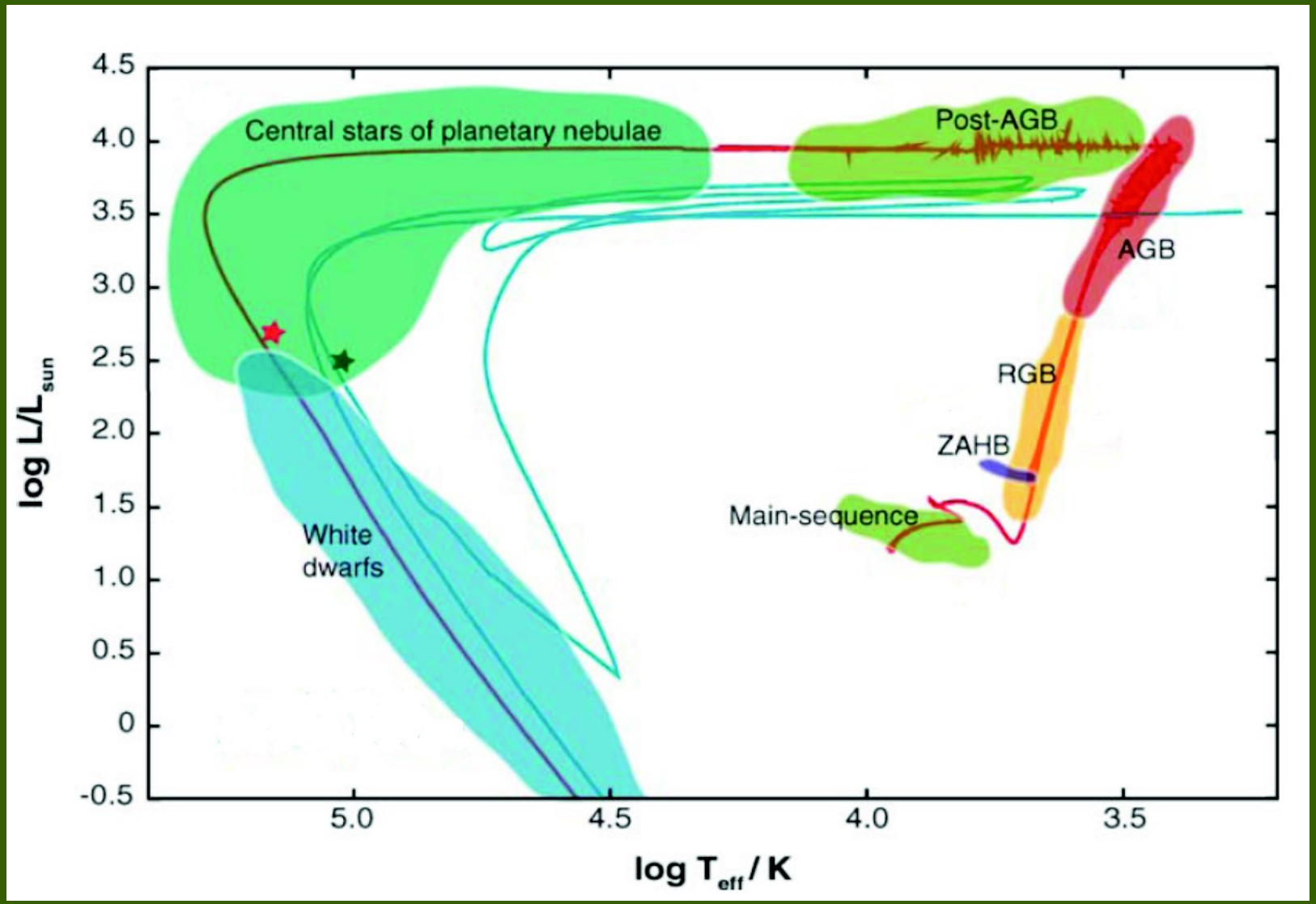
Properties of planetary nebulae observed by Spitzer

S.K. Górny

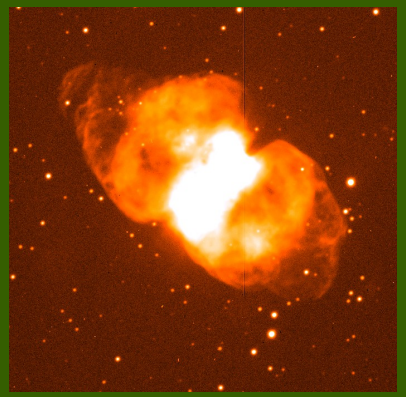
(NCAC) Toruń

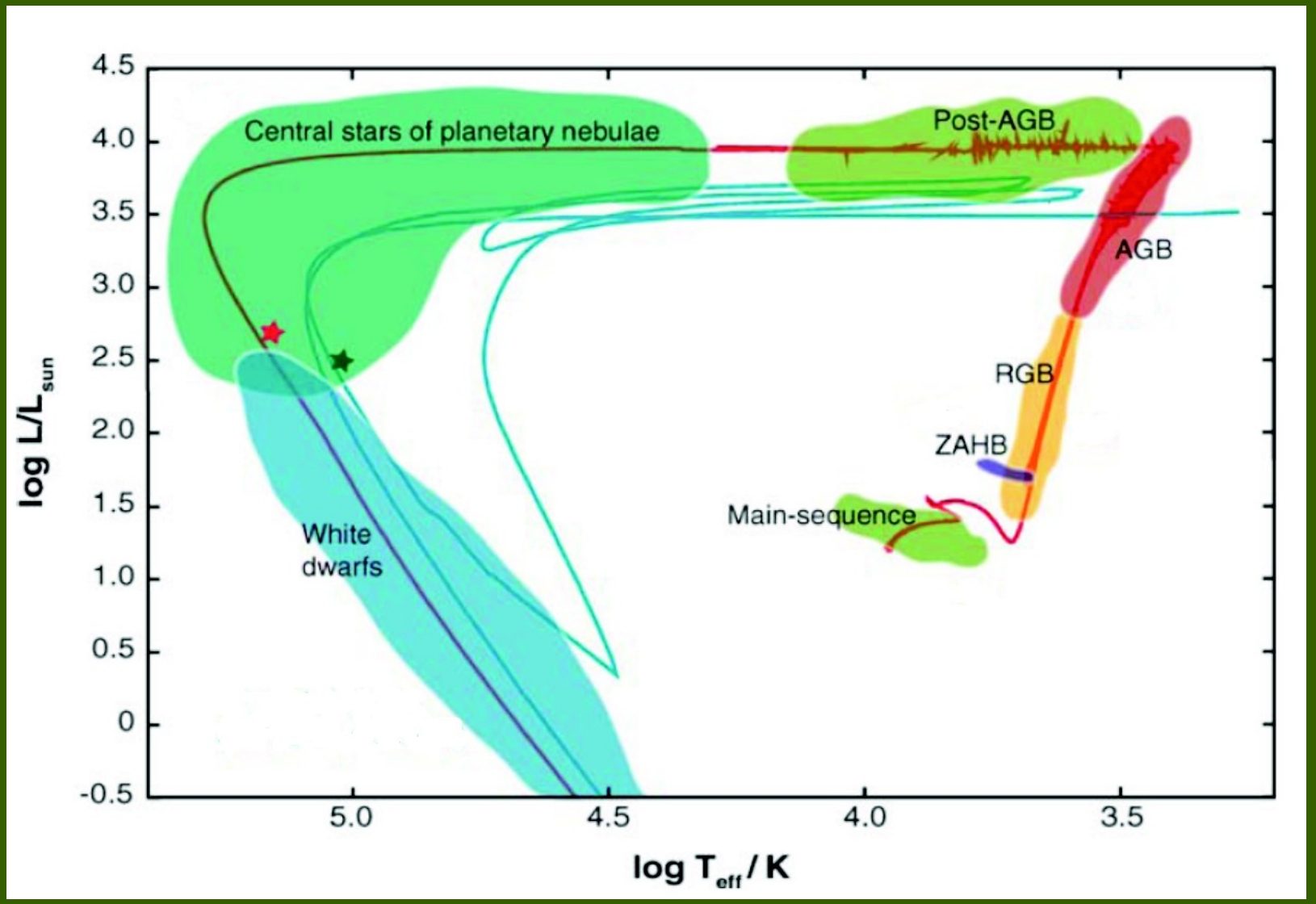
in collabration with D.A. García-Hernández

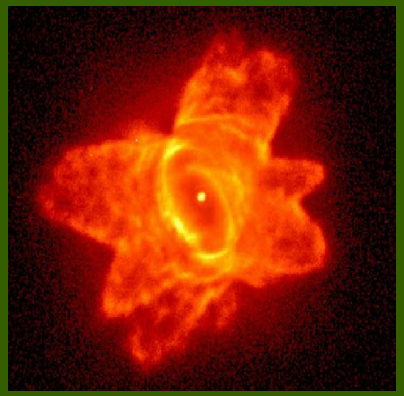
IAC La Laguna

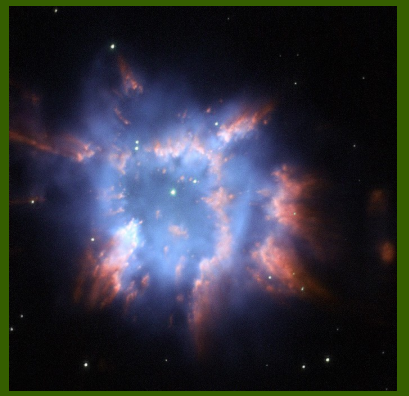

Central stars of planetary nebulae
Post-AGB
AGB
RGB
ZAHB
Main-sequence
White
dwarfs
log L/L$_{sun}$
log T$_{eff}$ / K
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
5.0
4.5
4.0
3.5

(F.Herwig)

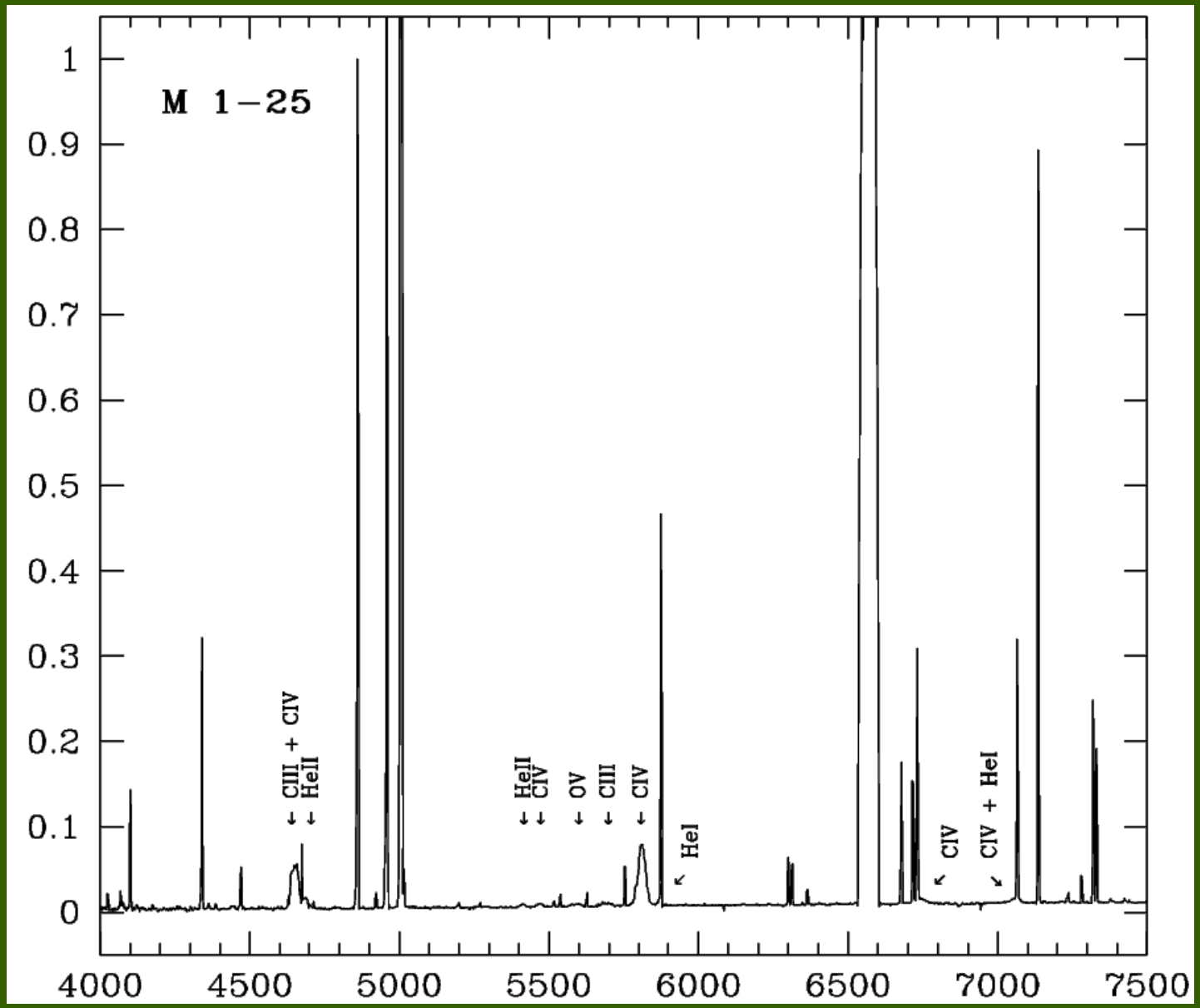



Central stars of planetary nebulae
Post-AGB
AGB
RGB
ZAHB
Main-sequence
White dwarfs
log L/L$_{sun}$
log T$_{eff}$ / K
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
5.0
4.5
4.0
3.5





