

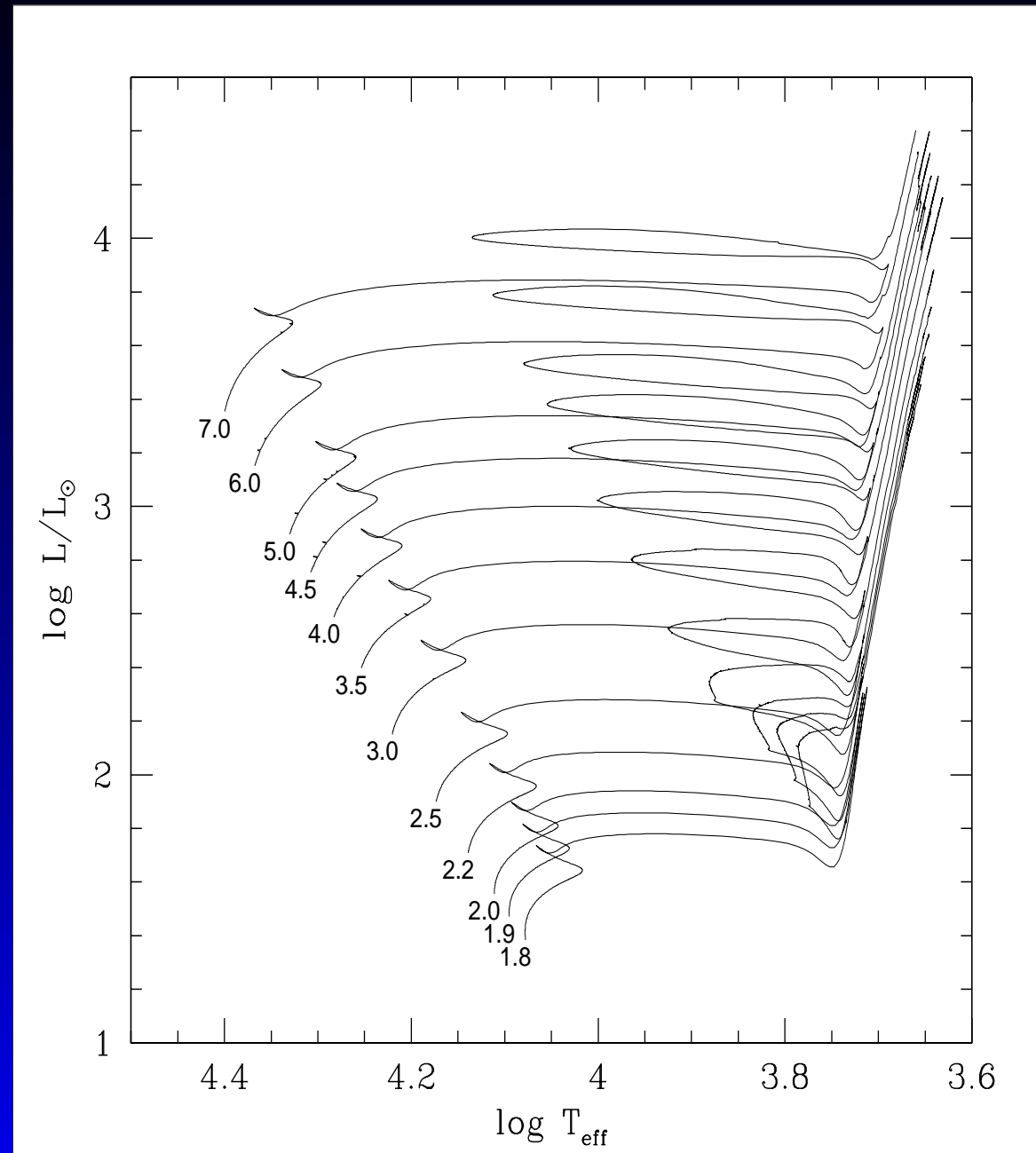
Carbon stars in the Local Group

Martin Groenewegen
groen@ster.kuleuven.ac.be

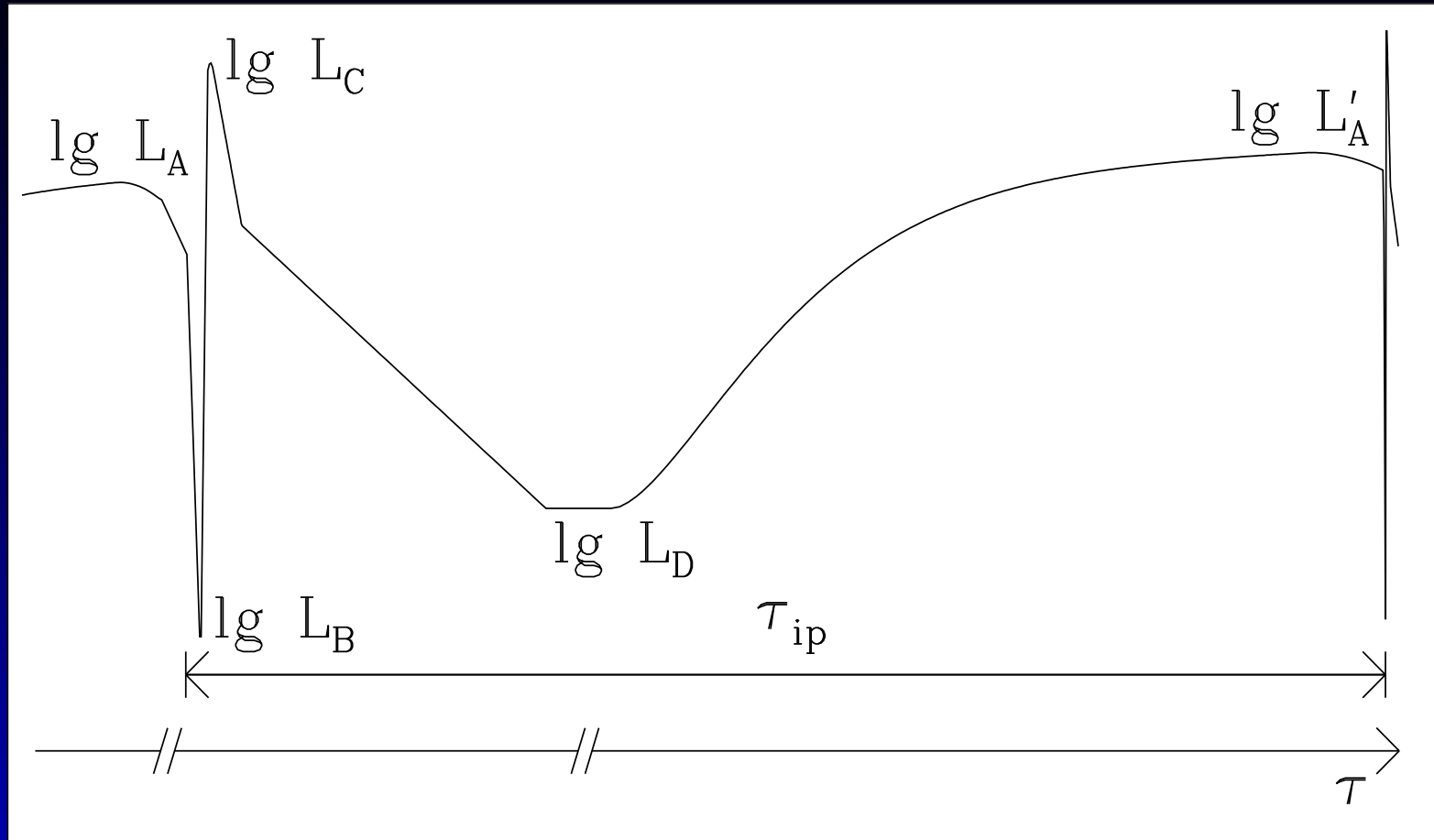
Instituut voor Sterrenkunde - K.U.Leuven

Overview

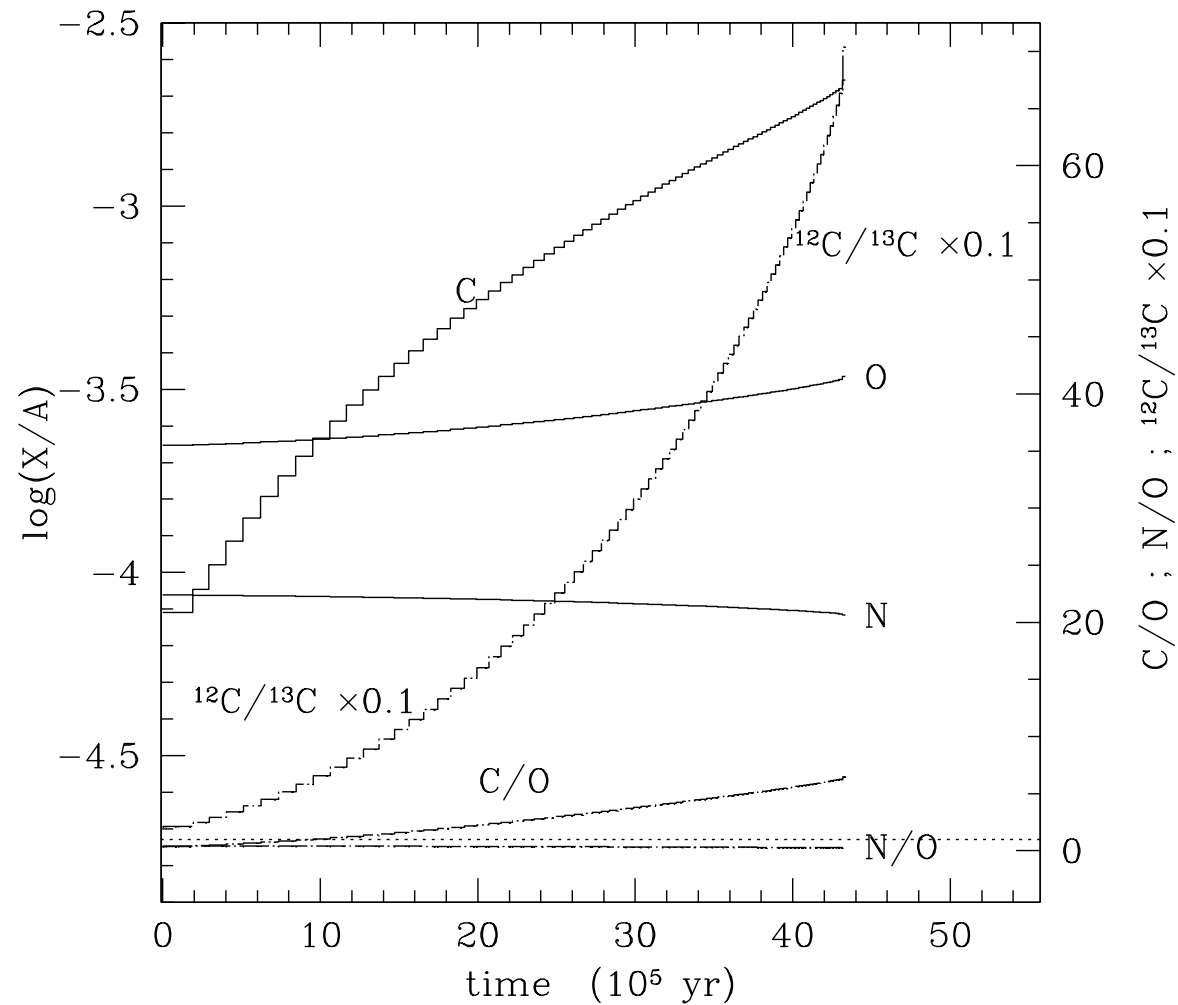
- Late-type stars
- How to find them?
- Inventory / Status report



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 ?

