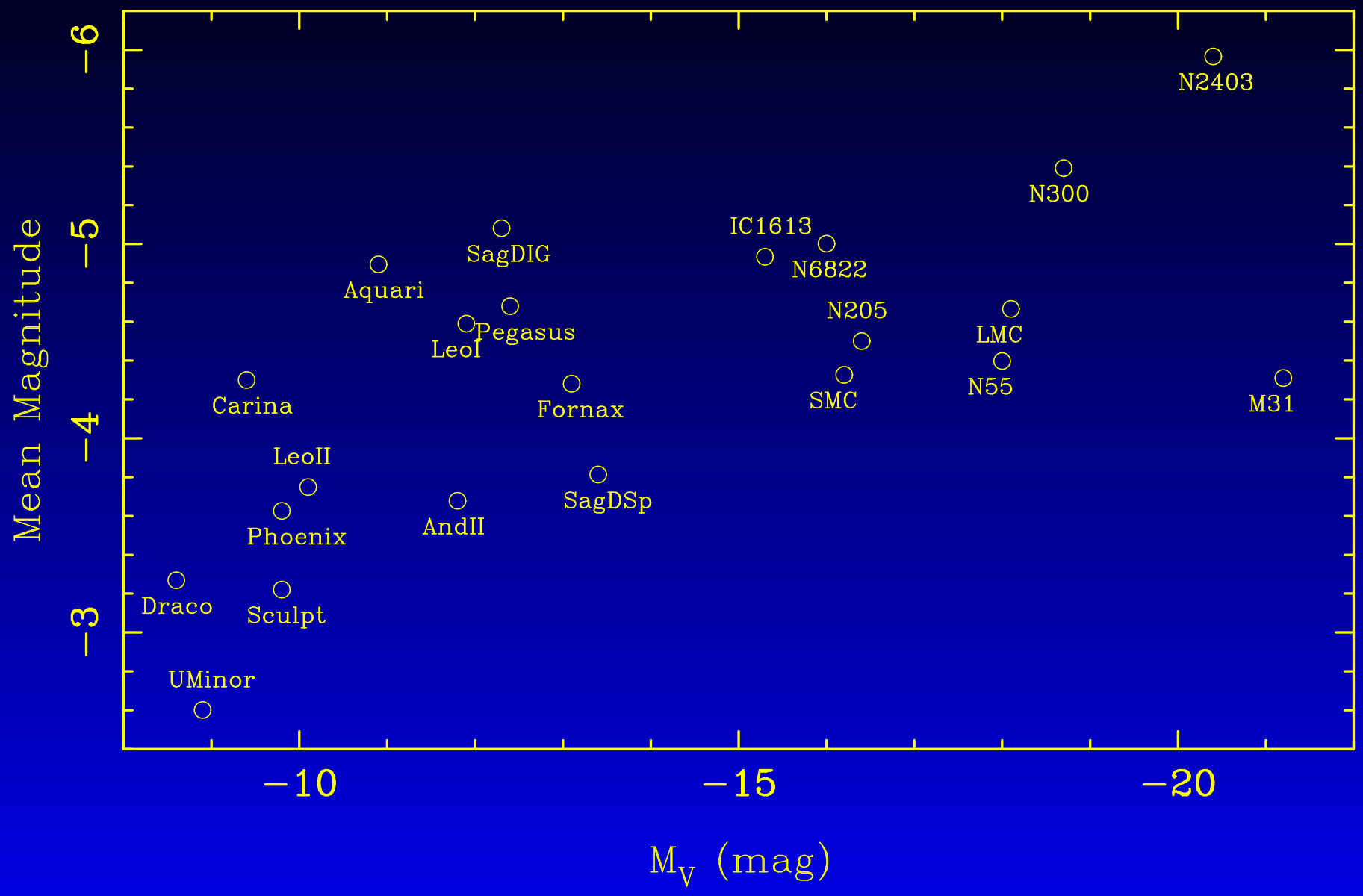

Draco
UMinor
Carina
SMC
Sculp
LeoII
SagDSph
LMC
Fornax
Pegasus
LeoI
N6822
M33
Galaxy
Phoenix
SagDIG
WLM
IC1613
Aquari
N205
M31
N300
N55
N2403
−3
−4
−5
Log (Total N_C) + 0.4 M_V
−2.5
−2
−1.5
−1
−0.5
0
[Fe/H]

