

Optical Surveys of Galaxies: Past, Present, and Future

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(Hosei University)

Recent review :

'Sky Surveys', Djorgovski et al. 2012, in Astronomical Techniques, Software, and Data (ed. H. Bond), Vol.2 of Planets, Stars, and Stellar Systems (Springer)

<http://ned.ipac.caltech.edu/level5/March12/Djorgovski/Djorgovski1.html>

1. Early Photometric Surveys
2. Early Redshift Surveys
3. Modern Surveys
4. Impacts of Modern Large Surveys
5. Future Surveys

- 1. Early Photometric Surveys**
2. Early Redshift Surveys
3. Modern Surveys
4. Impacts of Modern Large Surveys
5. Future Surveys

Shapley-Ames Catalog (1932)

Shapley, H. and Ames, A. 1932, Harvard College Observatory Bulletin No. 887, pp.1-6
Annals of Harvard College Observatory, vol. 88, pp.41-76

HARVARD COLLEGE OBSERVATORY

BULLETIN 887

May 1, 1932

Photometric Survey of the Nearer Extragalactic Nebulae.— As a contribution to the study of the structure of the metagalactic system, we have completed a photometric catalogue, appearing later in the Annals, of the more than a thousand

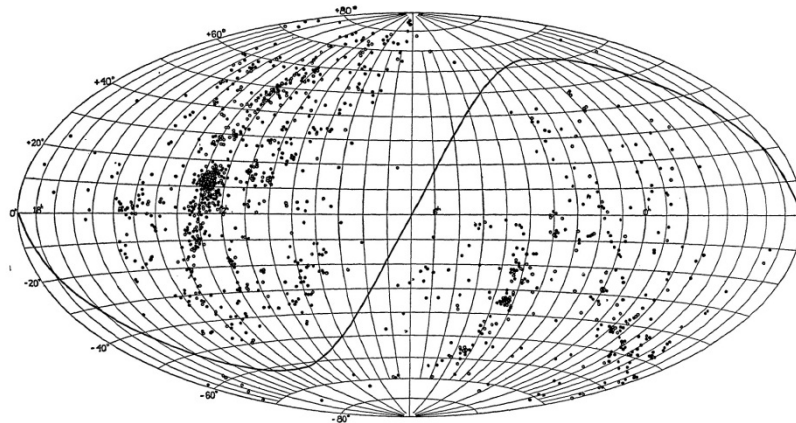


FIGURE 1. — The distribution of the extragalactic nebulae brighter than the 13th photographic magnitude. The 291 nebulae brighter than the 12th magnitude are shown by open circles; dots represent the 734 nebulae between the 12th and 13th magnitudes. The central line of the Milky Way is indicated.

extragalactic objects brighter than the thirteenth magnitude. The primary virtues of the survey are its essential completeness and the fair homogeneity of the magnitudes over the whole sky. It has the further merit that the magnitudes, which

CONTENTS. Photometric Survey of the Nearer Extragalactic Nebulae (Harlow Shapley and Adelaide Ames). — Charts for Faint Variable Stars, Second Series: Milky Way Field 185 (Henrietta H. Swope). — New Variable Stars in Aquila (Dorrit Hoffleit). — Remeasurement of an Early Harvard Photograph of Pluto (Dorothy Johnstone). — Period and Range of RT Lupi (W. F. H. Waterfield).

PRINTED FROM THE STURGIS FUND

The Local Supercluster

As a contribution to the study of the structure of the metagalactic system, we have completed a photometric catalogue, appearing later in annals, of more than a thousand extragalactic objects brighter than the thirteenth magnitude. The primary virtues of the survey are its essential completeness and the fair homogeneity of the magnitudes over the whole sky.

Compilation of 1249 mostly known 'Extragalactic Nebulae'

Original Source	Pg. Mag. [13.0	Pg. Mag. [12.9	Total Number
New General Catalogue (NGC)	980	208	1188
Index Catalogues (I & II) (IC I+II)	35	13	48
Small Magellanic Cloud	1		1
Large Magellanic Cloud	1		1
H.A., 72, No. 2		1	1
H.A., 85, No. 6	1	1	2
Reinmuth (Heid. Obs. Pub., 8, No. 12)		1	1
Fath (Astr. Journ., 28, No. 658)	1		1
New	6		6
Total Numbers	1025	224	1249

First magnitude-limited catalog based on more or less uniform photographic plates



Not naked eye!

Magnitude	North	Number of Nebulae South	Total
] 10.0	10	10	20
10.0-10.9	33	17	50
11.0-11.9	124	97	221
12.0-12.9	371	363	734
13.0-13.3	100	124	224
Total Numbers	638	611	1249

Large efforts to give calibrated magnitudes

Des.

Mag. Res.

α (1950) δ

Diams. Type

λ β

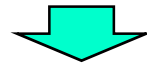
Aut.

