ENHANCED ABUNDANCES IN SPIRAL GALAXIES OF THE PEGASUS I CLUSTER

Paul Robertson, Gregory A. Shields, and Guillermo A. Blanc
The University of Texas at Austin

Abstract

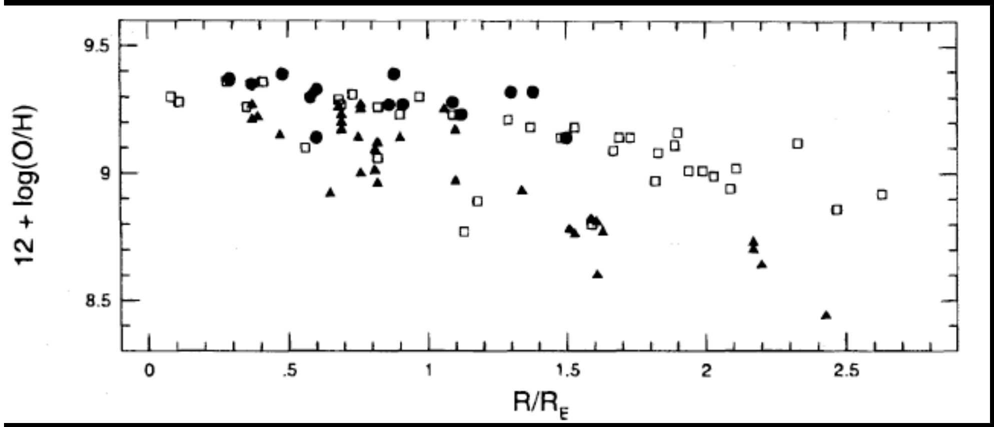
The metallicity of the H I deficient spirals in the Pegasus cluster core is elevated by 0.14 dex, compared to a control sample of H I normal Pegasus spirals. H I deficient spirals in the Virgo cluster also show enhanced abundances, suggesting similar environmental mechanisms at work in both clusters.

Introduction

- Galaxies in clusters experience different phenomena from field galaxies .
- As a result, we see different morphologies, gas content, SF histories, etc. in clusters.
- This study examines galactic chemical abundances for cluster spirals.

Enhanced abundances in Virgo

Skillman et al. 1996



Virgo H II Regions

Key:

Closed circles = H I-deficient galaxies
Closed triangles = H I-normal galaxies
Open squares = Intermediate deficiency

- Observation of high abundances for gas-poor Virgo spirals (Skillman et al. 1996) first demonstrated this effect.
- Virgo: nearby, high density, high gas deficiencies => ideal test bed.
- Result: gas-deficient core spirals more abundant by ~0.3 dex.

