Carbon stars in the Local Group

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Overview

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

Update of Groenewegen (1999, IAU Symp 191)
Azzopardi (1999, Ap&SS 265, 291)

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

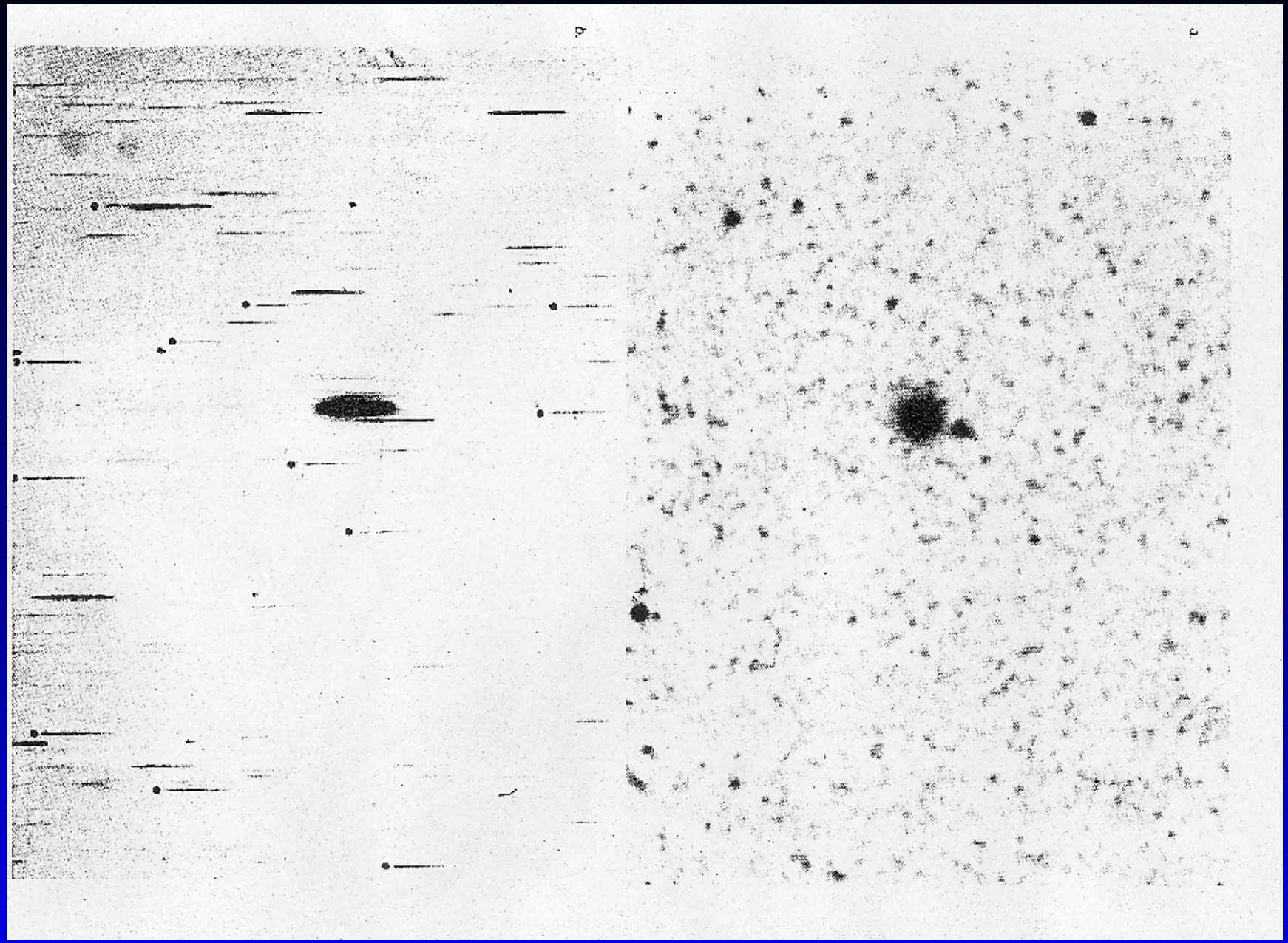
In general:
stars which show Tc are presently on the AGB

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



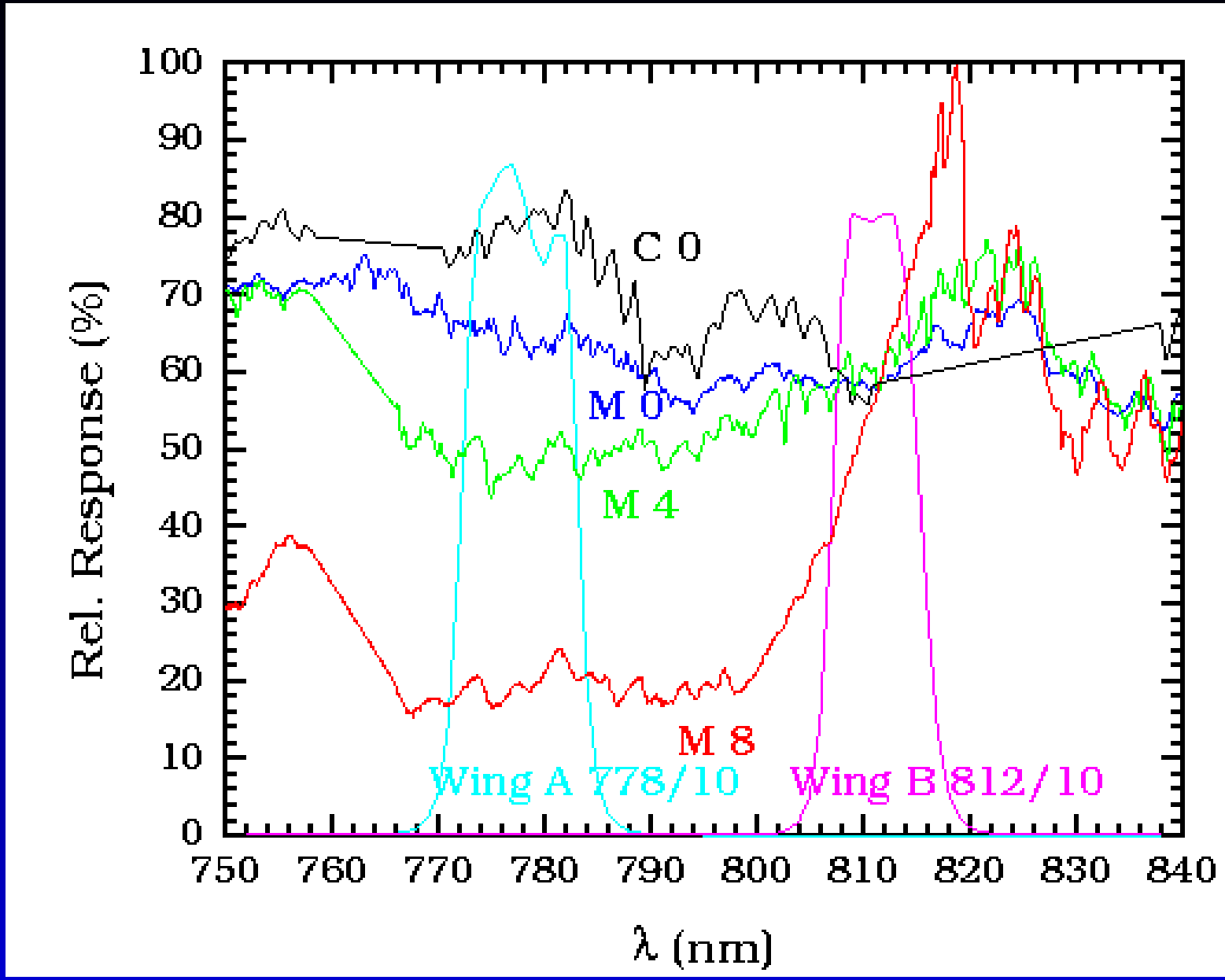
Westerlund 1978

How to identify late-type stars ?