Des.	α 1950 δ	λ β	Mag. Res.	Diams. Type Aut.
7814	0.7 +15 51	75 -45	12.4 <u>111</u>	3.0 0.8 Sa H,C
16	6.5 +27 27	80 -35	13.0 <u>001</u>	R
23	7.3 +25 39	82 -36	12.7 <u>111</u>	1.0 0.6 .. R
24	7.4 -25 15	14 -82	12.2 <u>120</u>	4.0 1.0 S a
45	11.4 -23 27	28 -82	12.1 <u>132</u>	10.0 7.0 S G
55	12.5 -39 30	295 -77	7.8 <u>223</u>	25.0 3.0 S K
95	19.6 +10 12	81 -52	13.1 <u>100</u>	R
128	26.7 +02 33	81 -60	12.9 <u>201</u>	2.5 0.4 S: R
134	27.9 -33 32	296 -83	11.4 <u>001</u>	5.0 1.0 S K
147	30.4 +48 14	87 -14	12.1 <u>001</u>	6.5: 3.8: S: R
148	30.8 -32 4	300 -85	12.9 <u>001</u>	1.2 0.5 E a'
151	31.6 - 9 58	80 -72	12.5 <u>001</u>	4.0 2.0 S C
150	31.8 -28 5	1 -88	12.2 <u>011</u>	2.0 1.0 SB K
157	32.3 - 8 40	81 -71	11.1 <u>111</u>	2.5 2.0 Sc H, a'
175	34.9 -20 12	80 -82	12.8 <u>201</u>	1.8 1.4 SB a
185	36.1 +48 4	89 -14	11.8 <u>100</u>	3.5 2.8 Ep L,H
178	36.6 -14 27	83 -77	12.9 <u>111</u> K
205	37.6 +41 25	89 -21	10.8 <u>111</u>	8.0 3.0 Ep H,C
210	38.0 -14 9	85 -76	12.5 <u>001</u>	4.5 2.5 S K
214	38.7 +25 14	88 -37	12.8 <u>101</u>	1.1 0.7 S: R
224	40.0 +41 0	89 -20	5: <u>412</u>	160 40 Sb H
221	40.0 +40 36	89 -22	9.5 <u>412</u>	2.6 2.1 E: H
227	40.1 - 1 48	90 -64	13.1 <u>001</u>	R
237	40.9 - 0 24	90 -63	13.2 <u>101</u>	
245	43.7 - 1 59	92 -65	12.9 <u>010</u>	1.0 0.8 S R

A Revised Shapley-Ames Catalog (1981)

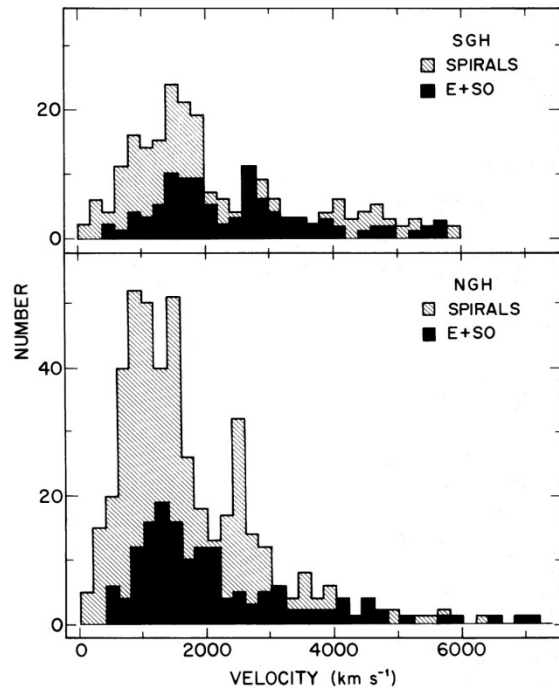
Sandage, A. and Tammann, G., Carnegie Institution of Washington

The present catalog is, then, a compilation of available data on redshifts, morphological types, and magnitudes for Shapley-Ames galaxies, using literature sources to summer 1980. (1246 galaxies)



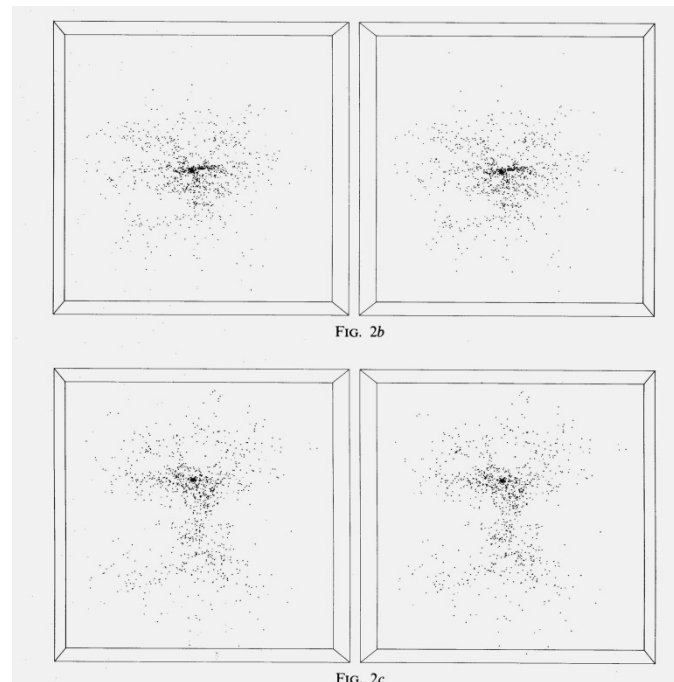
Study of the Local Supercluster and Field Luminosity Function