Enhanced abundances in Virgo

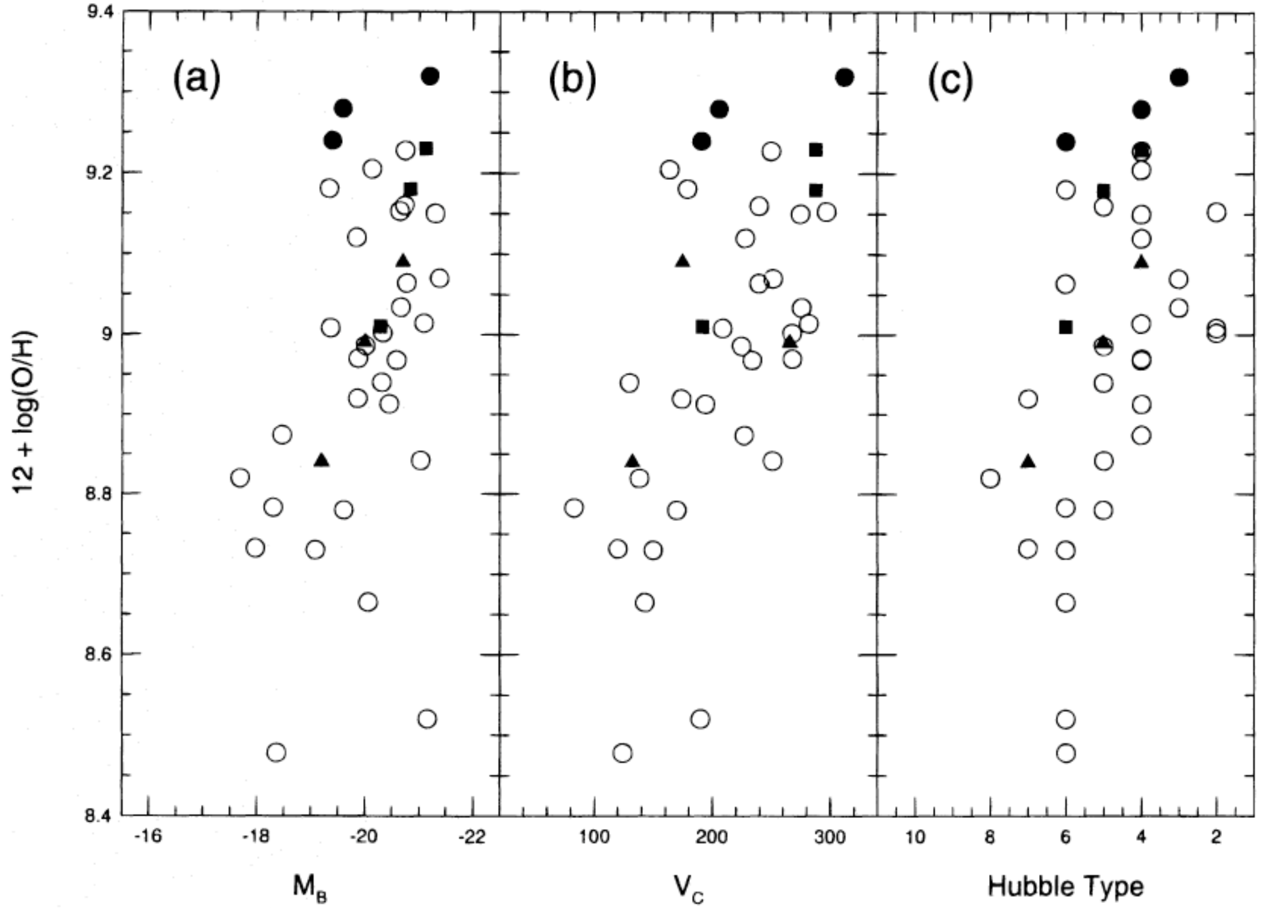


FIG. 6.—Mean O/H as a function of (*a*) absolute blue magnitude, (*b*) maximum rotation curve velocity, and (*c*) Hubble type for the Virgo spirals and the nonbarred spirals of the ZKH sample. The open circles correspond to the field sample of ZKH, while the points for the Virgo spirals have been coded as in Fig. 1.

Skillman et al. 1996

Enhanced abundances in cluster spirals

- SDSS galaxies (Cooper et al. 2008, Ellison et al. 2009) show higher characteristic metallicities when found in clusters & high-density environments.
- Zhang et al. (2009) demonstrate SDSS galaxies' metallicity increases as gas content decreases.
- The Hercules cluster (Petropoulo et al. 2011) shows elevated abundances in dwarfs (unclear for spirals).

The Pegasus I Cluster

- Hypothesis: If Pegasus spirals show H I stripping from ICM-ISM interactions, we expect to see higher nebular metallicity as well.

- Experiment: Use the VIRUS-P integral-field spectrograph on the McDonald Observatory 2.7-meter telescope to measure H II region abundances for six Pegasus galaxies.

The Pegasus I Cluster

- Low density, low velocity dispersion cluster.
- Appears to be in earliest stages of collapse (Vigroux et al. 1989).
- Despite above points, Pegasus displays H I deficiency and suppressed star formation similar to, but less than, Virgo (Levy et al. 2007, Rose et al. 2010)!

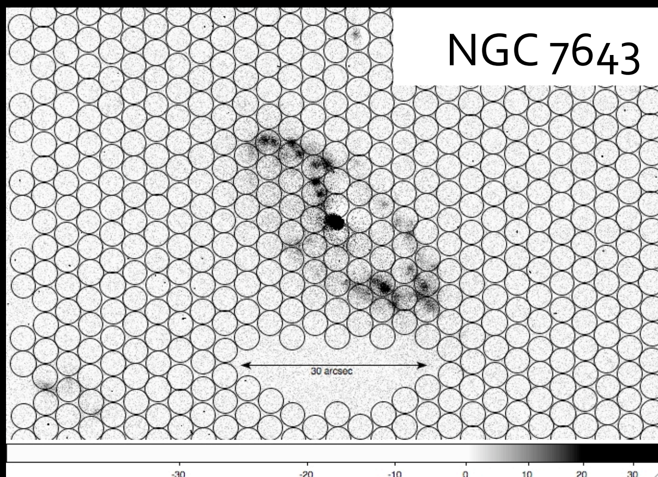
TABLE 4
CLUSTER PROPERTIES

Levy et al. 2007

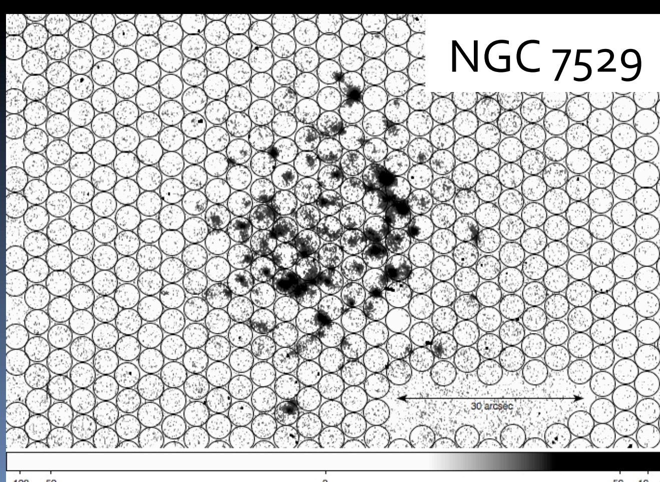
Cluster Name (1)	Percentage (E+S0) : Percentage (S+IRR) (2)	σ_v (km s^{-1}) (3)	X-Ray Luminosity (ergs s^{-1}) (4)	Electron Density (cm^{-3}) (5)	ρv^2 (km^2 s^{-2} cm^{-3}) (6)
Coma	86 : 14[a]	1010[b]	(0.5–3 keV) 25.7×10^{43}[c]	2.5×10^{-3}[d]	2550
Virgo	37 : 63[e]	632[f]	(0.5–3 keV) 4.4×10^{43}[c]	6.4×10^{-3}[d]	2556
Pegasus	18 : 82[g]	240[h]	(0.2–4 keV) 1.3×10^{42}[i]	2×10^{-4}[i]	12
Eridanus	46 : 54[e]	240[e]	(0.1–2 keV) 2.5×10^{41}[e]	2×10^{-4}[e]	12
Ursa Major	15 : 85[e]	150[e]	...[e]	[e]	...