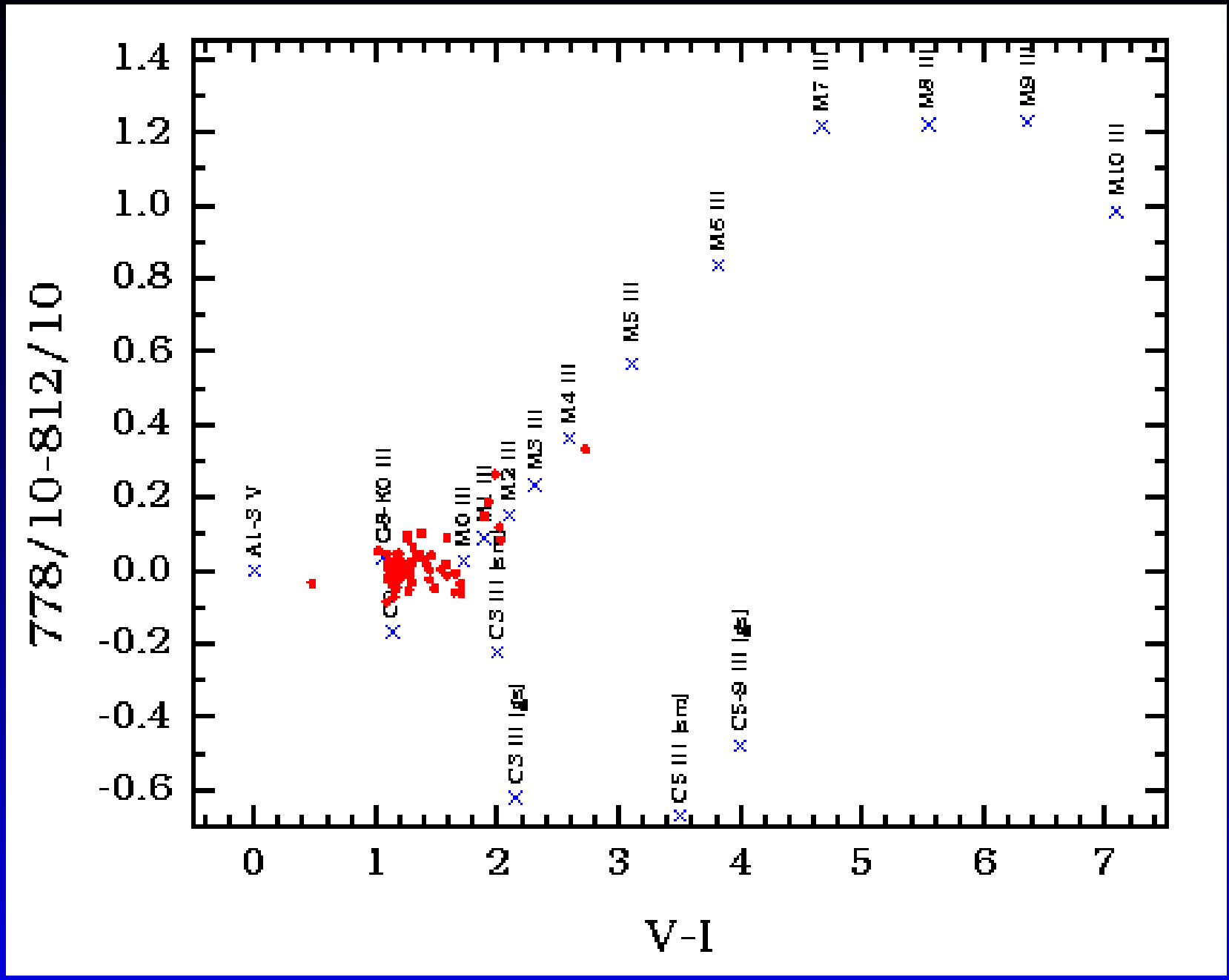
- Narrow-band filters

  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

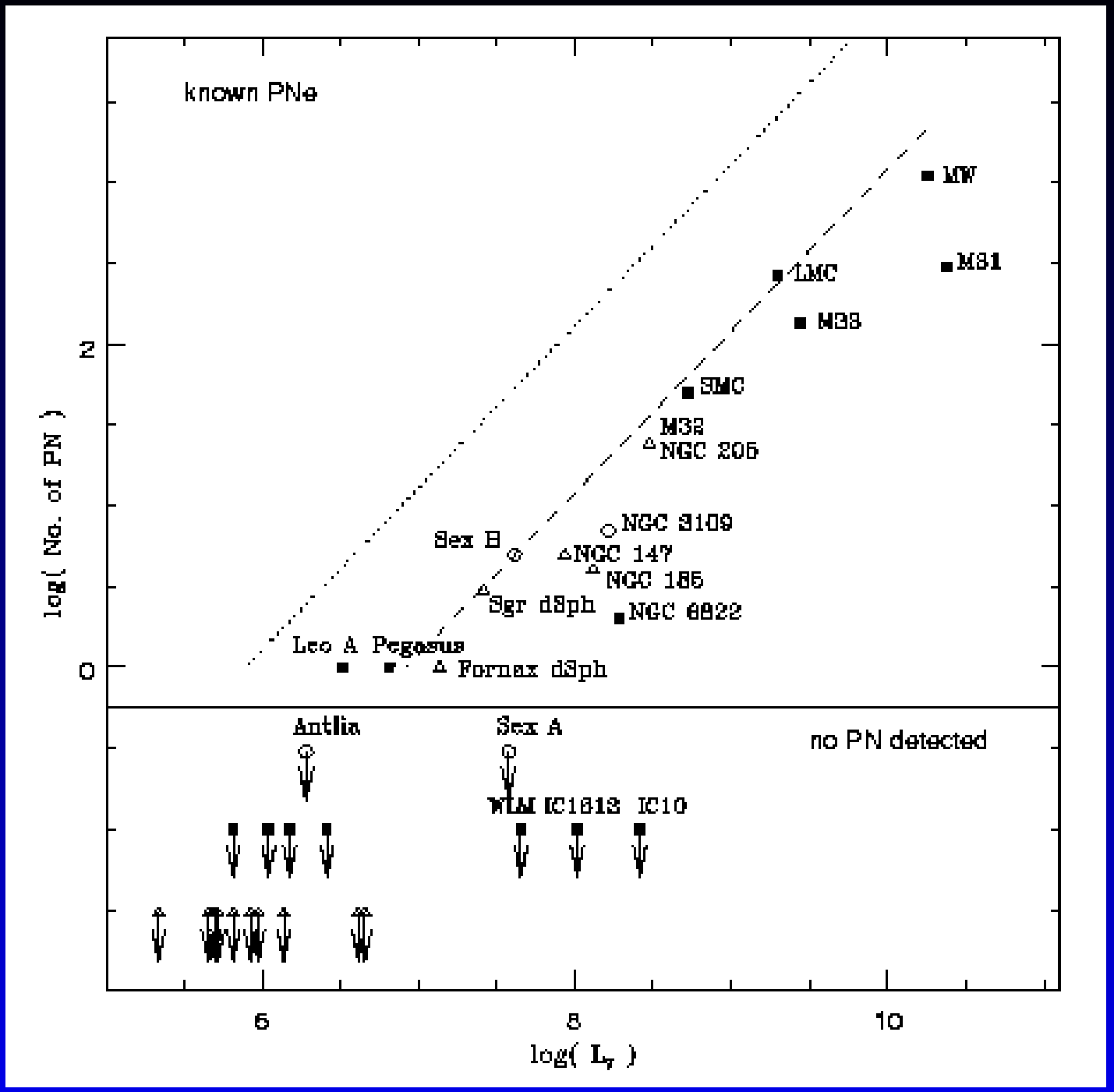
- Planetary Nebulae
- Long-Period variables

  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
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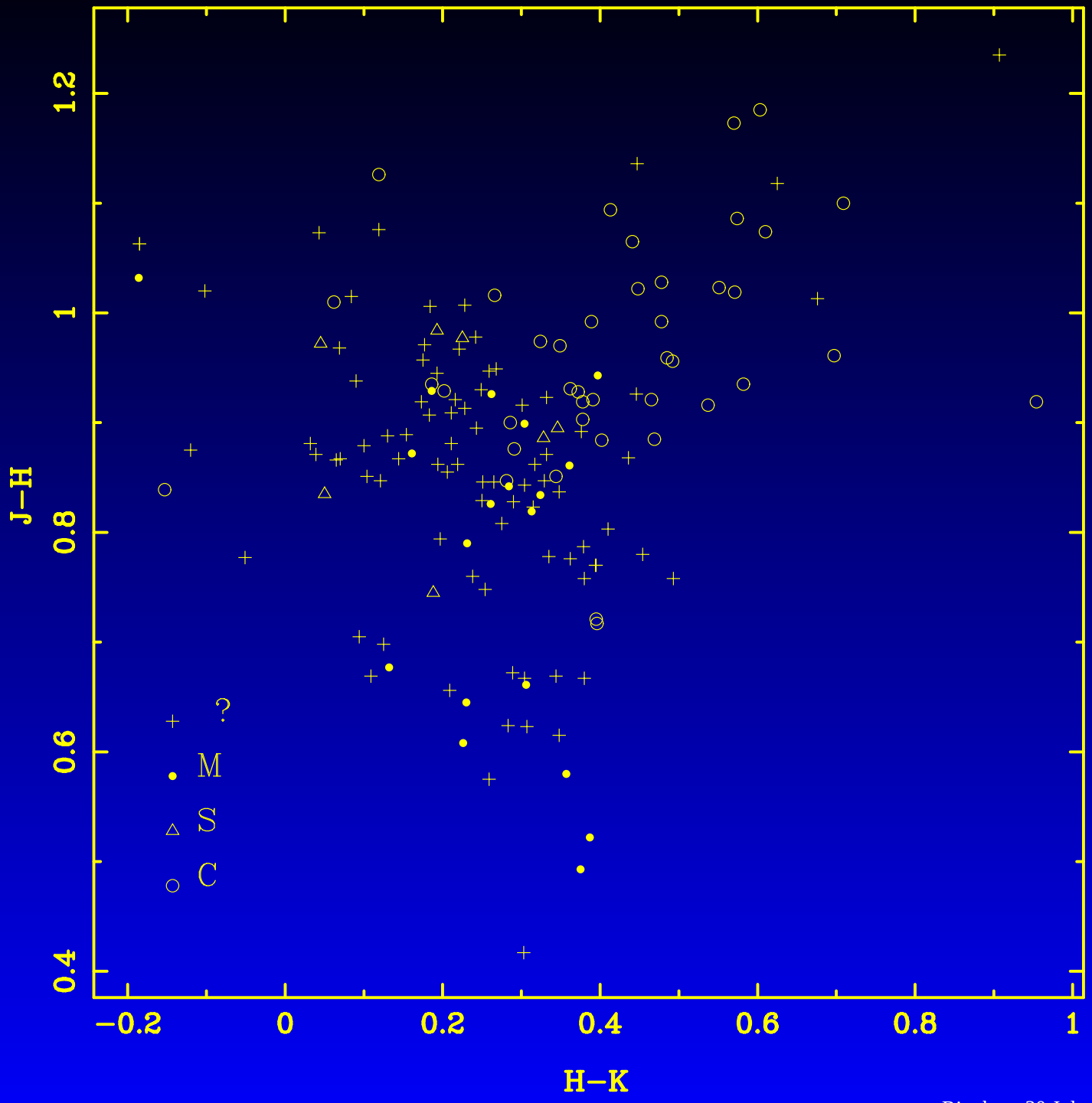
Some new results