Redshift distribution

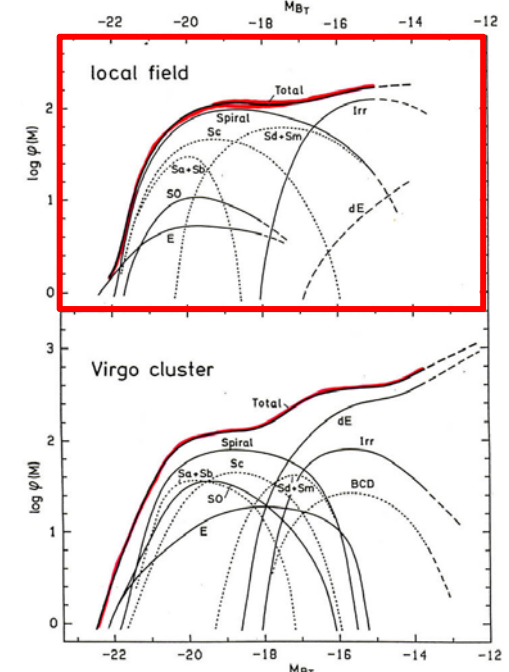


Yahil et al. 1980, ApJ, 242, 448

Spatial Structure



Luminosity Function



Binggeli et al. 1988, ARAA, 26, 509

Shane-Wirtanen (Lick) Count (1954)

Shane and Wirtanen 1954, AJ, 59, 285

Counts of extragalactic nebulae
($m < 18.4$) in $10' \times 10'$ cells over
 $12h < \alpha < 18h, -23^\circ < \delta < 20^\circ$

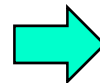


Plates taken with 20-inch Carnegie
Astrograph of the Lick Observatory



Figures 12-16. Contour maps of clouds of nebulae, based on smoothed counts by 0.5° squares.

210,980 nebulae



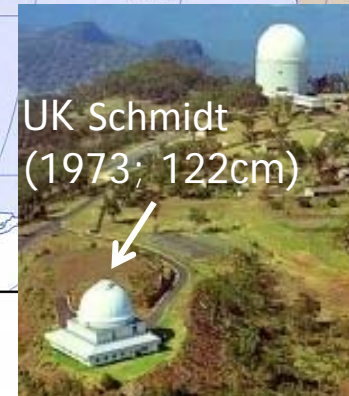
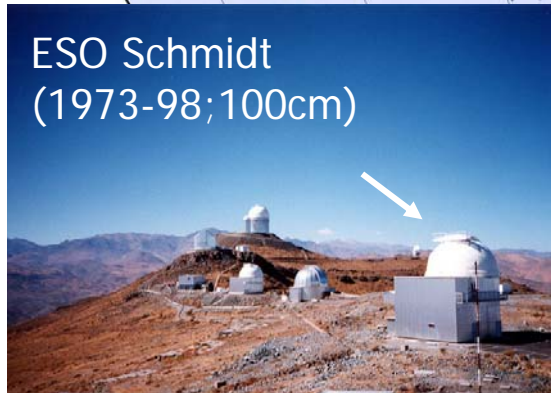
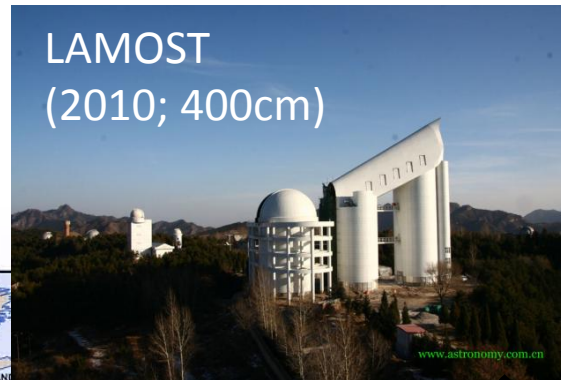
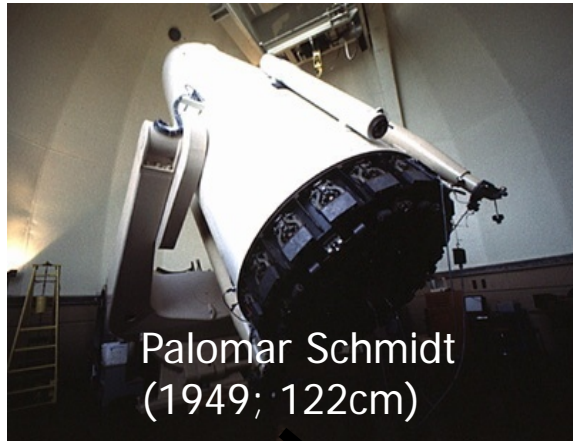
First analysis of correlation function
of galaxy distribution

Totsuji & Kihara 1969, PASJ, 21, 221

Peebles 1973, AJ, 185, 413

Fry and Peebles 1980, ApJ, 238, 785, ...