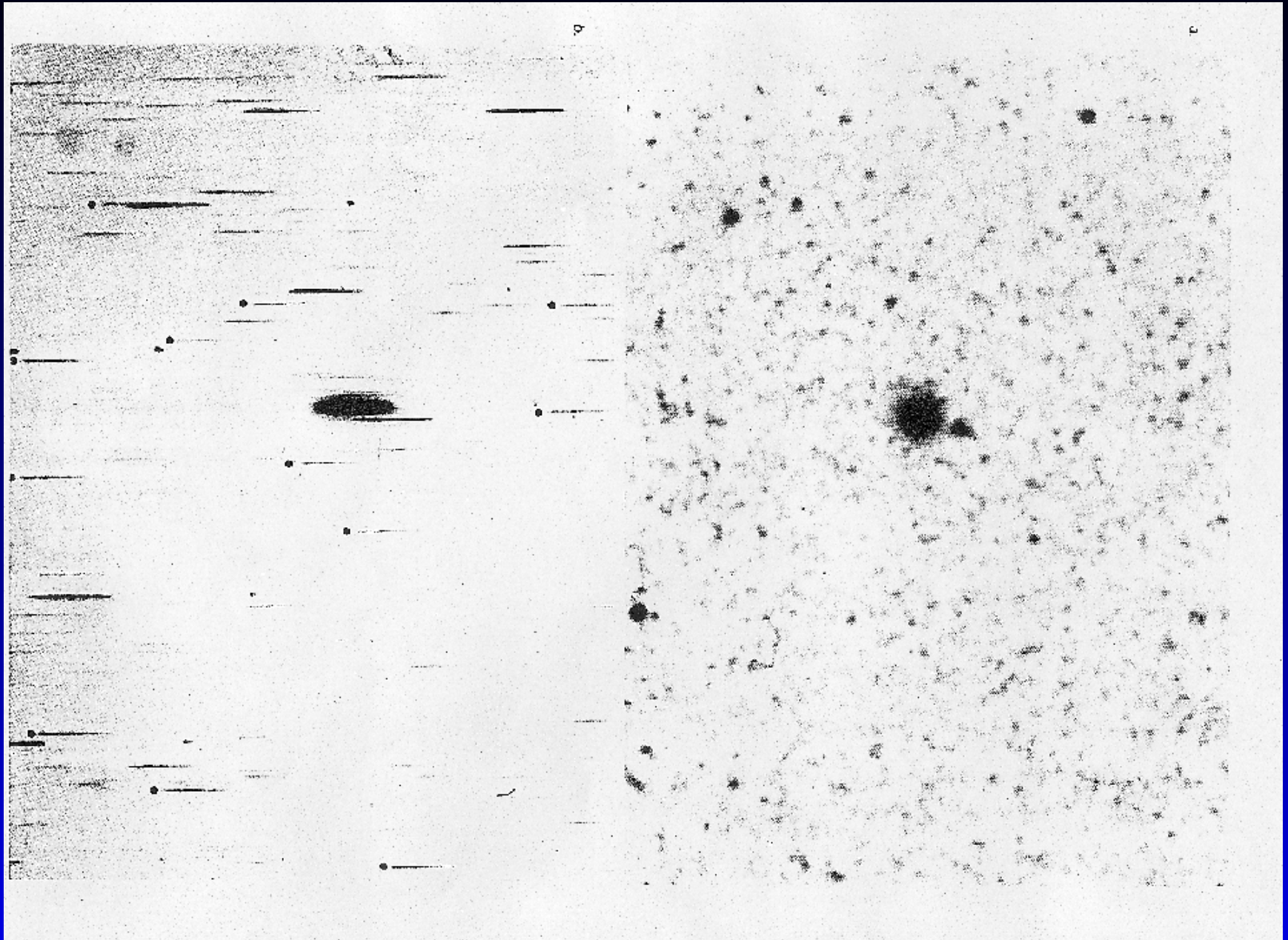
- Follow-up spectroscopy on red stars
- GRENS, GRISMS

Azzopardi and Westerlund

CN bands near 8000 Å

C₂ bands 4737, 5165 Å

disadvantage: crowding, sensitivity



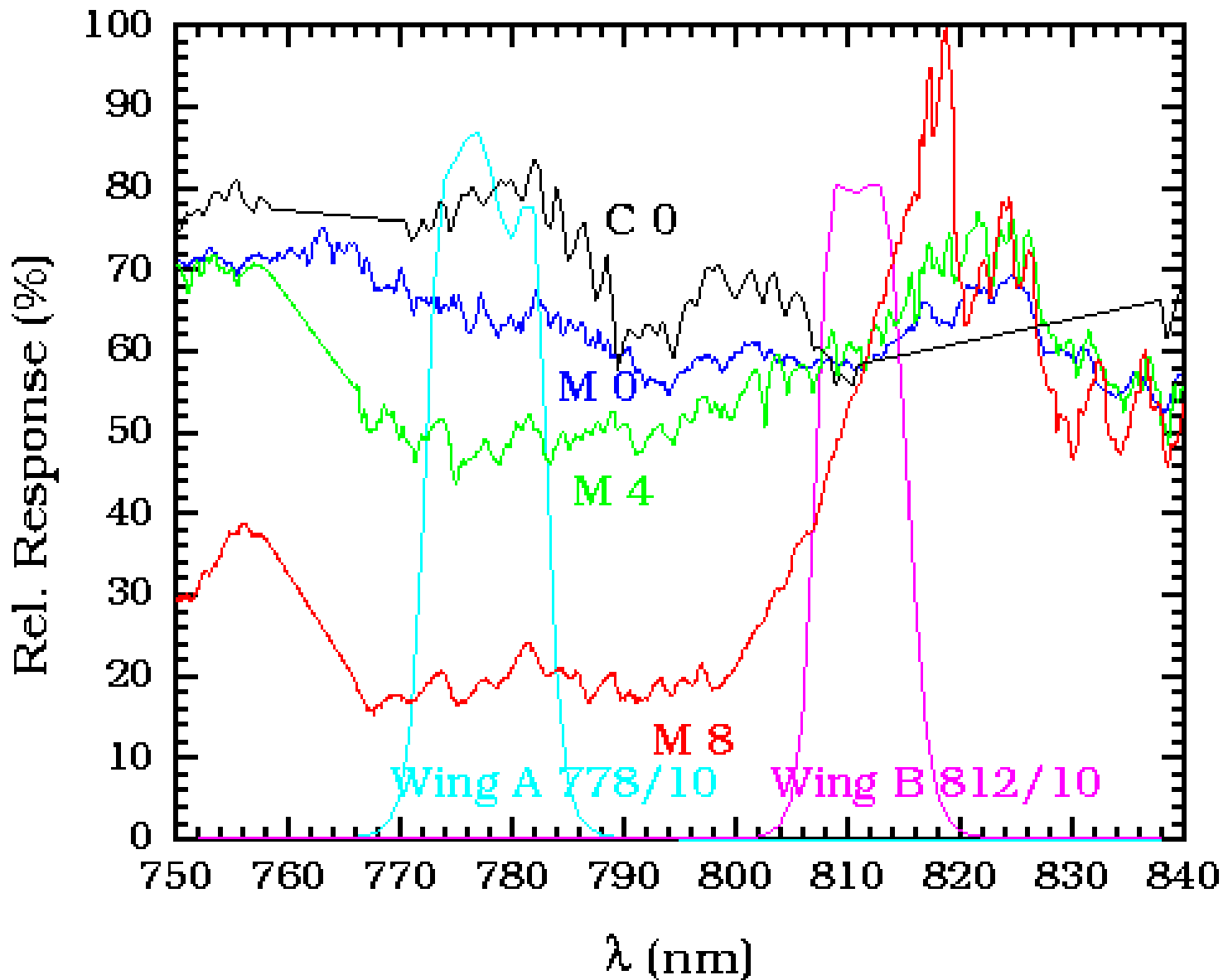
Westerlund 1978

How to identify late-type stars ?