Galaxy Selection

3 face-on, gas-deficient spirals



3 face-on, gas-normal spirals

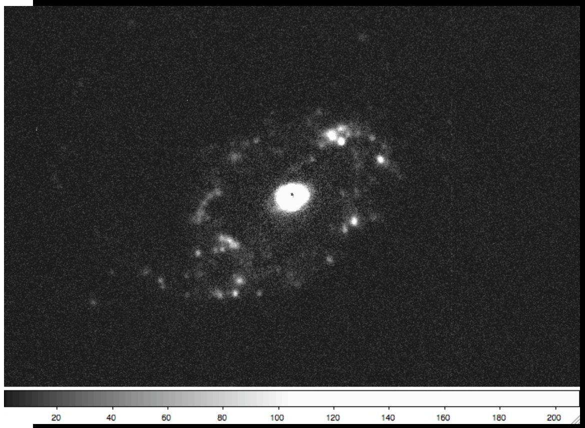
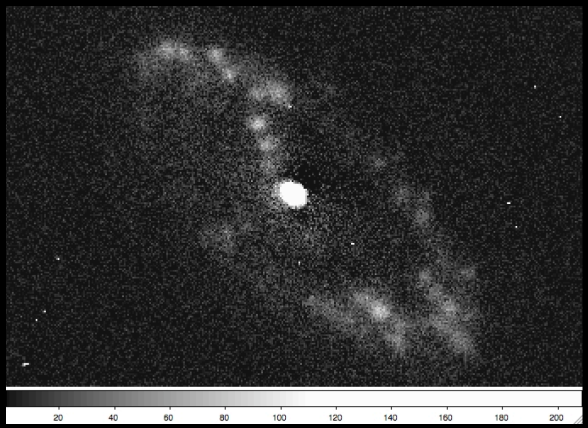
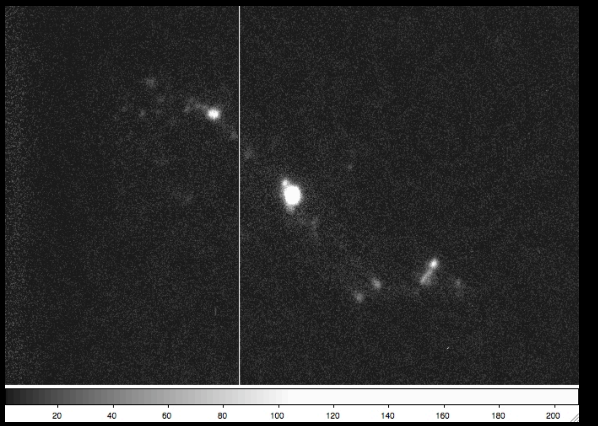


Target Galaxies

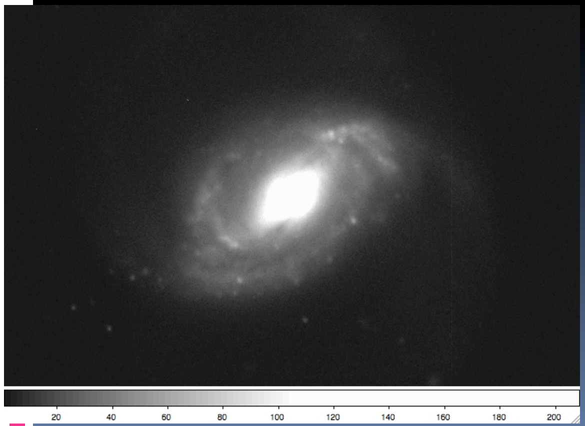
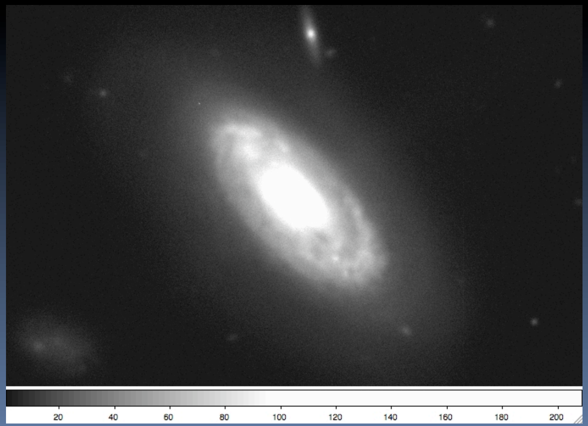
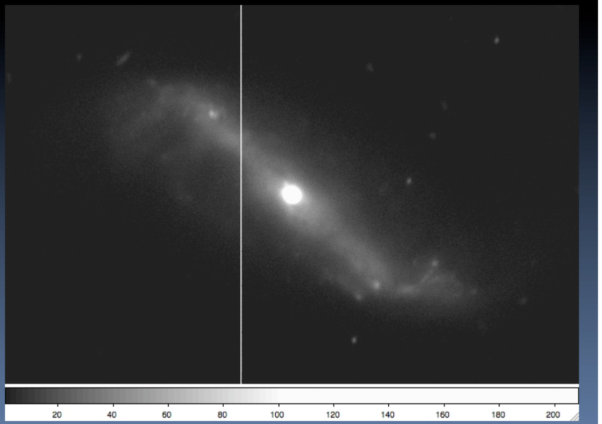
Galaxy	R.A.	Decl.	M_B	R_e	R_{iso}
IC 1474	23:12:51.2	+05:48:23	-19.84	14.	34.
NGC 7518	23:13:12.8	+06:19:18	-19.93	22.	43.
NGC 7529	23:14:03.2	+08:59:33	-19.66	11.	29.
NGC 7591	23:18:16.2	+06:35:09	-21.40	14.	62.
IC 5309	23:19:11.7	+08:06:34	-20.37	19.	56.
NGC 7643	23:22:50.4	+11:59:20	-20.21	20.	43.