World' Major Schmidt Telescopes



Major Surveys with Schmidt Telescopes

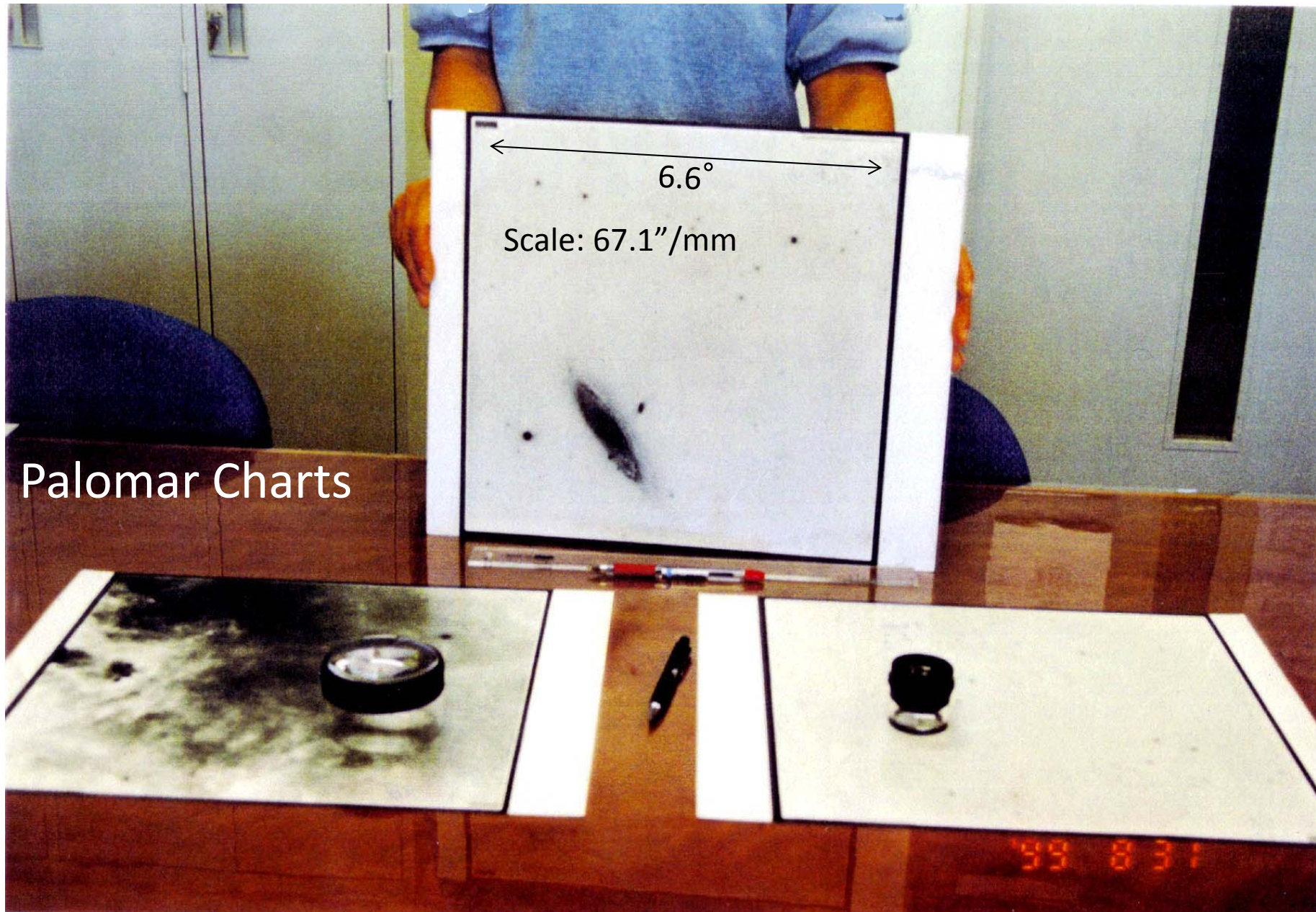
Designation	Survey Area	Emulsion+ Filter	# of plates	year	
Palomar Schmidt (POSS=Palomar Observatory Sky Survey)					
Northern Sky	POSS- I (B)	103 a-O+	936	} 1949-56	
		$-30^\circ < \delta < +90^\circ$ none			
	POSS- I (R)	103 a-E+ Plexiglass 2444	936		
	POSS- II (J)		III a-J+ GG 385	894 (894*)	} 1987-1999
	POSS- II (R)	$0^\circ < \delta < +90^\circ$	III a-F+ RG 610	894 (891*)	
	POSS- II (I)		IV-N+ RG 9	894 (780*)	
USNO(J)	$0^\circ < \delta < +90^\circ$	III a-J	894	1995?-99	

