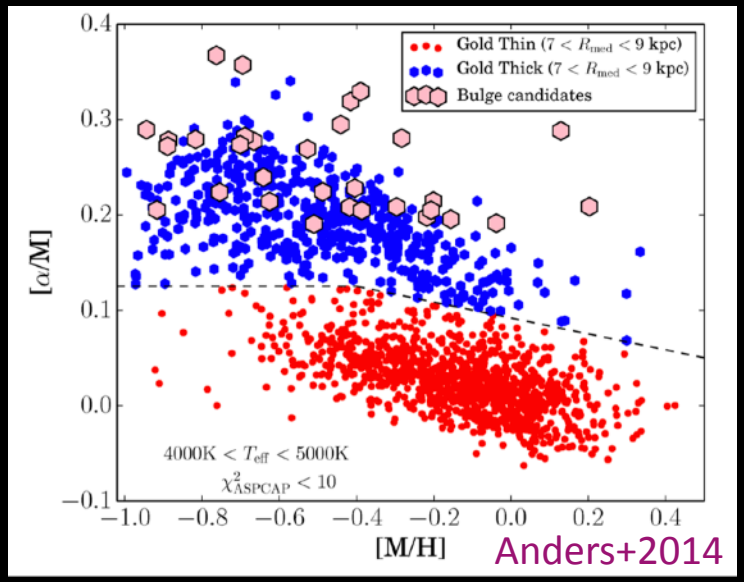
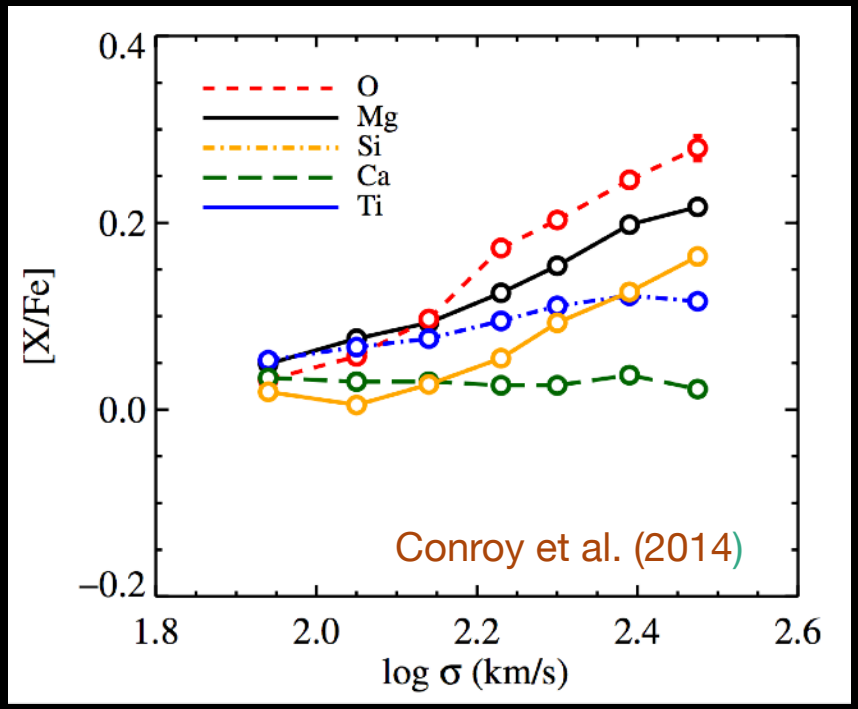
Ay21 Slides
21 January 2020