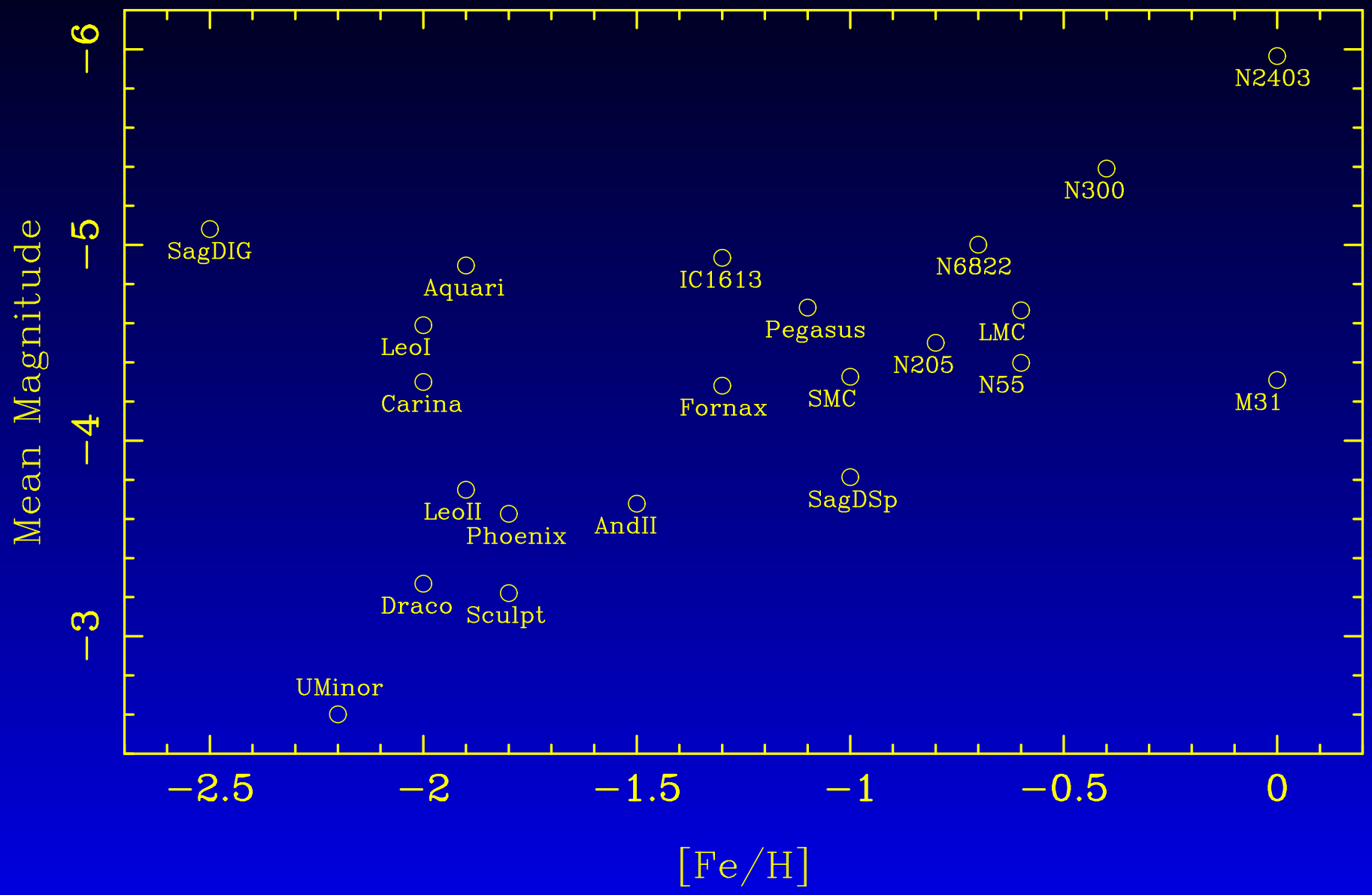
Name	$M_{\rm bol}^{\rm max}$ (mag)	$M_{\rm bol}^{\rm min}$ (mag)	$M_{\rm bol}^{\rm mean}$ (mag)	spread (mag)	$N_{\rm all}$	$N_{\rm M_{bol}>-3.5}$
M 31	-6.13	-3.34	-4.31	0.50	243	16
NGC 2403	-6.05	-5.89	-5.97	0.08	4	0
NGC 300	-5.93	-4.68	-5.39	0.41	13	0
LMC	-8.01	-1.33	-4.67	0.61	7650	378
NGC 55	-4.98	-3.37	-4.40	0.51	9	1
NGC 205	-5.14	-4.04	-4.50	0.44	7	0
SMC	-8.17	-1.62	-4.33	0.81	1626	226
NGC 6822	-6.48	-3.65	-5.00	0.44	904	0
IC 1613	-6.34	-3.48	-4.94	0.56	195	2
SagDSph	-4.37	-3.11	-3.81	0.40	16	5
Fornax	-5.22	-3.64	-4.28	0.36	41	0