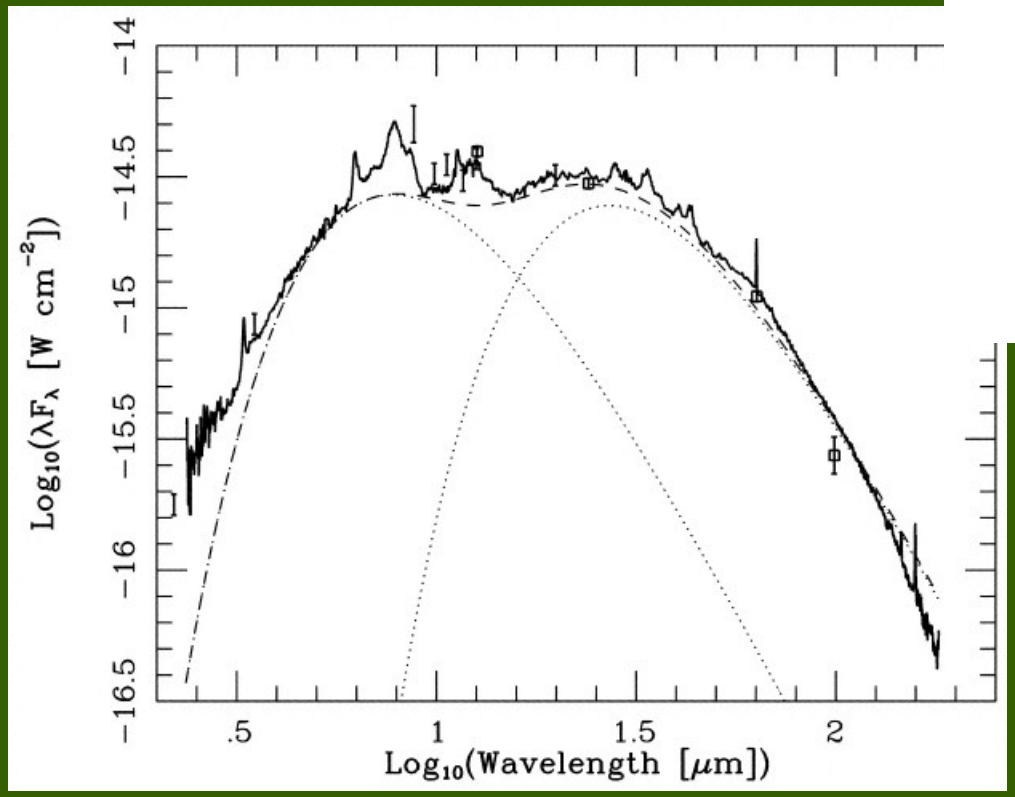
HST

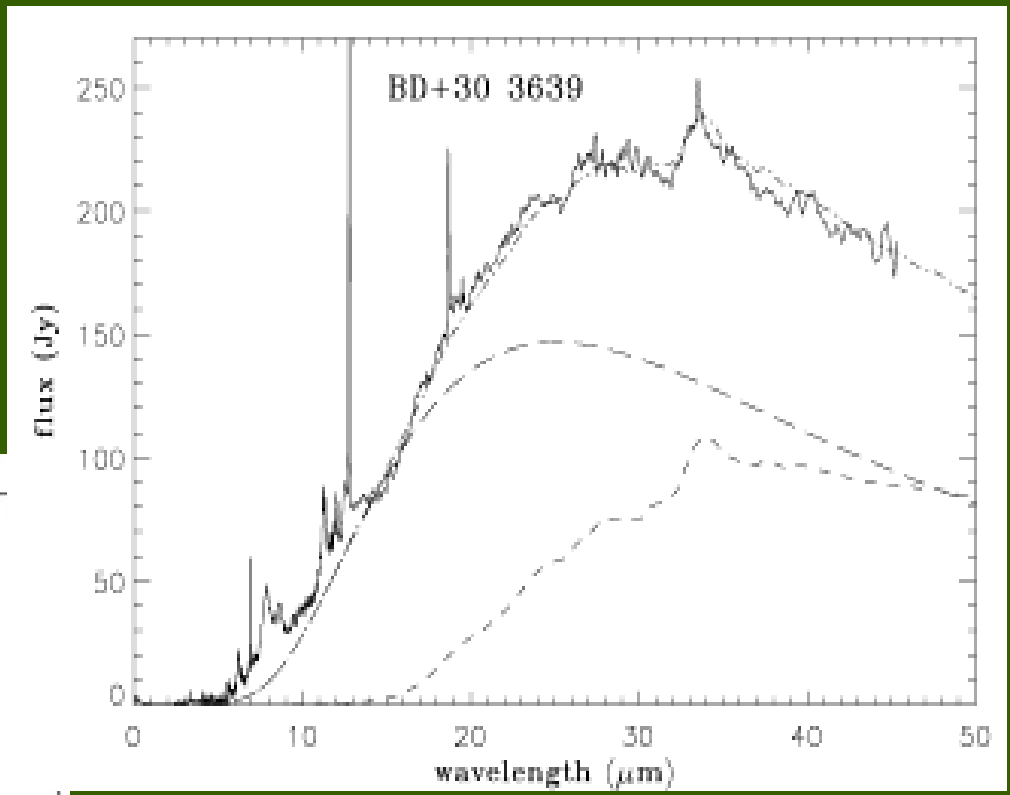

M 1−25
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4000
4500
5000
5500
6000
6500
7000
7500
CIII + CIV
HeII
HeII
CIV
OV
CIII
CIV
HeI
CIV
CIV + HeI

A.Acker

ISO

Cohen et al. 1999

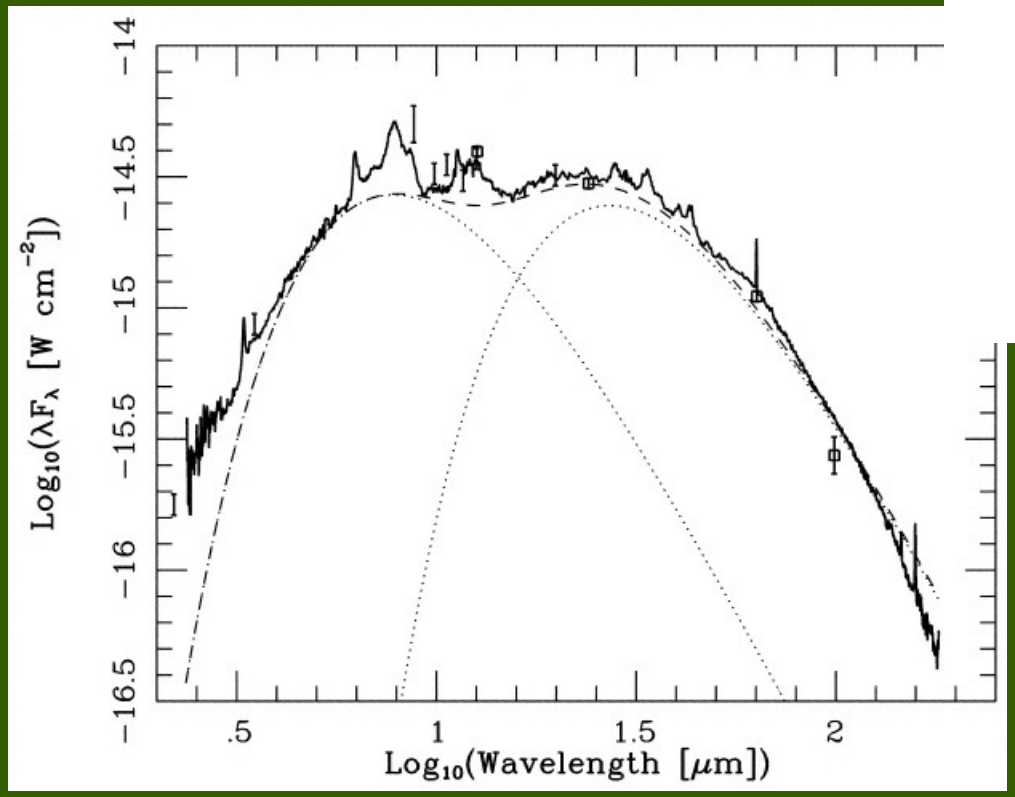


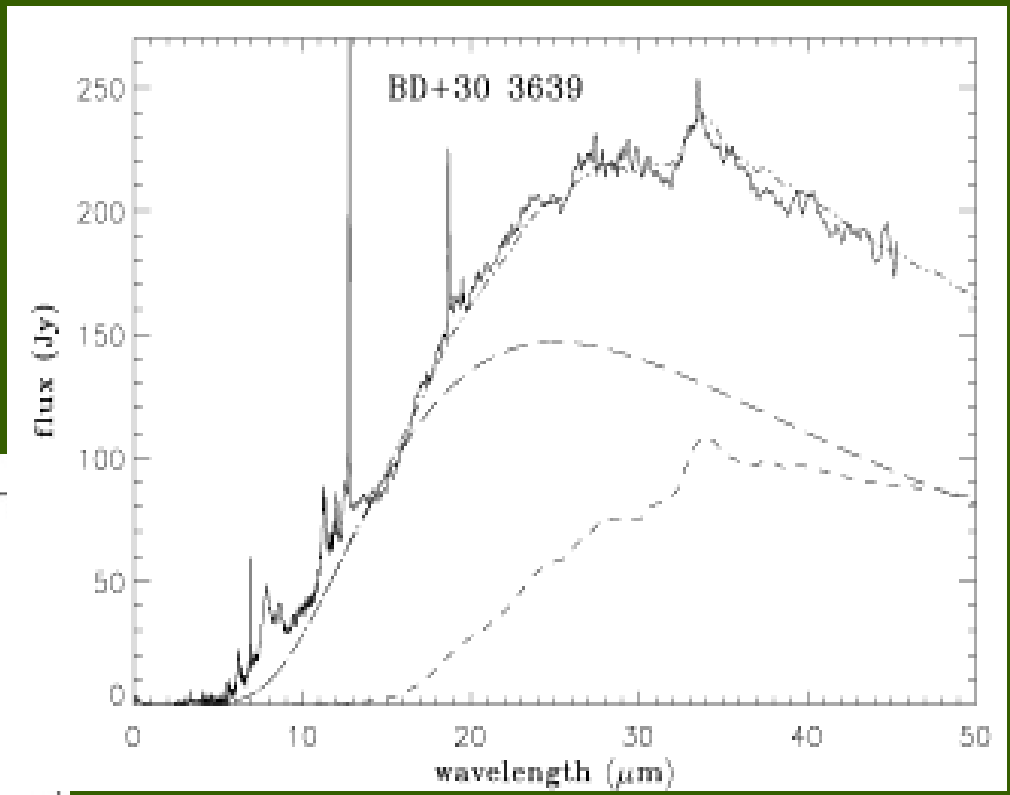


Waters et al. 1998

ISO

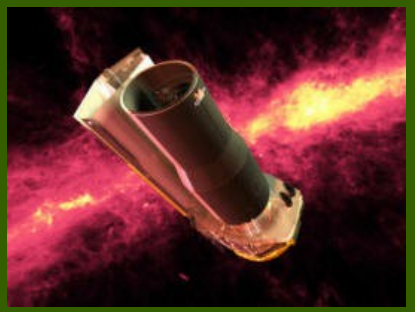
Cohen et al. 1999





Waters et al. 1998

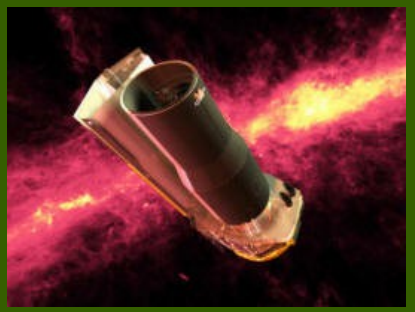
Spitzer



Gutenkunst et al. 2008: 5 oxygen-rich dust

6 mixed chemistry dust

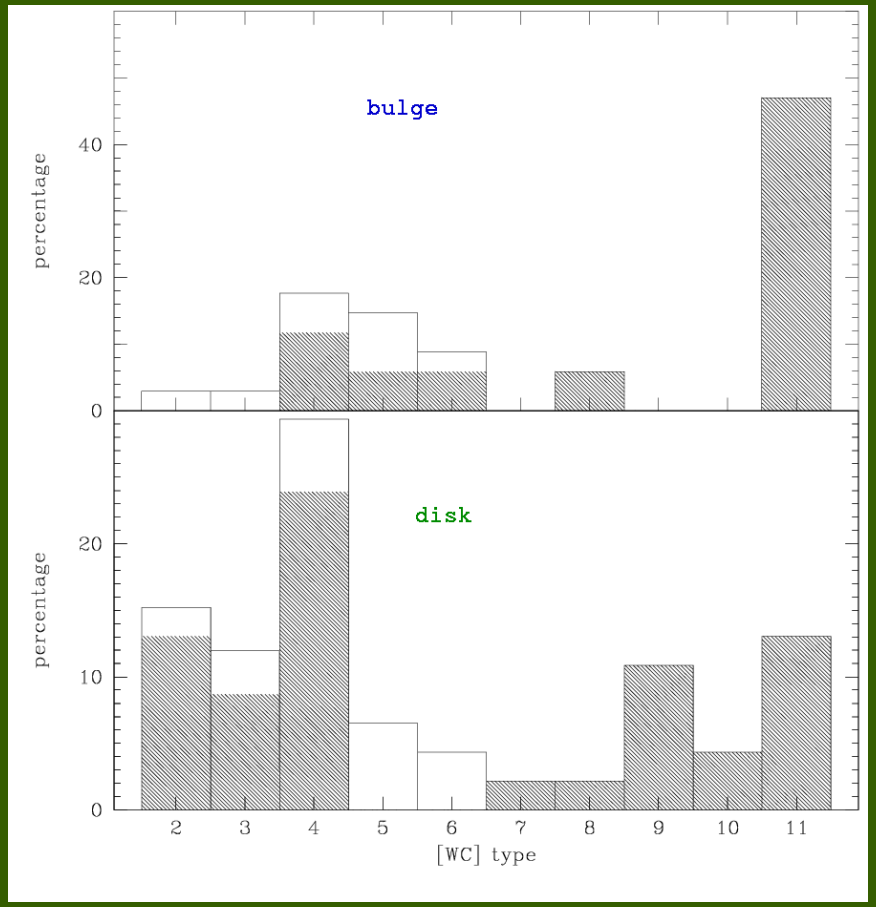
Spitzer



Gutenkunst et al. 2008: 5 oxygen-rich dust

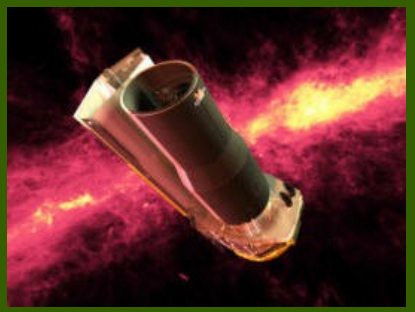
6 mixed chemistry dust

explanation: There are more [WR] PNe in the bulge!