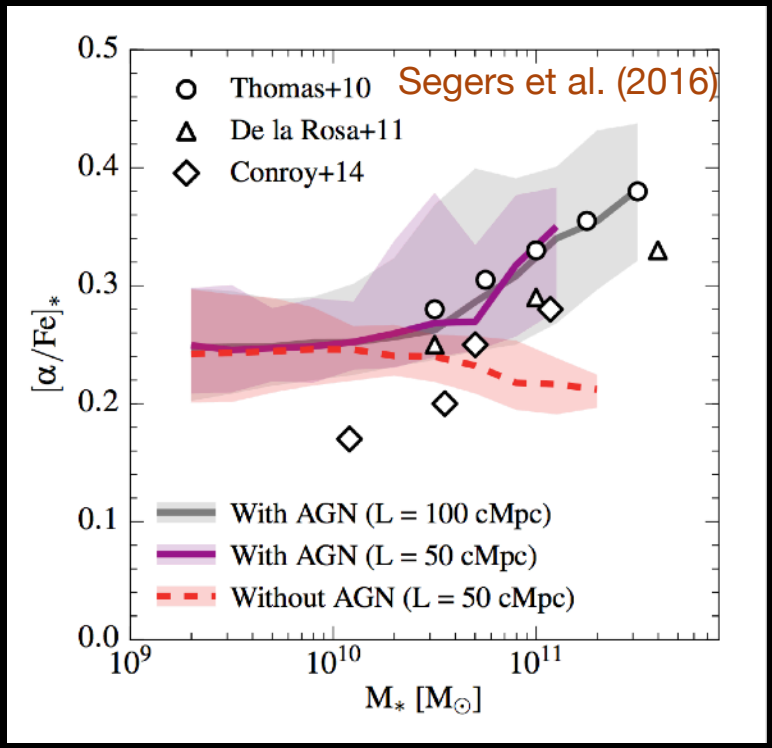
Anders+2014

Milky Way

Early-type Galaxies

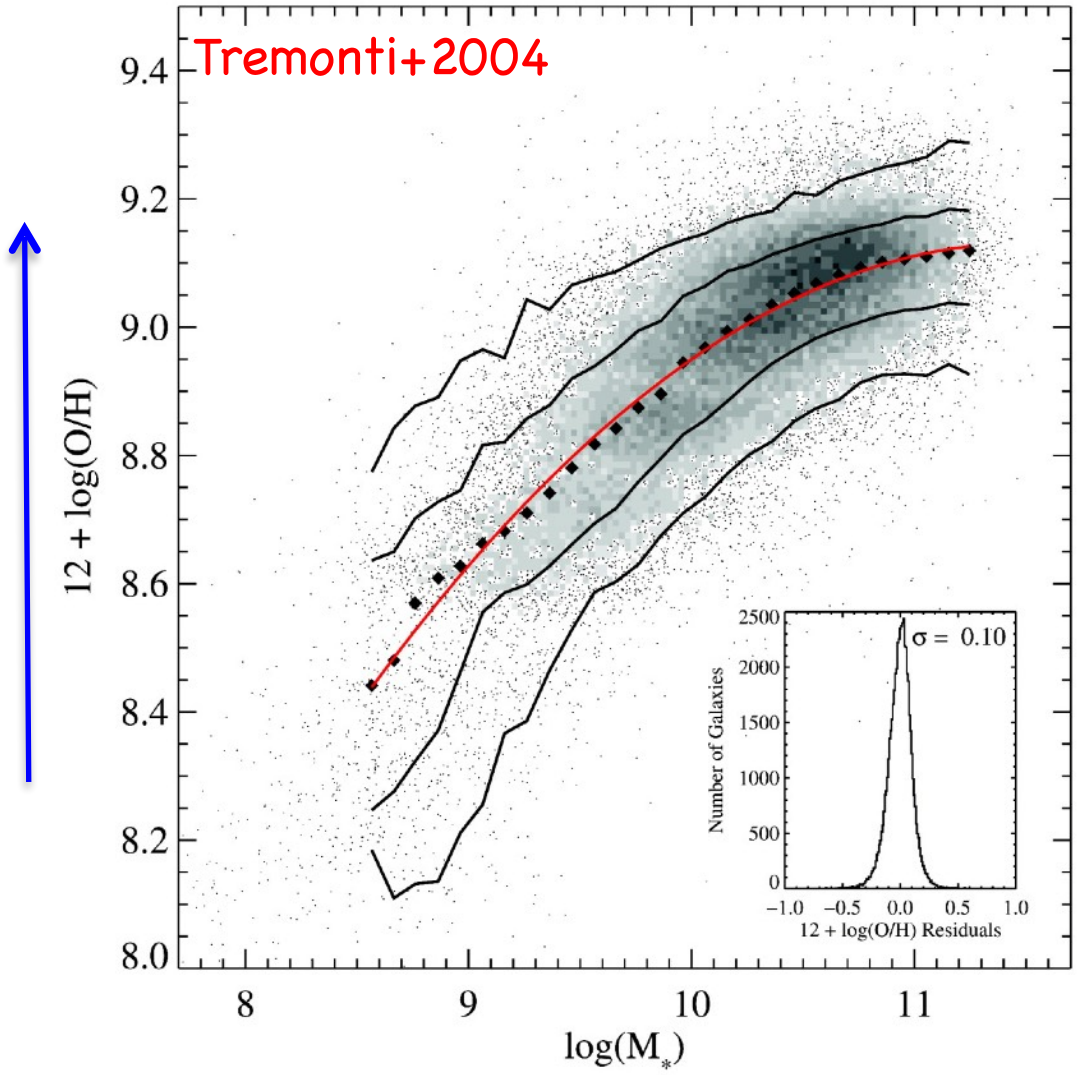


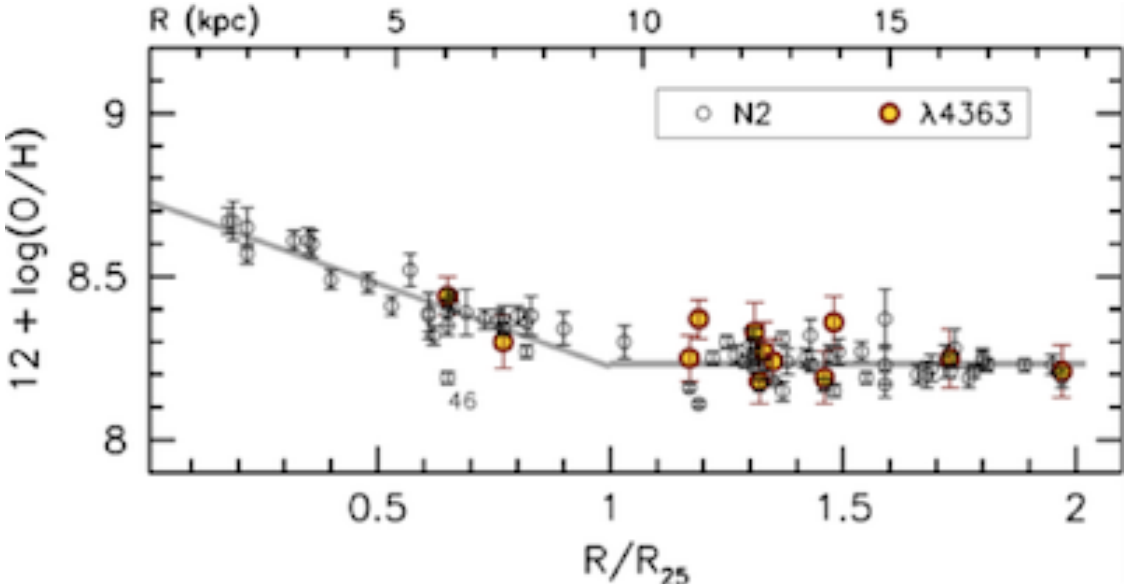
Conroy et al. (2014)