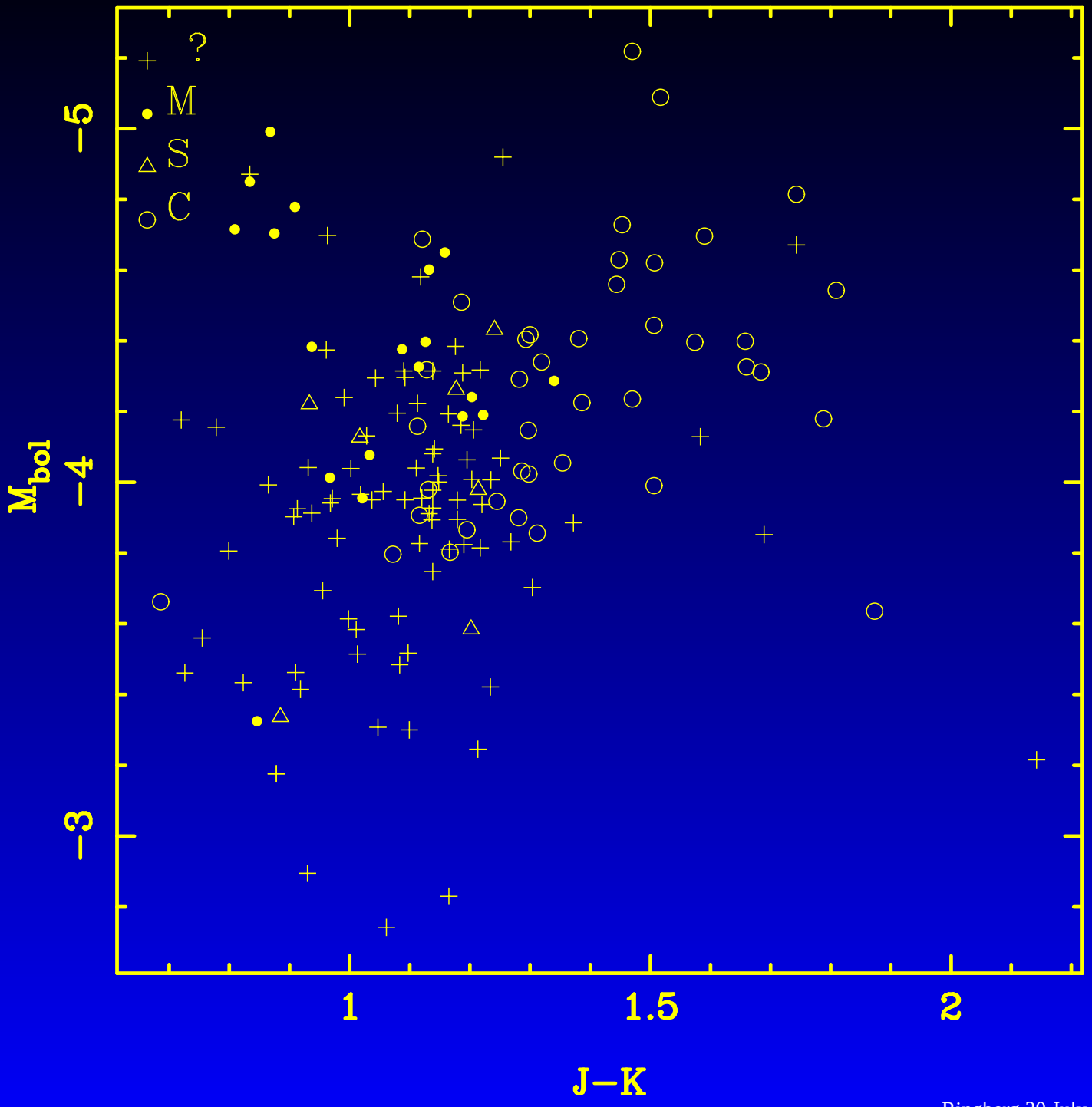
New surveys

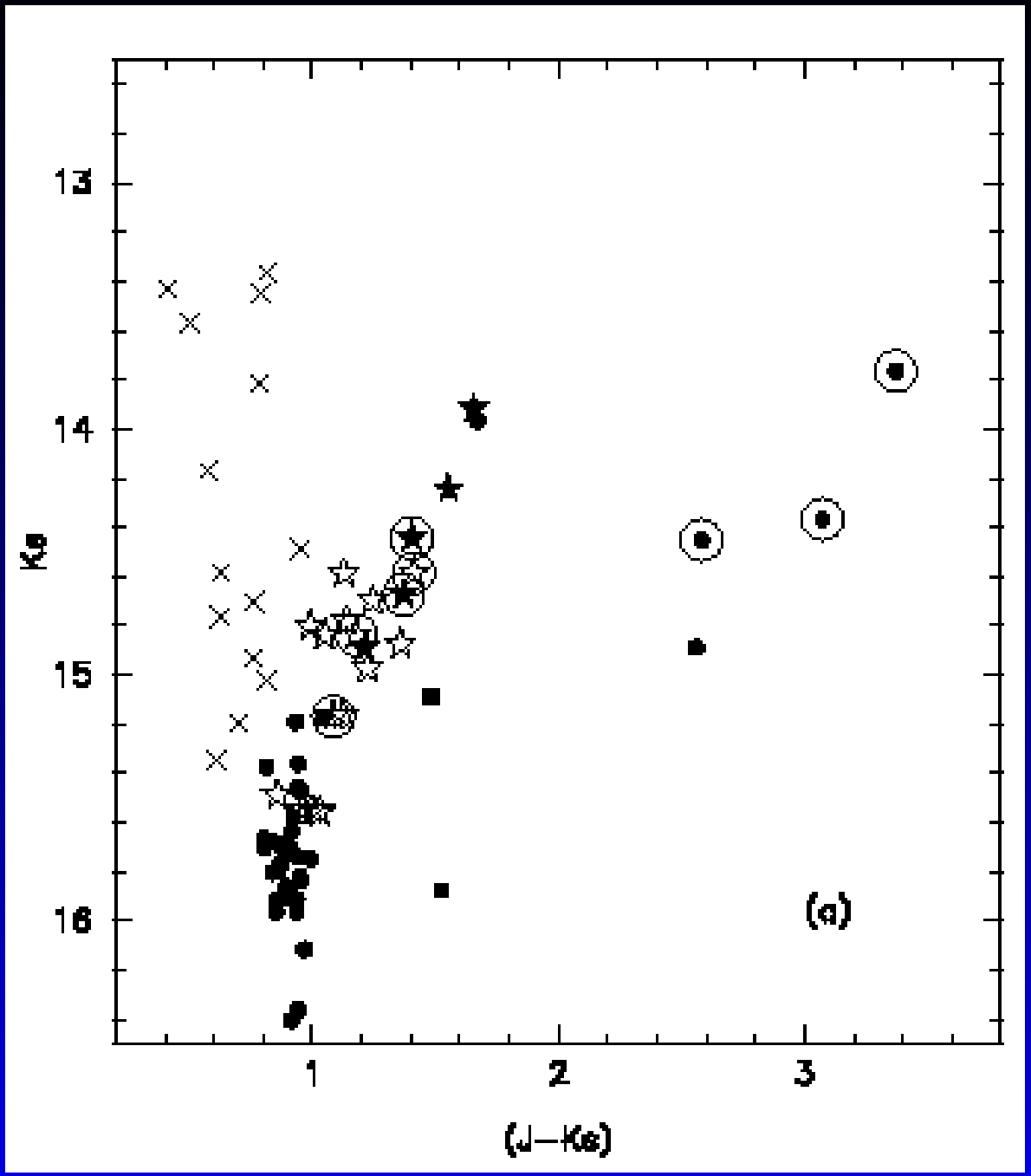
- Demers/Battinelli: SagDIG, Leo I, NGC 6822, Pegasus, Aquarius, Tucana, IC1613
- Nowotny et al.: M 31
- Kontizas et al.: LMC (7760 stars)

2MASS

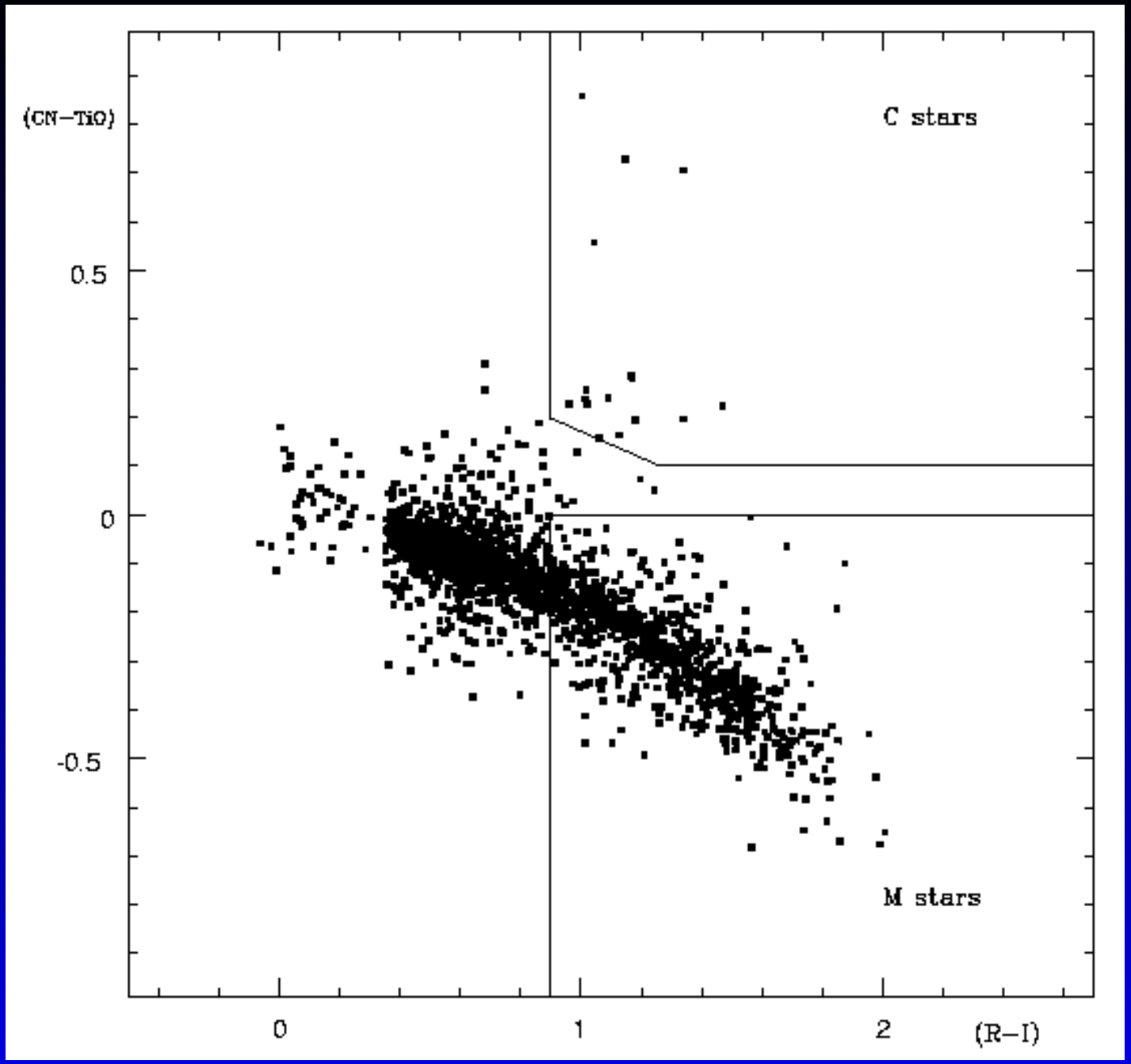
- Demers et al. (2002) on Fornax and LMC
- Correlated known carbon stars in Sculptor, Sagittarius DSph, Leo II, Ursa Minor, red stars in Fornax from Stetson et al. (1998)