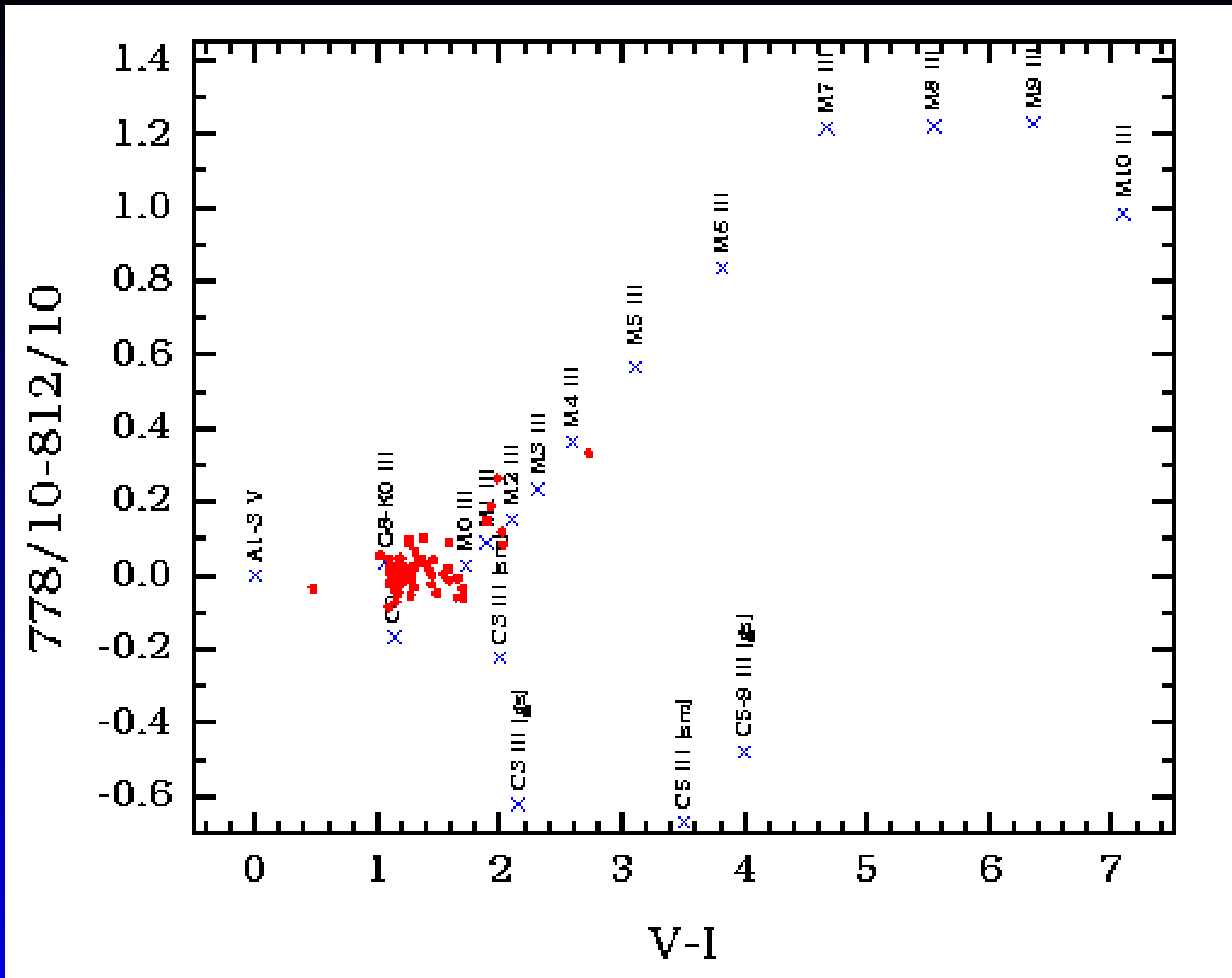
- Narrow-band filters

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

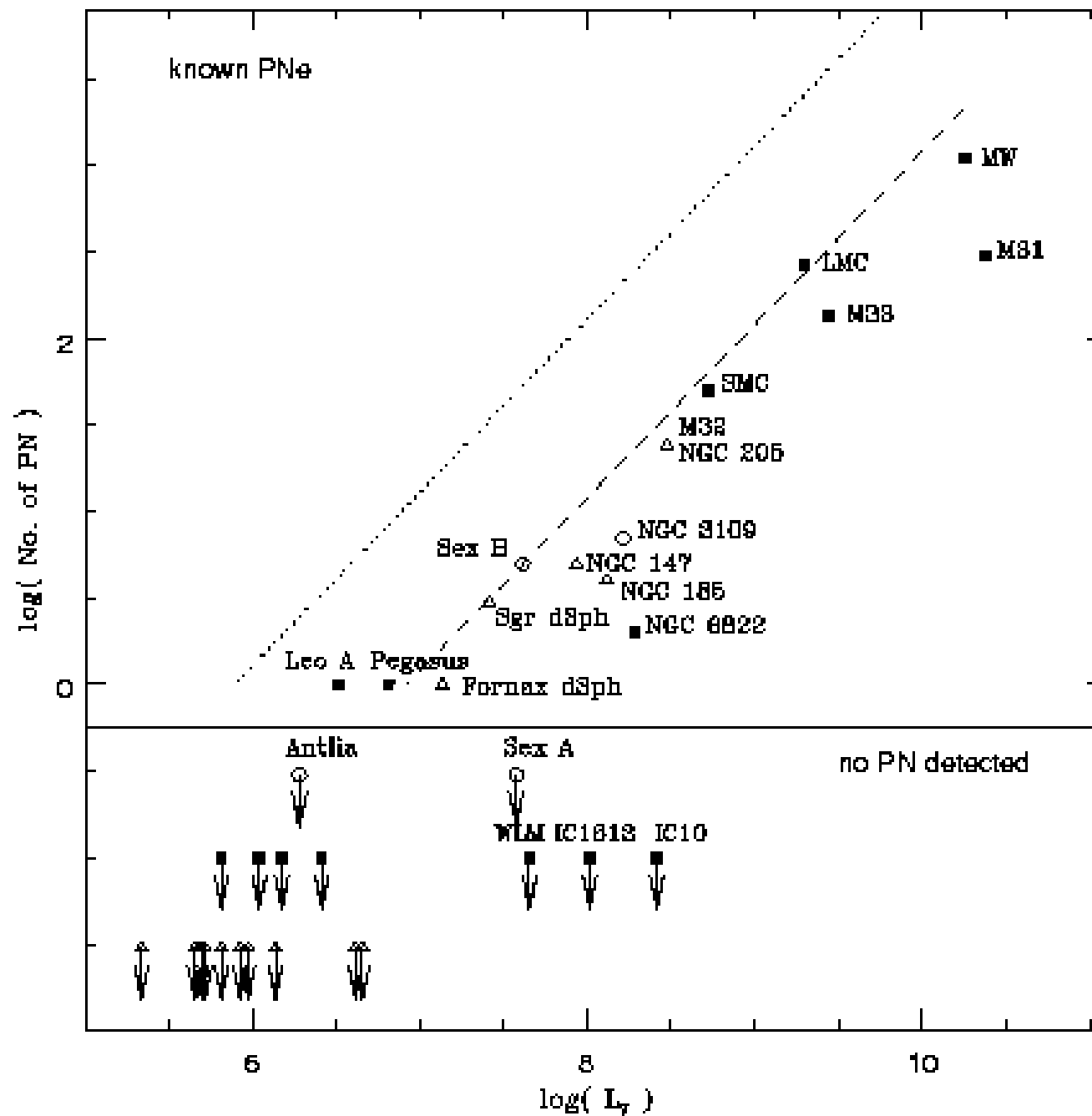
- Planetary Nebulae
- Long-Period variables

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



Other tracers

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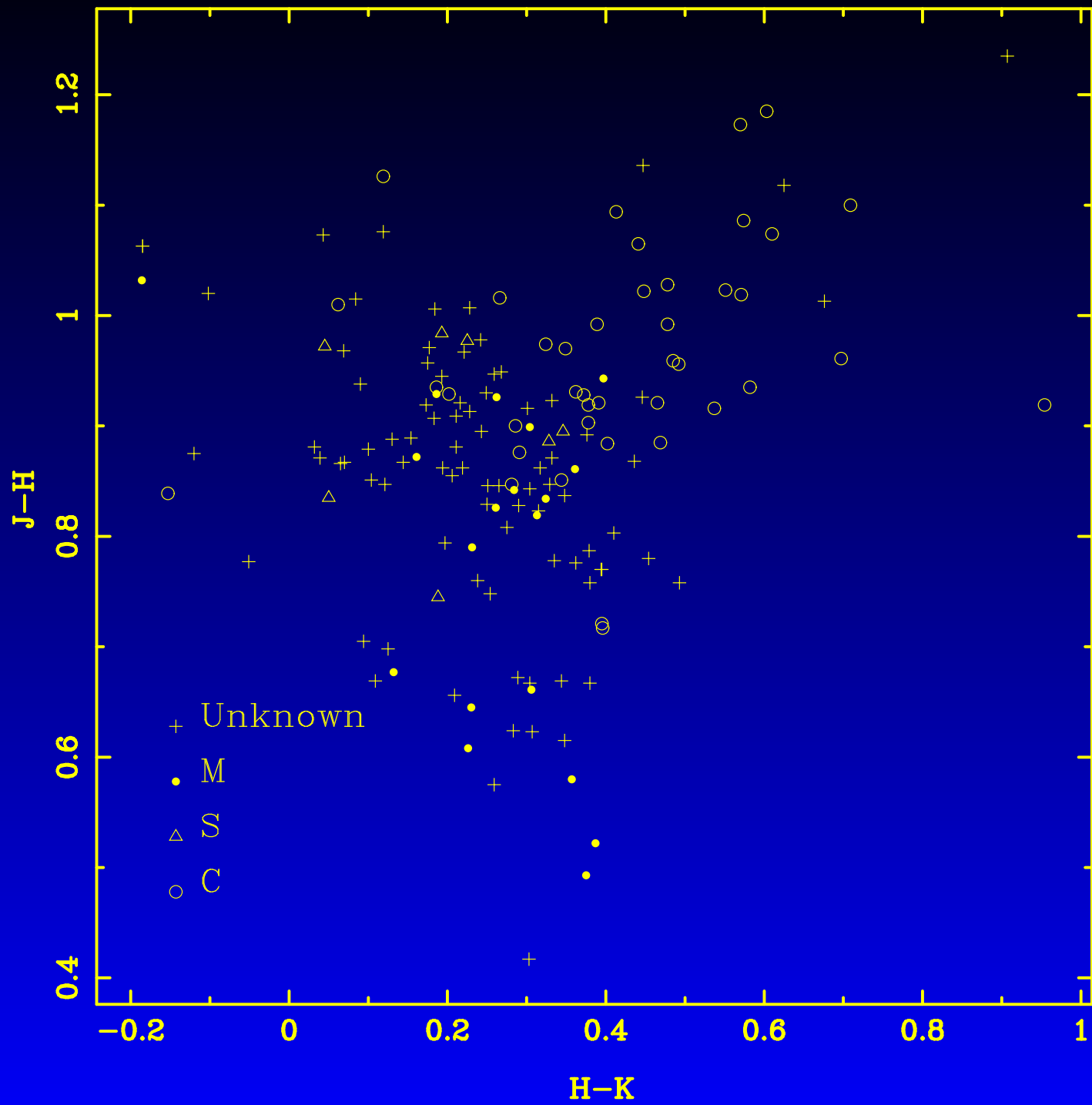
Some new results

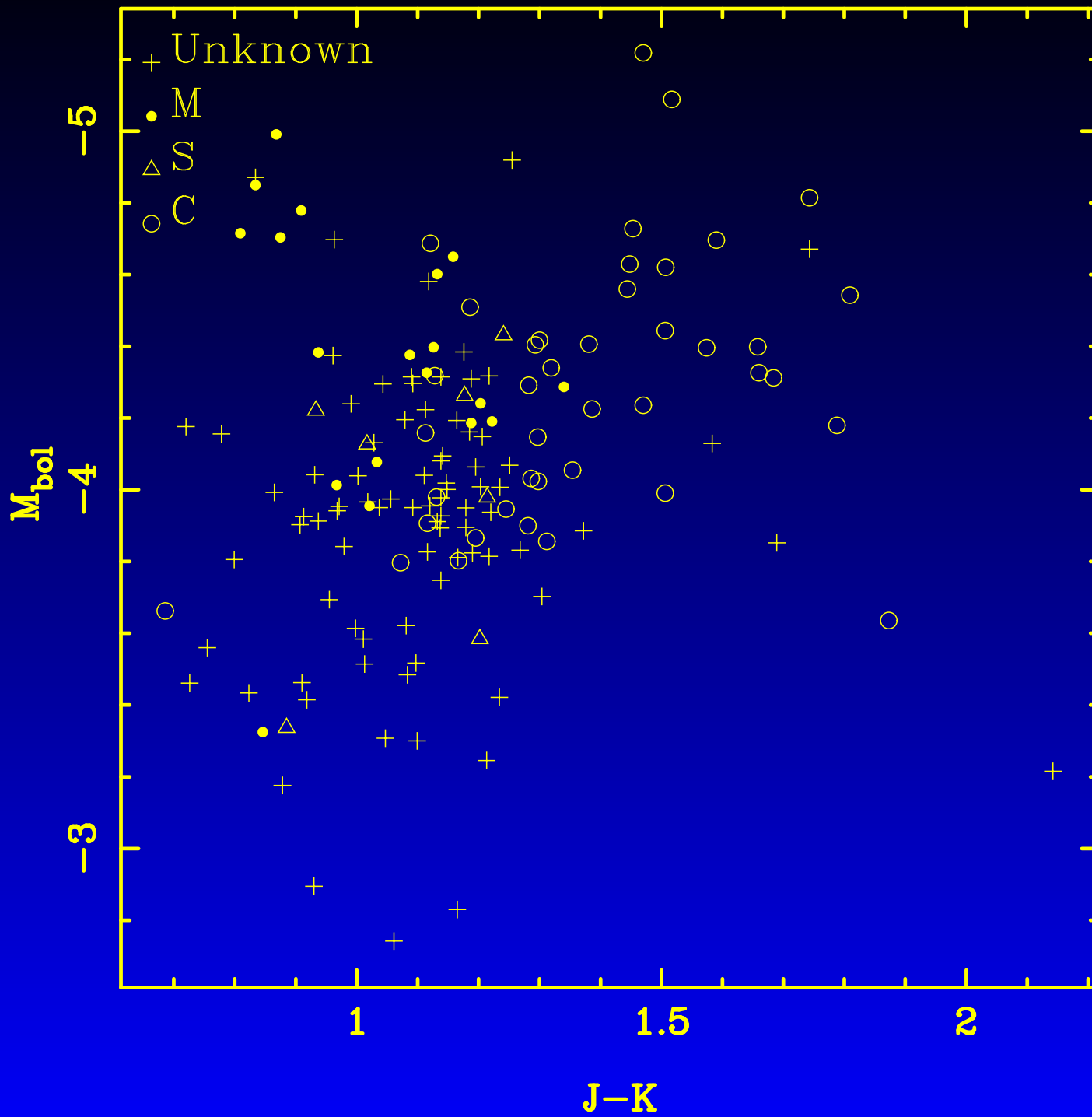
New surveys

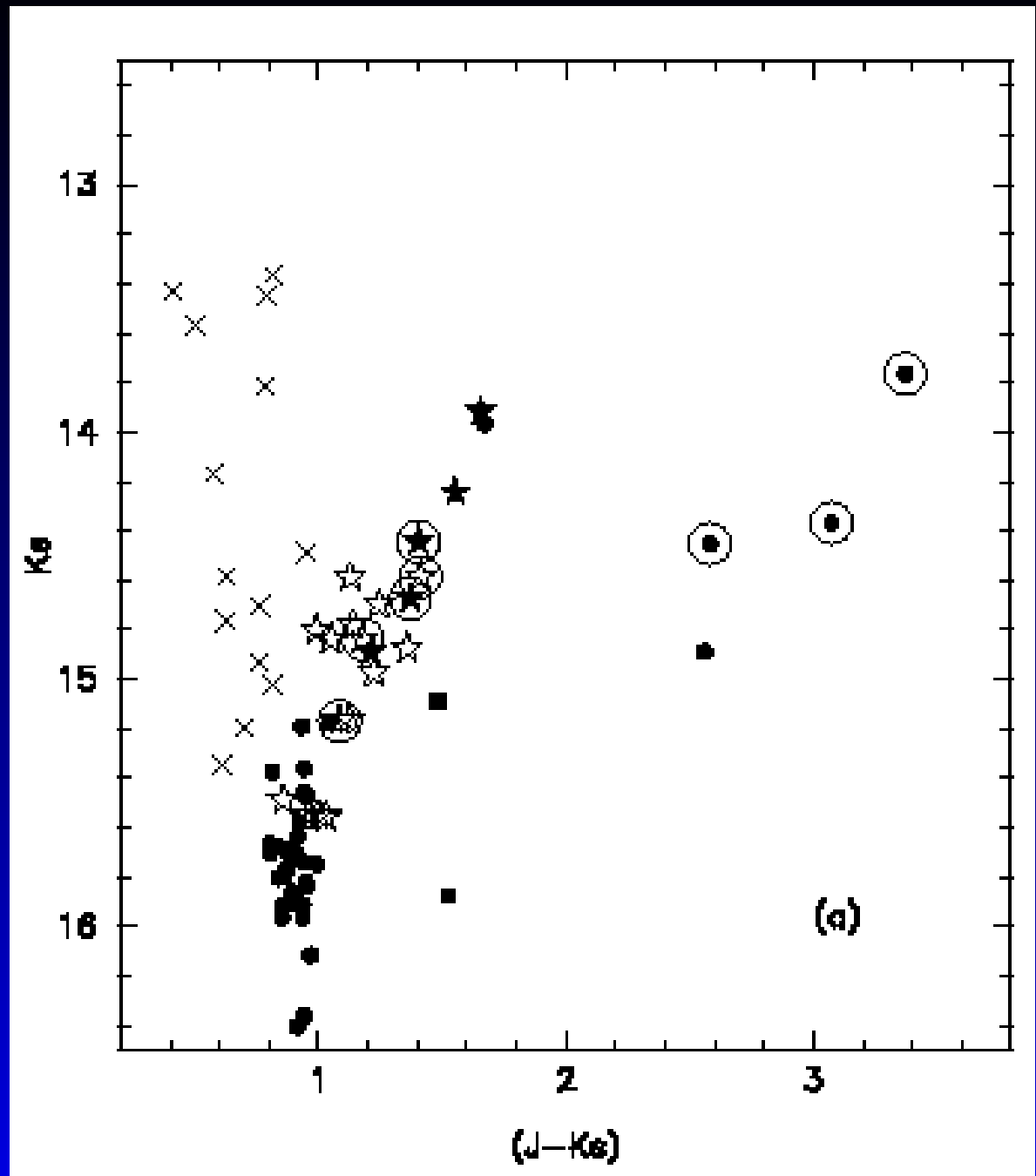
- Demers/Battinelli: SagDIG, Leo I, NGC 6822, Pegasus, Aquarius, Tucana, IC1613
- Nowotny et al.: M 31
- Kontizas et al.: LMC (7760 stars)