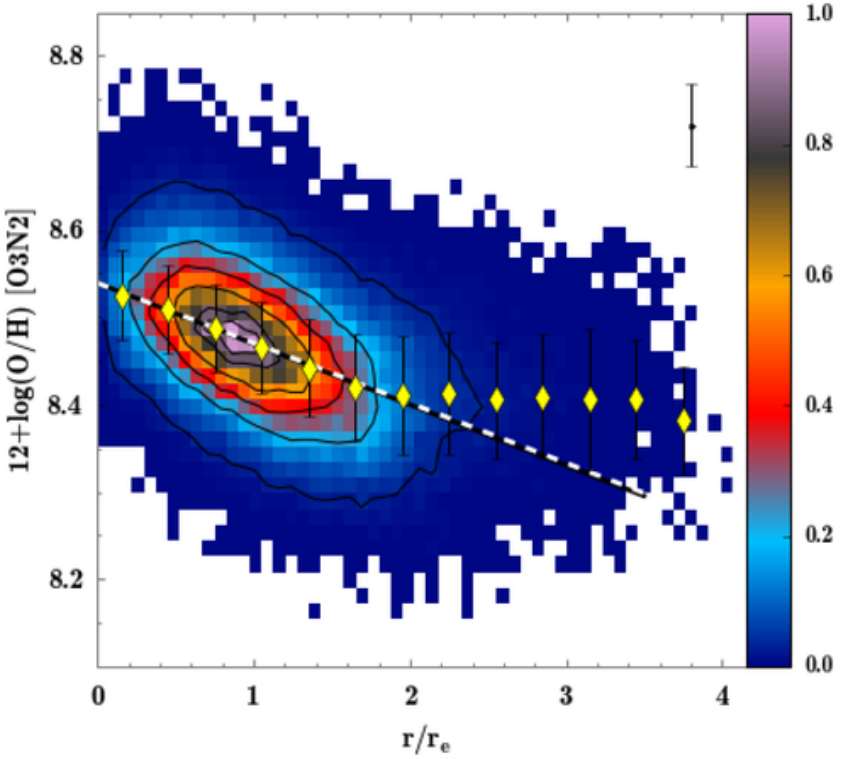


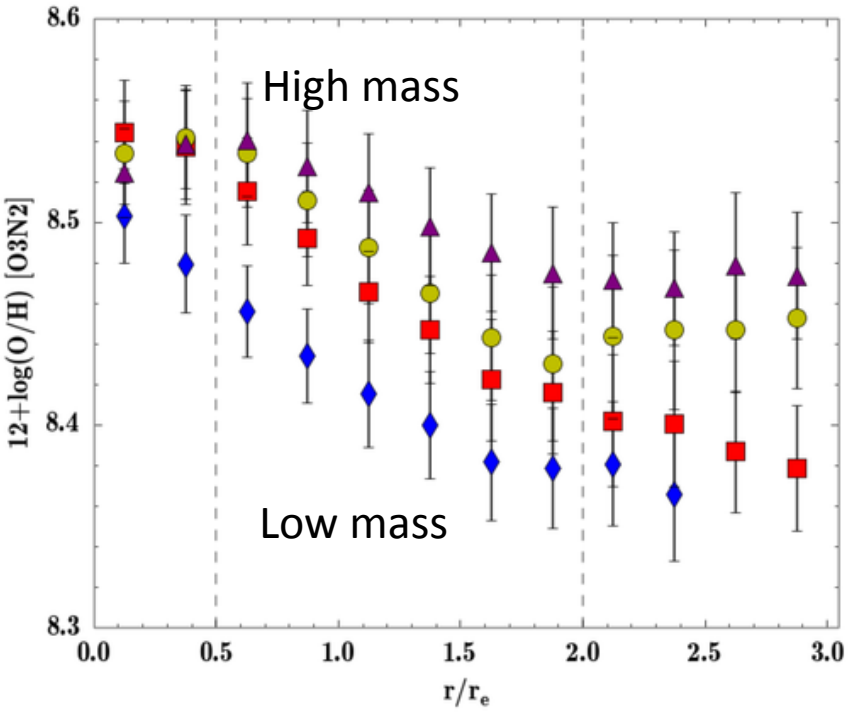
Segers et al. (2016)