(* as of April 1999)

Southern Sky

Designation	Survey Area	Emulsion+ Filter	# of plates	year
UK Schmidt (SERC=Science and Engineering Research Council)				
SERC(J)	$-90^\circ < \delta < -20^\circ$	III a-J+ GG 395	606	1974-87
E(J)	$-15^\circ < \delta < 0^\circ$	III a-J+ GG 395	288	1979-90
E(R)		III a-F+ RG 630	288 (272*)	
SERC(I)	$-90^\circ < \delta < 0^\circ$	IV-N+ RG 715	894 (767*)	1984-
AAO(R)	$-90^\circ < \delta < -20^\circ$	III a-F+ OG 590	606 (583*)	1989-
H α	銀河面	Tech-Pan + H α 659	233 (108*)	1997-
	マゼラン雲	Tech-Pan + H α 659	40 (24*)	
(* as of April 1999)				
ESO Schmidt				
ESO(B)	$-90^\circ < \delta < -20^\circ$	II a-O+ GG 385	606	1973-78
ESO(R)	$-90^\circ < \delta < -20^\circ$	III a-F+ RG 630	606	1973-88?

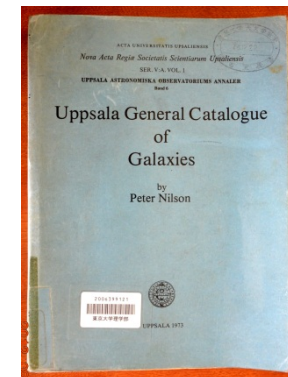
Eye Inspection of Survey Plates or Printed Charts



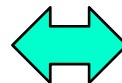
Major galaxy catalogs made from Schmidt surveys

Eye Inspection

- Northern Sky**
- Morphological Catalogue of Galaxies (MCG): 4 volumes
Vorontsov-Velyaminov et al. 1962-68 (Moscow State Univ.)
~29,000 galaxies from POSS-I
 - Catalogue of Galaxies and Clusters of Galaxies (CGCG): 6 volumes
Zwicky et al. 1961-68 (California Institute of Technology) →
~28,000 galaxies from POSS-I complete down to $m_z = 15.5$ mag and
~9700 clusters of galaxies
↑
Zwicky mag.
 - Uppsala General Catalogue of Galaxies (UGC)
Nilson 1973, Acta Uppsala Univ., Ser. V, A, Vol.1 →
12,921 galaxies from POSS-I with $\delta > -2.5$ down to 14.5 mag
- Southern Sky**
- The ESO/Uppsala Survey of ESO(B) Atlas
Lauberts 1982 (ESO)
~16,000 galaxies from ESO quick B survey with $D > 1'$



10,000-30,000 galaxies



Man-power limit of a single person or a few people

Catalogue of Galaxies and Clusters of Galaxies (CGCG)

Symbols Used on the Charts

On the charts, the following symbols have been adopted for galaxies of different brightness:

✱	$m_p \leq 11.0$	●	$13.1 \leq m_p \leq 14.0$
■	$11.1 \leq m_p \leq 12.0$	○	$14.1 \leq m_p \leq 15.0$
□	$12.1 \leq m_p \leq 13.0$	△	$15.1 \leq m_p \leq 15.7$

The GC Stars, of which only a few have been selected on each plate, are represented on the charts by a cross: +, and the contour lines of the clusters are numbered on the outside according to the following example:

12 = Cluster No. 12 on the chart

CLUSTERS OF GALAXIES

Cluster	Character	Population	Diameter in cm	Distance	Number on chart
1215.6 + 1058	open	62	1.7	D	11
1216.2 + 1337	compact	47	0.8	VD	24
1219.0 + 1405	open	207	2.1	MD	4
1219.7 + 1237	open	128	1.9	D	6
1222.3 + 1121	compact	46	0.5	ED	8
1222.4 + 1033	compact	42	0.6	VD	13
1222.7 + 0946	medium compact	105	1.7	VD	