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
?
M
S
C

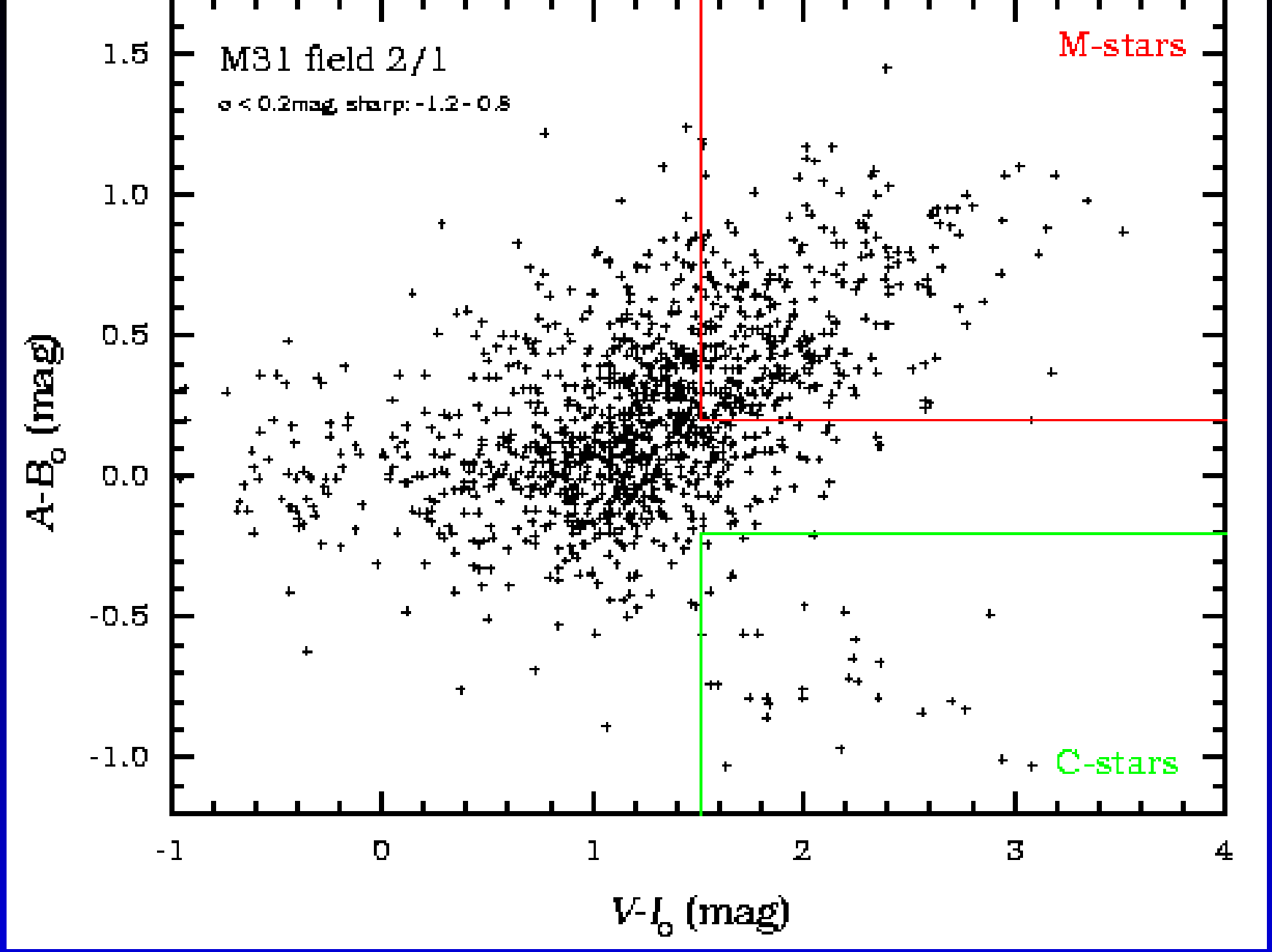

?
M
S
C
−5
−4
−3
M_{bol}
1
1.5
2
J−K



Menzies et al. 2002 on Leo I



Demers et al. 2002 on Leo I

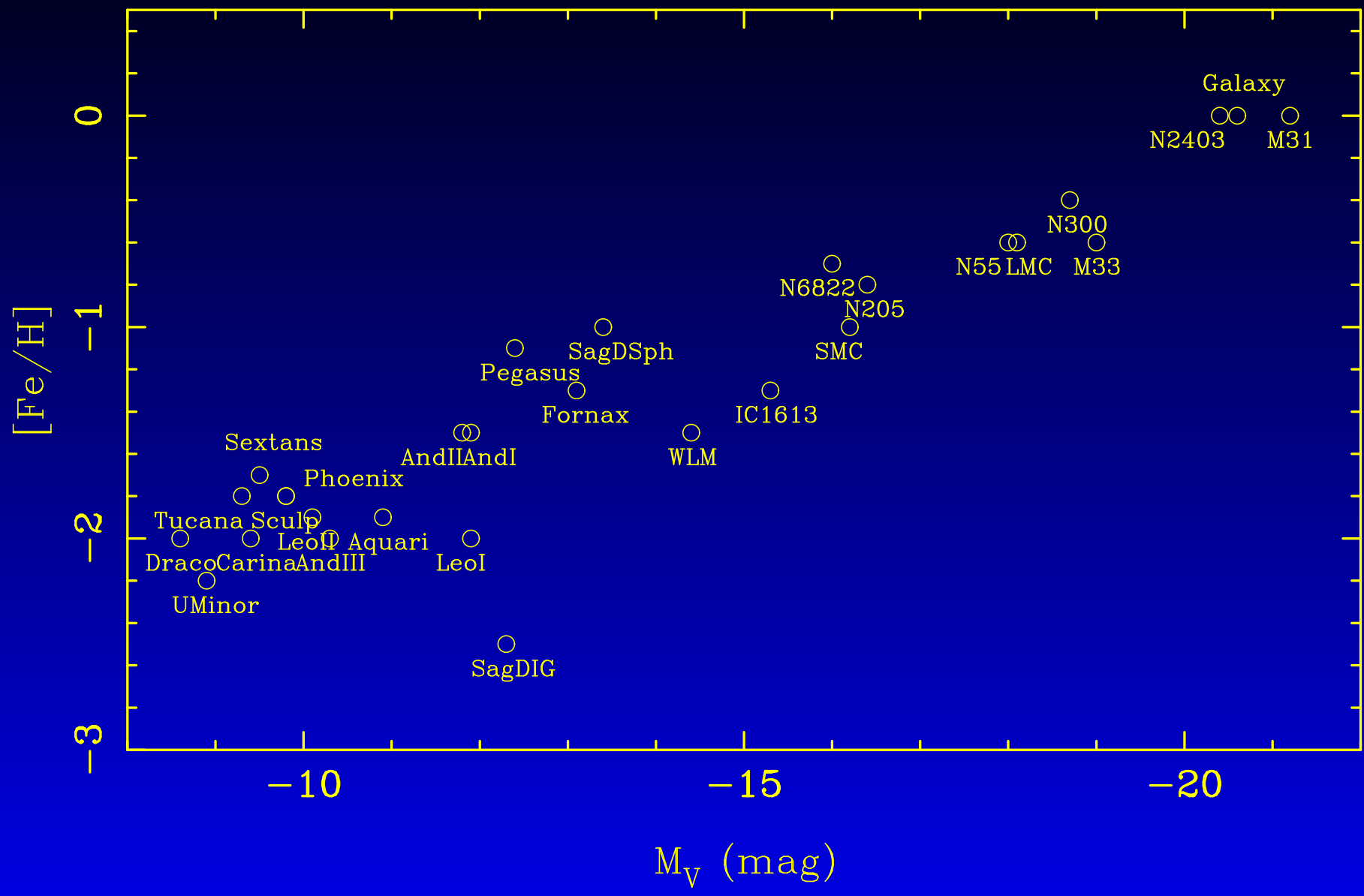


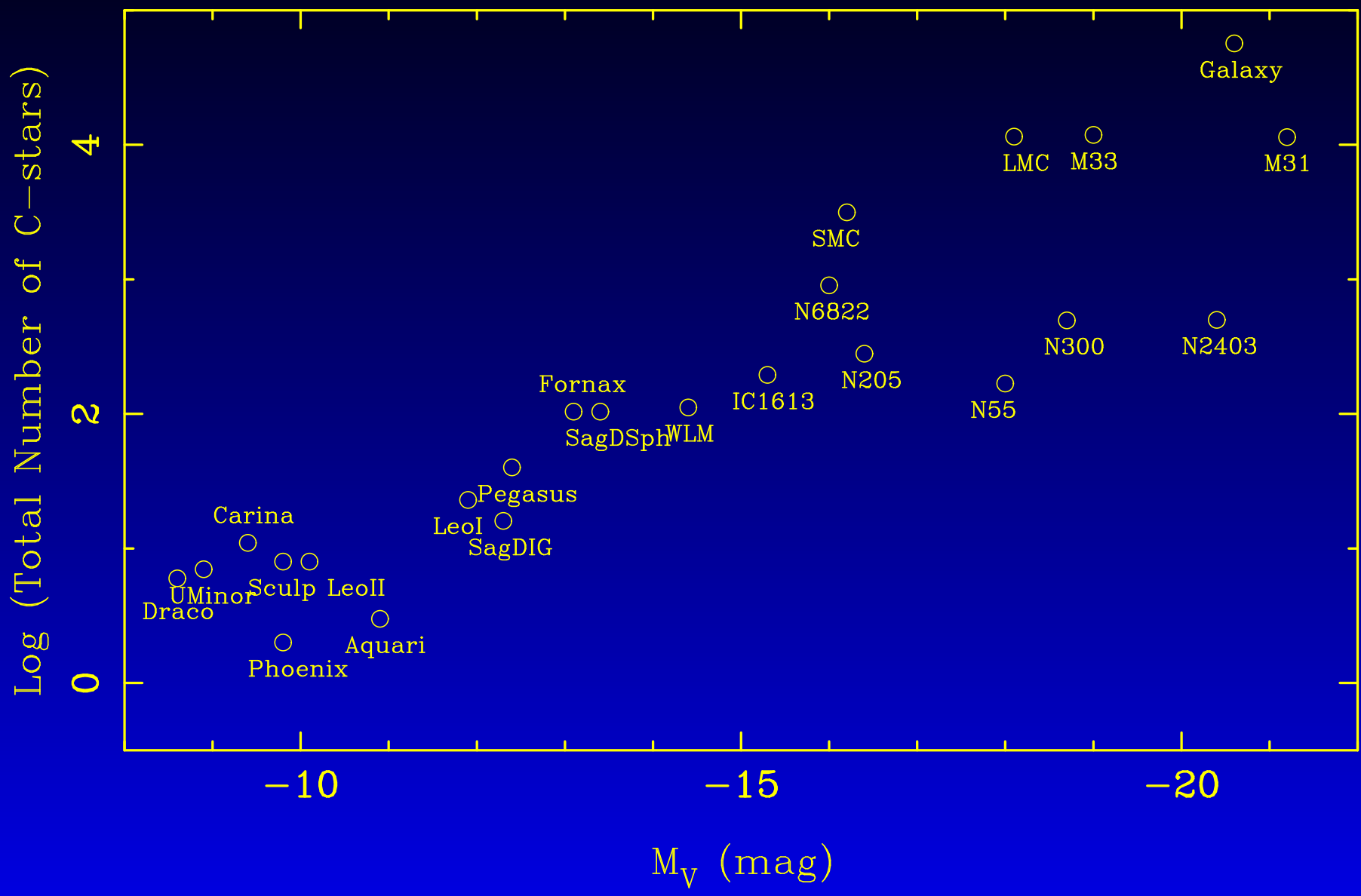
Nowotny et al. 2001

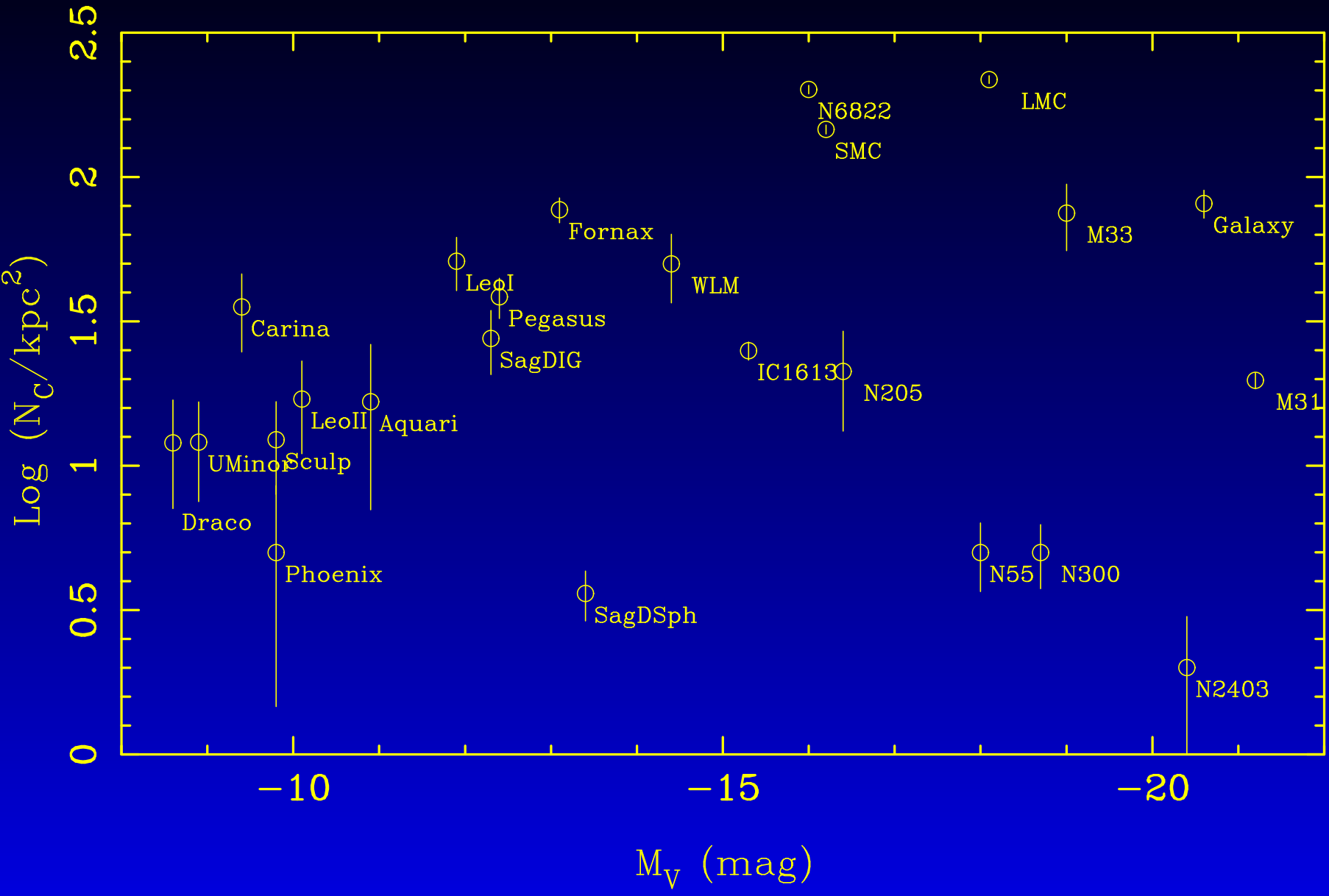
Name	D (kpc)	M_V (mag)	[Fe/H]	N_C	Area (kpc^2)	N_M
M31	770	–21.2	0.0	243	12.3	789 (5+)
Galaxy		–20.6	0.0	81	1.00	C/M $\approx$ 0.2
M33	840	–19.0	–0.6	15	0.20	5 (5+), 60 (0+)
LMC	50	–18.1	–0.6	1045	4.8	1300 (5+)