(Stellar) Mass- (Gas-phase) Metallicity Relation ("MZR")



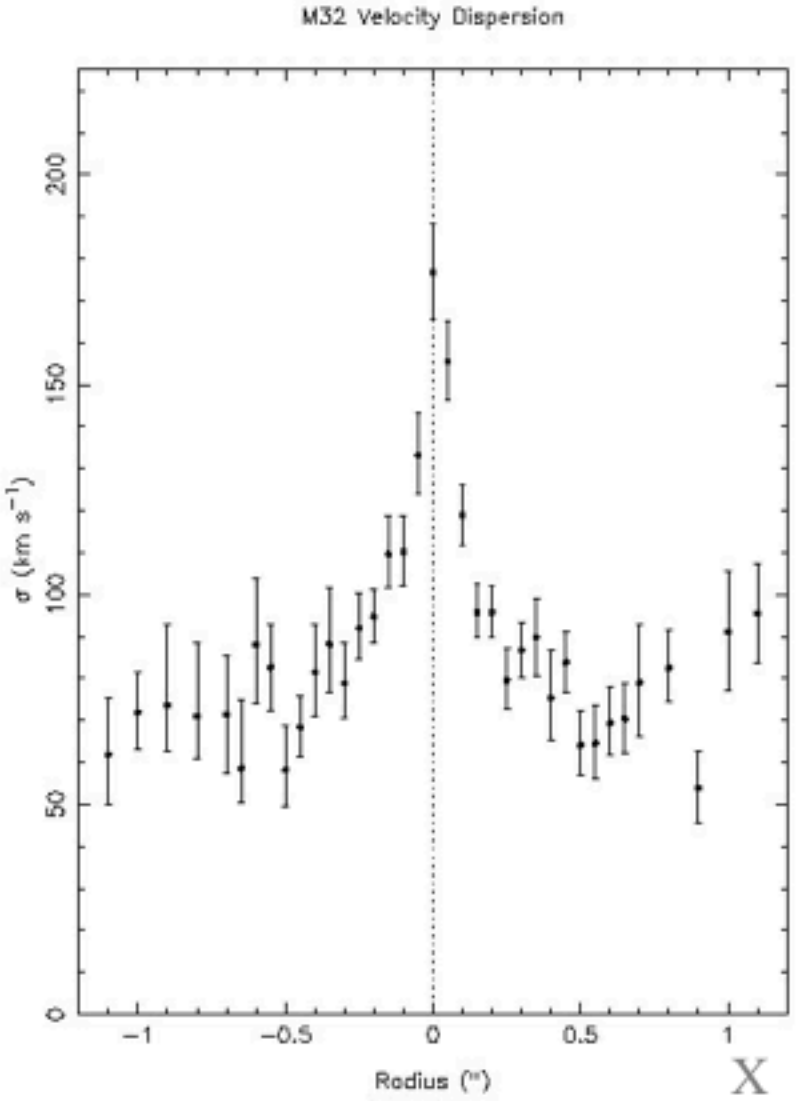

R (kpc)
5
10
15
N2
λ4363
12 + log(O/H)
9
8.5
8
46
0.5
1
1.5
2
R/R25


12+log(O/H) [O3N2]
8.8
8.6
8.4
8.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
r/re

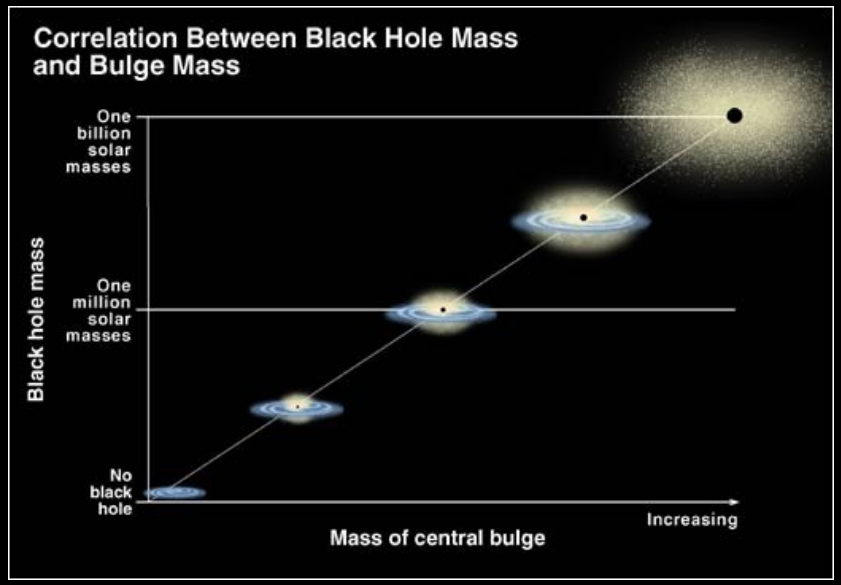

High mass
Low mass
12+log(O/H) [O3N2]
8.6
8.5
8.4
8.3
0.0
0.5
1.0
1.5
2.0
2.5
3.0
r/re

Many (all?) ellipticals (& bulges) have black holes- even compact ones like M32!