Name	$M_{\rm bol}^{\rm max}$ (mag)	$M_{\rm bol}^{\rm min}$ (mag)	$M_{\rm bol}^{\rm mean}$ (mag)	spread (mag)	$N_{\rm all}$	$N_{\rm M_{bol}>-3.5}$
Pegasus	-5.59	-4.05	-4.68	0.37	40	0
SagDIG	-5.66	-4.48	-5.08	0.31	16	0
Leo I	-5.38	-3.32	-4.59	0.47	23	1
And II	-4.11	-3.24	-3.68	0.62	2	1
Aquarius	-5.12	-4.71	-4.89	0.21	3	0
Leo II	-4.26	-3.20	-3.75	0.37	6	1
Sculptor	-4.49	-2.71	-3.22	0.57	8	7
Phoenix	-3.71	-3.55	-3.63	0.11	2	0
Carina	-4.85	-3.14	-4.30	0.61	6	1
Ursa Minor	-2.90	-2.04	-2.60	0.33	6	6
Draco	-3.62	-2.92	-3.27	0.35	3	2


M31
N2403
N300
LMC
N55
N205
SMC
N6822
IC1613
SagDSph
Fornax
Pegasus
−3
−4
−5
−6
−7
M_{bol}
M_{bol}


SagDIG
LeoI
AndII
Aquari
LeoII
Sculp
Phoenix
Carina
UMinor
Draco
−3
−4
−5
−6
−7
M_{bol}
M_{bol}


Mean Magnitude
−6
−5
−4
−3
−10
−15
−20
M_V (mag)
N2403
N300
IC1613
N6822
SagDIG
Aquari
N205
LMC
Pegasus
LeoI
N55
Carina
Fornax
SMC
M31
LeoII
SagDSp
AndII
Phoenix
Draco
Sculpt
UMinor


Mean Magnitude
−6
−5
−4
−3
−2.5
−2
−1.5
−1
−0.5
0
[Fe/H]
N2403
N300
SagDIG
Aquari
IC1613
N6822
Pegasus
LMC
LeoI
N205
N55
Carina
Fornax
SMC
M31
SagDSp
LeoII
Phoenix
AndII
Draco
Sculpt
UMinor