				7750	220.	
NGC 205	815	–16.4	–0.8	7	0.33	4 (5+), 17 (0+)
SMC	63	–16.2	–1.0	789	5.4	180 (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+)

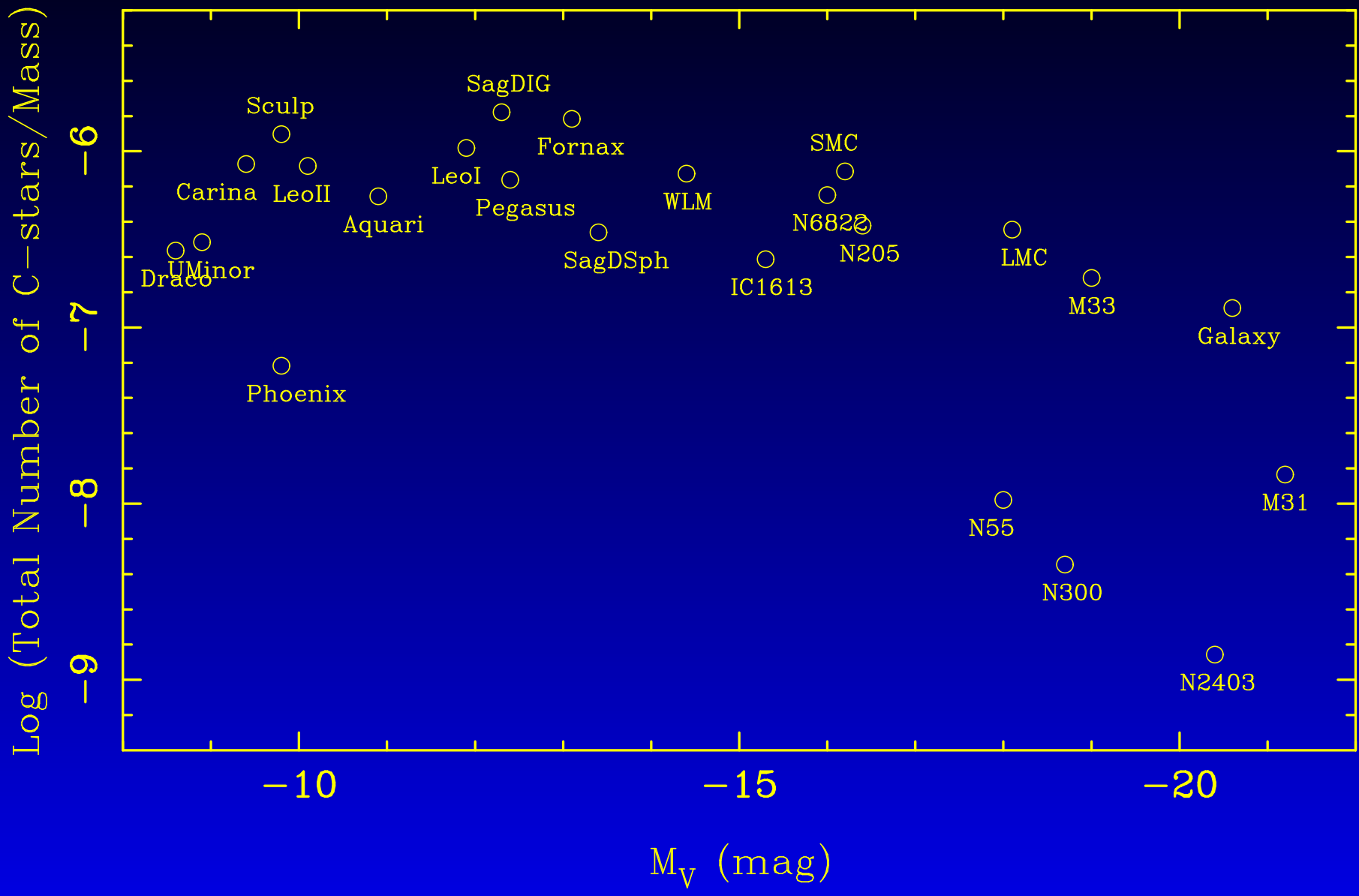
Name	D (kpc)	M_V (mag)	[Fe/H]	N_C	Area (kpc^2)	N_M
SagDSph	24	–13.4	–1.0	26	7.2	
Fornax	138	–13.1	–1.3	104	1.35	4 (5+), 25 (2+)
Pegasus	955	–12.4	–1.1	40	1.04	77 (0+)
SagDIG	1060	–12.3	–2.5	16	0.58	1 (0+)
Leo I	250	–11.9	–2.0	23	0.45	1 (5+), 15 (0+)
And I	790	–11.9	–1.5	0		
And II	680	–11.8	–1.5	8		1 (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+)