Gas-Deficient Spirals

Hα Narrow-Band

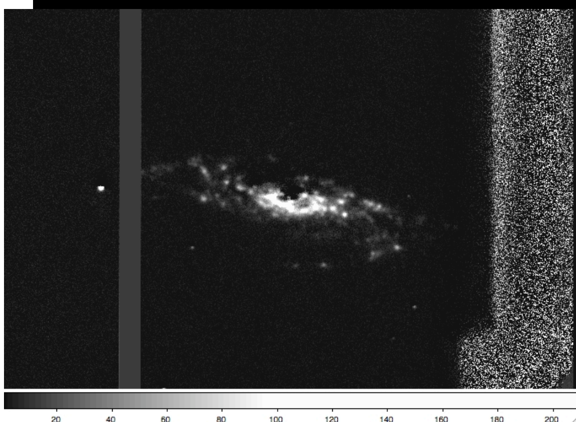
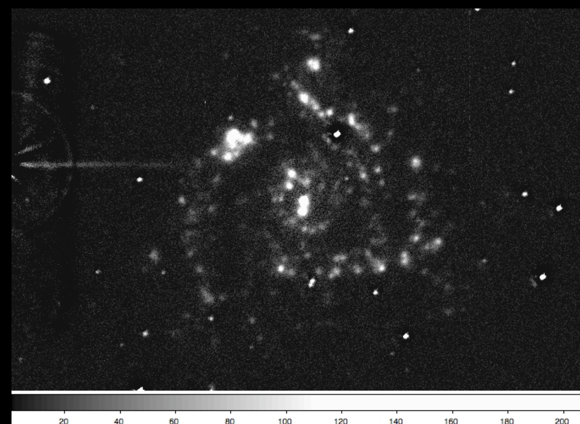
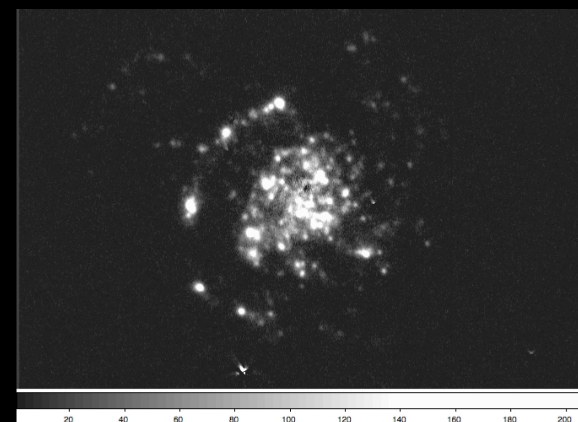
R Band

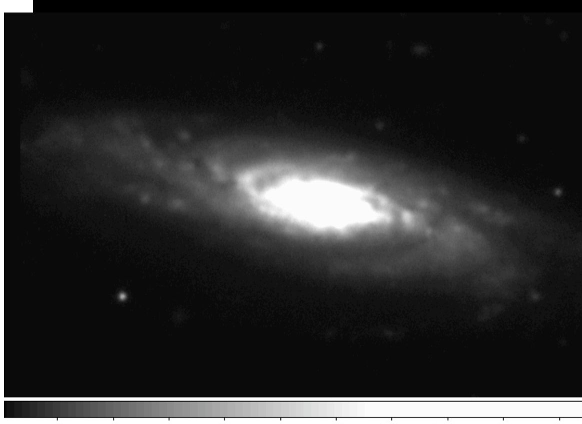
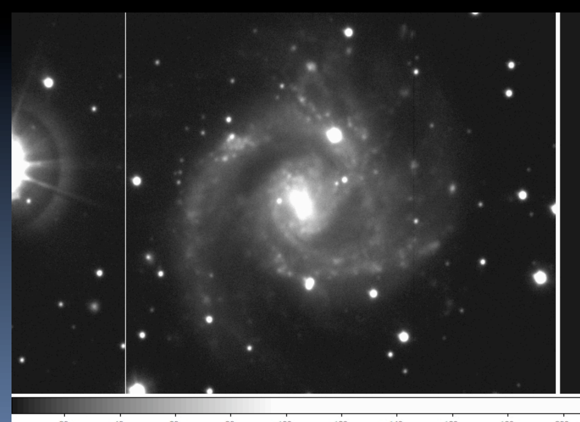
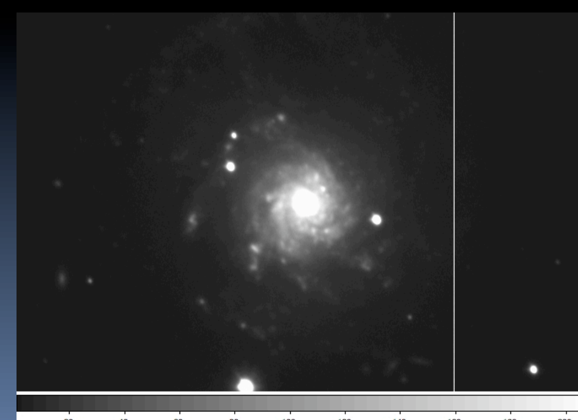
NGC 7518 NGC 7643 UGC 164

Gas-Normal Pegasus I Spirals

Hα Narrow-Band

R Band

NGC 7537 UGC 11524 UGC 11759

Nebular abundance in cluster spirals

Observational signature: strong-line [O II], [O III] emission

Increasing abundance => more collisional cooling in fine structure lines => weaker [O II], [O III]!