2MASS

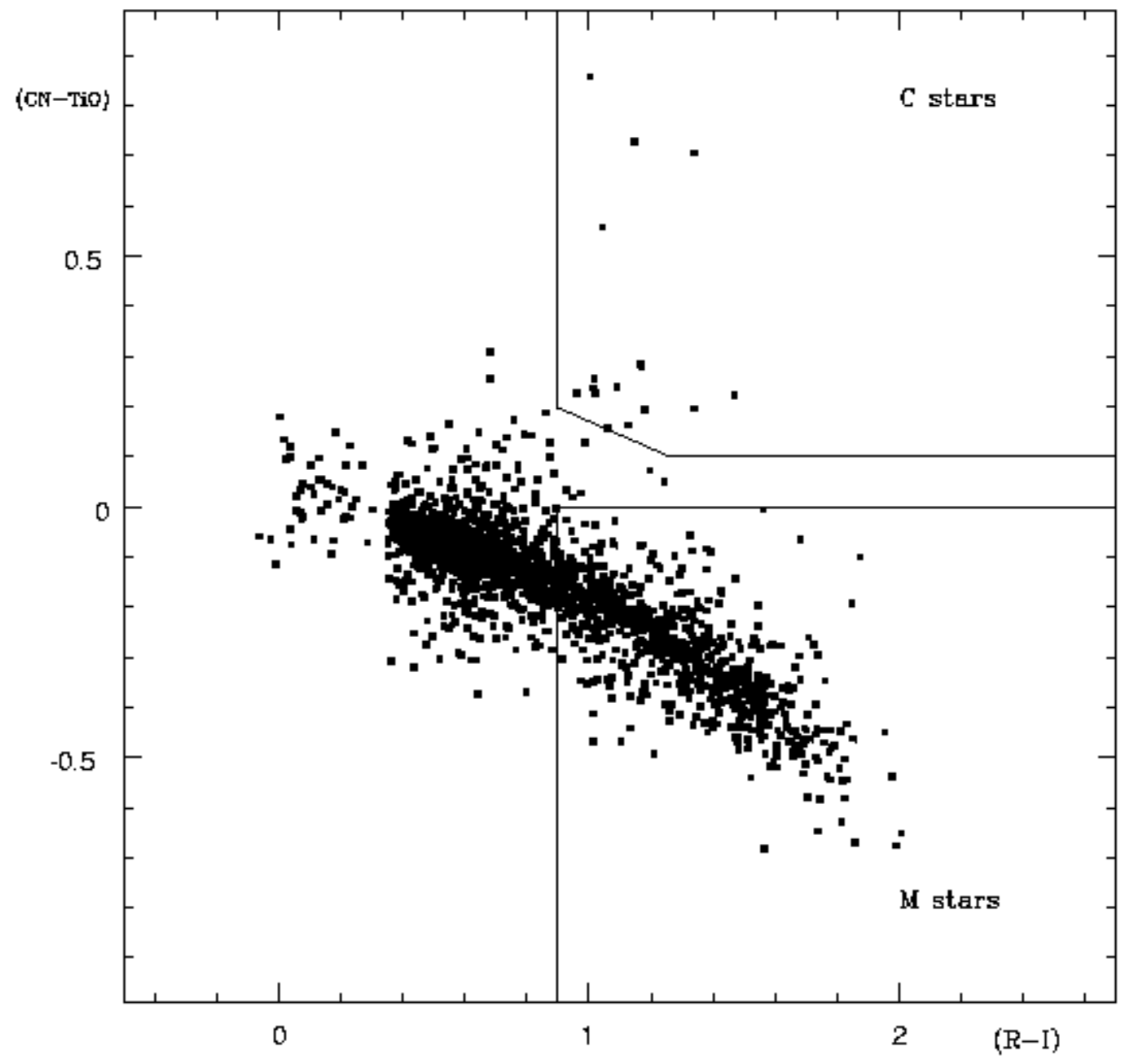
- Demers et al. (2002) on Fornax and LMC
- Correlated known carbon stars in Sculptor, Sagittarius DSph, Leo II, Ursa Minor, red stars in Fornax from Stetson et al. (1998)