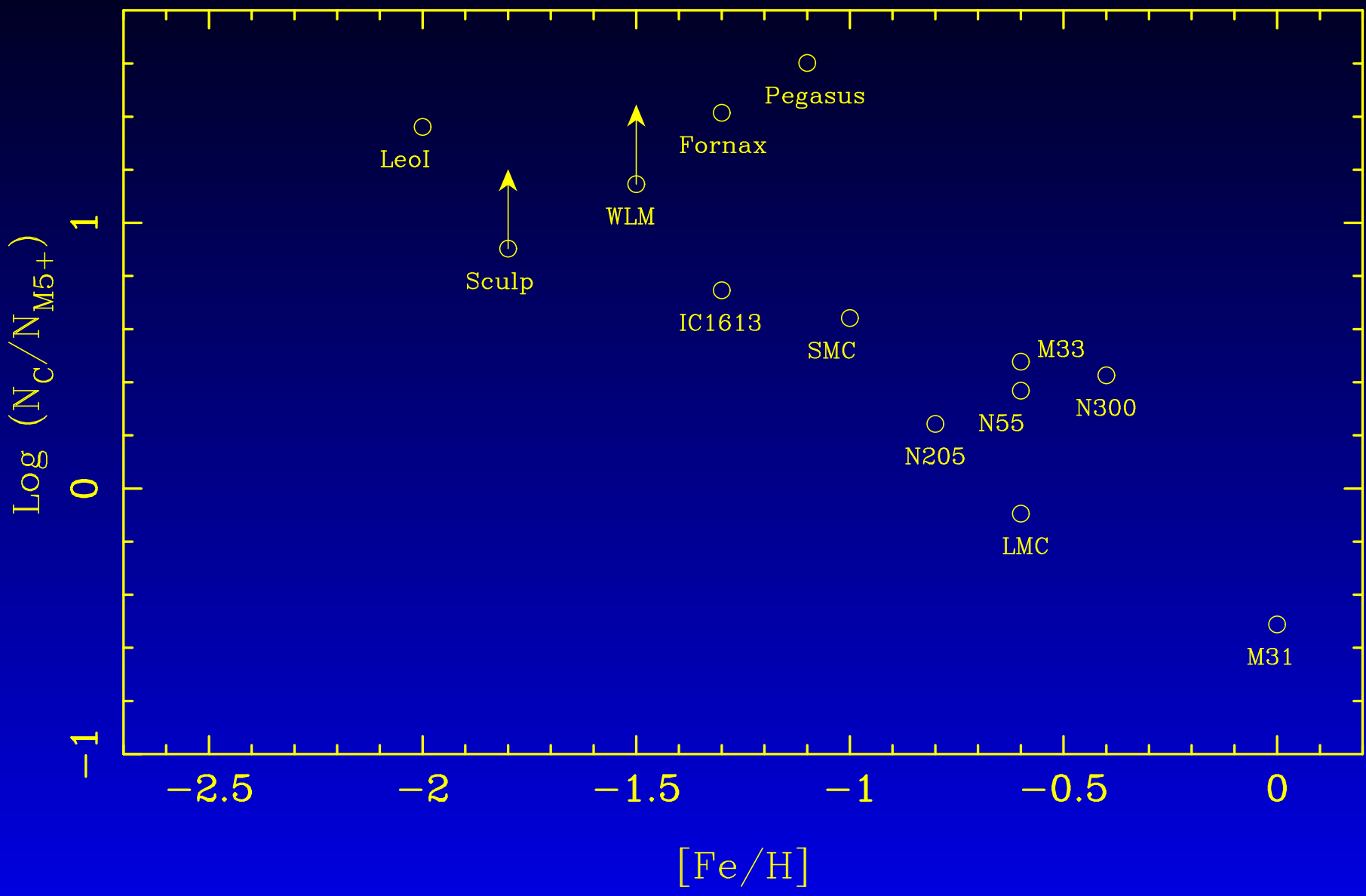
Name	D (kpc)	M_V (mag)	[Fe/H]	N_C	Area (kpc^2)	N_M
Phoenix	400	–9.8	–1.8	2	0.40	
Sextans	86	–9.5	–1.7	(0)		
Carina	100	–9.4	–2.0	11	0.31	
Tucana	870	–9.3	–1.8	0	0.22	
Ursa Minor	69	–8.9	–2.2	7	0.58	
Draco	82	–8.6	–2.0	6	0.50	
NGC 2403	3390	–20.4	0.0	4	2.0	7 (0+)
NGC 300	2170	–18.7	–0.4	16	3.2	23 (0+),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

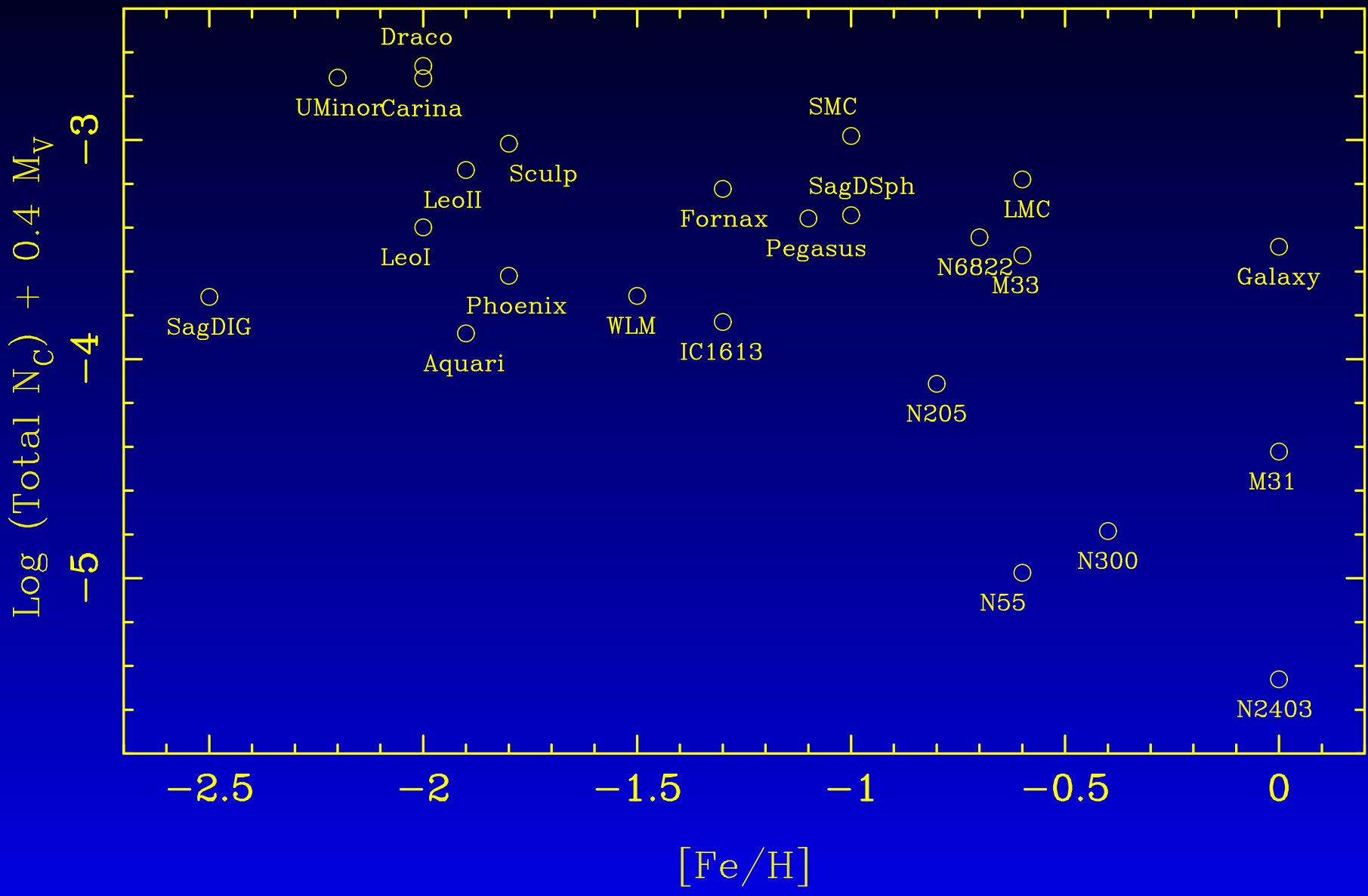

Galaxy
N2403
M31
N300
N55
LMC
M33
N6822
N205
SMC
SagDSph
Pegasus
Fornax
IC1613
WLM
AndII
AndI
Sextans
Phoenix
Tucana
Sculp
Leo II
Aquari
LeoI
Draco
Carina
AndIII
UMinor
SagDIG
0
−1
−2
−3
[Fe/H]
−10
−15
−20
M_V (mag)


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)
0
0.5
1
1.5
2
2.5
−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
SagDSph
N55
N300
N2403