Decreasing ionization due to lower stellar T_{eff} augments the phenomenon.

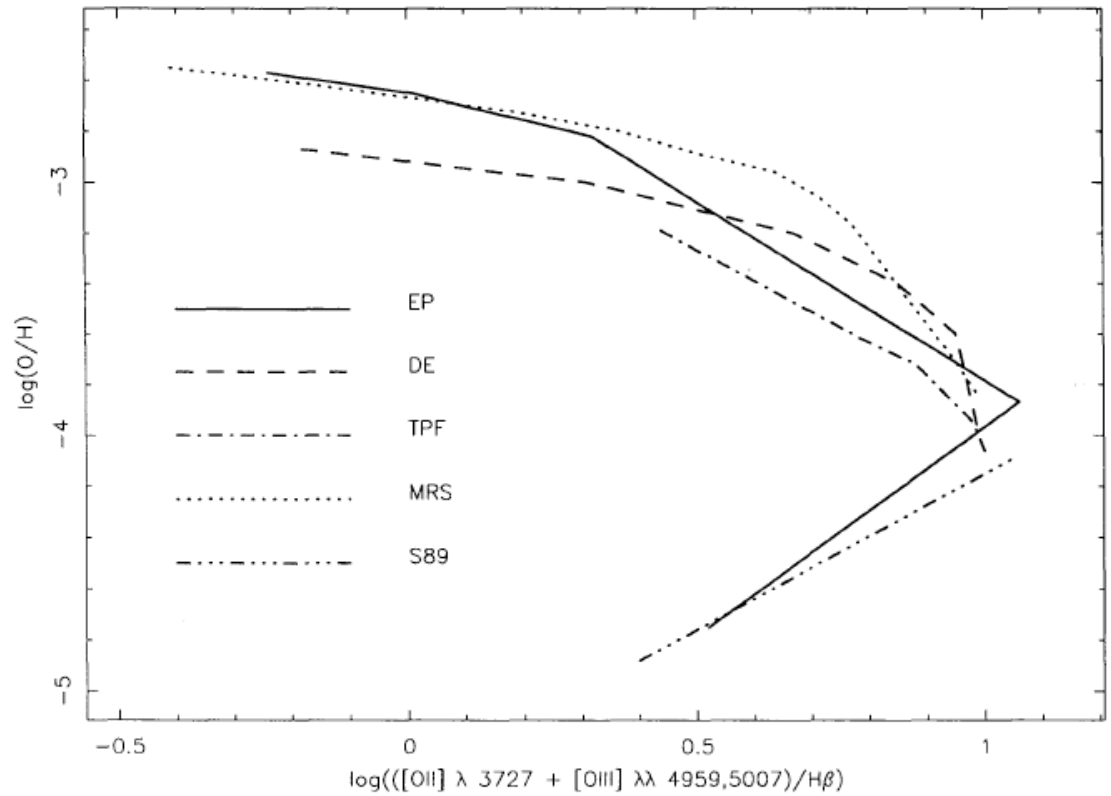
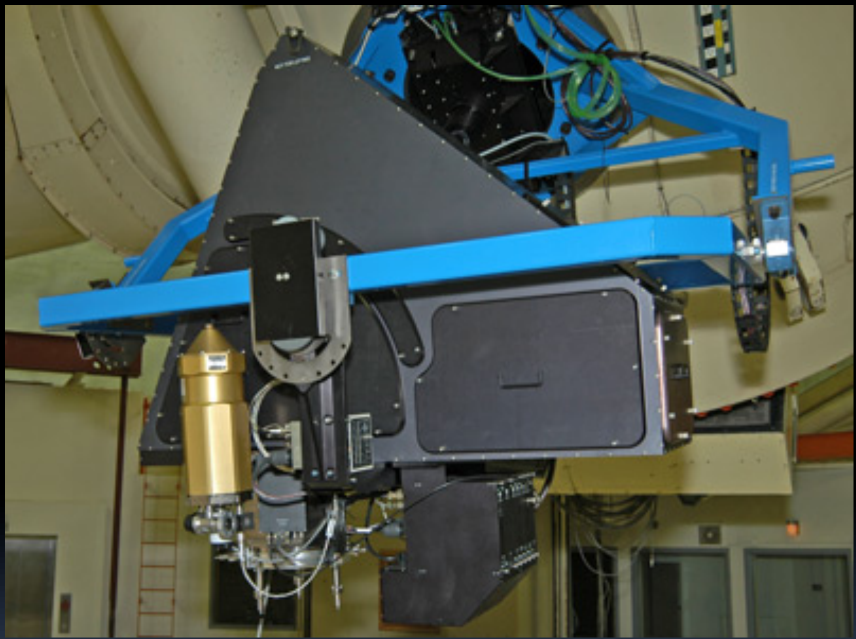


FIG. 1.—Published calibrations of the abundance indicator R_{23}. *Solid line*: Edmunds & Pagel (1984). *Dashed line*: Dopita & Evans (1986). *Dash-dotted line*: Torres-Peimbert, Peimbert, & Fierro (1989). *Dotted line*: McCall, Rybski, & Shields (1985). *Dash-triple dotted line*: Skillman (1989).