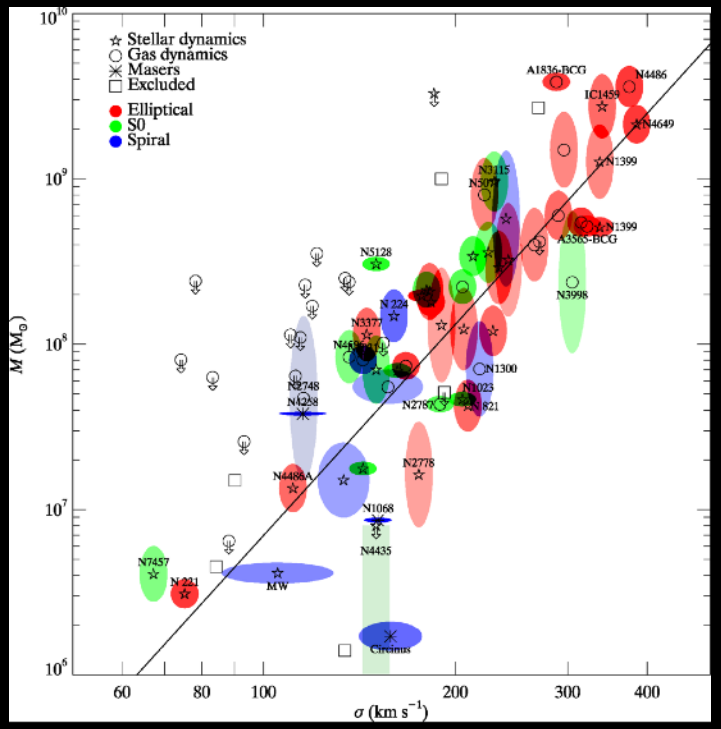
Can measure BH masses for galaxies via their velocity dispersion



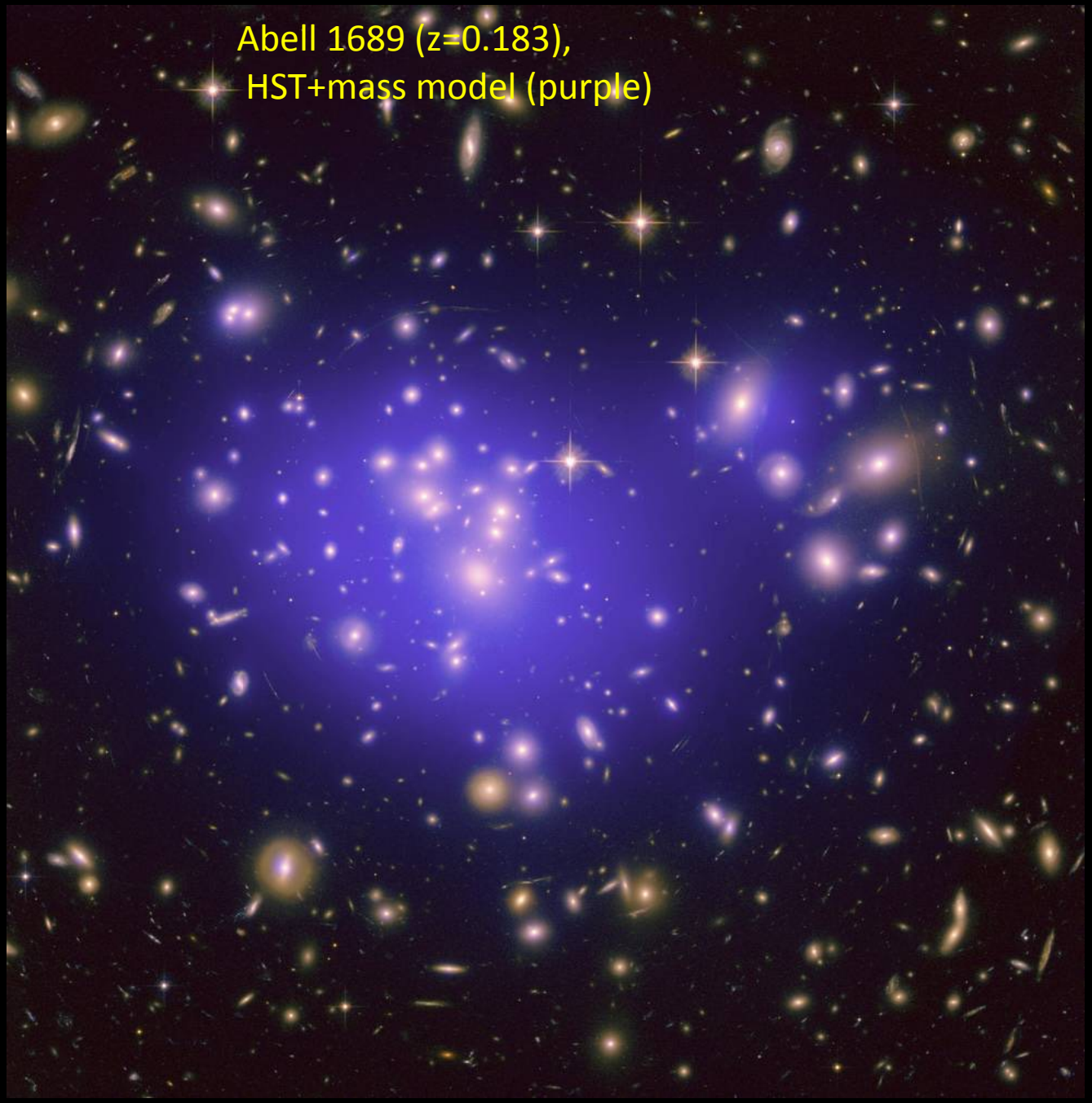
Correlation Between Central Black Hole Mass and Galaxy Properties