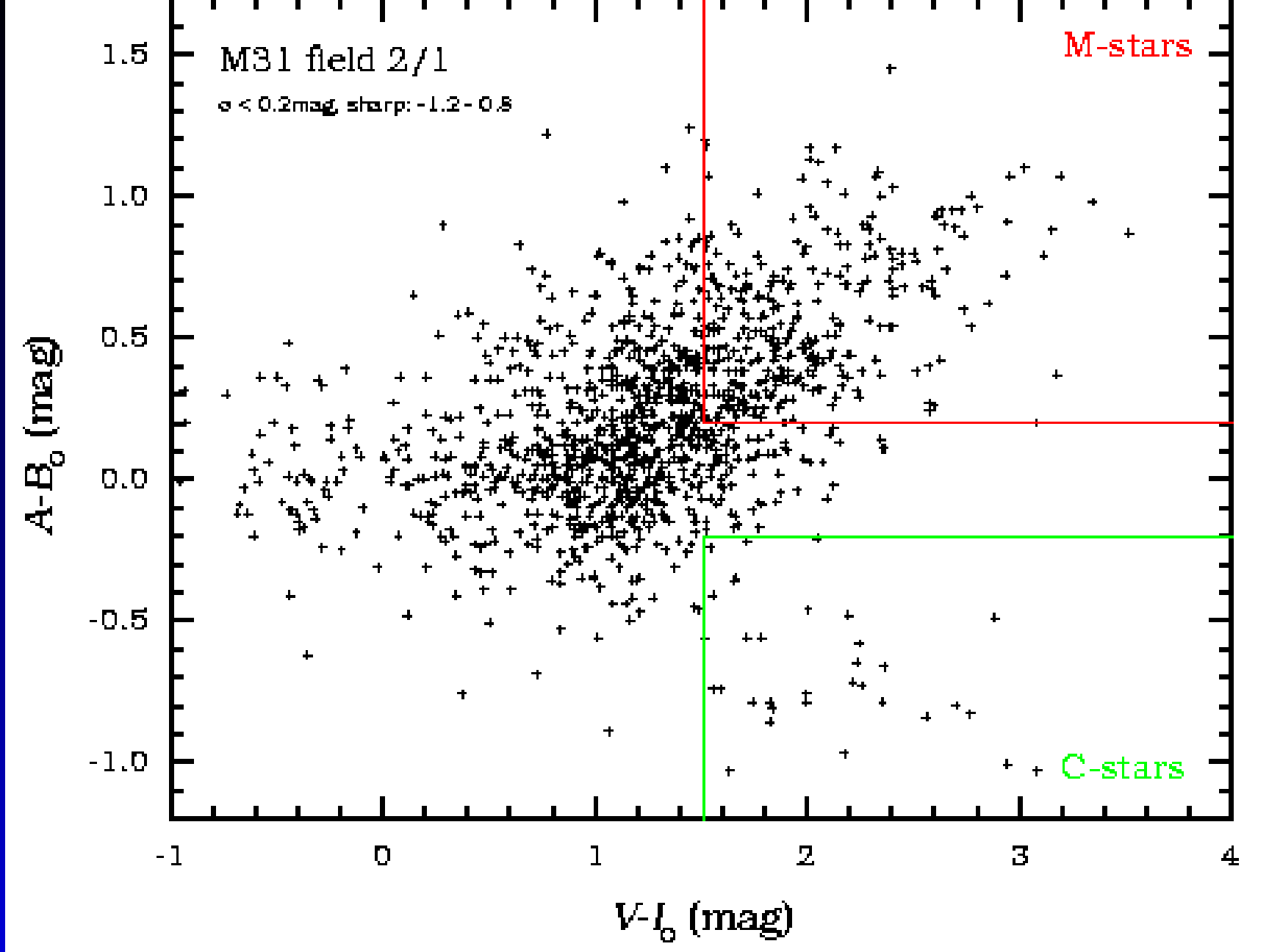




Menzies et al. 2002 on Leo I



Demers et al. 2002 on Leo I

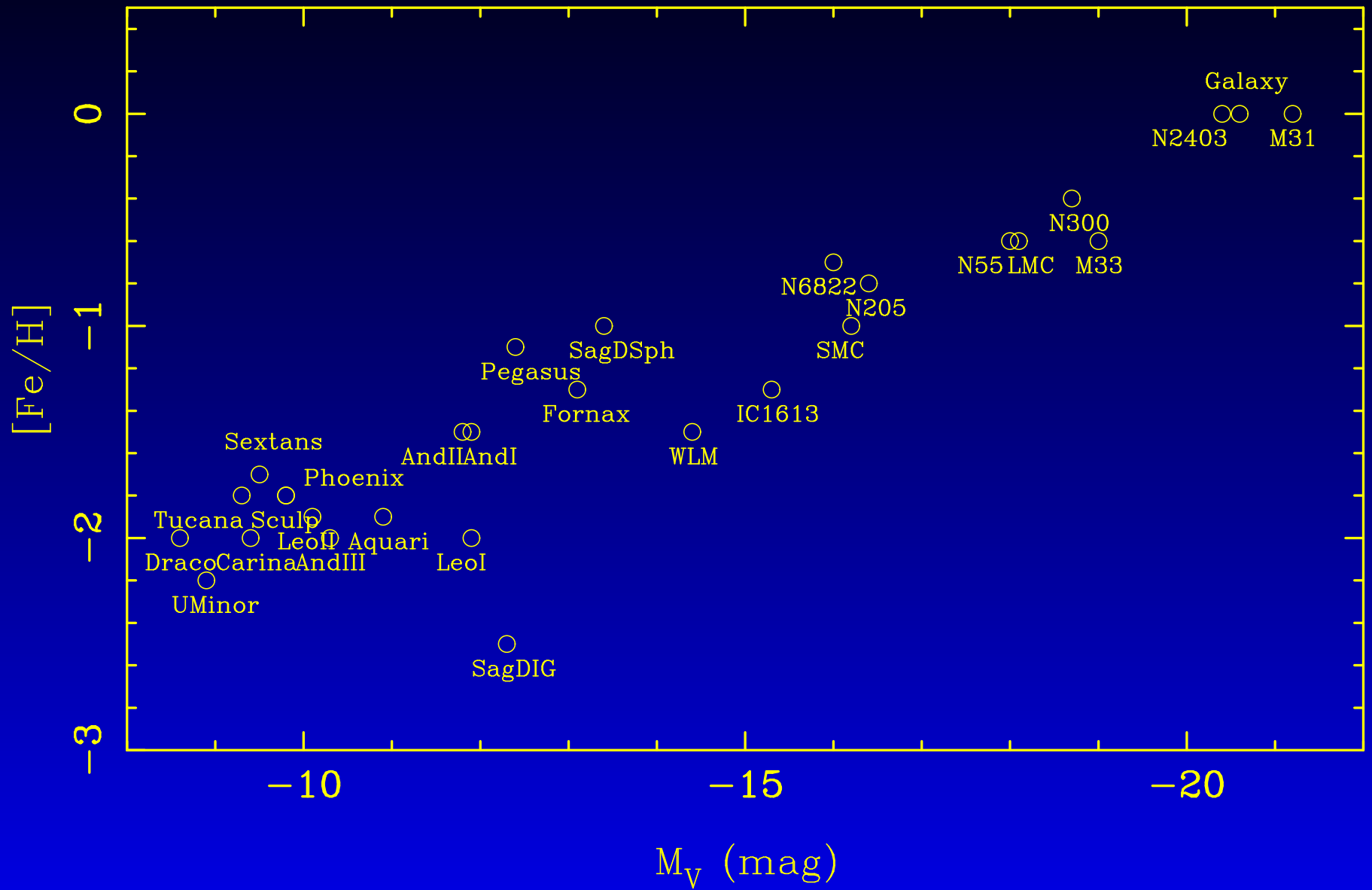


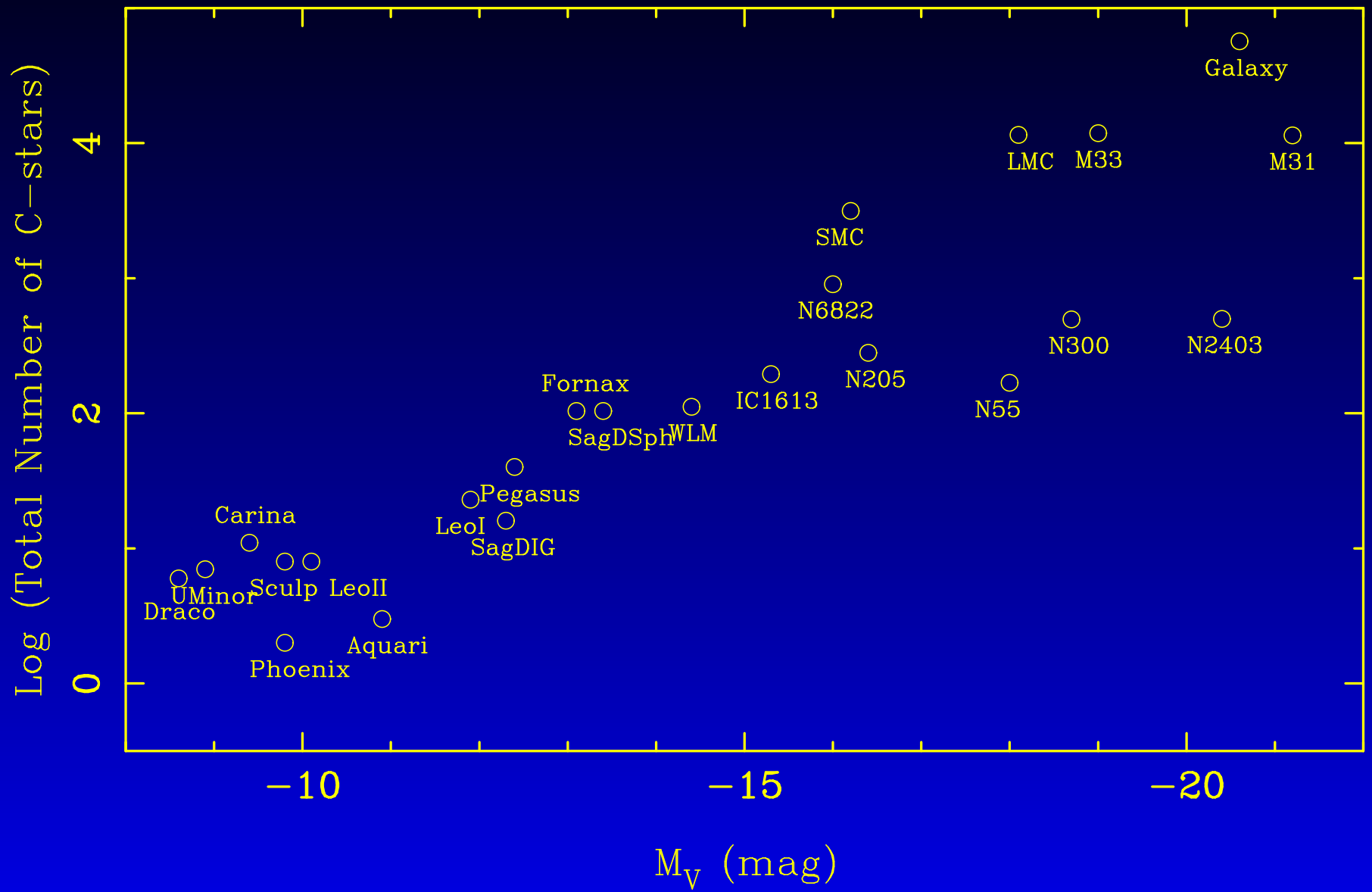
Nowotny et al. 2001

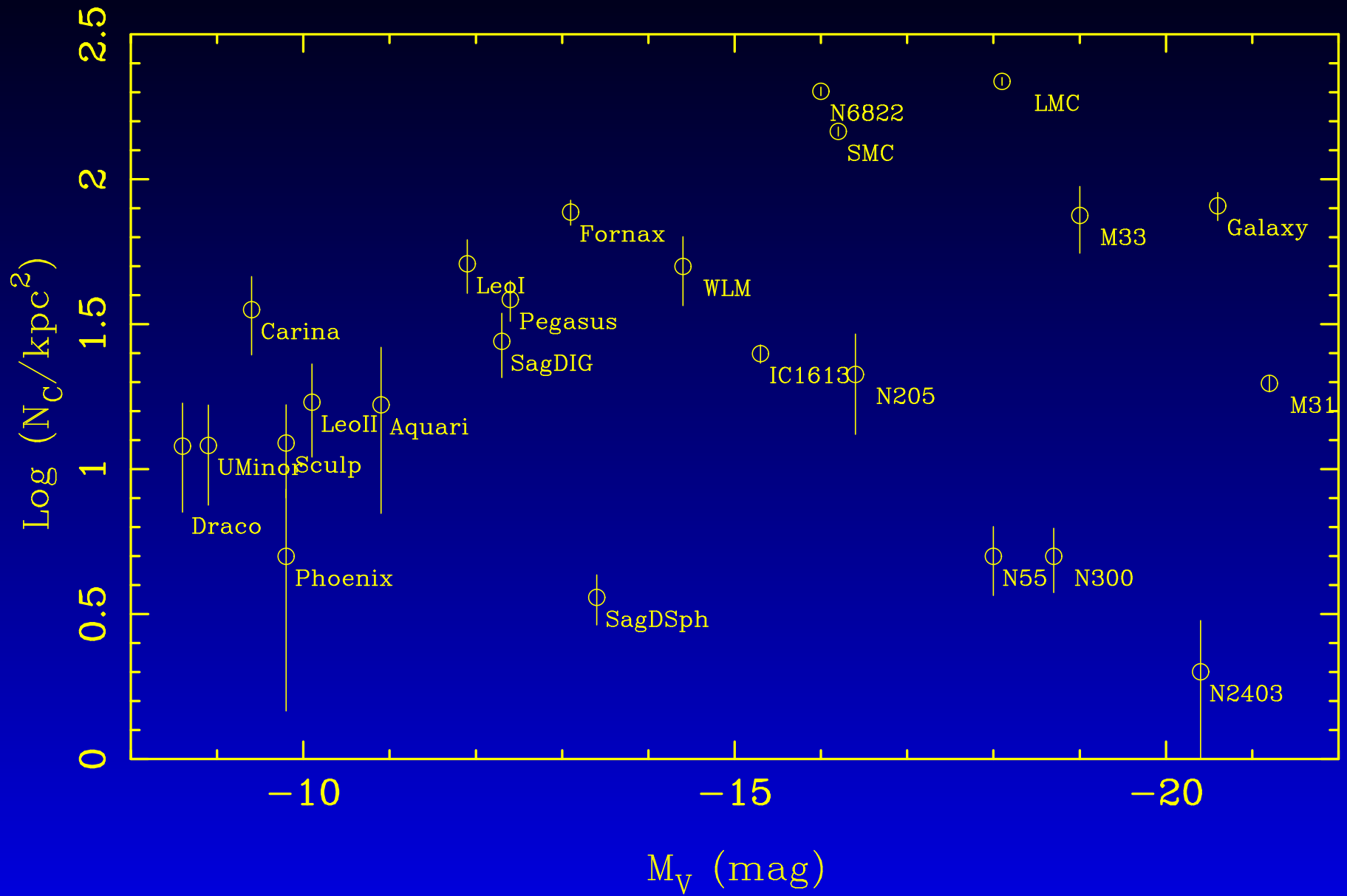
Name	D	M_V	[Fe/H]	N_C	Area	N_M
	(kpc)	(mag)			(kpc ²)	
M31	770	-21.2	0.0	243	12.3	789 (5+)
Galaxy		-20.6	0.0	81	1.00	C/M \approx 0.2
M33	840	-19.0	-0.6	15	0.20	5 (5+), 60 (0+)
LMC	50	-18.1	-0.6	1045	4.8	1300 (5+)
				7750	220.	
NGC 205	815	-16.4	-0.8	7	0.33	4 (5+), 17 (0+)
SMC	63	-16.2	-1.0	789	5.4	180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

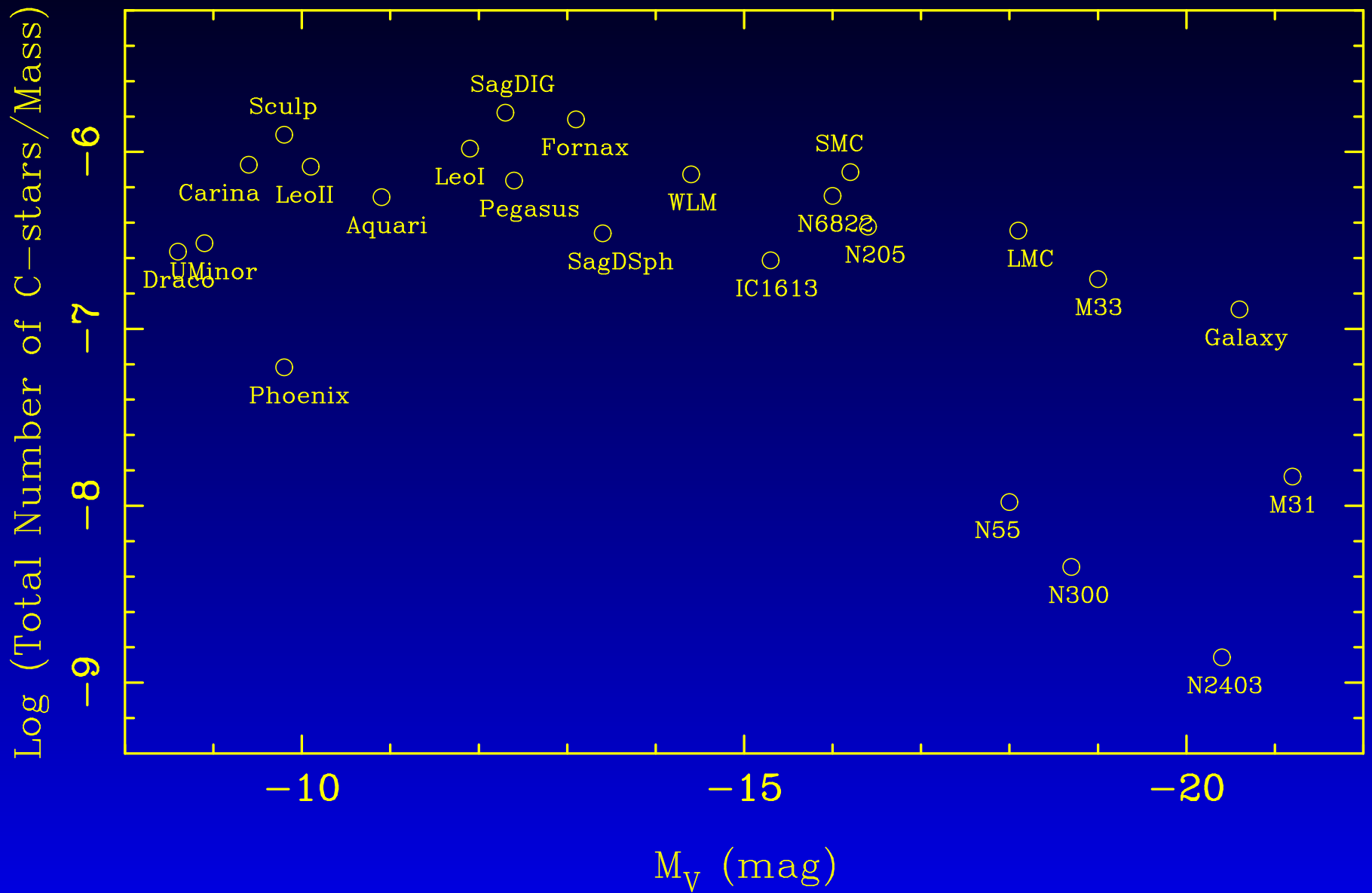
Name	D	M_V	[Fe/H]	N_C	Area	N_M
	(kpc)	(mag)			(kpc ²)	
SagDSph	24	-13.4	-1.0	26	7.2	
Fornax	138	-13.1	-1.3	104	1.35	4 (5+), 25 (2+)
Pegasus	955	-12.4	-1.1	40	1.04	77 (0+)
SagDIG	1060	-12.3	-2.5	16	0.58	1 (0+)
Leo I	250	-11.9	-2.0	23	0.45	1 (5+), 15 (0+)
And I	790	-11.9	-1.5	0		
And II	680	-11.8	-1.5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