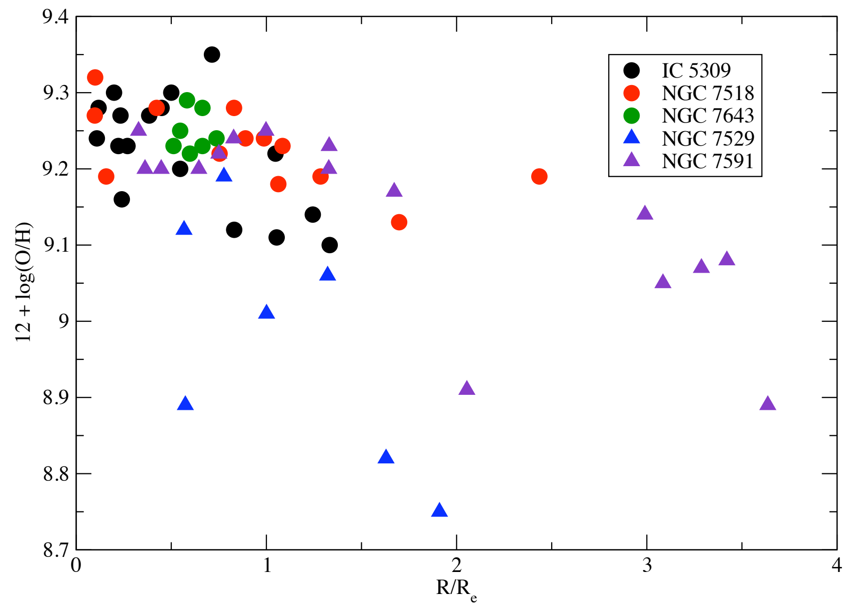
McGaugh 1991

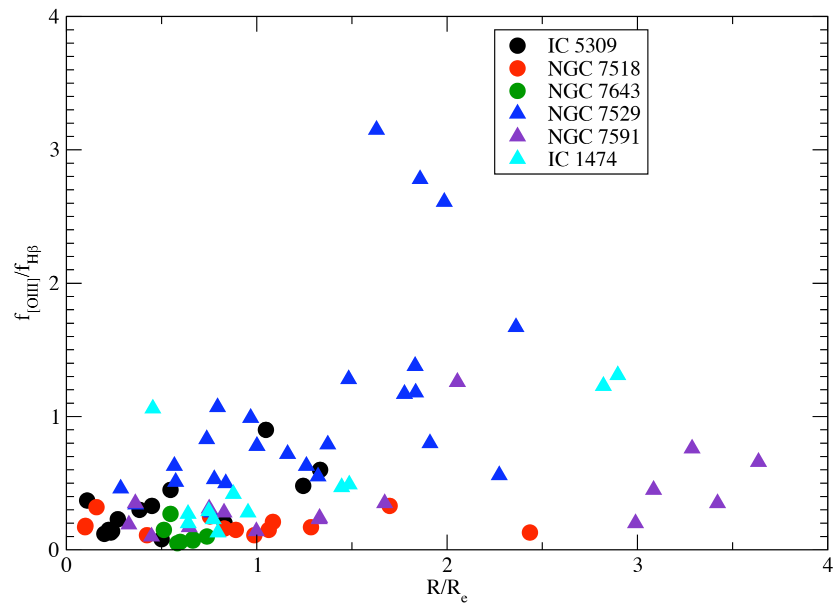
VIRUS-P



- 246 4″ diameter fibers
- Two grating settings provide wavelength coverage from ~3500-7000 Å
- 3.5 arcmin² field of view

Results





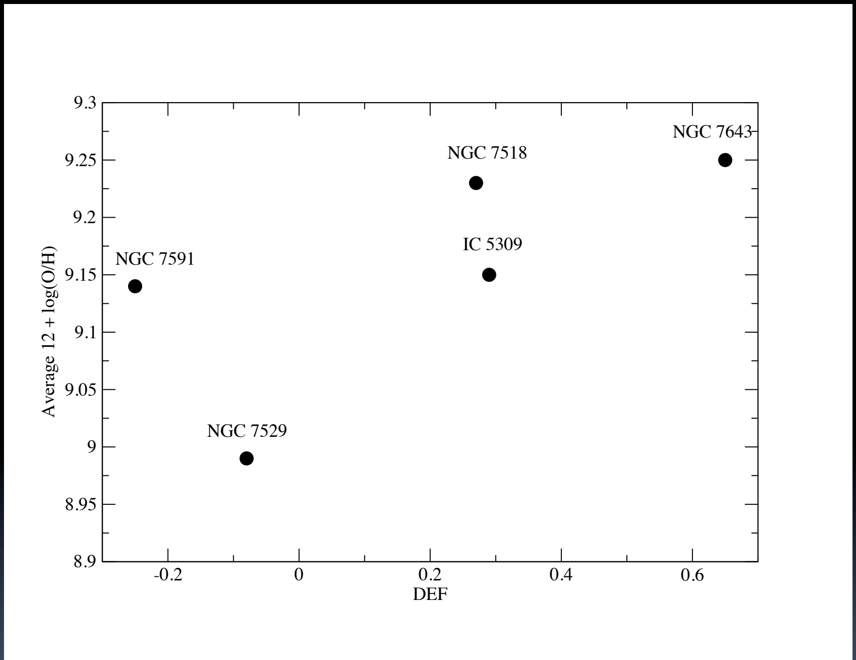
12 + log(O/H)

[O III] flux only

Abundance gradients vary with H I deficiency!