Górny et al. 2004, Górny et al. 2009

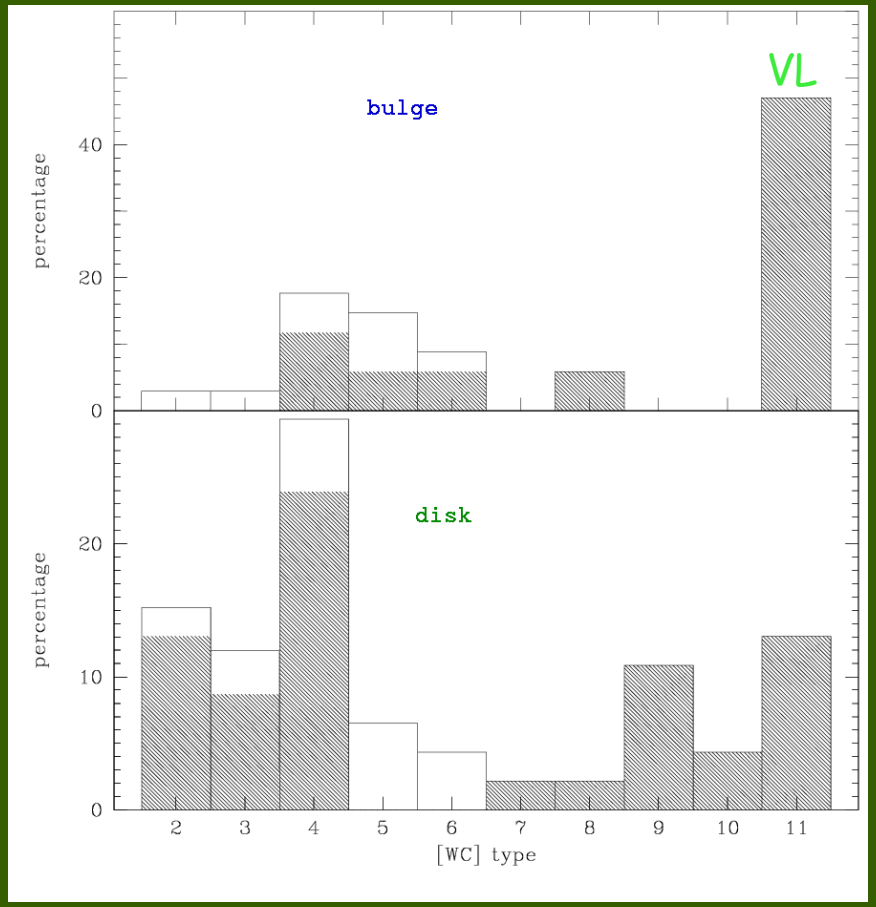
Spitzer



Gutenkunst et al. 2008: 5 oxygen-rich dust

6 mixed chemistry dust

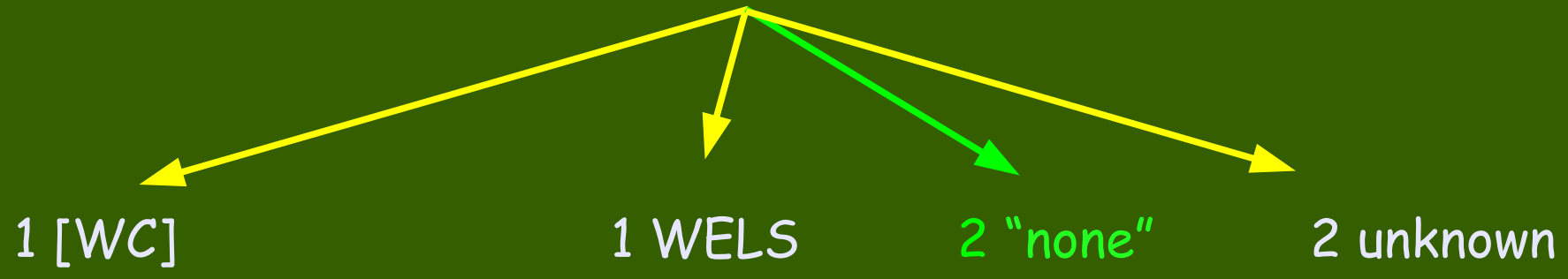
~~explanation: There are more [WR] PNe in the bulge!~~



Górny et al. 2004, Górny et al. 2009

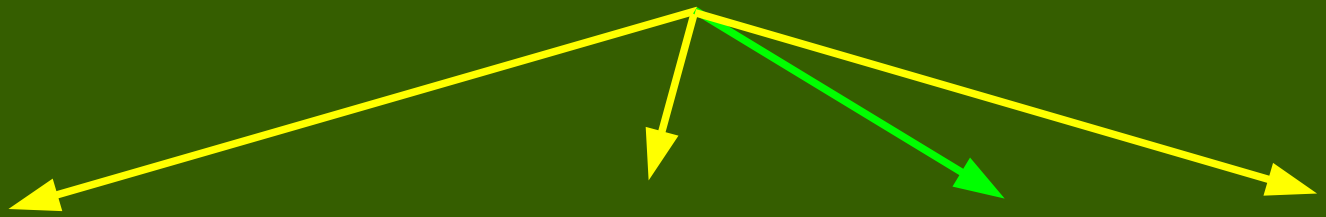
Gutenkunst et al. 2008: 5 oxygen-rich dust

6 mixed chemistry dust



Gutenkunst et al. 2008: 5 oxygen-rich dust

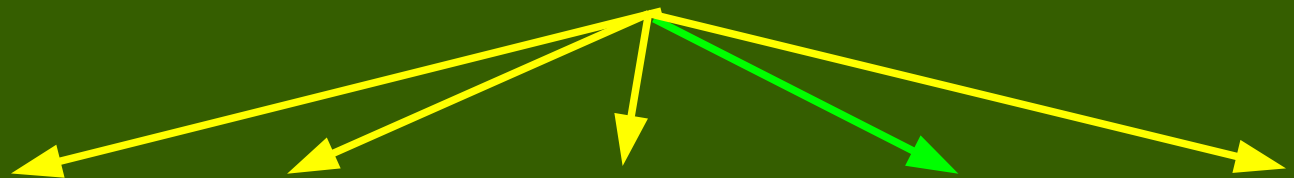
6 mixed chemistry dust



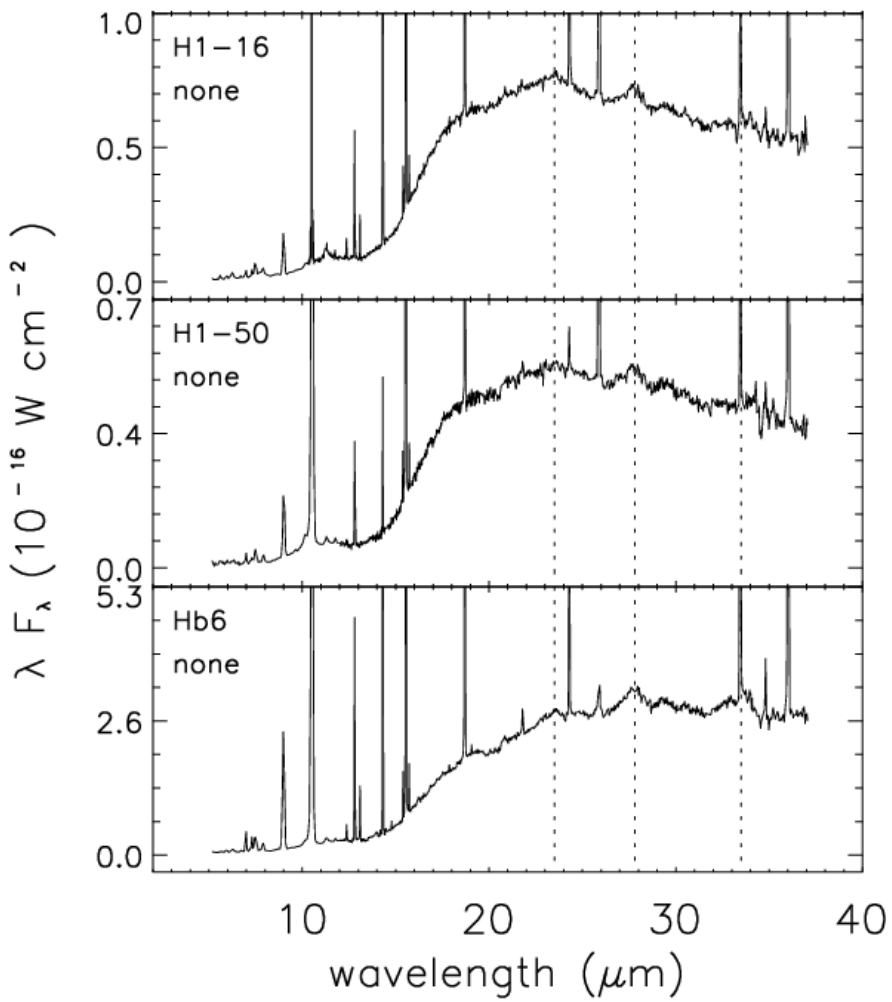
1 [WC] 1 WELS 2 "none" 2 unknown

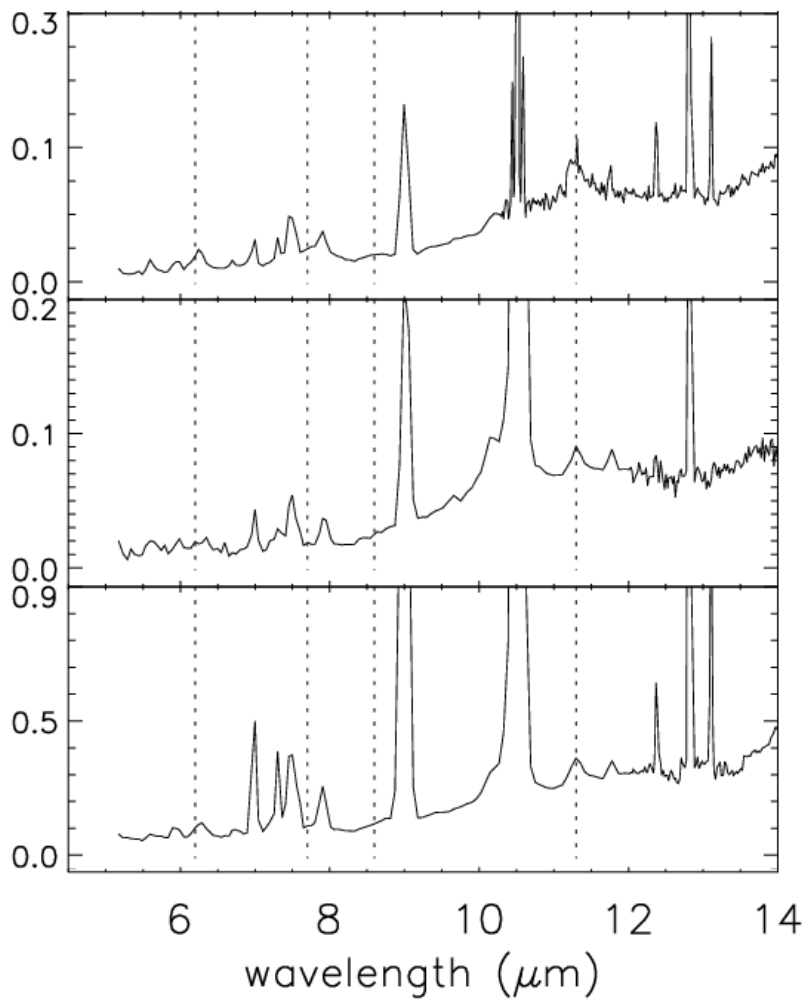
Perea-Calderón et al. 2009: 5 oxygen-rich dust