K.Gebhardt



"Nuker" Collaboration

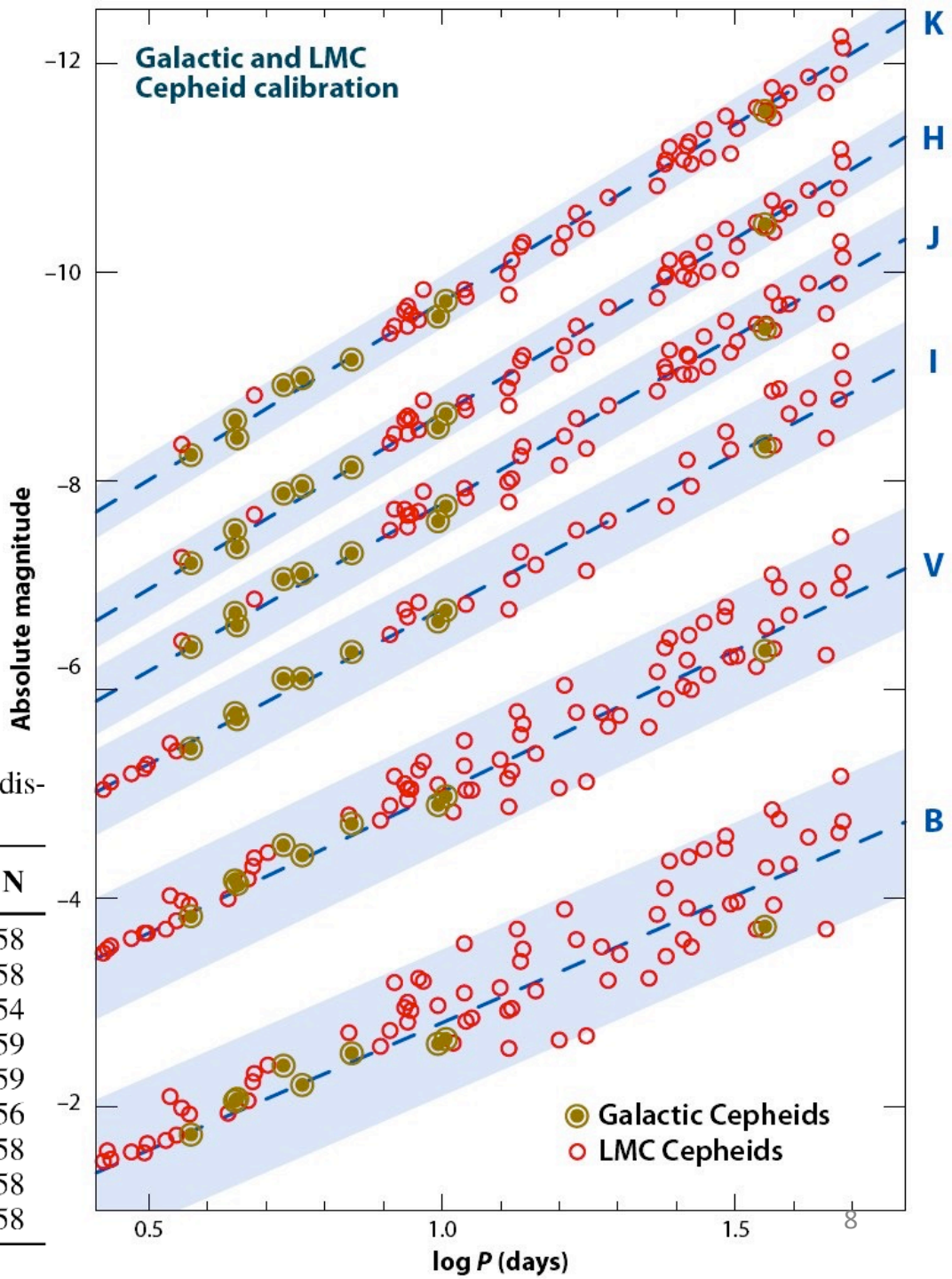

Abell 1689 (z=0.183),
HST+mass model (purple)

Cepheid P-L Rel'n in different photometric bandpasses

Amplitudes are larger in bluer bands, but extinction and metallicity corrections are also larger; redder bands may be better overall