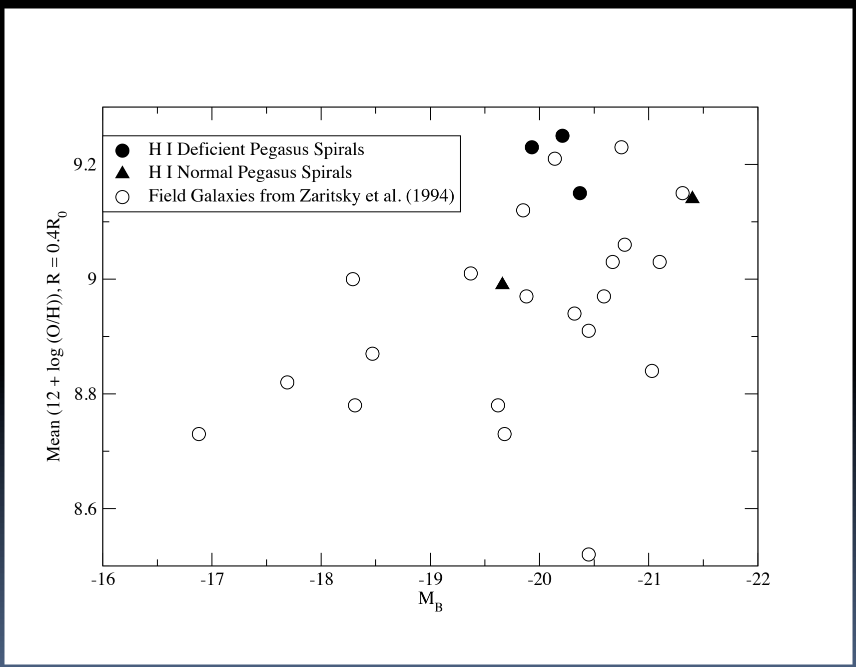
Defining Galactic Metallicity

- Mean galactic metallicity defined as metallicity at some fiducial radius (see Zaritsky et al. 1994).
- We define mean abundance as metallicity at 0.4 R_{iso}, determined from radial gradient.
- Result: More deficient galaxies are more abundant!