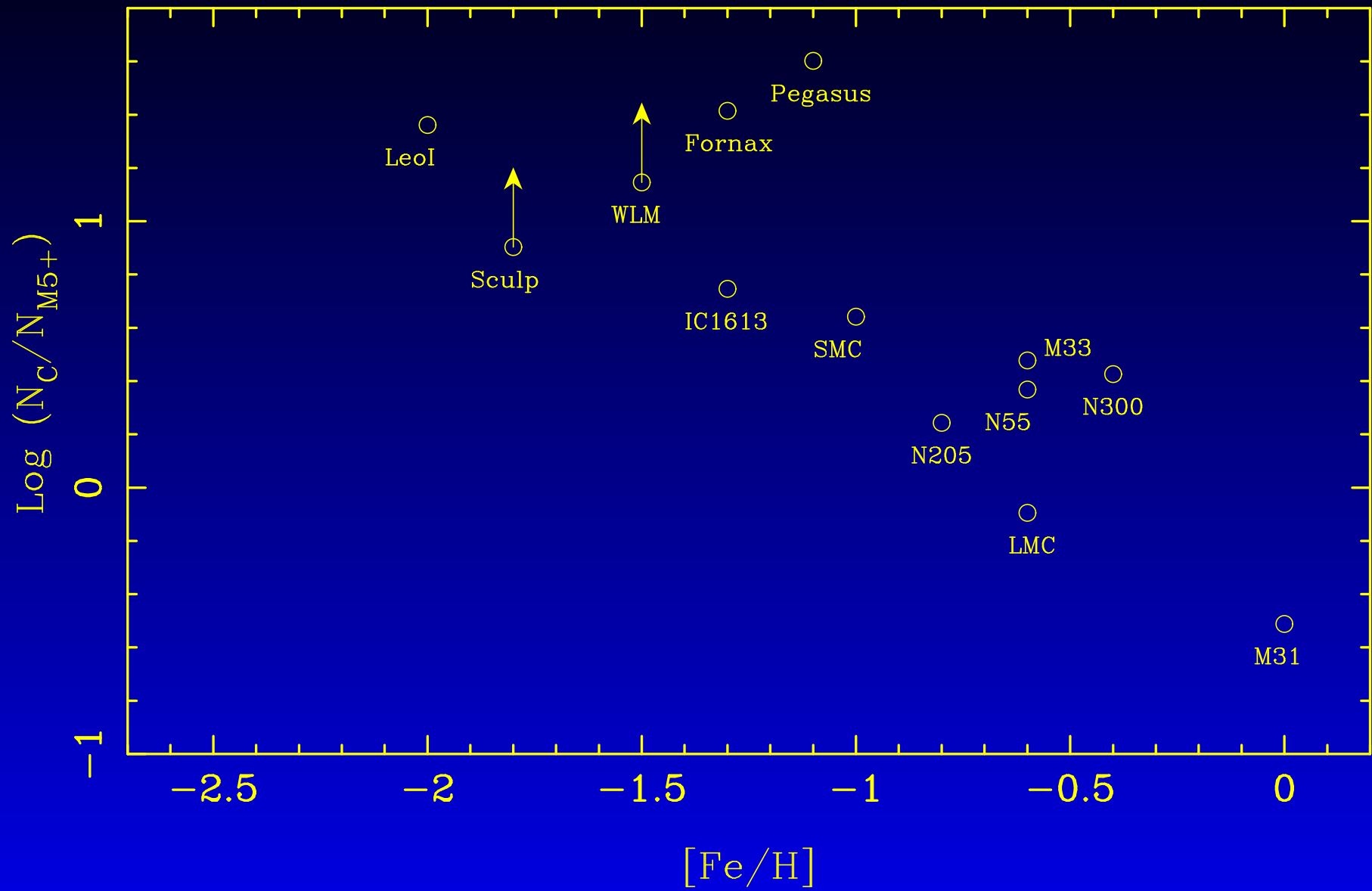
Name	D	M_V	[Fe/H]	N_C	Area	N_M
	(kpc)	(mag)			(kpc ²)	
Phoenix	400	-9.8	-1.8	2	0.40	
Sextans	86	-9.5	-1.7	(0)		
Carina	100	-9.4	-2.0	11	0.31	
Tucana	870	-9.3	-1.8	0	0.22	
Ursa Minor	69	-8.9	-2.2	7	0.58	
Draco	82	-8.6	-2.0	6	0.50	
NGC 2403	3390	-20.4	0.0	4	2.0	7 (0+)
NGC 300	2170	-18.7	-0.4	16	3.2	23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