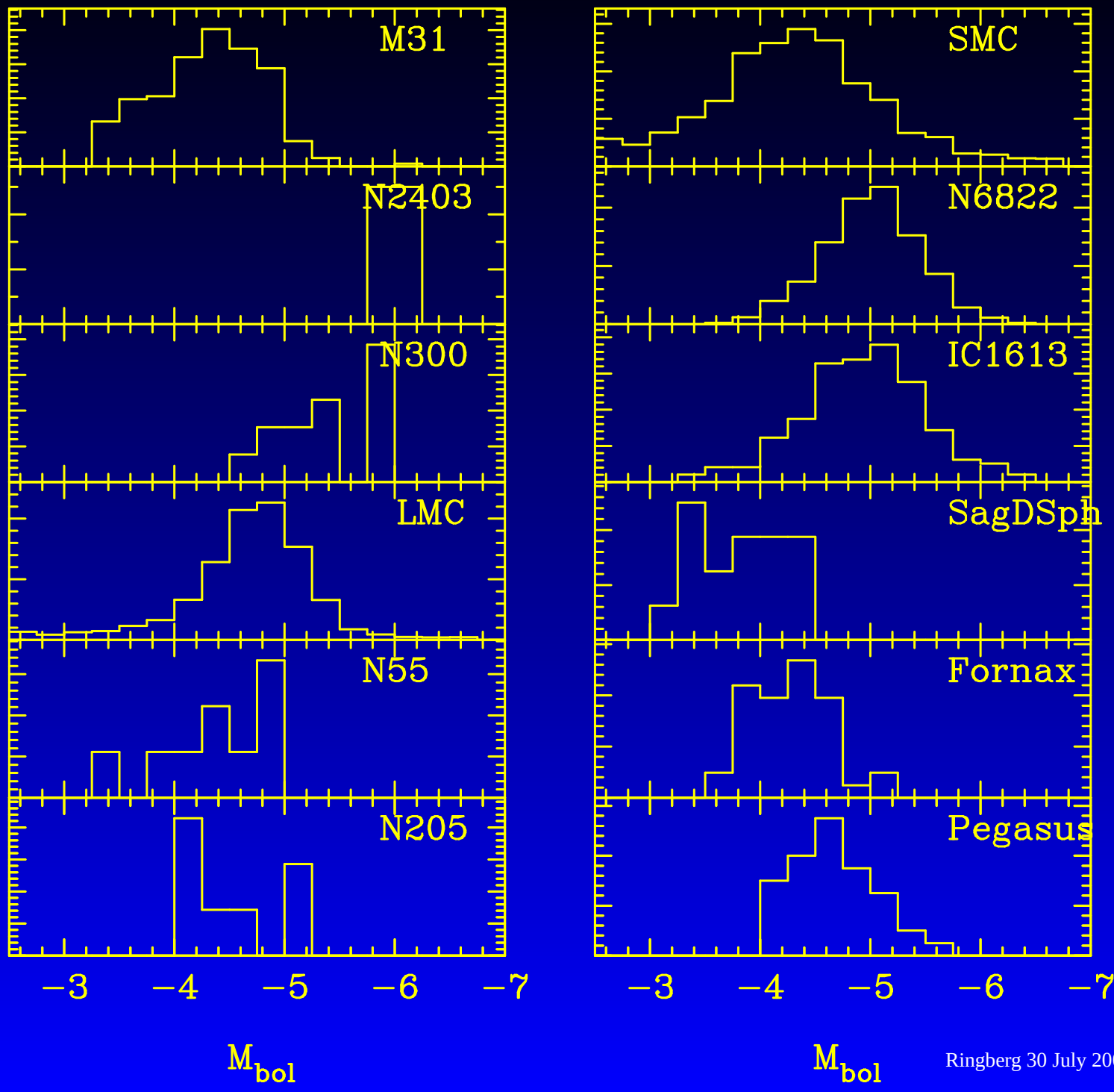

Log (Total Number of C−stars/Mass)
−6
−7
−8
−9
−10
−15
−20
M_V (mag)
SagDIG
Sculp
Fornax
SMC
LeoI
Carina
LeoII
Pegasus
WLM
Aquari
N6822
SagDSph
N205
LMC
UMinor
Draco
IC1613
M33
Galaxy
Phoenix
M31
N55
N300
N2403

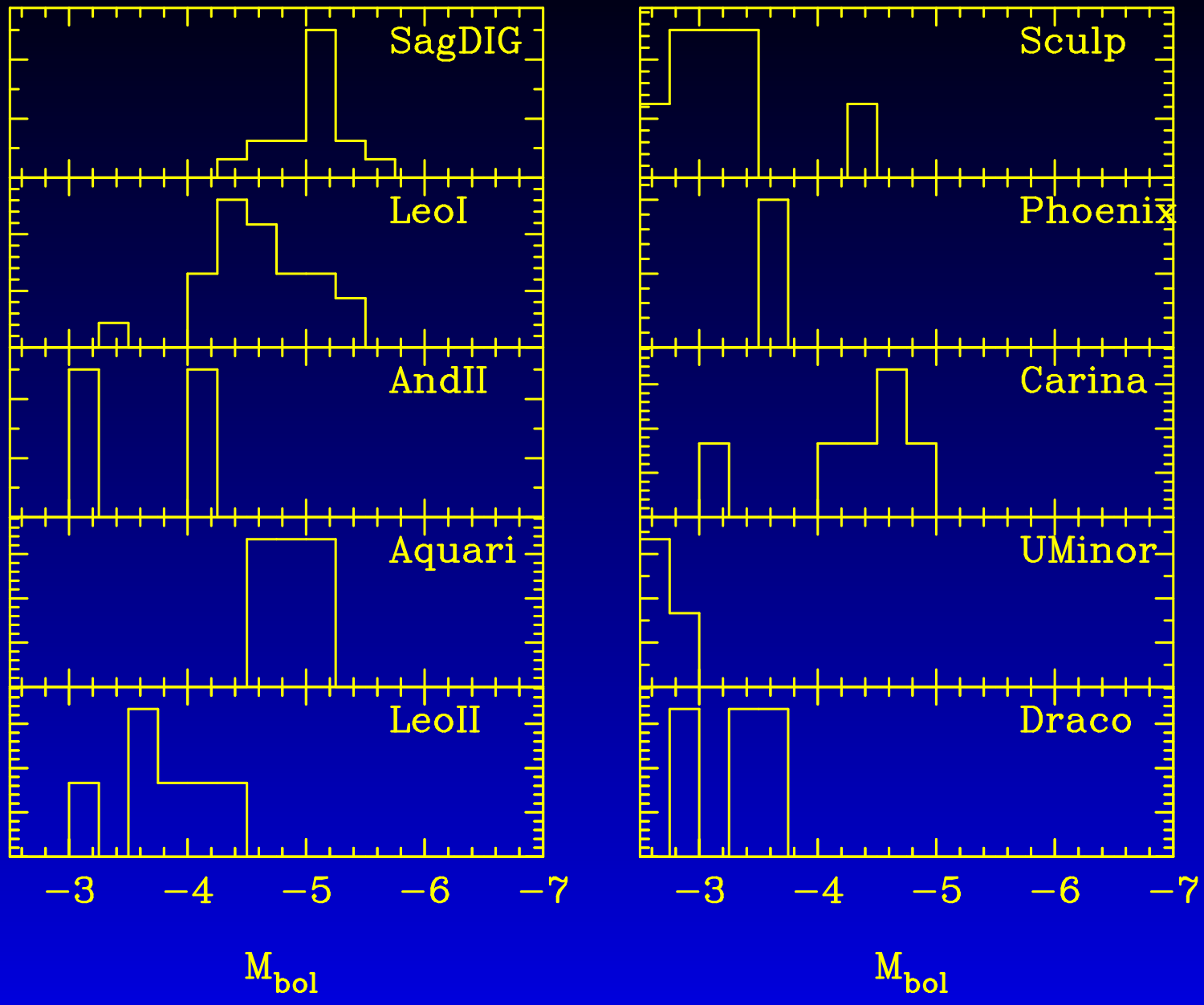

Pegasus
Fornax
LeoI
WLM
Sculp
IC1613
SMC
M33
N300
N55
N205
LMC
M31
Log (N_C/N_M5+)
1
0
−1
−2.5
−2
−1.5
−1
−0.5
0
[Fe/H]