CLUSTERS OF GALAXIES

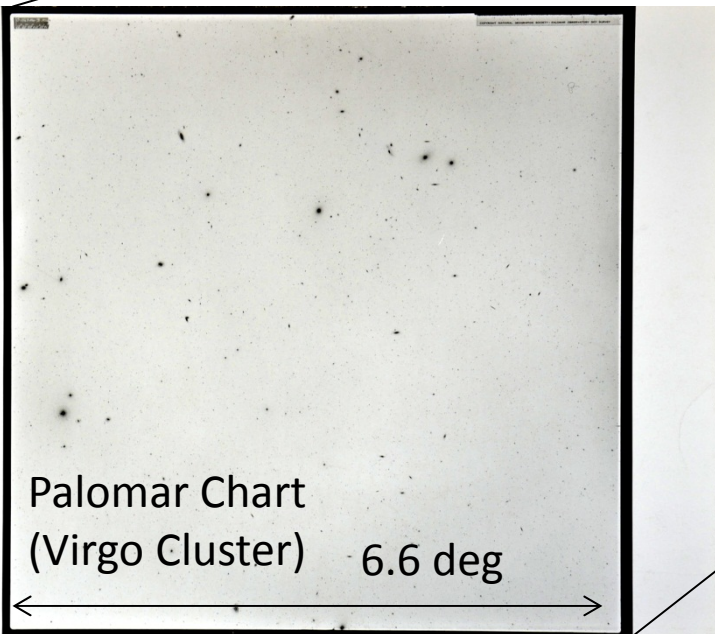
Cluster	Character	Population	Diameter in cm	Distance	Number on chart
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1222.4 + 1033	compact	42	0.6	VD	13
1222.7 + 0946	medium compact	105	1.7	VD	

Average number of galaxies per cluster = 112.4

This field also contains the center of the Virgo cluster of galaxies the position of which is 1224.0 + 1328.

GALAXIES

Position a 1950 δ	NGC IC*	m_p	v_s km/sec	Remarks
12 16.0 + 12 08	3127*	15.7		extremely diffuse
12 16.1 + 12 01	3128*	15.2		double nebula
12 16.4 + 09 15	3134*	15.4		
12 16.4 + 13 11	775*	14.8		double nebula
12 16.6 + 14 15	3142*	15.7		double nebula
12 16.7 + 12 20	3147*	15.5		
12 16.8 + 12 21	3149*	15.9		
12 16.8 + 12 35	3149*	15.9		
12 17.0 + 09 18	3154*	15.1		
12 17.2 + 09 26	3156*	15.9		
12 17.2 + 12 42	3157*	15.5		
12 17.2 + 13 05	4207	12.4	+ 1240	$m_p = 12.6$ E
12 17.5 + 08 53		14.8		
12 17.6 + 08 55		15.1		
12 17.7 + 08 49		15.9		
12 17.7 + 09 49	3167*	15.1		
12 17.9 + 09 42	3170*	15.9		
12 17.9 + 10 07	3175*	15.5		
12 17.9 + 10 11	3174*	15.4		



GALAXIES

Position a 1950 δ	NGC IC*	m_p	v_s km/sec	Remarks
12 16.0 + 12 08	3127*	15.7		extremely diffuse
12 16.1 + 12 01	3128*	15.2		double nebula
12 16.4 + 09 15	3134*	15.4		
12 16.4 + 13 11	775*	14.8		double nebula

These galaxy catalogs had been an important and indispensable basis of galaxy studies and observational cosmology until recently.

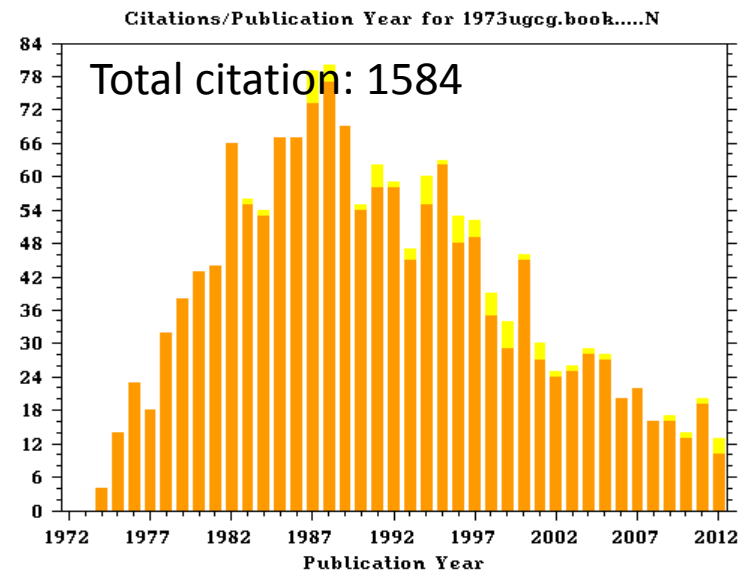
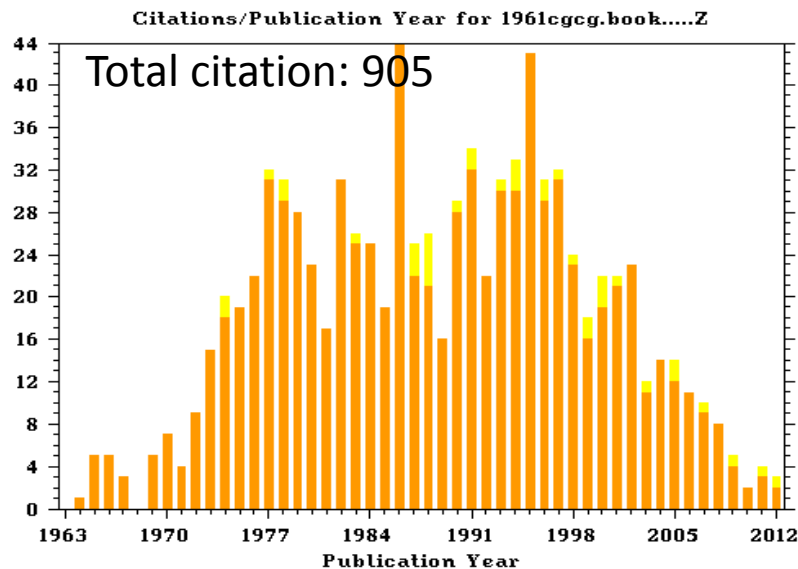
CGCG (Zwicky et al. 1961-68)