Theory

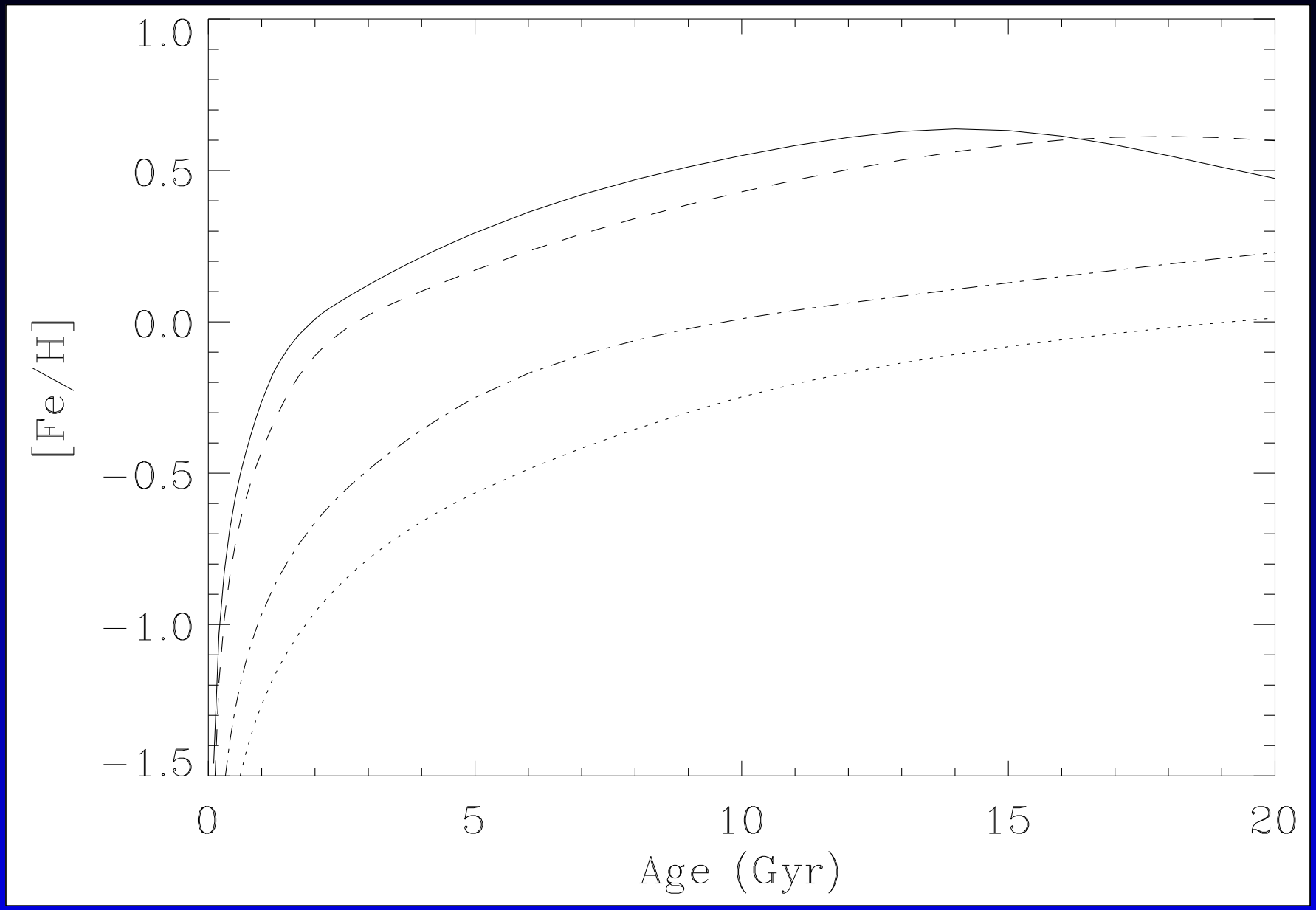
- Mouhcine & Lançon (2002)

  Evolutionary population synthesis models, including chemical evolution.