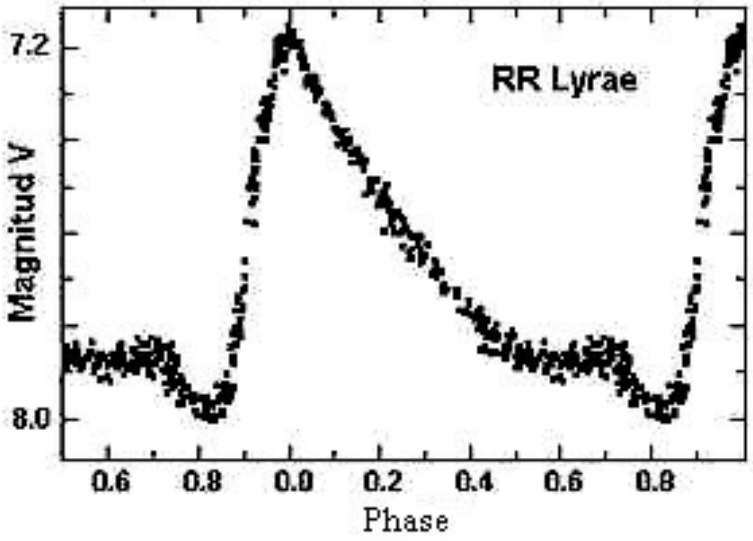
TABLE 3. Galactic Leavitt Laws from fundamental distances. Table adapted from Fouqué *et al.* 2007.

Band	Slope	Intercept	σ	N
B	-2.289 ± 0.091	-0.936 ± 0.027	0.207	58
V	-2.678 ± 0.076	-1.275 ± 0.023	0.173	58
R_c	-2.874 ± 0.084	-1.531 ± 0.025	0.180	54
I_c	-2.980 ± 0.074	-1.726 ± 0.022	0.168	59
J	-3.194 ± 0.068	-2.064 ± 0.020	0.155	59
H	-3.328 ± 0.064	-2.215 ± 0.019	0.146	56
K_s	-3.365 ± 0.063	-2.282 ± 0.019	0.144	58
W_{vi}	-3.477 ± 0.074	-2.414 ± 0.022	0.168	58
W_{bi}	-3.600 ± 0.079	-2.401 ± 0.023	0.178	58



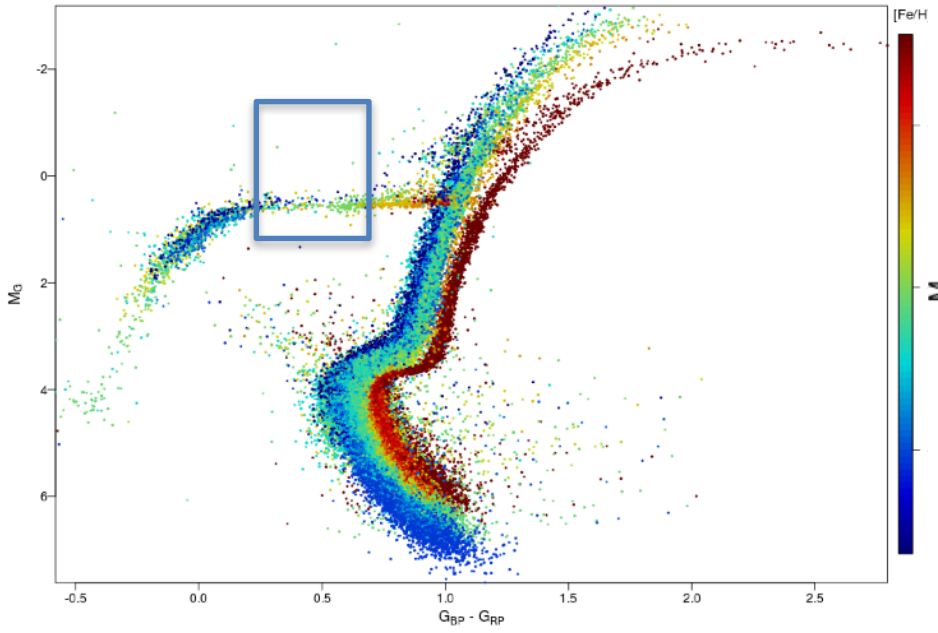
RR Lyrae Stars

- Pulsating variables, evolved old, low mass, low metallicity stars
  - Pop II indicator, found in globular clusters, galactic halos
- Lower luminosity than Cepheids, $M_V \sim 0.75$ +/- 0.1
  - There may be a metallicity dependence
- Have periods of 0.4 – 0.6 days, so don't require as much observing to find or monitor
- **Advantages:** less dust, easy to find
- **Disadvantages:** fainter (2 mag fainter than Cepheids). Used for Local Group galaxies only. The calibration is still uncertain (uses globular cluster distances from their main sequence fitting; or from Magellanic Clouds clusters, assuming that we know their distances)