21 mixed dust



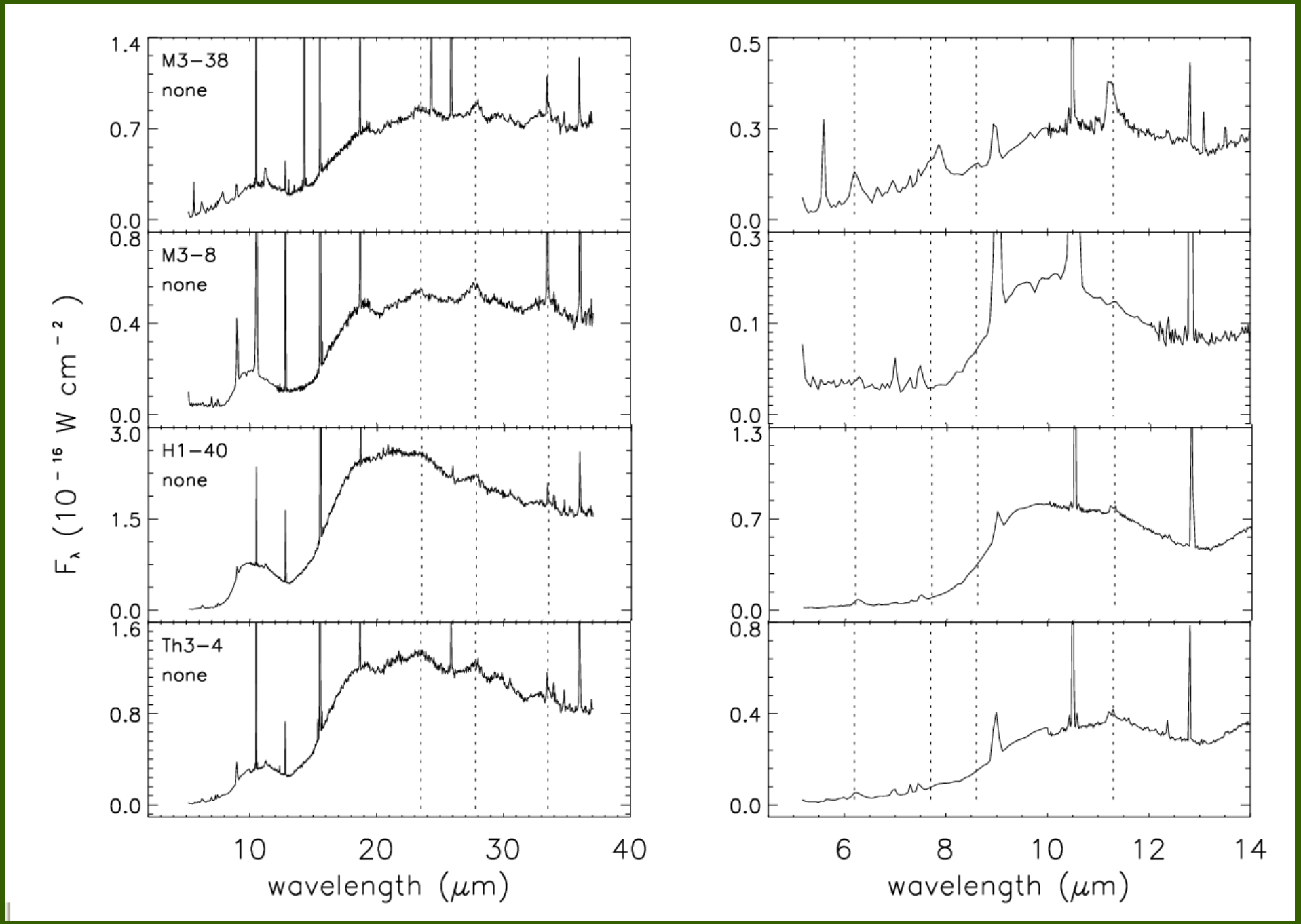
5 [WC] 3 VL 5 WELS 6+1 "none" 1 unknown





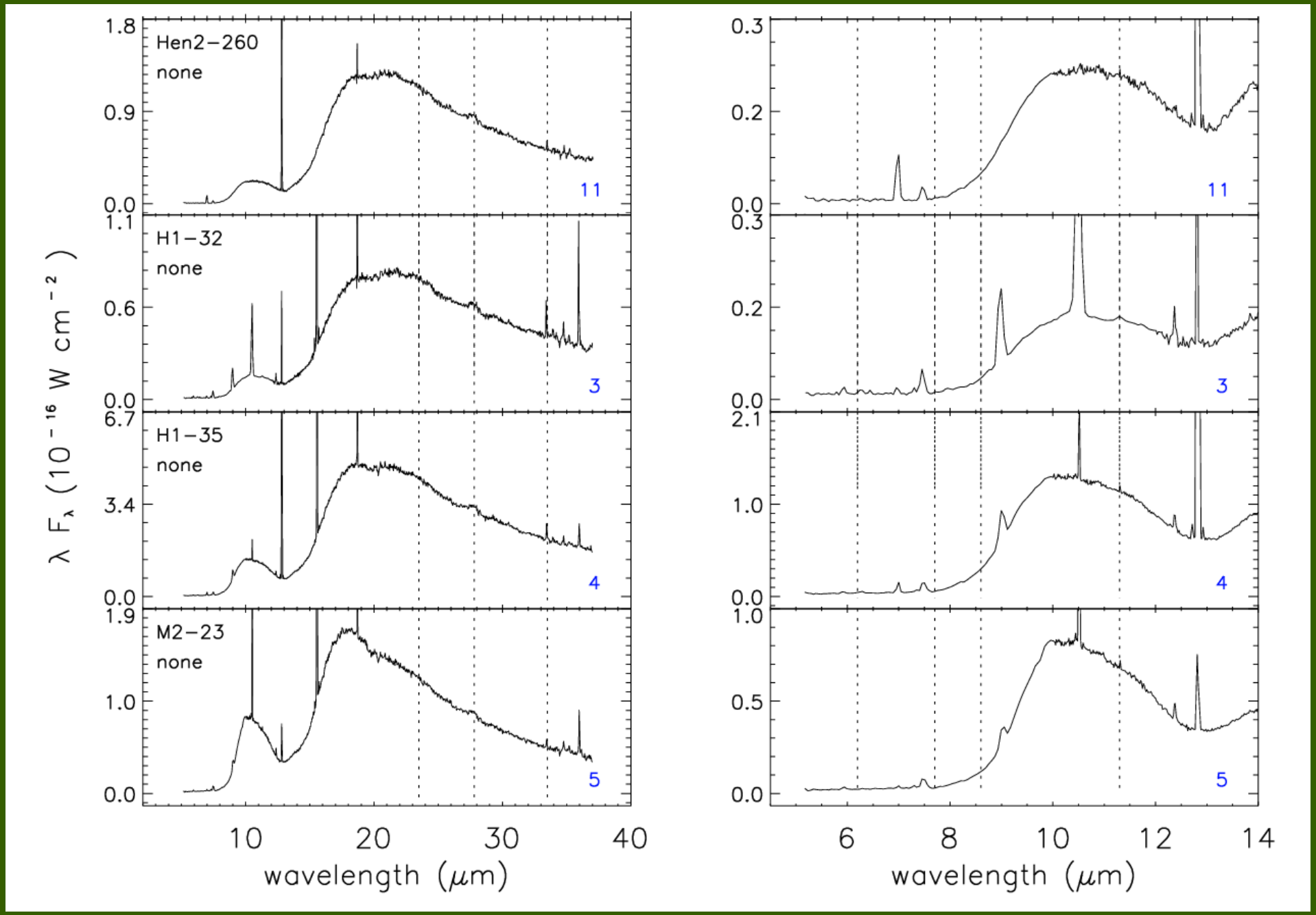
DC cr

Górny et al. 2010



Górny et al. 2010

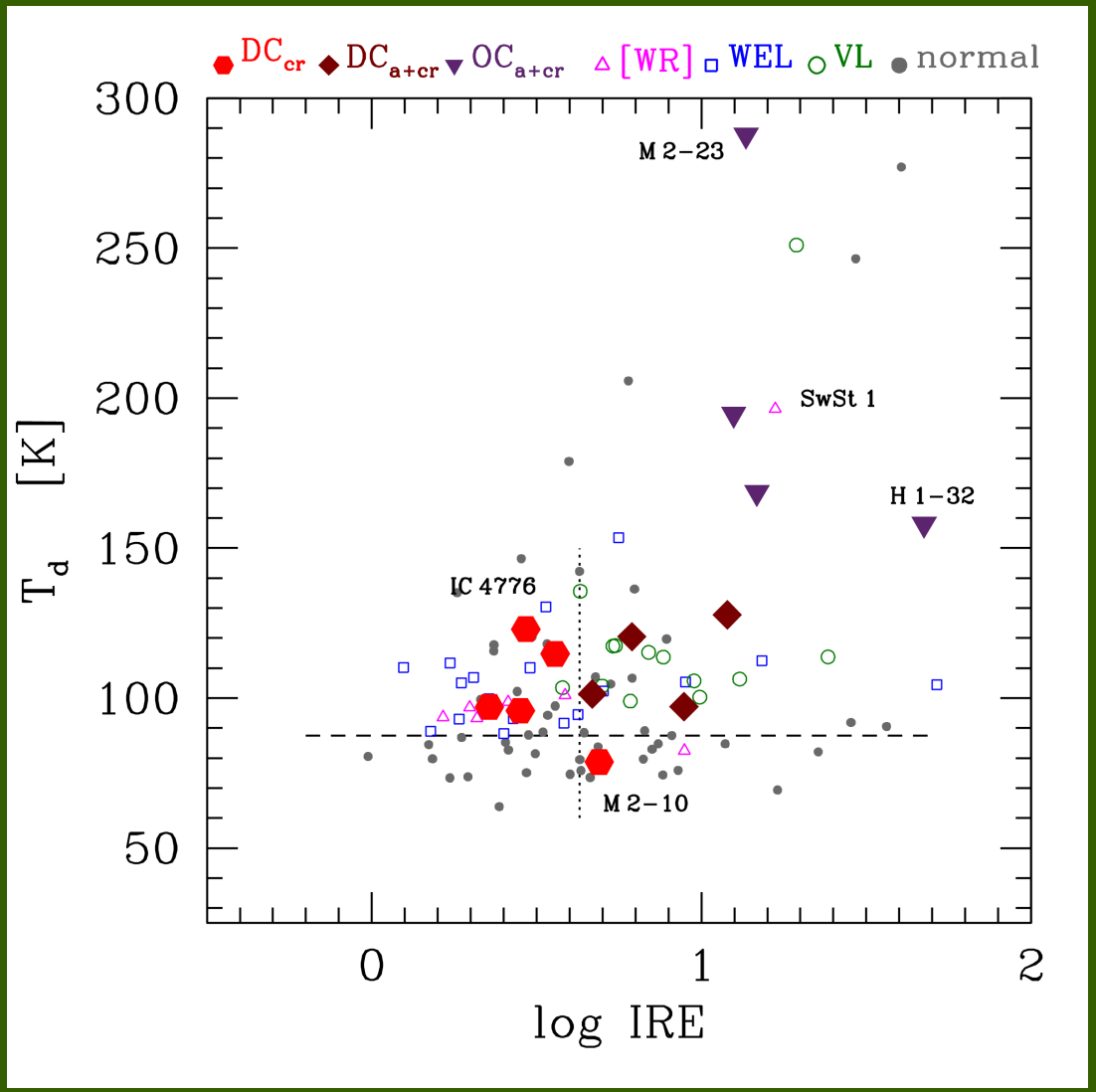
DC am+cr

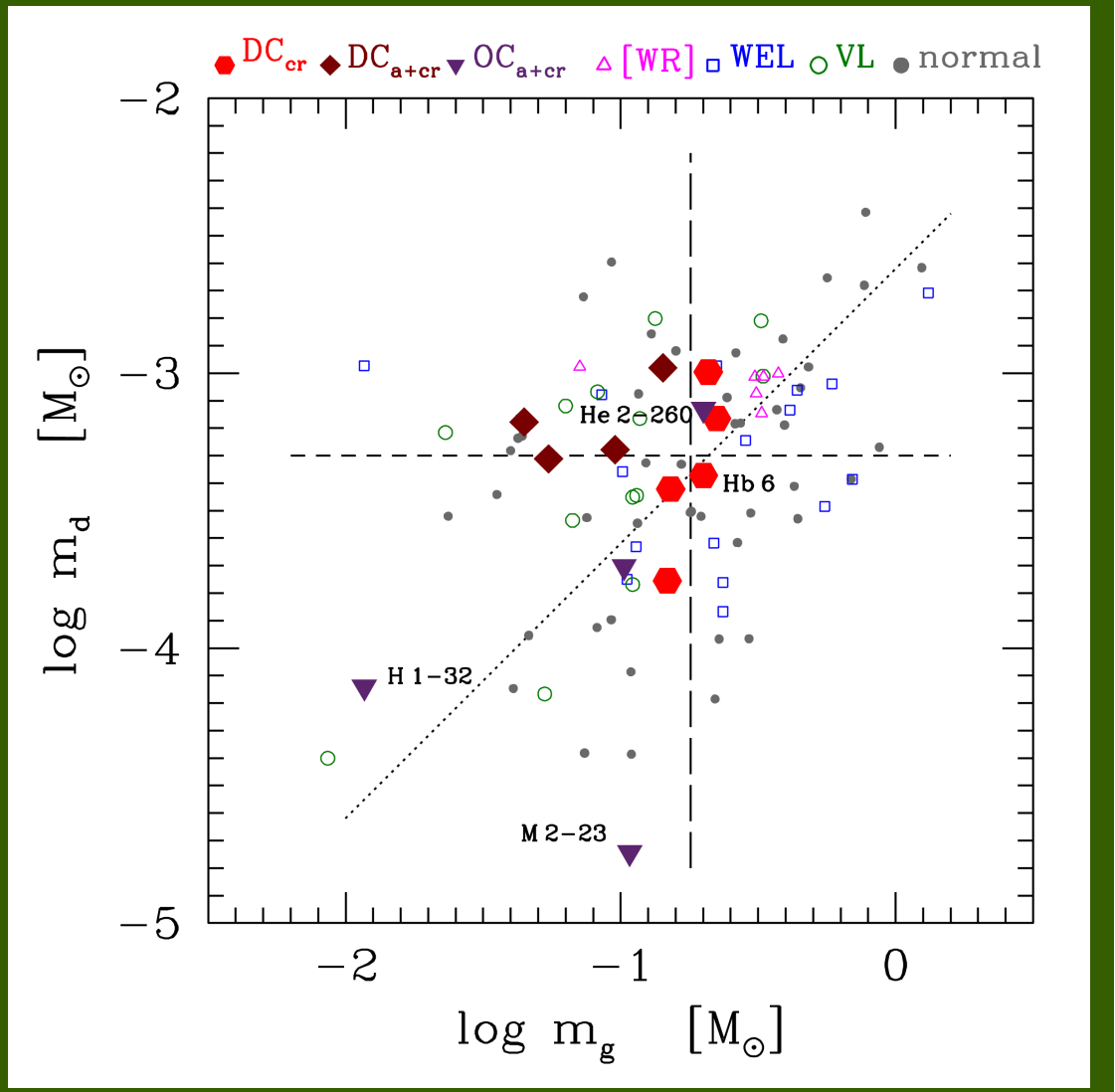


Górny et al. 2010

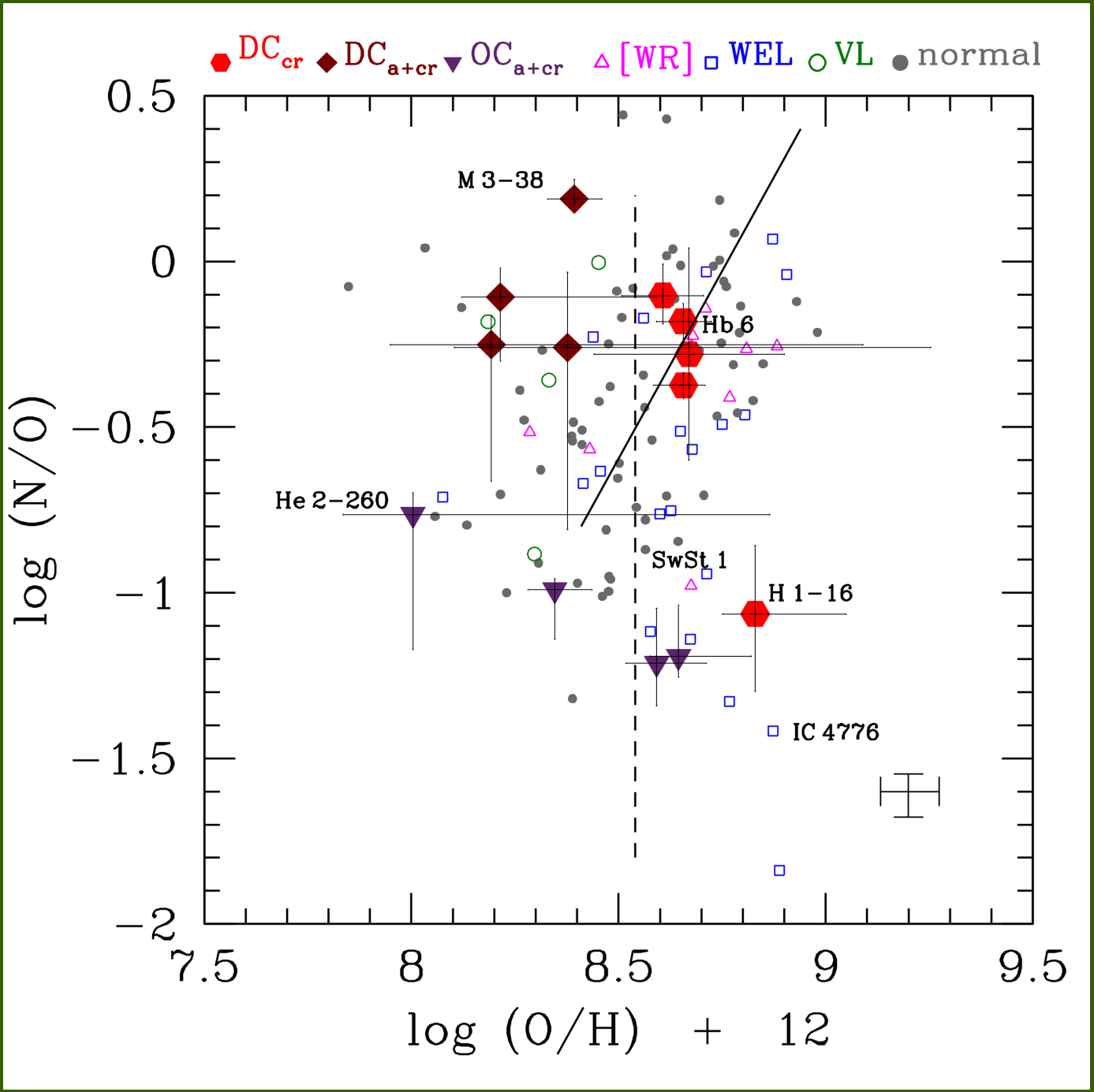
OC am+cr

$$IRE = F_{IR} / 22.3\ F_{H\beta}$$

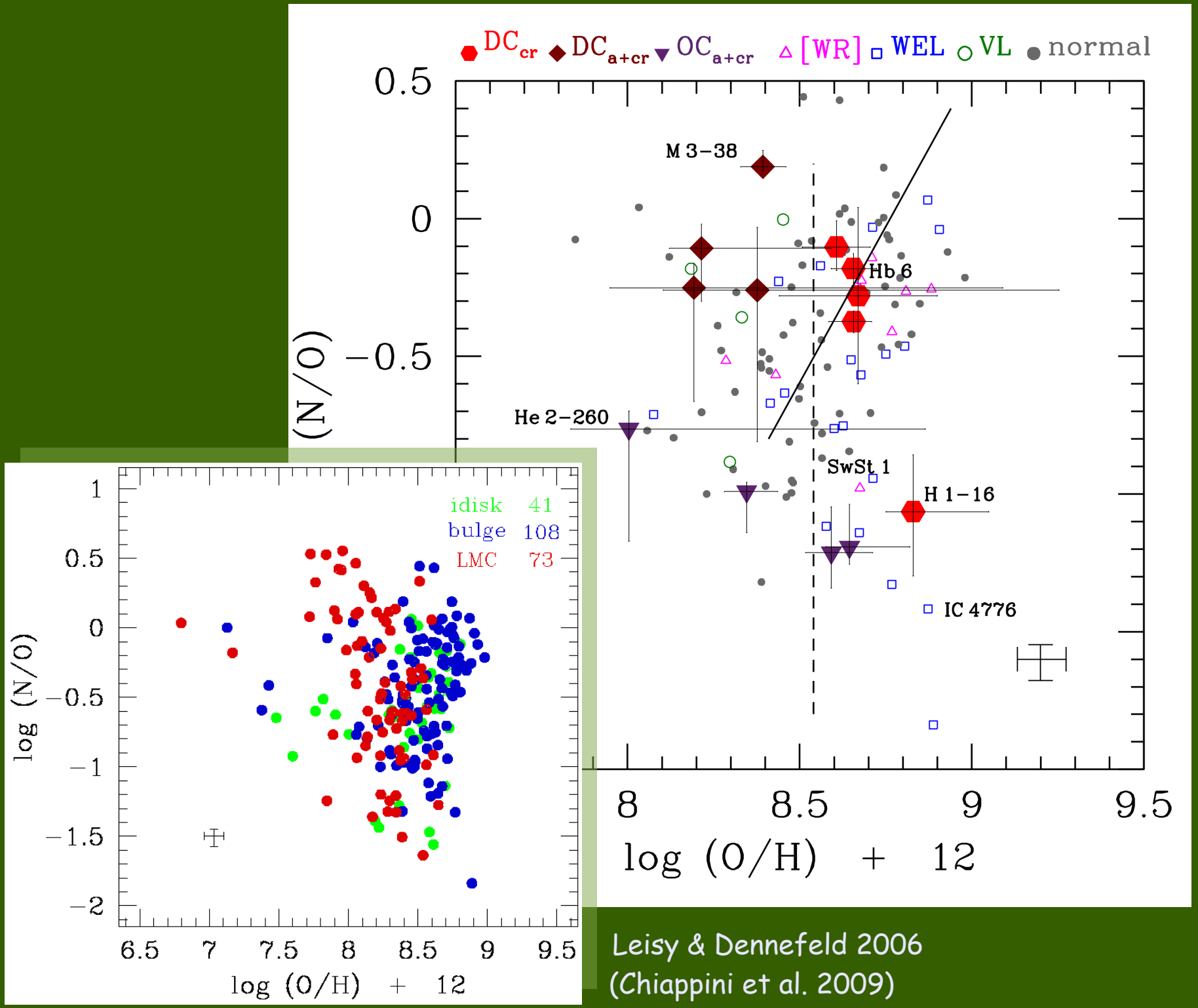




Górny et al. 2010

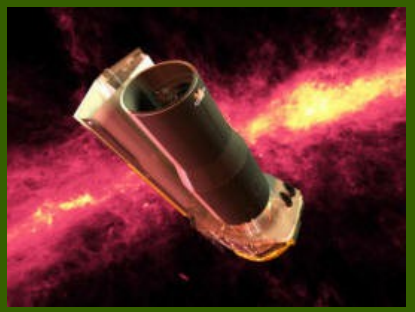


Górny et al. 2010



Leisy & Dennefeld 2006
(Chiappini et al. 2009)

Spitzer



Stanghellini et al. 2012: 157 compact Galactic PNe

"belong predominantly to the disk"

this work	Stanghellini et al. (2012)
CC_{ar}	1 (CRD)
CC_{al}	2 (CRD)
CC_{ar+al}	3 (CRD)
OC_{cr}	4 (ORD)
OC_{am}	5 (ORD)
OC_{am+cr}	6 (ORD)
DC_{cr}	7 = MCD *
DC_{am+cr}	7 = MCD *
F	0 = F

dust type	bulge	disk
F	13% (7)	19% (18)
CC	10% (5)	33% (32)
OC	27% (14)	31% (31)
DC	48% (25)	18% (17)

subtype	bulge	disk
CC_{ar}	(3)	31% (10)
CC_{al}	(1)	66% (21)
CC_{ar+al}	(1)	3% (1)
OC_{cr}	50% (7)	29% (9)
OC_{am}	36% (5)	61% (19)
OC_{am+cr}	14% (2)	10% (3)
DC_{cr}	68% (17)	53% (9)
DC_{am+cr}	32% (8)	47% (8)

Combined sample:

Gutenkunst et al. 2008:

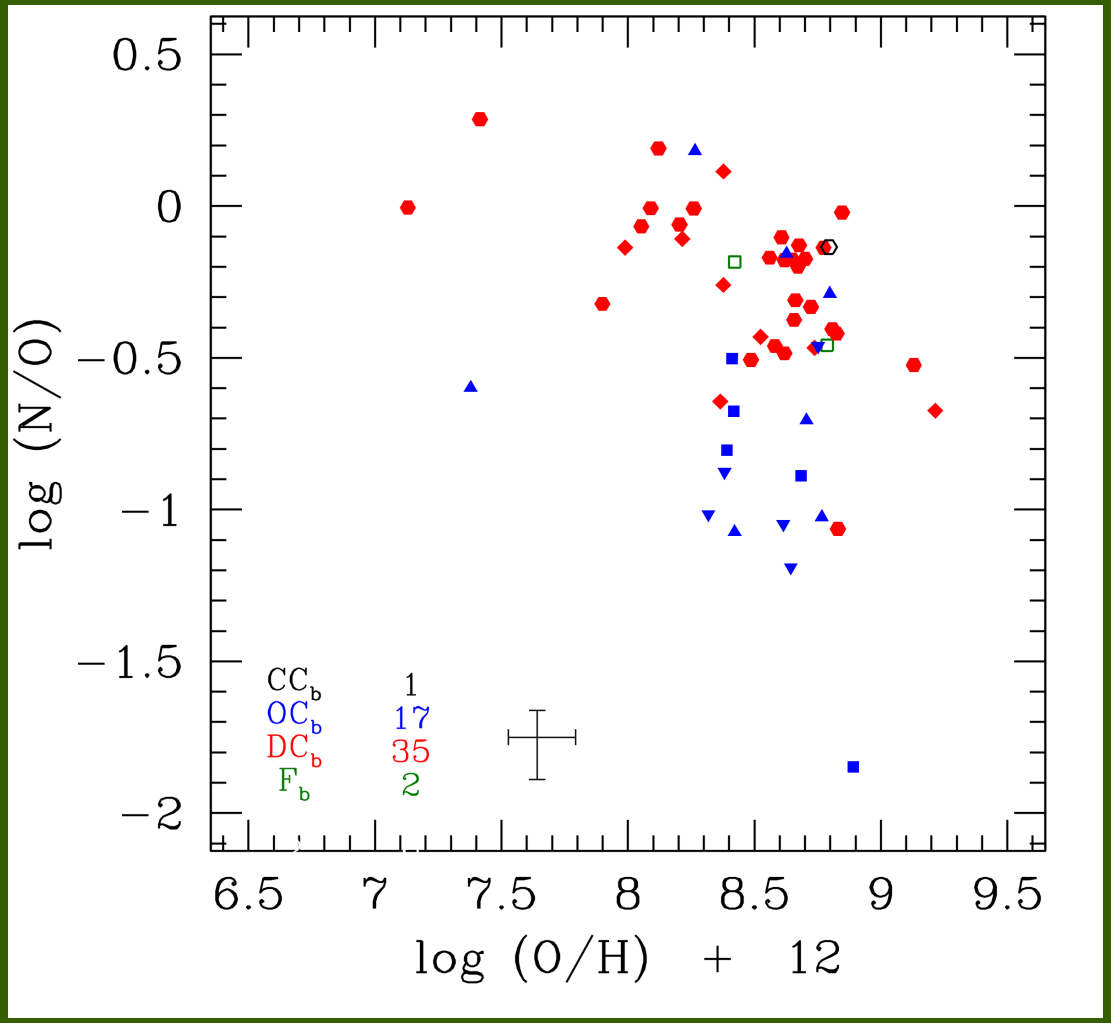
Perea-Calderón et al. 2009

Stanghellini et al. 2012

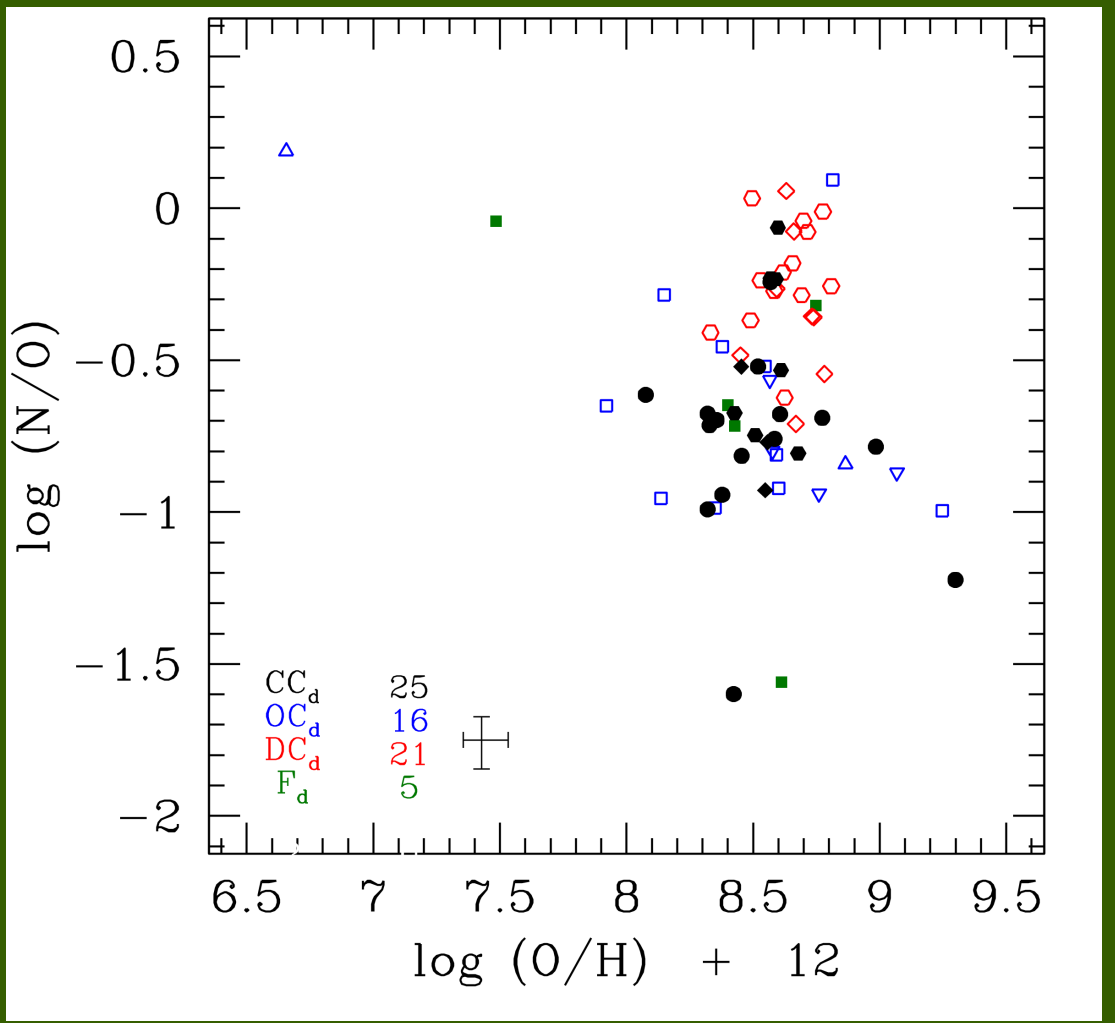
Optical spectroscopy collected for 140 PNe

(including 34 unpublished observations from SAAO and TNG)

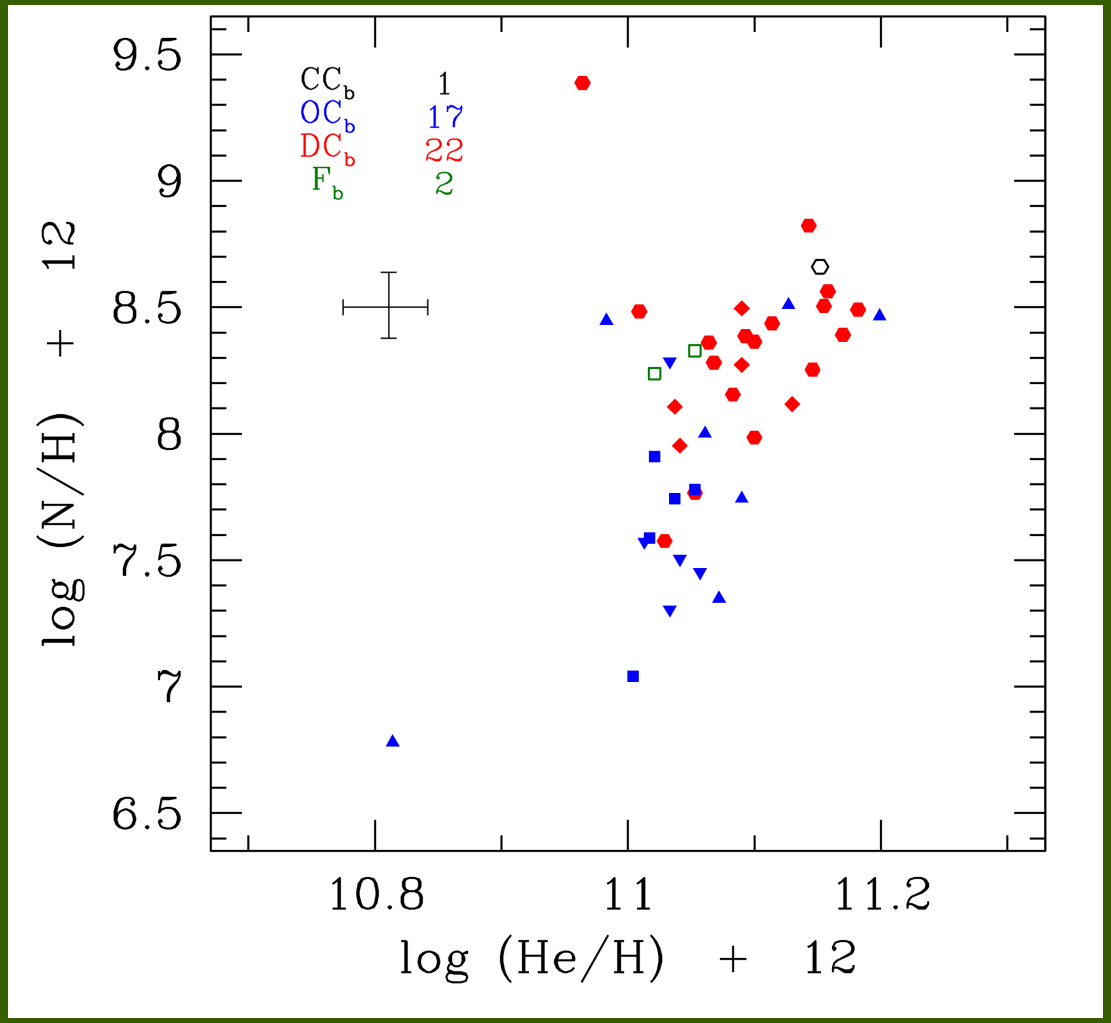
bulge


0.5
0
−0.5
−1
−1.5
−2
log (N/O)
6.5
7
7.5
8
8.5
9
9.5
log (O/H) + 12
CC_b 1
OC_b 17
DC_b 35
F_b 2

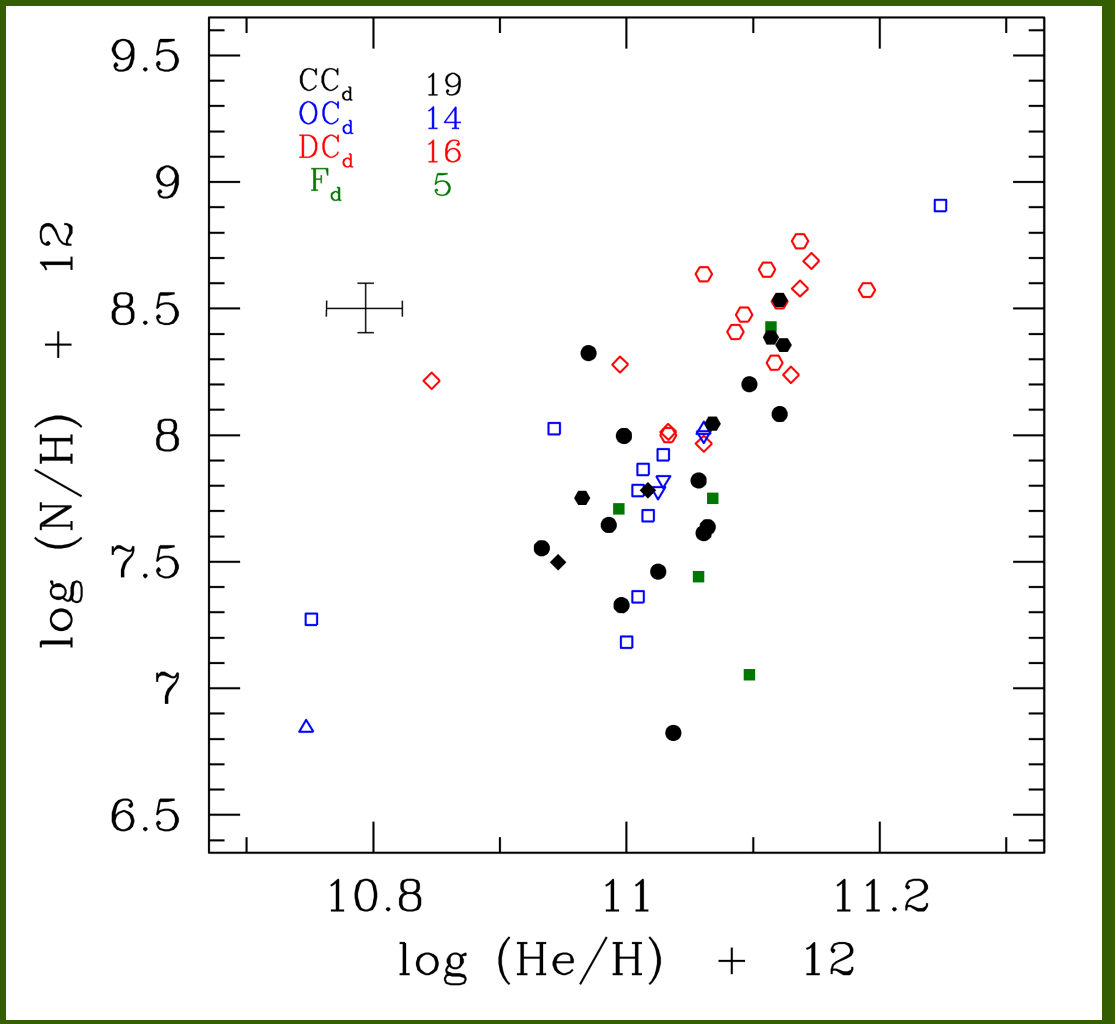
disk


0.5
0
−0.5
−1
−1.5
−2
log (N/O)
6.5
7
7.5
8
8.5
9
9.5
log (O/H) + 12
CC_d 25
OC_d 16
DC_d 21
F_d 5

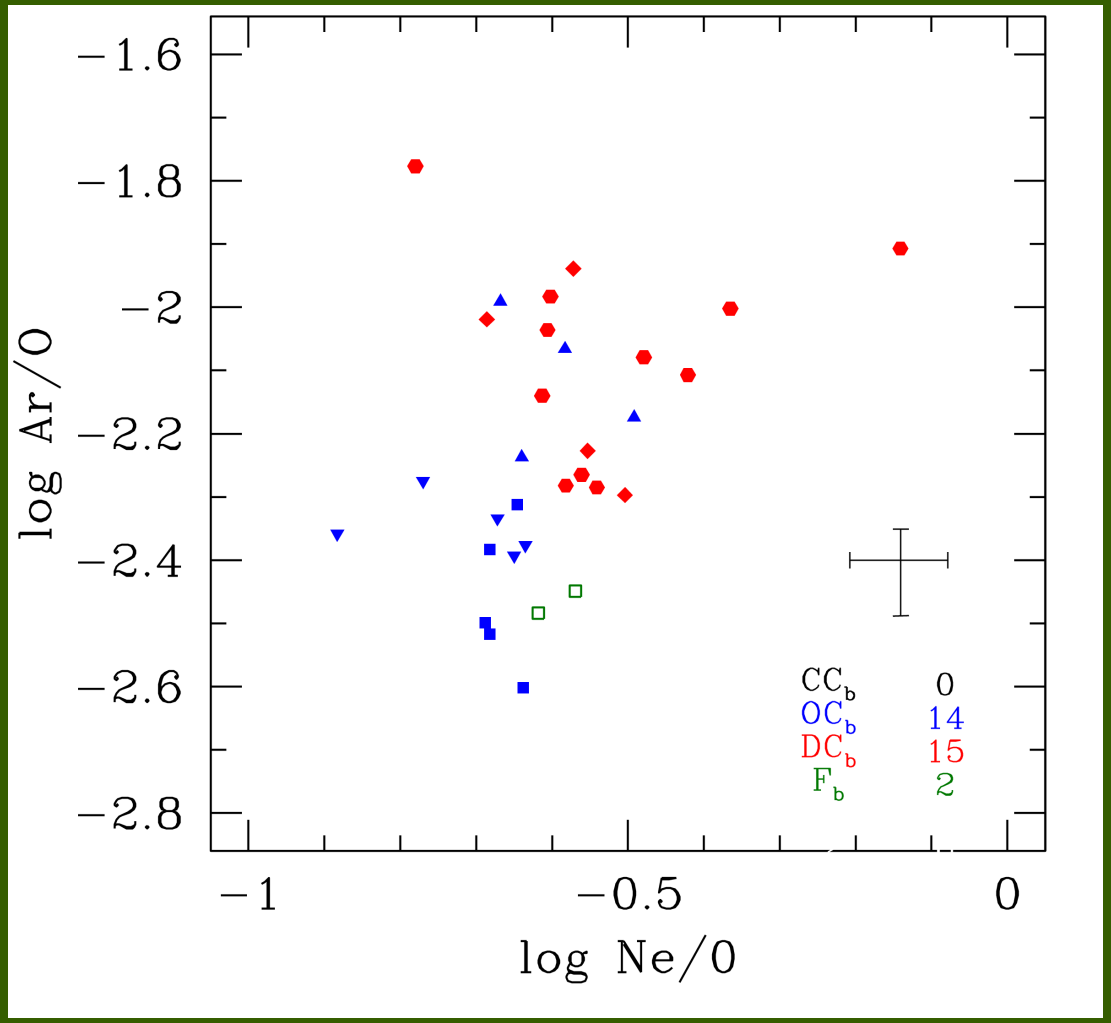
bulge


CC$_b$ 1
OC$_b$ 17
DC$_b$ 22
F$_b$ 2
9.5
9
8.5
8
7.5
7
6.5
log (N/H) + 12
10.8
11
11.2
log (He/H) + 12