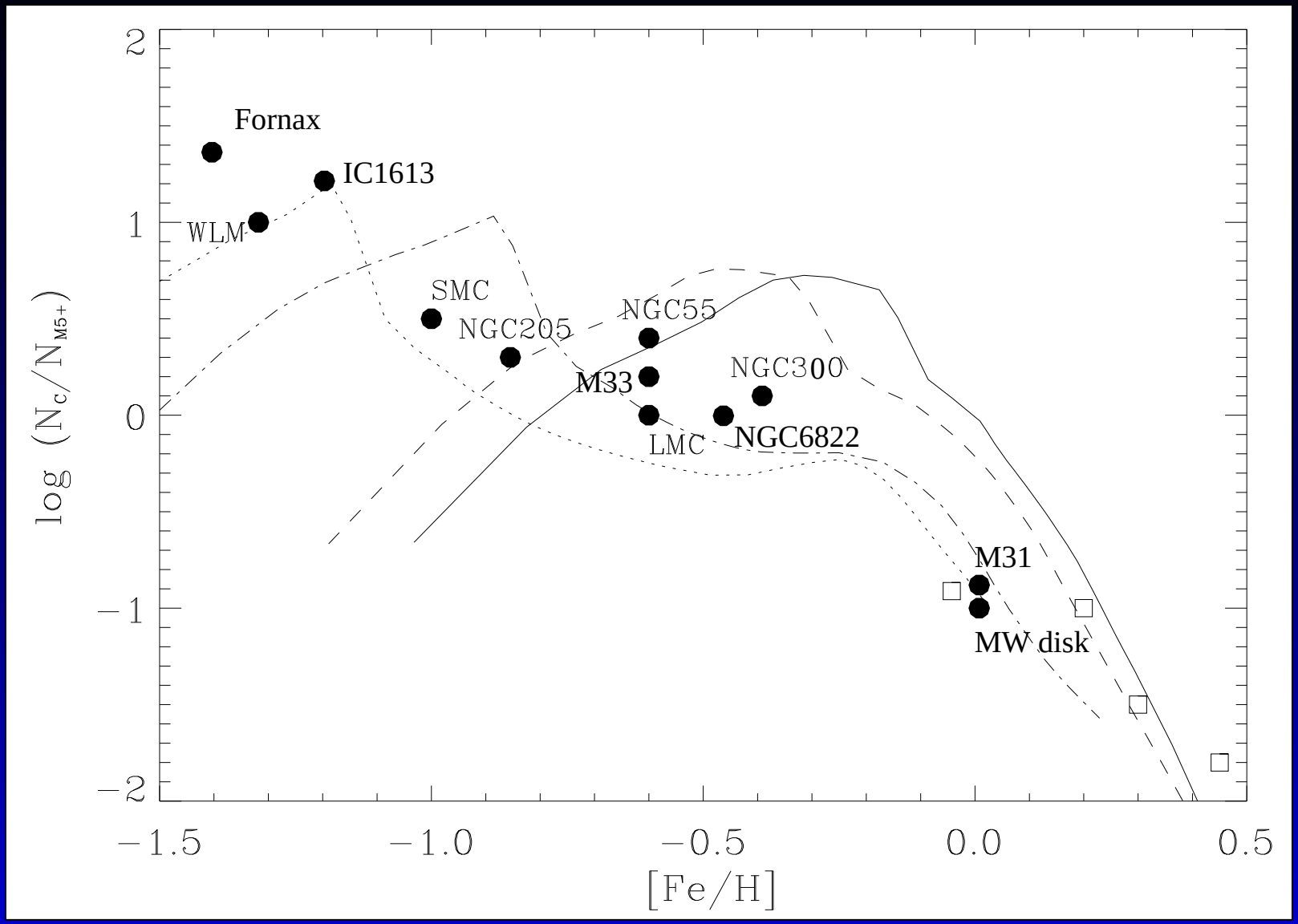
  Semi-analytical treatment of the third dredge-up, with efficiency parameters set to values that fit the LMC carbon star LF.

  Assume typical SFRs, characteristic of Sa, Sb, Sc and Irr type galaxies.

  Sa = solid ; dashed= Sb ; dot-dash = Sc ; dot = Irr



Mouhcine & Lançon 2002



Mouhcine & Lançon 2002
[data points from Groenewegen 1999 !]

Conclusions

Narrow-band filter technique most efficient

- At the moment limited to $\lesssim$ 1 Mpc
- Different groups adopt different selection criteria
- Data on the M-stars often not published

Infra-red view

- Nearby galaxies: MOS of objects with $J - K \gtrsim 1.5$

Carbon stars as distance indicators

- Metallicity dependence of the mean magnitude

Conclusions

Theory

- First attempts have been made
- Fit specific galaxies using SFR determined independently: feedback on third dredge-up efficiency

Future Work

2MASS

- Final data release available end-2002
- Identification of new [red] AGB stars

New observations

- ESO proposal

More modelling

- Understanding AGB evolution