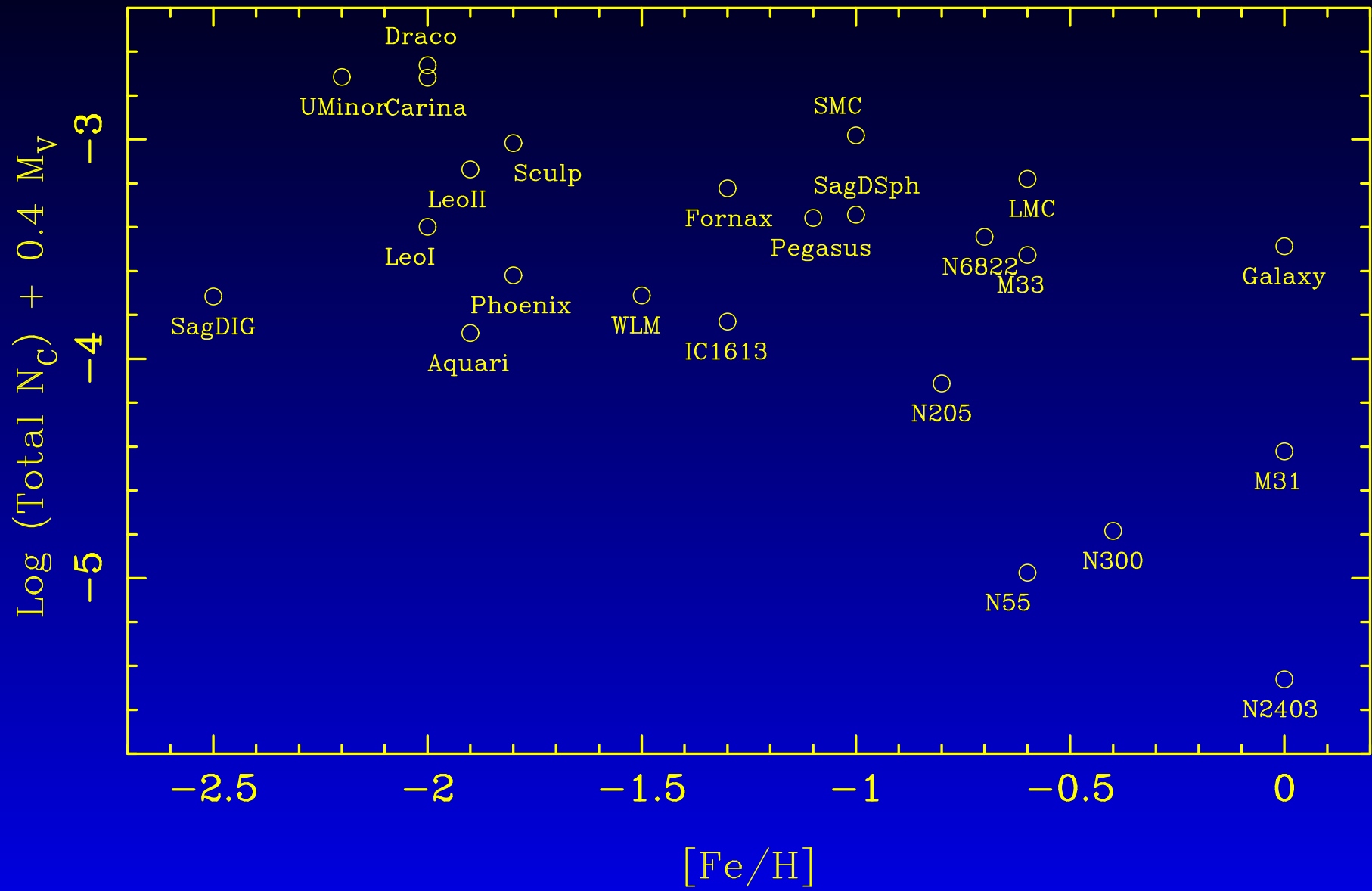






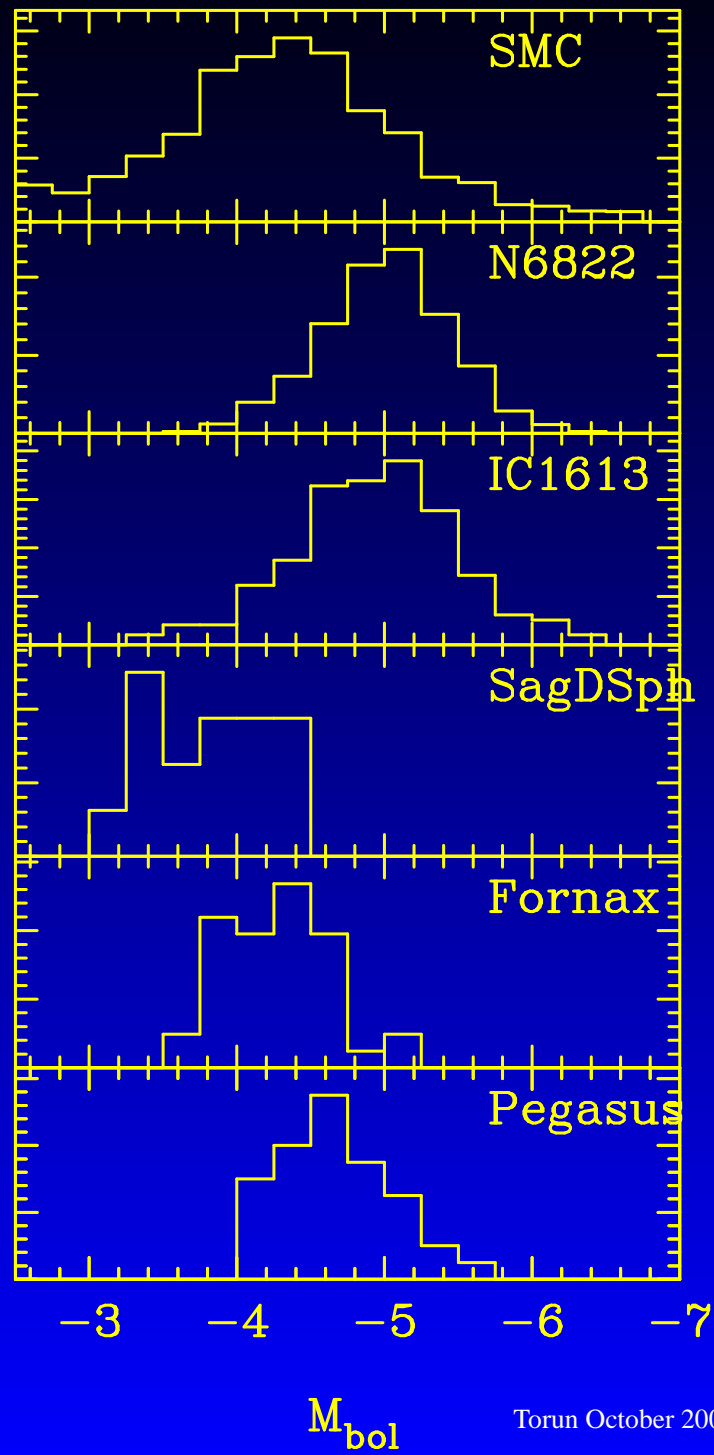
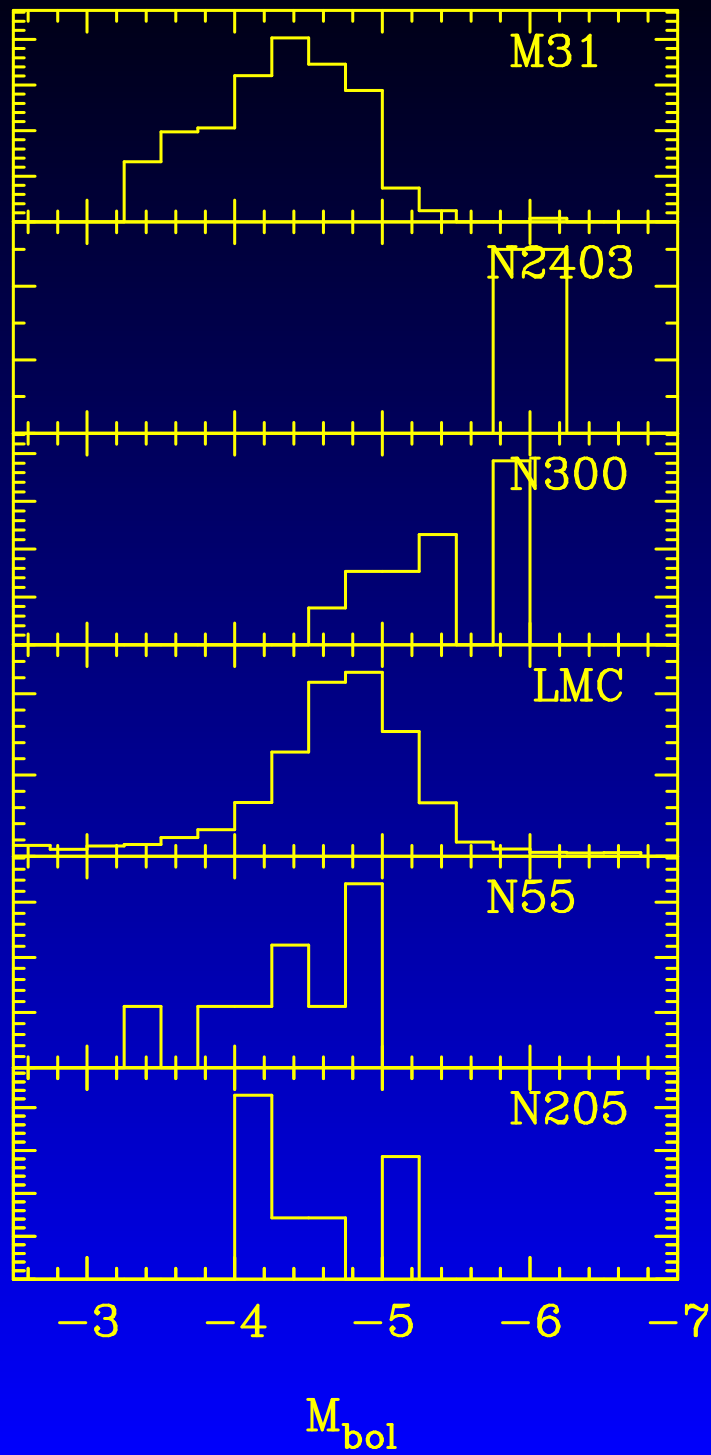


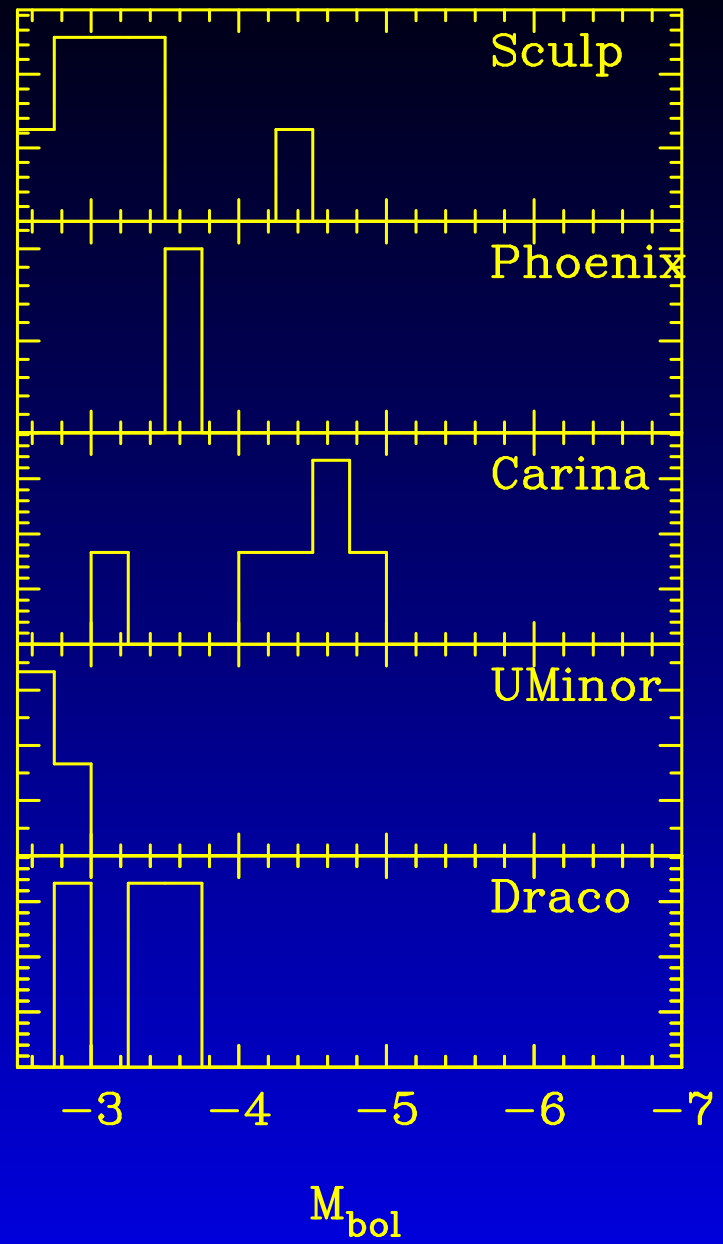
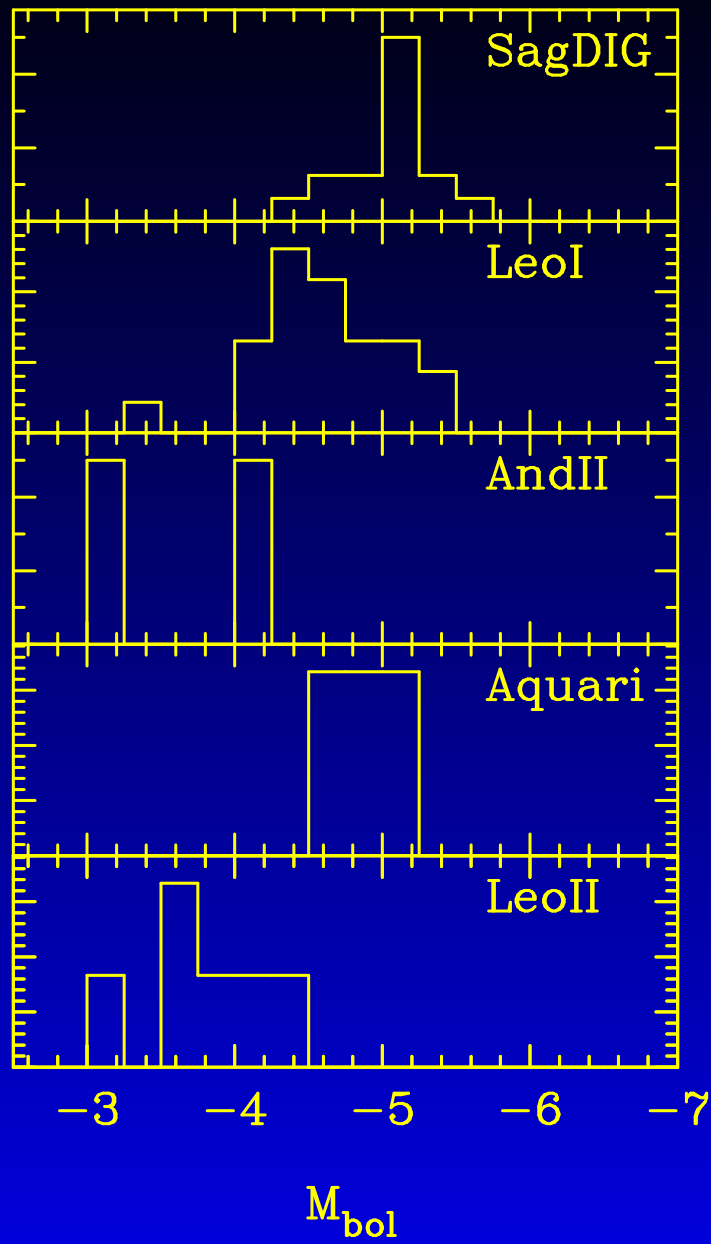