UGC (Nilson 1973)

as of Aug. 5, 2012

of papers whose abstracts include 'Zwicky catalog' is about **270** (except IAUC and CBET)

of papers whose abstracts include 'Uppsala catalog' is about **150** (except IAUC and CBET)



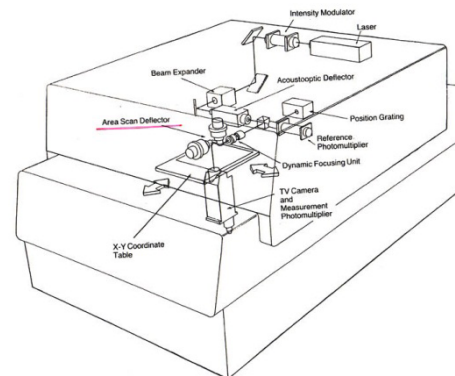
Digitization of Schmidt Plates (1980s-90s)

Plate Scanning Machines

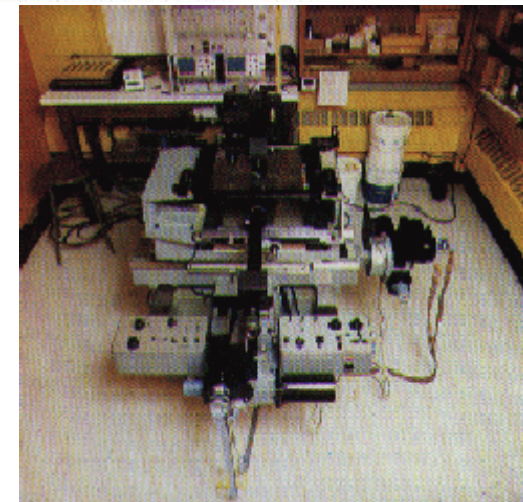
COSMOS: **C**o-ordinates, **S**izes,
Magnitudes, **O**rientations, **S**hape



Automated Photographic
Measuring System (APM)



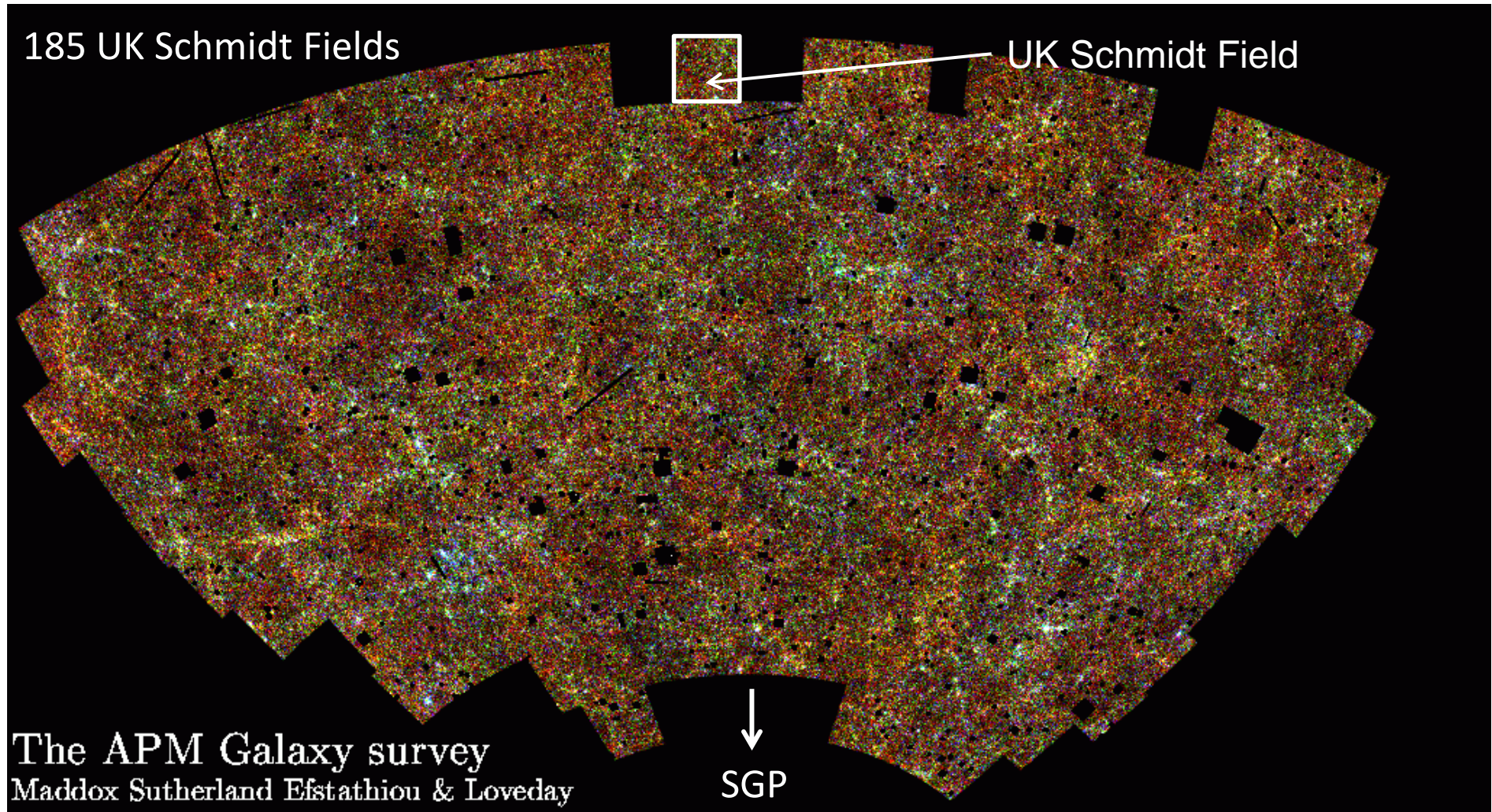
PDS microdensitometer
(PDS 2020 GMS)