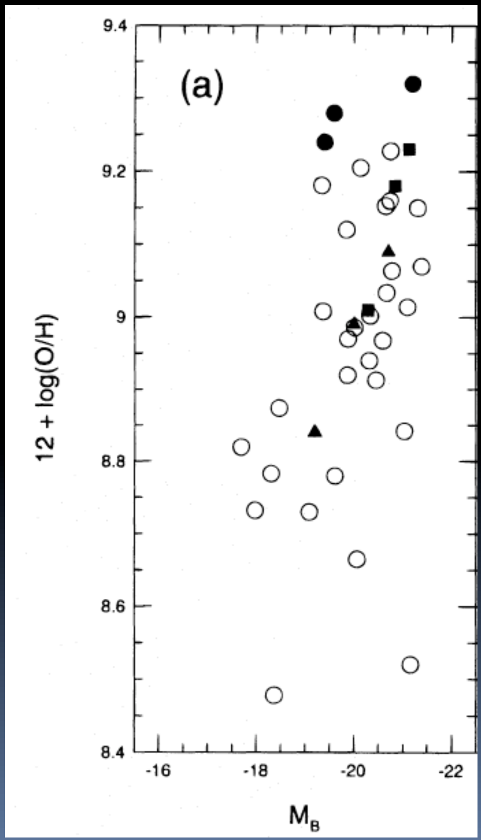


Comparison to Virgo/Field

Pegasus



Virgo



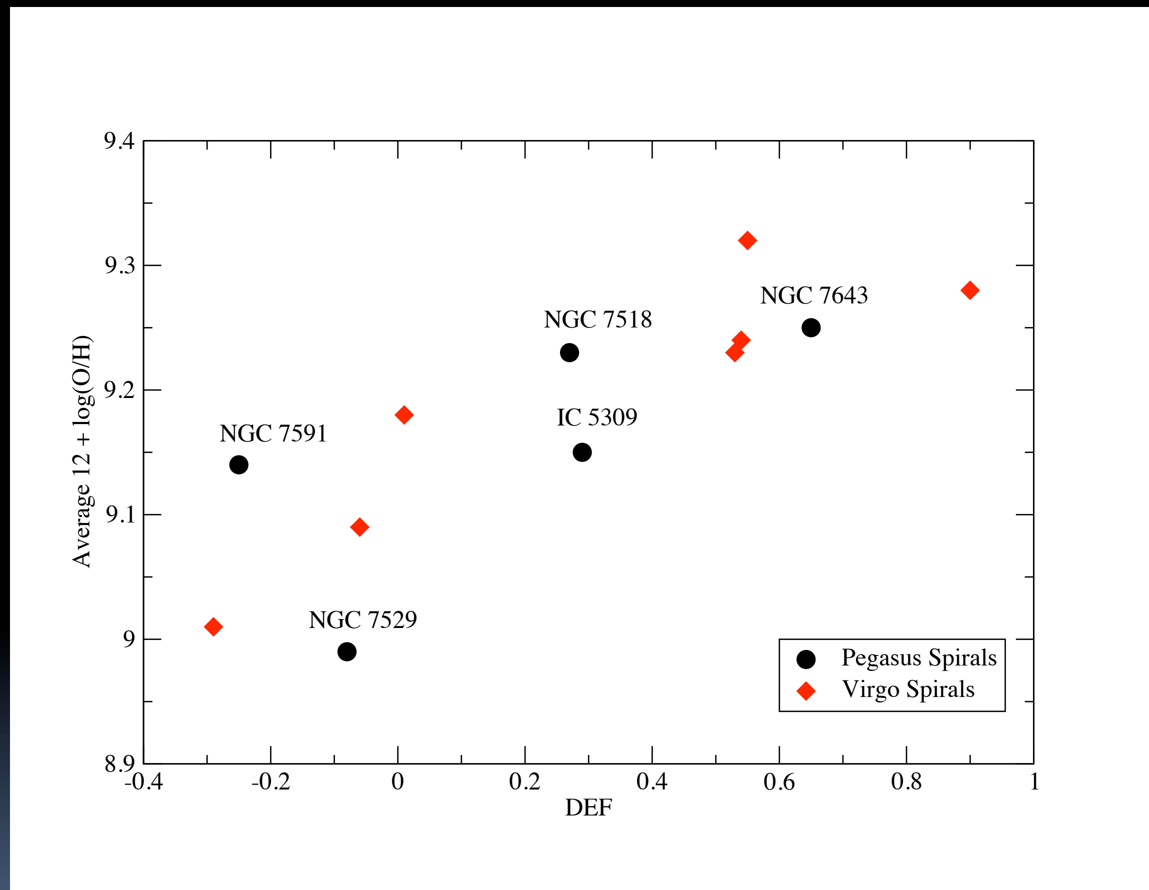
How much of an offset?

- H I-deficient Pegasus spirals are, on average, ~0.15 dex more metal-rich than the control sample, compared to 0.3 dex for Virgo.
- BUT, the Virgo control galaxies are much further from the cluster center than our controls—they're basically field galaxies!
- As it turns out, this smaller offset is what we would expect.

How much of an offset?

The “normal” galaxies in the Pegasus cluster are actually analogous to the “intermediate” galaxies in the Skillman et al. (1996) Virgo sample.

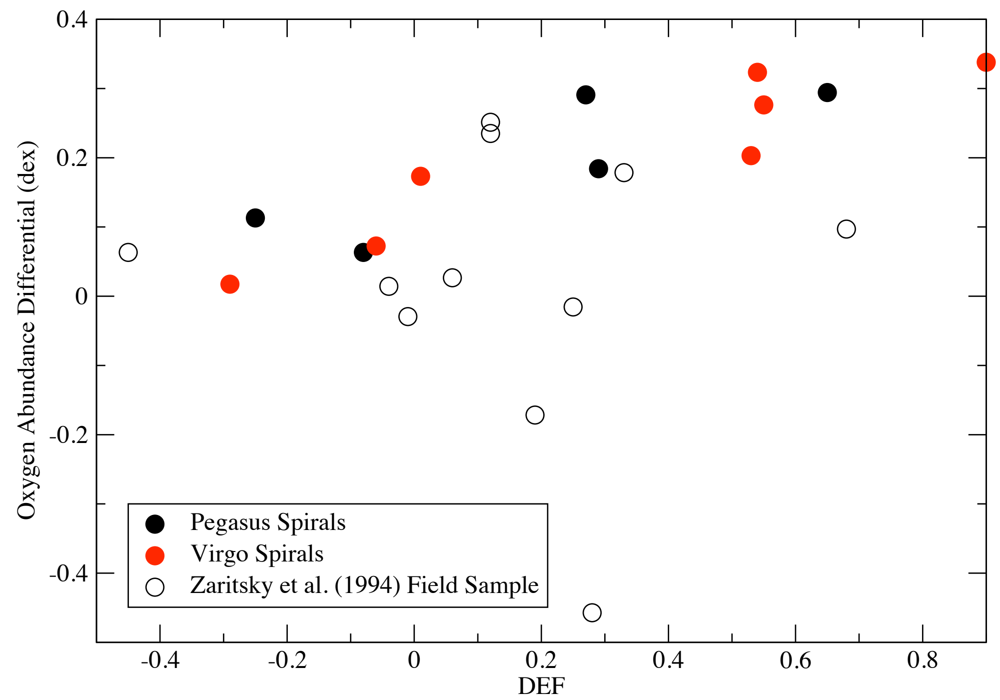
Abundances at a given gas deficiency level are similar for both clusters!



Comparison to field

Normalize O/H to field galaxy O/H – M_B trend (fit to Zaritsky et al 1994).

Trend clear for cluster galaxies but absent for field galaxies.



Nebular abundance in cluster spirals

- ISM-ICM interactions strip hydrogen gas from spirals as they fall through the cluster.
- Additionally, this process cuts off infall of primordial gas into the disk.
- Result: less dilution of heavy elements from SNe.

Conclusions

- Like Virgo and other high-density environments, spiral galaxies in the Pegasus cluster that have experienced H I loss show proportionally higher heavy element content.
- While the observed abundance increase is of a modest nature, it is what we expect for the range of H I deficiency considered.
- This metallicity offset may be caused primarily by infall cutoff (Skillman et al. 1996), but second-order effects related to H I disk truncation (Shields et al. 1991) may also occur.