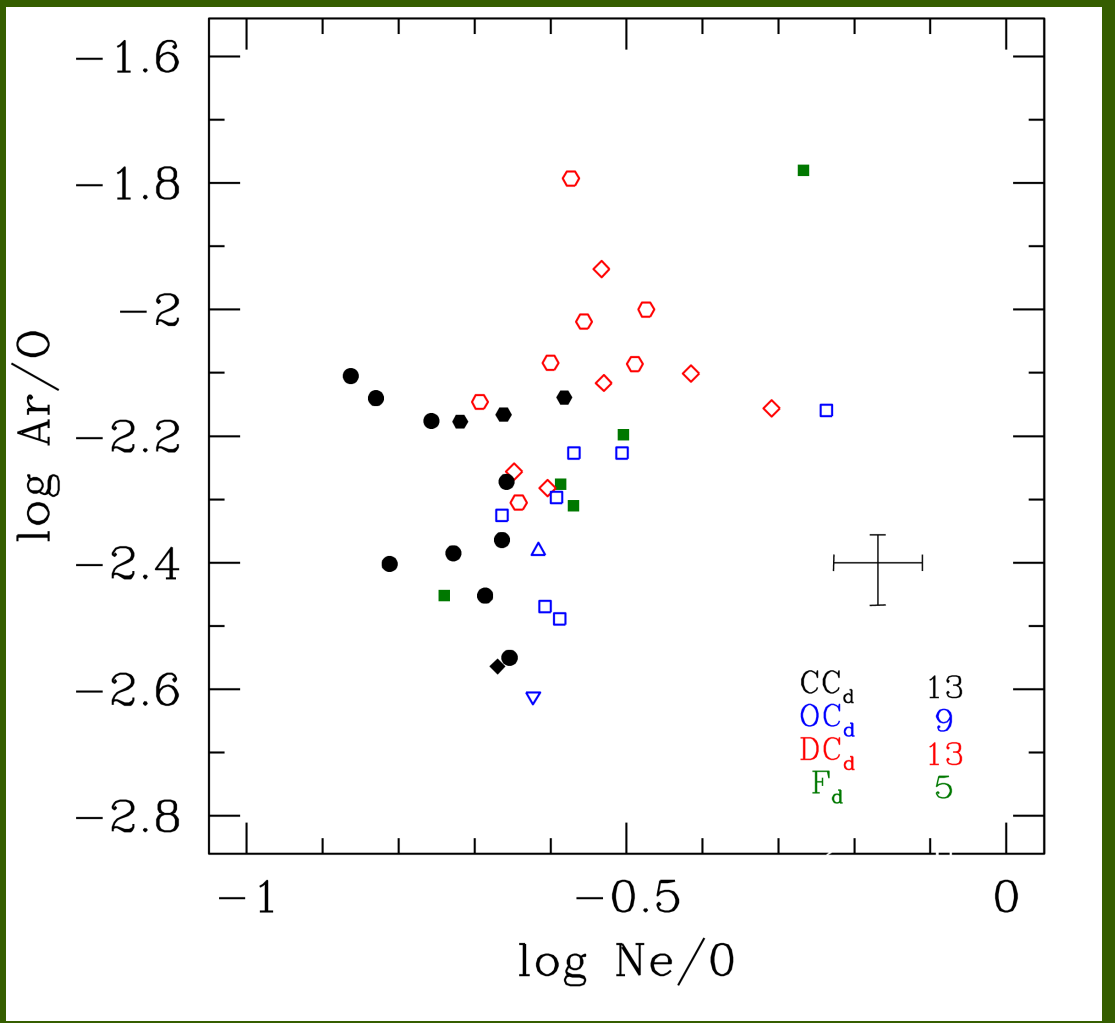
disk


CC$_d$ 19
OC$_d$ 14
DC$_d$ 16
F$_d$ 5
9.5
9
8.5
8
7.5
7
6.5
log (N/H) + 12
10.8
11
11.2
log (He/H) + 12

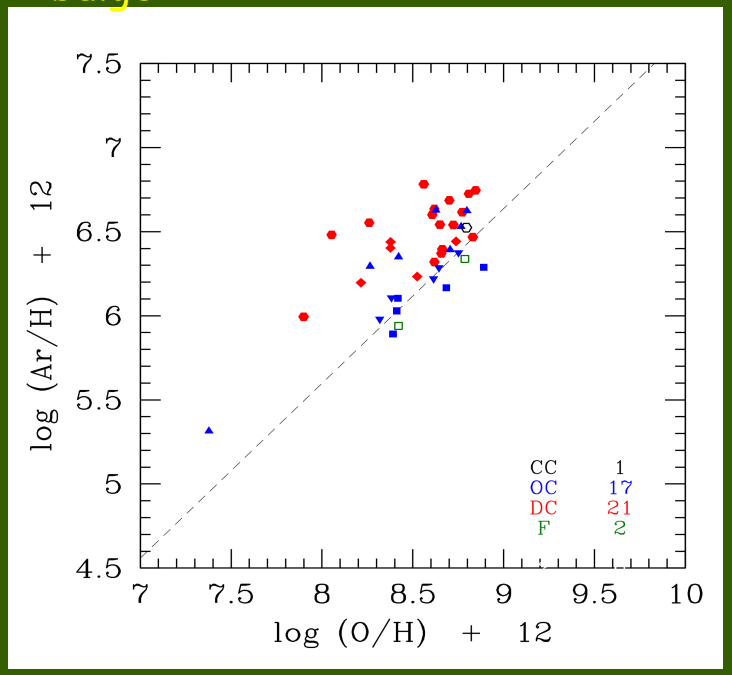
bulge

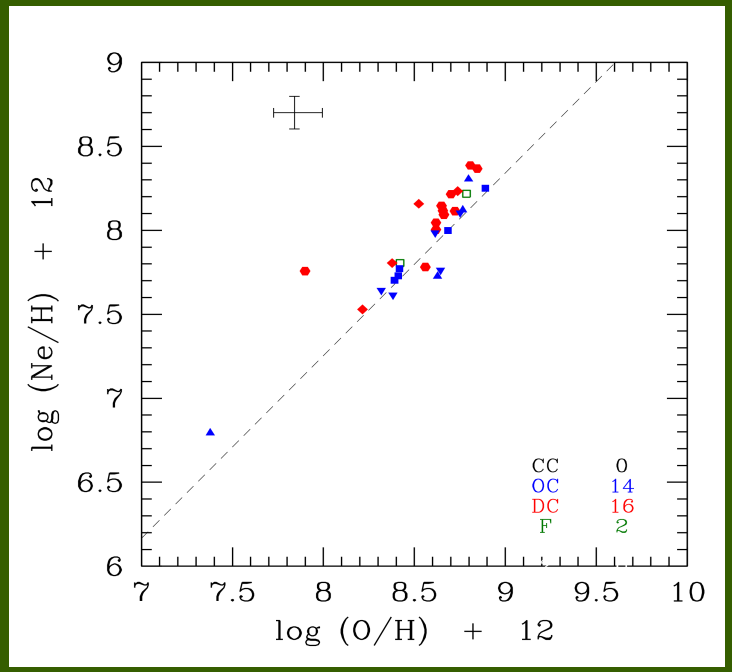

−1.6
−1.8
−2
−2.2
−2.4
−2.6
−2.8
log Ar/O
−1
−0.5
0
log Ne/O
CC$_b$ 0
OC$_b$ 14
DC$_b$ 15
F$_b$ 2

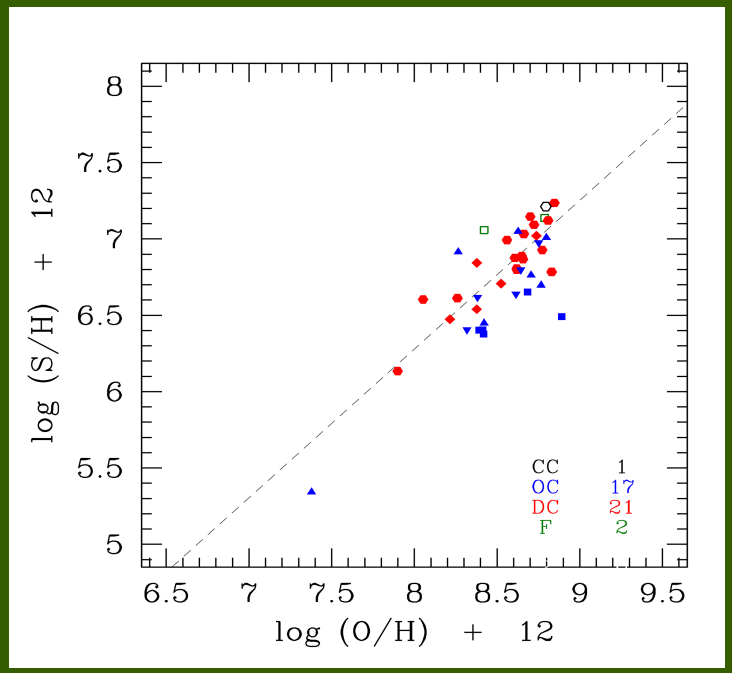
disk

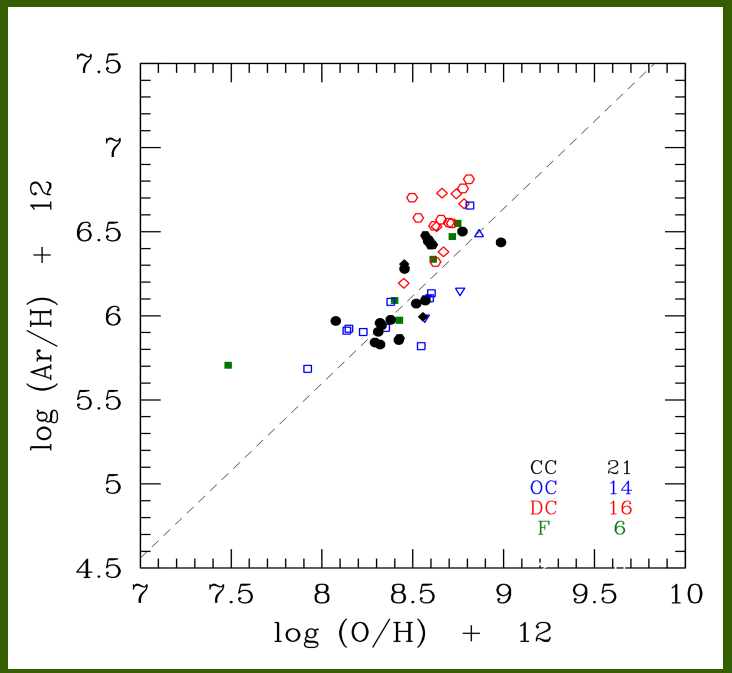

−1.6
−1.8
−2
−2.2
−2.4
−2.6
−2.8
log Ar/O
−1
−0.5
0
log Ne/O
CC$_d$ 13
OC$_d$ 9
DC$_d$ 13
F$_d$ 5