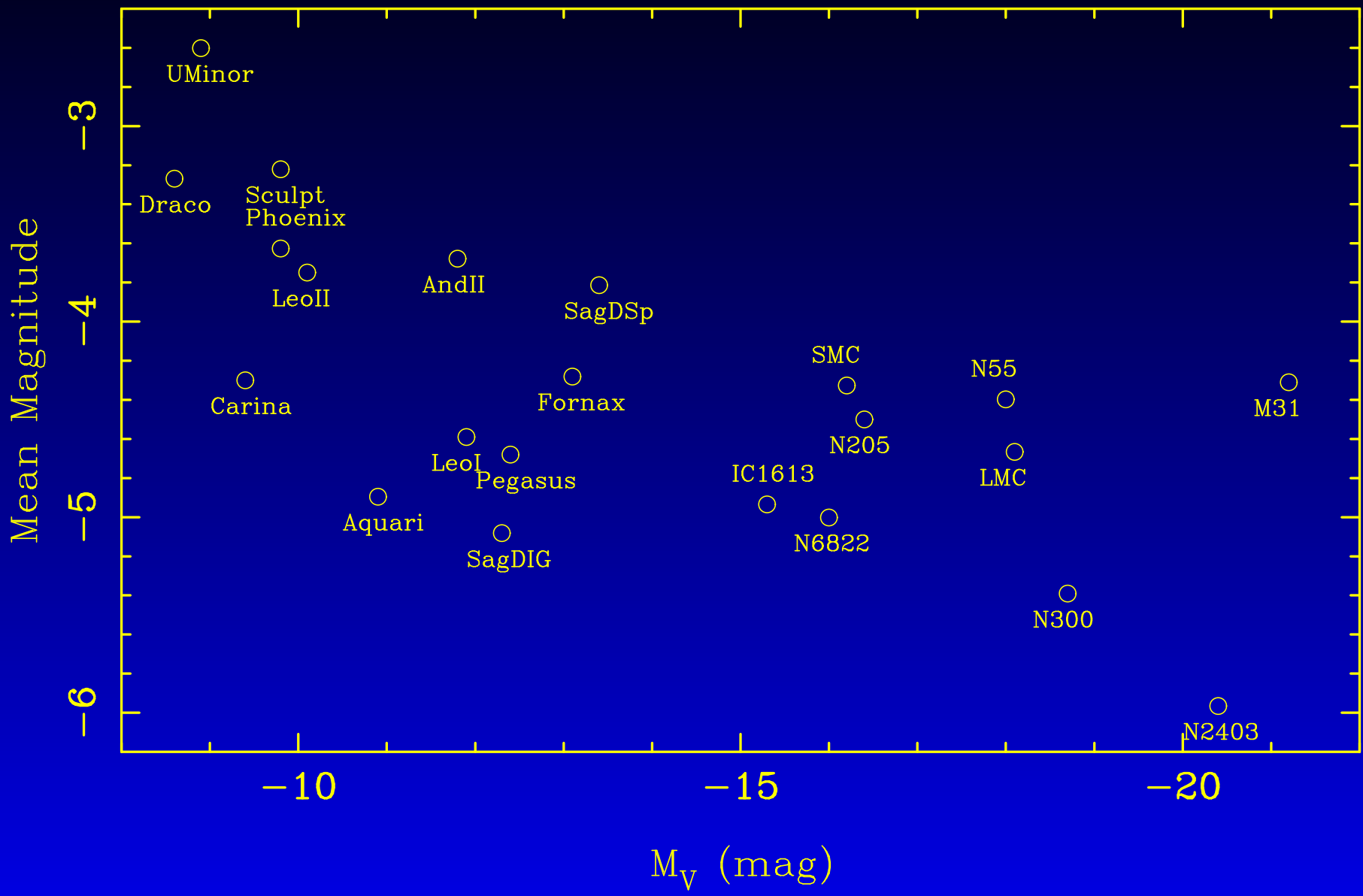

Draco
UMinor
Carina
Sculp
LeoII
LeoI
Phoenix
SagDIG
Aquari
WLM
IC1613
SMC
SagDSph
Fornax
Pegasus
LMC
N6822
M33
Galaxy
N205
M31
N300
N55
N2403
Log (Total N_C) + 0.4 M_V
−3
−4
−5
−2.5
−2
−1.5
−1
−0.5
0
[Fe/H]

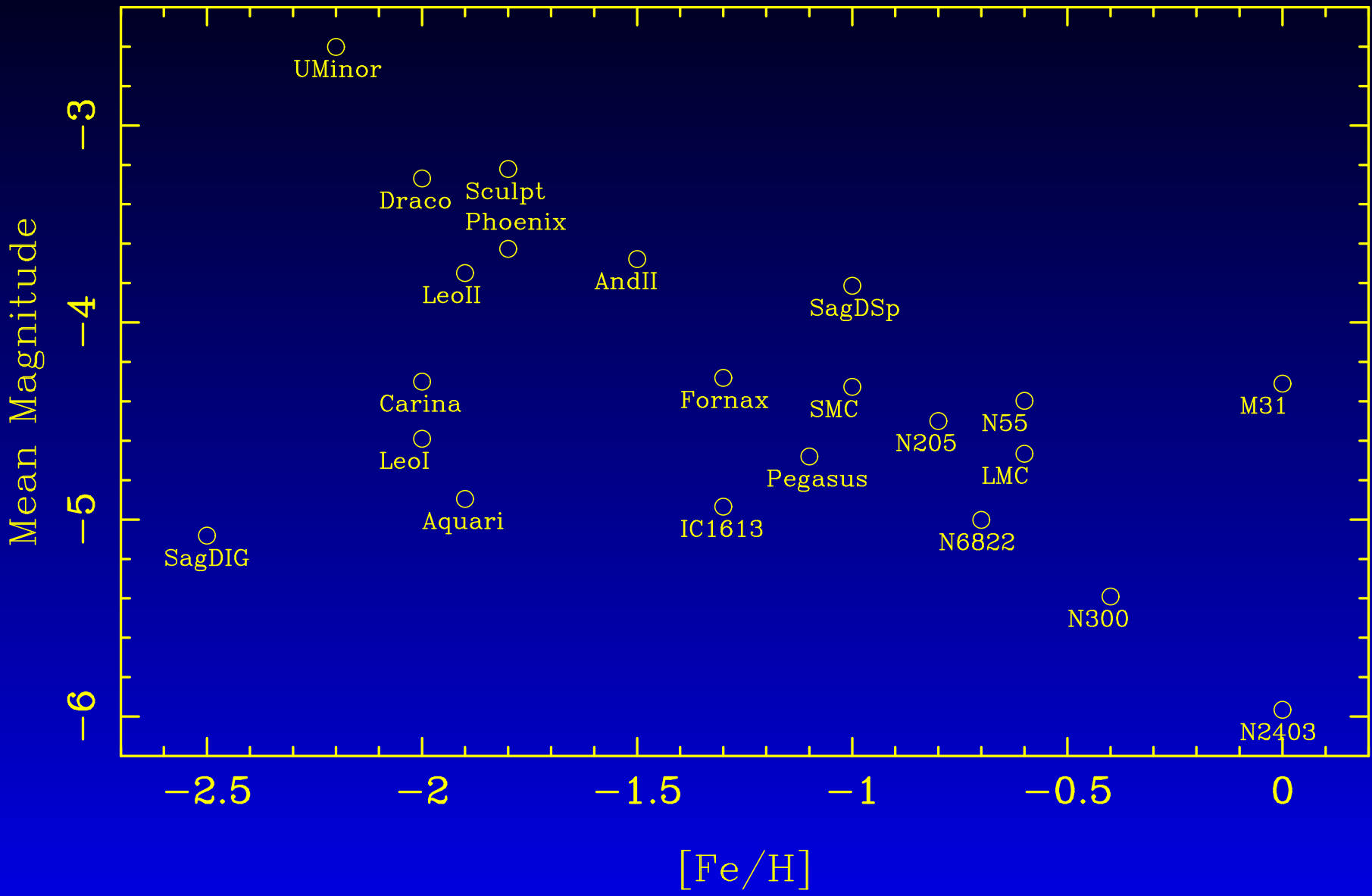
Name	$M_{\rm bol}^{\rm max}$ (mag)	$M_{\rm bol}^{\rm min}$ (mag)	$M_{\rm bol}^{\rm mean}$ (mag)	spread (mag)	$N_{\rm all}$	$N_{\rm M_{bol}>-3.5}$
M 31	-6.13	-3.34	-4.31	0.50	243	16
NGC 2403	-6.05	-5.89	-5.97	0.08	4	0
NGC 300	-5.93	-4.68	-5.39	0.41	13	0
LMC	-8.01	-1.33	-4.67	0.61	7650	378
NGC 55	-4.98	-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


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


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

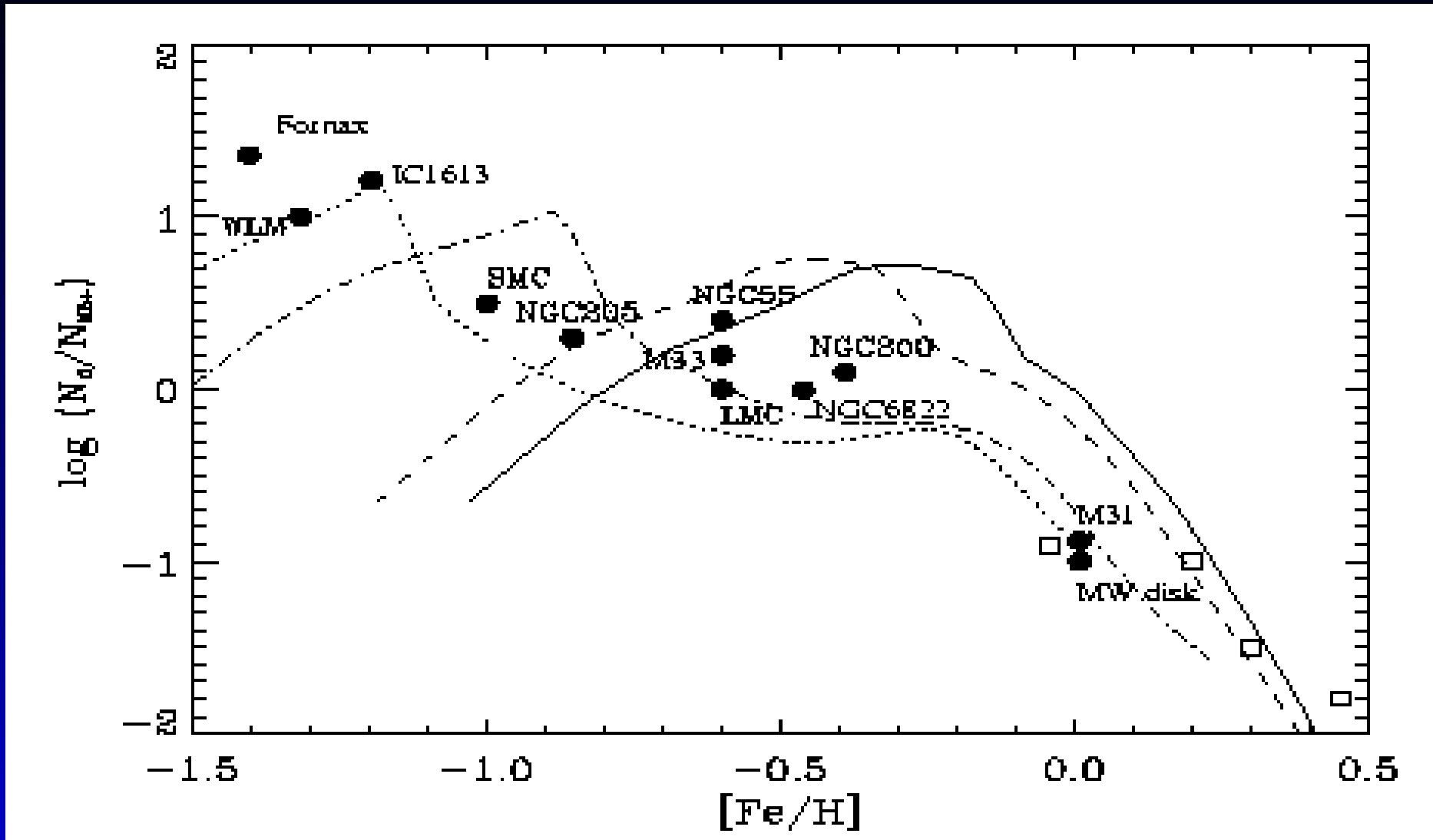
Theory

- 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.



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