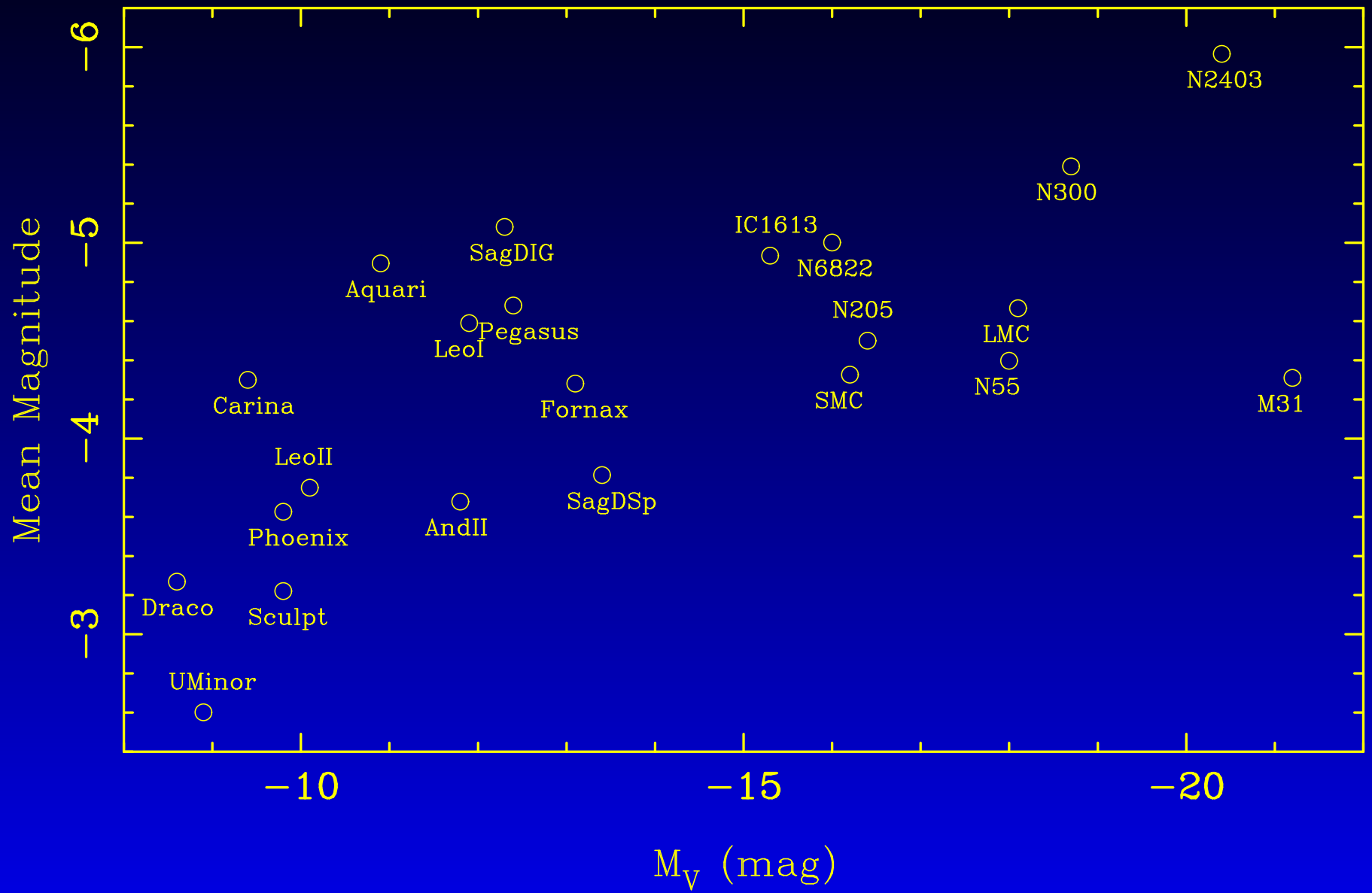


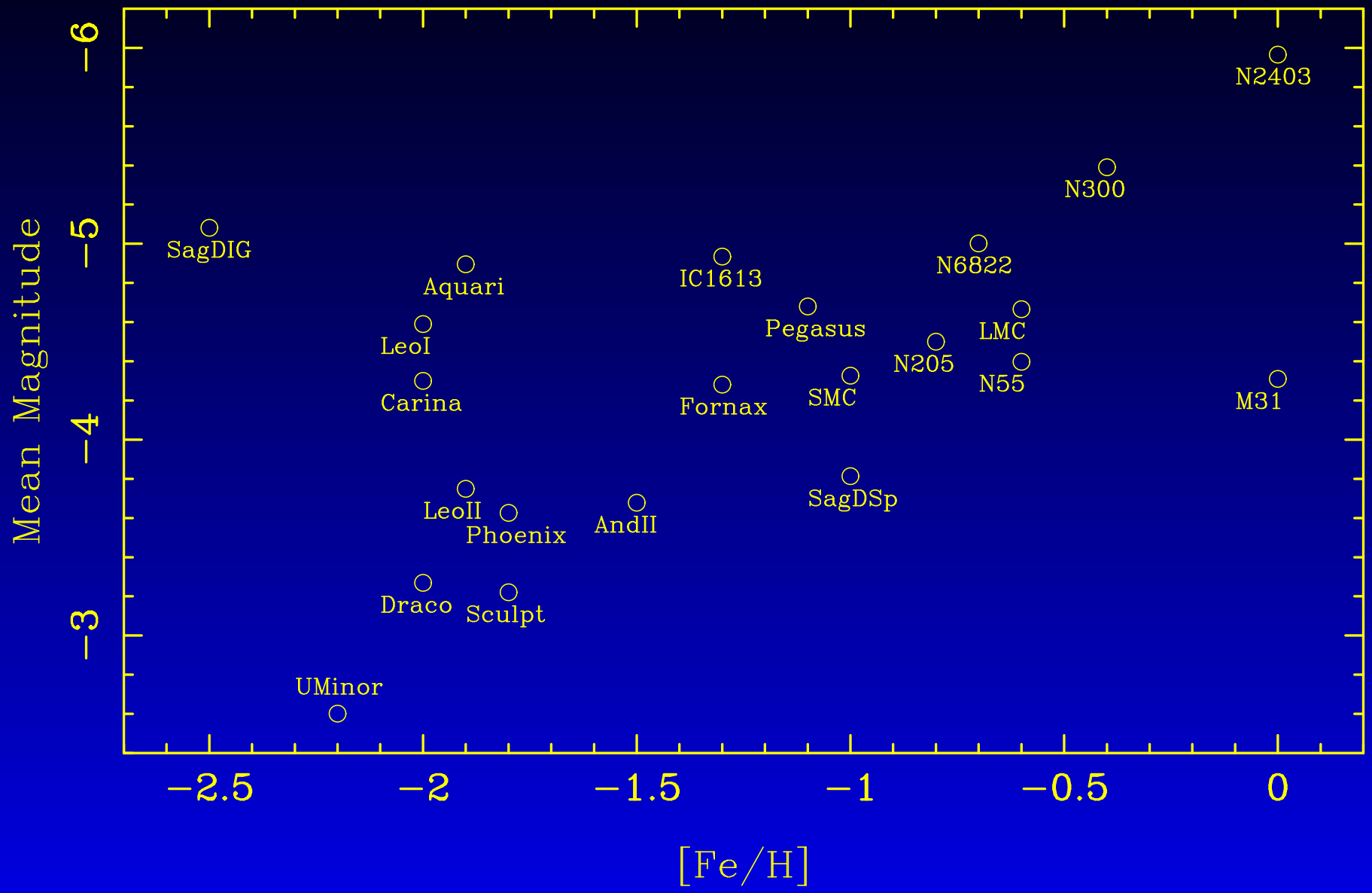
Name	$M_{\text{bol}}^{\text{max}}$	$M_{\text{bol}}^{\text{min}}$	$M_{\text{bol}}^{\text{mean}}$	spread	N_{all}	$N_{M_{\text{bol}} > -3.5}$
	(mag)	(mag)	(mag)	(mag)		
M 31	-6.13	-3.34	-4.31	0.50	243	16
NGC 2403	-6.05	-5.89	-5.97	0.08	4	0
NGC 300	-5.93	-4.68	-5.39	0.41	13	0
LMC	-8.01	-1.33	-4.67	0.61	7650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









Theory

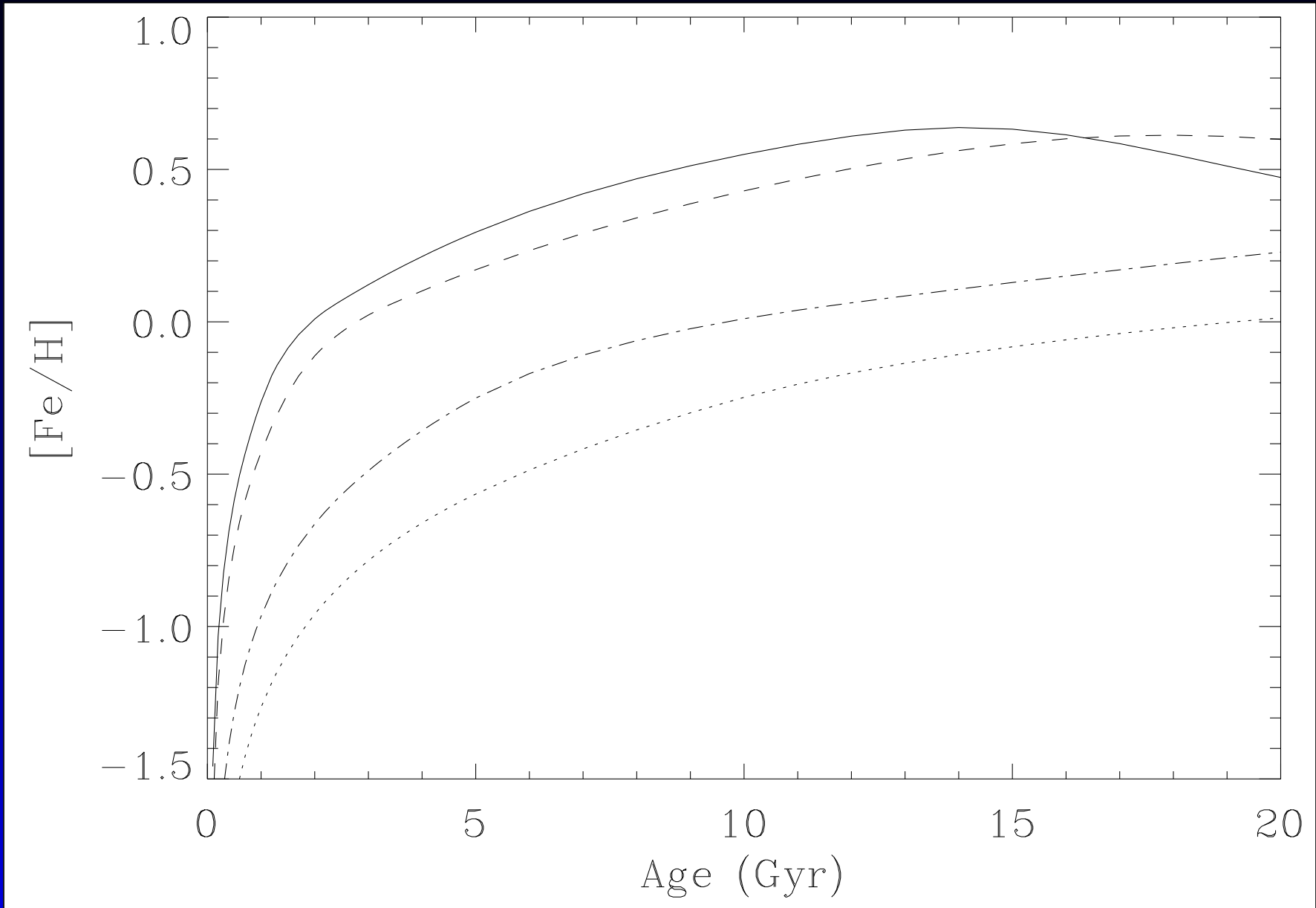
- Mouhcine & Lançon (2002)

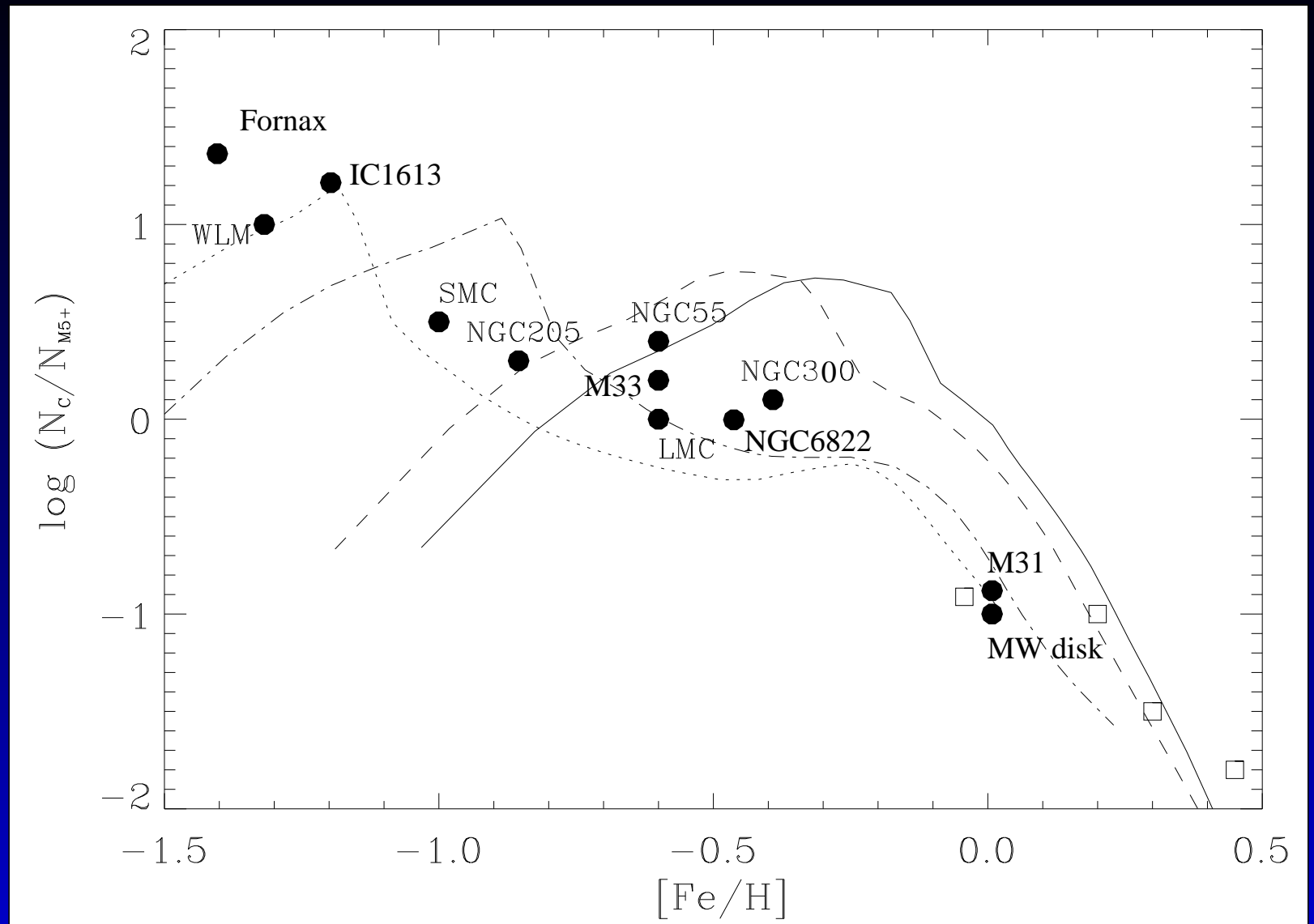
Evolutionary population synthesis models, including chemical evolution.

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
 [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