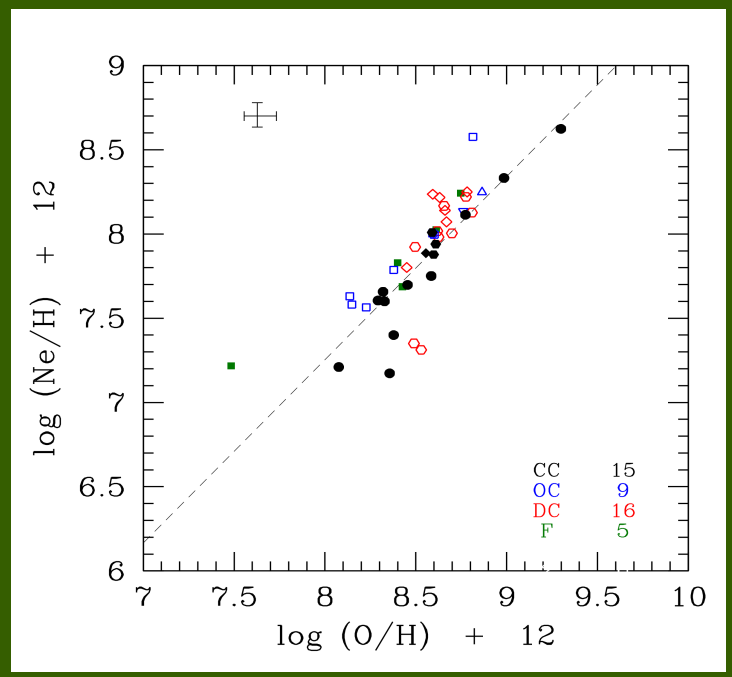
bulge

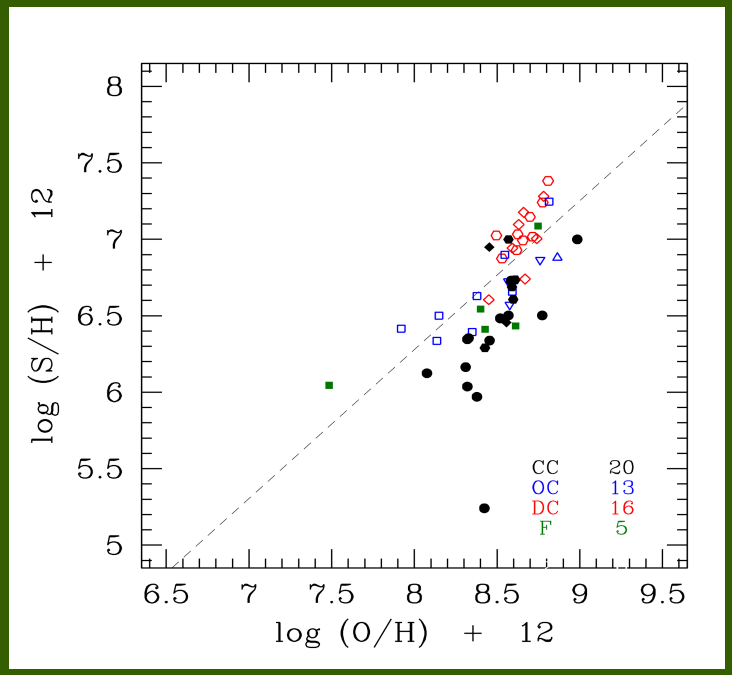

log (Ar/H) + 12
log (O/H) + 12
CC 1
OC 17
DC 21
F 2


log (Ne/H) + 12
log (O/H) + 12
CC 0
OC 14
DC 16
F 2


log (S/H) + 12
log (O/H) + 12
CC 1
OC 17
DC 21
F 2


log (Ar/H) + 12
log (O/H) + 12
CC 21
OC 14
DC 16
F 6

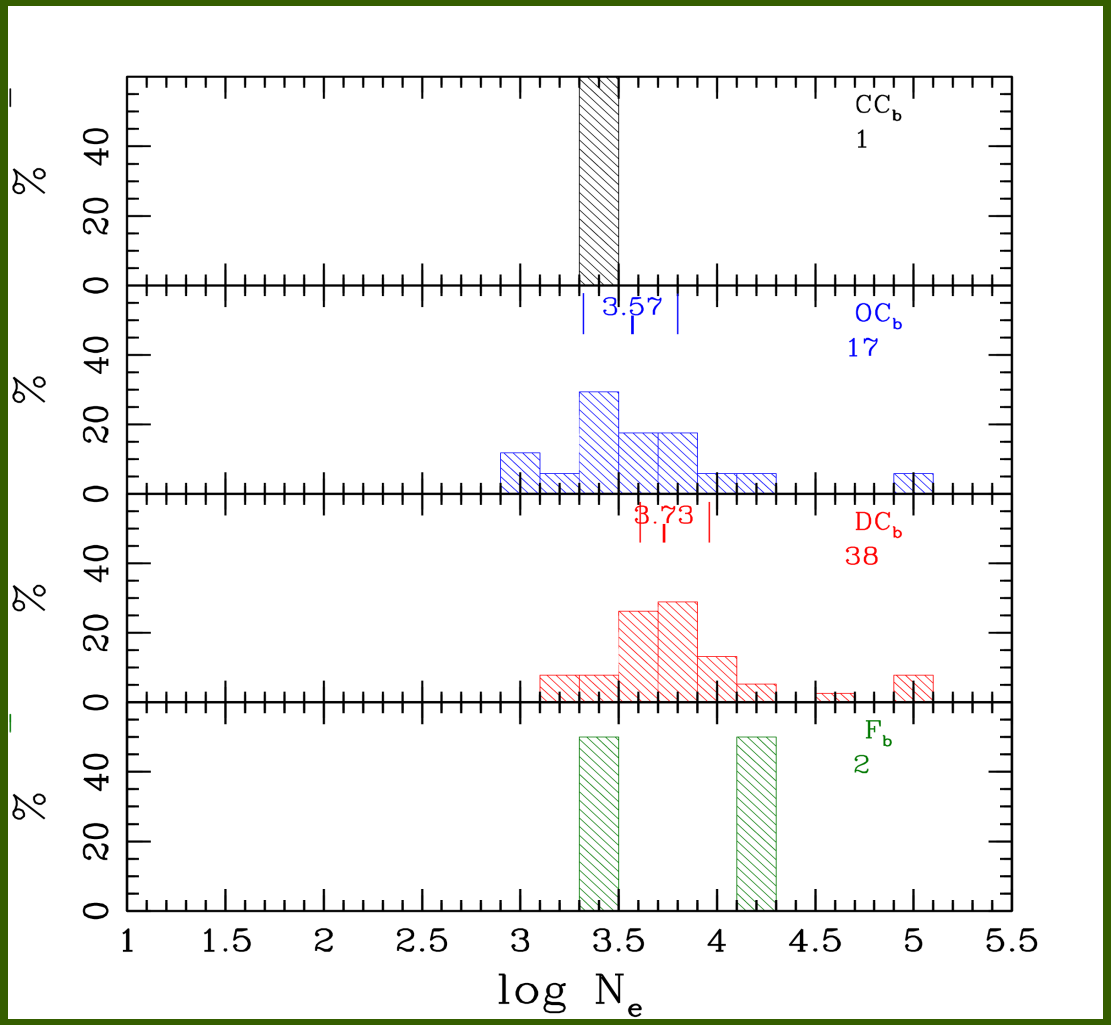

log (Ne/H) + 12
log (O/H) + 12
CC 15
OC 9
DC 16
F 5

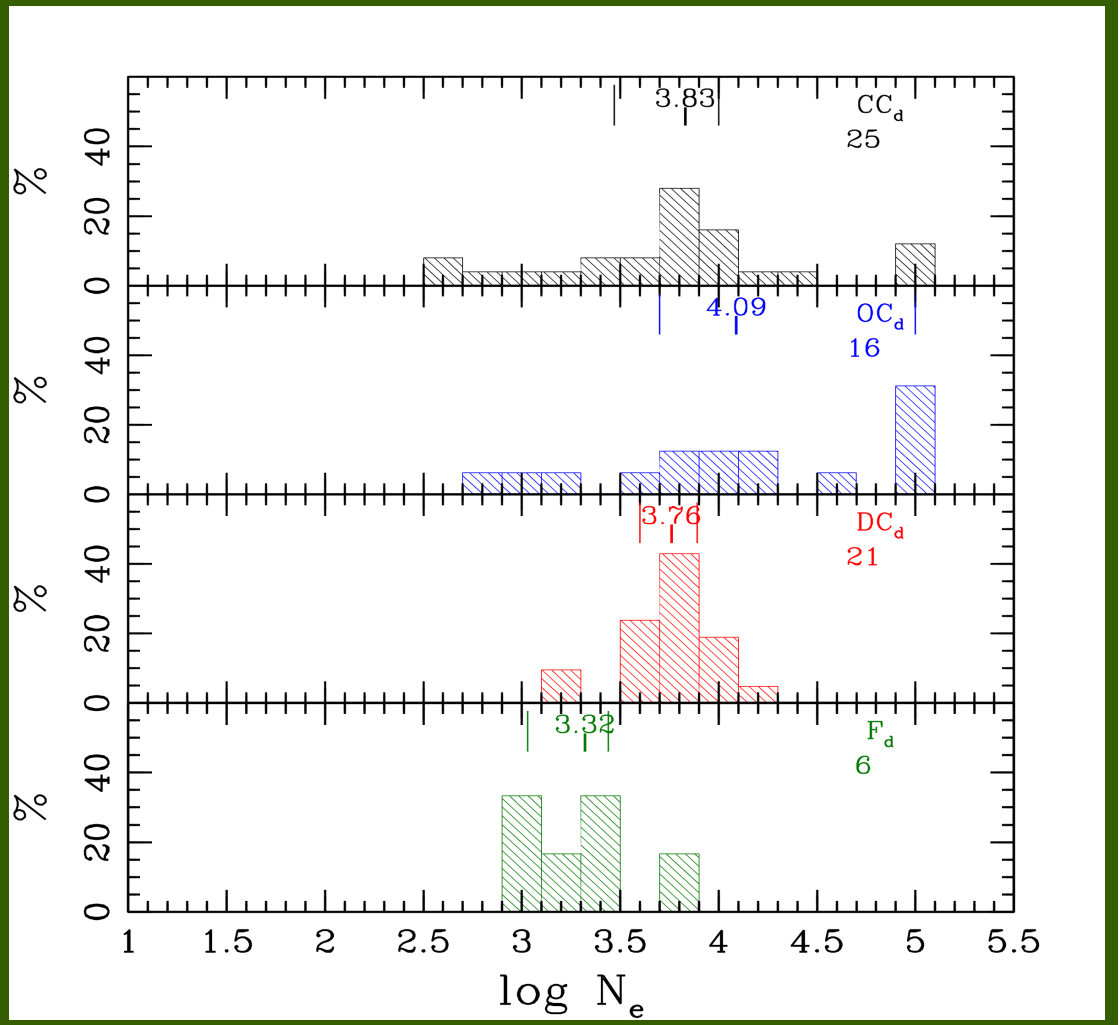

log (S/H) + 12
log (O/H) + 12
CC 20
OC 13
DC 16
F 5

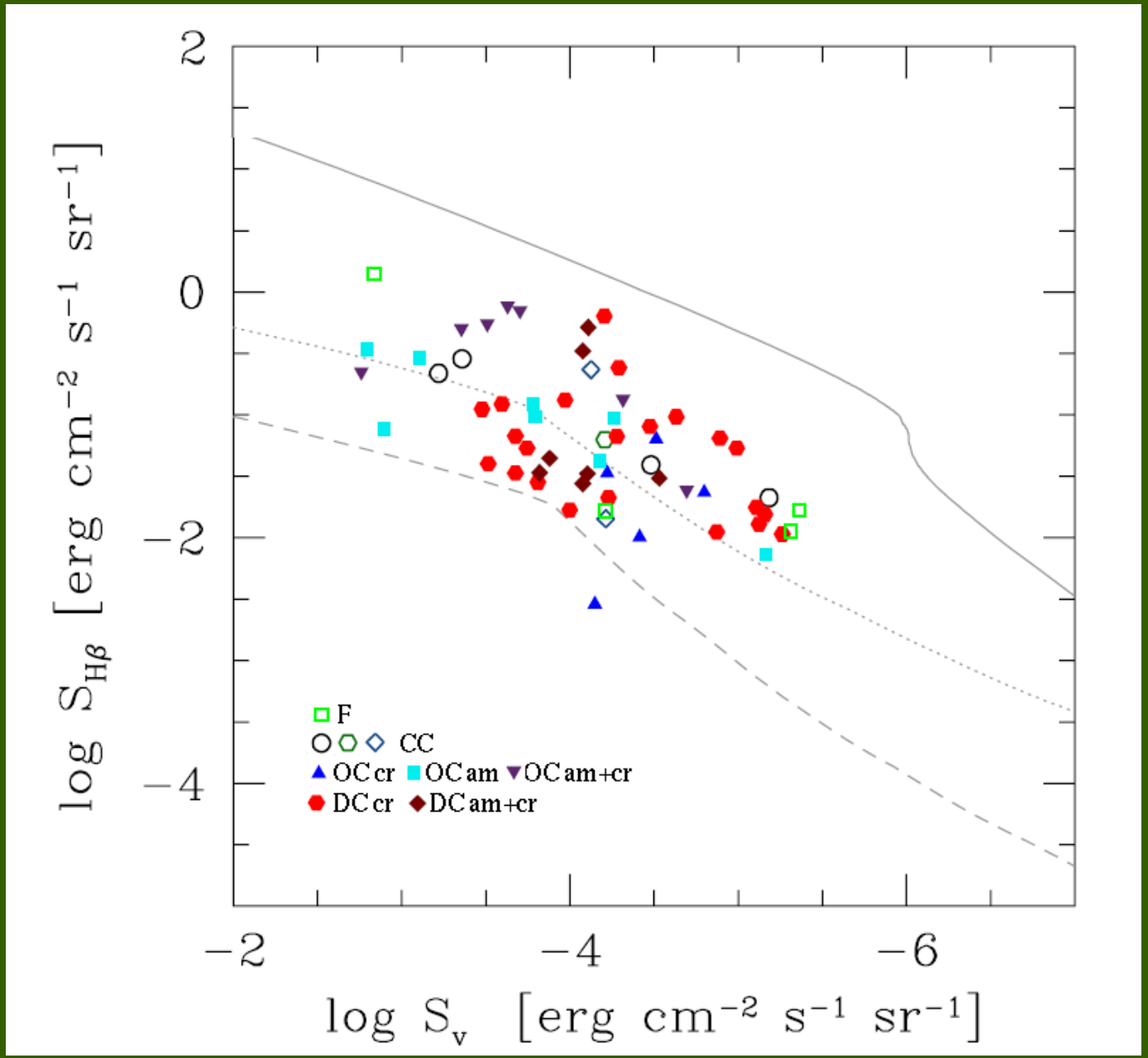
disk

bulge

disk


CC$_b$
1
3.57
OC$_b$
17
3.73
DC$_b$
38
F$_b$
2
%
0 20 40
1 1.5 2 2.5 3 3.5 4 4.5 5 5.5
log N$_e$


3.83
CC$_d$
25
4.09
OC$_d$
16
3.76
DC$_d$
21
3.32
F$_d$
6
%
0 20 40
1 1.5 2 2.5 3 3.5 4 4.5 5 5.5
log N$_e$


2
0
−2
−4
log $S_{H\beta}$ [erg cm^{-2} s^{-1} sr^{-1}]
F
CC
OC cr
OC am
OC am+cr
DC cr
DC am+cr
−2
−4
−6
log S_ν [erg cm^{-2} s^{-1} sr^{-1}]

bulge + disk

Summary

- Dust composition of PNe is an important property related to the origin and the evolutionary history of their progenitor stars