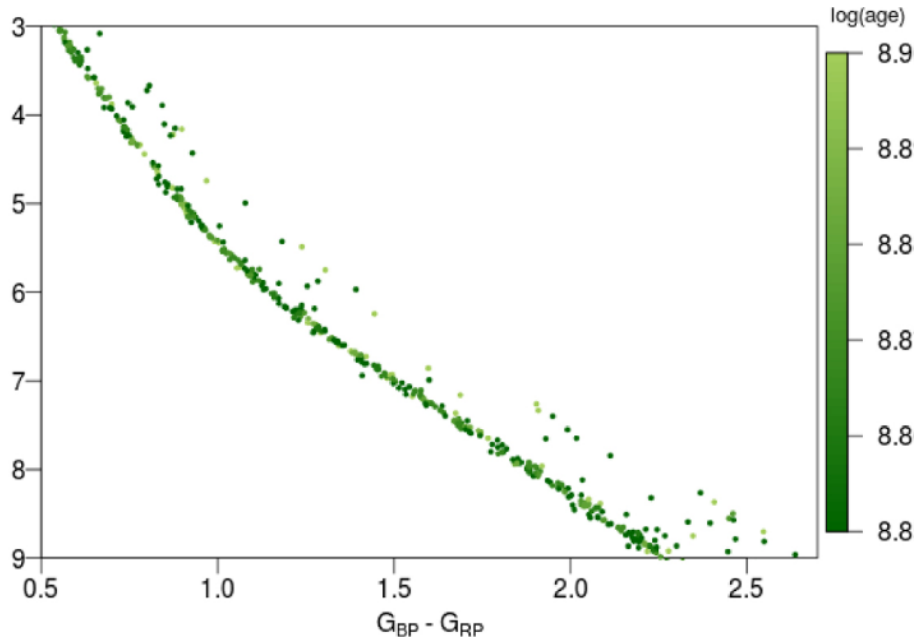


GAIA DR2 H-R Diagrams (using astrometric distances to stars)

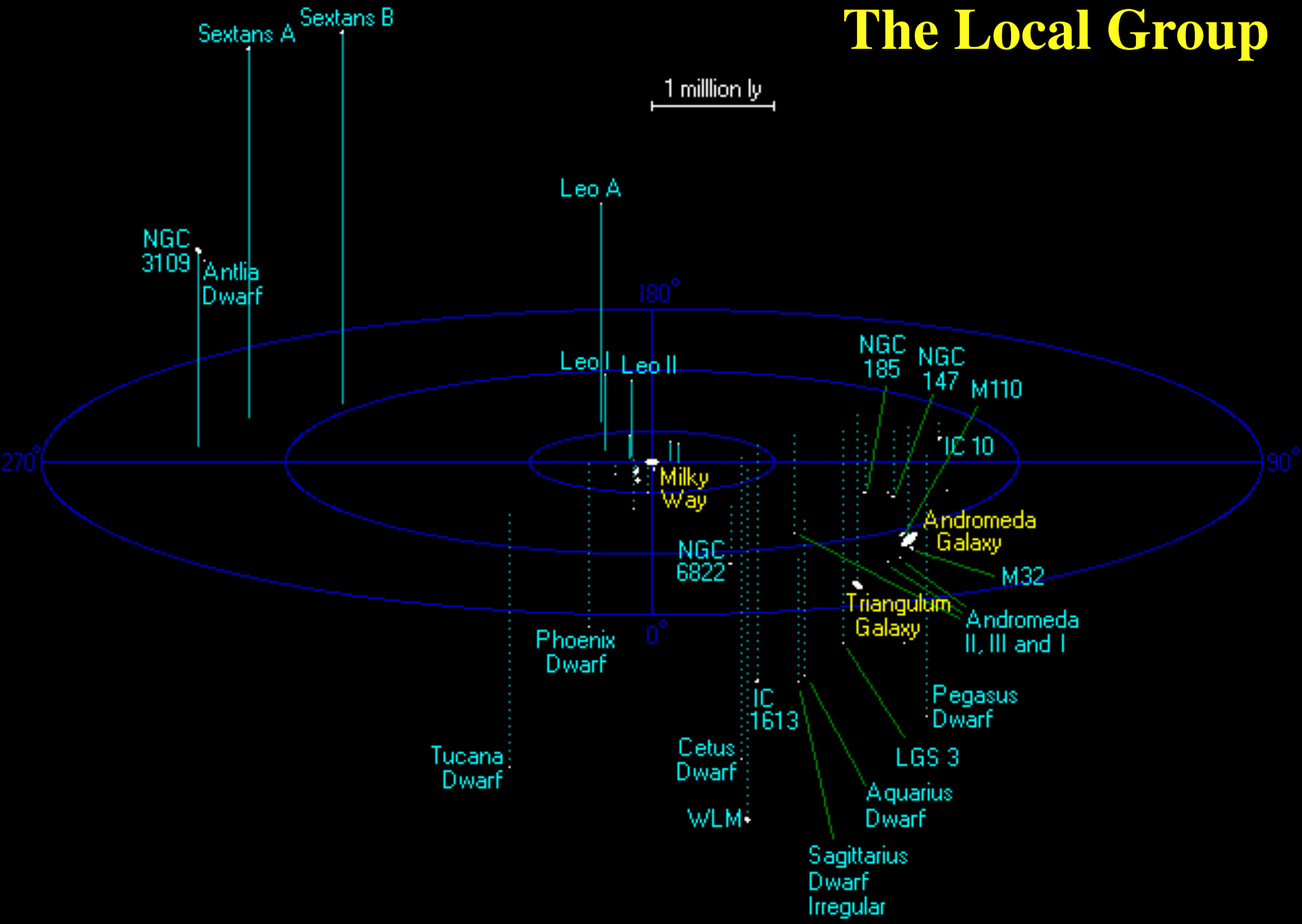
Globular Clusters



Hyades and Praesepe Open Clusters



The Local Group



rpowell