The Minnesota Automated
Plate Scanner (APS)

APM Galaxy Survey

~3 million galaxies from UK Schmidt plates down to $b_j=22$ over 7000 square degrees.



<http://vo.iucaa.ernet.in/2df/Survey/apm.html>

Input catalog of 2dFGRS (2dF Galaxy Redshift Survey)

Reference Catalogue of Bright Galaxies

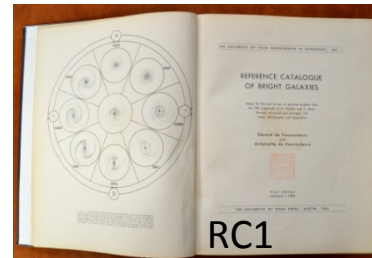
Morphological type, magnitude, diameter,

Not complete in any sense

(1) Reference Catalogue of Bright Galaxies (RC1)

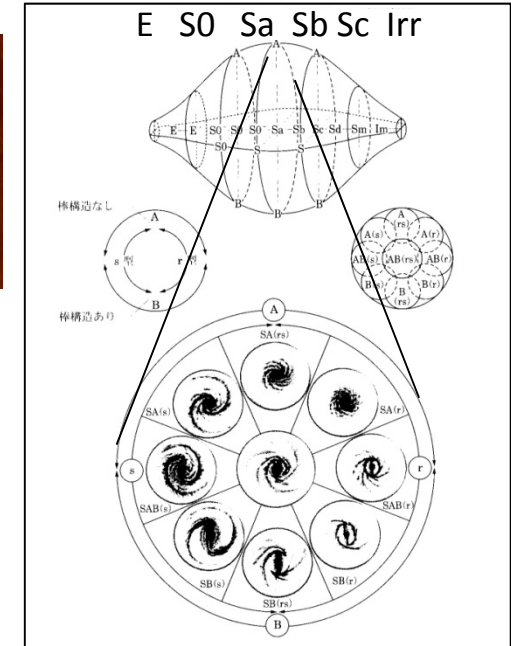
G. & A. de Vaucouleurs 1964, University of Texas Press

2599 galaxies



RC1

Revised Hubble Classification



(2) Second Reference Catalogue of Bright Galaxies (RC2)

G. & A. de Vaucouleurs, H.G. Corwin 1976, University of Texas Press

4364 galaxies



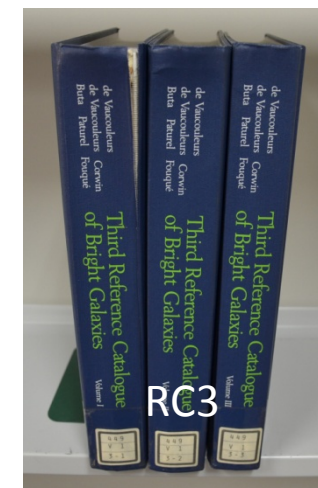
RC2

(3) Third Reference Catalogue of Bright Galaxies (RC3)

G. de Vaucouleurs et al. 1991, New York: Springer

23,024 galaxies

Exponential increase!



RC3

1. Early Photometric Surveys
- 2. Early Redshift Surveys**
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4. Impacts of Modern Large Surveys
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Era of Redshift Surveys (1980's- 90's)

First hint of large-scale structure

Importance of completeness!

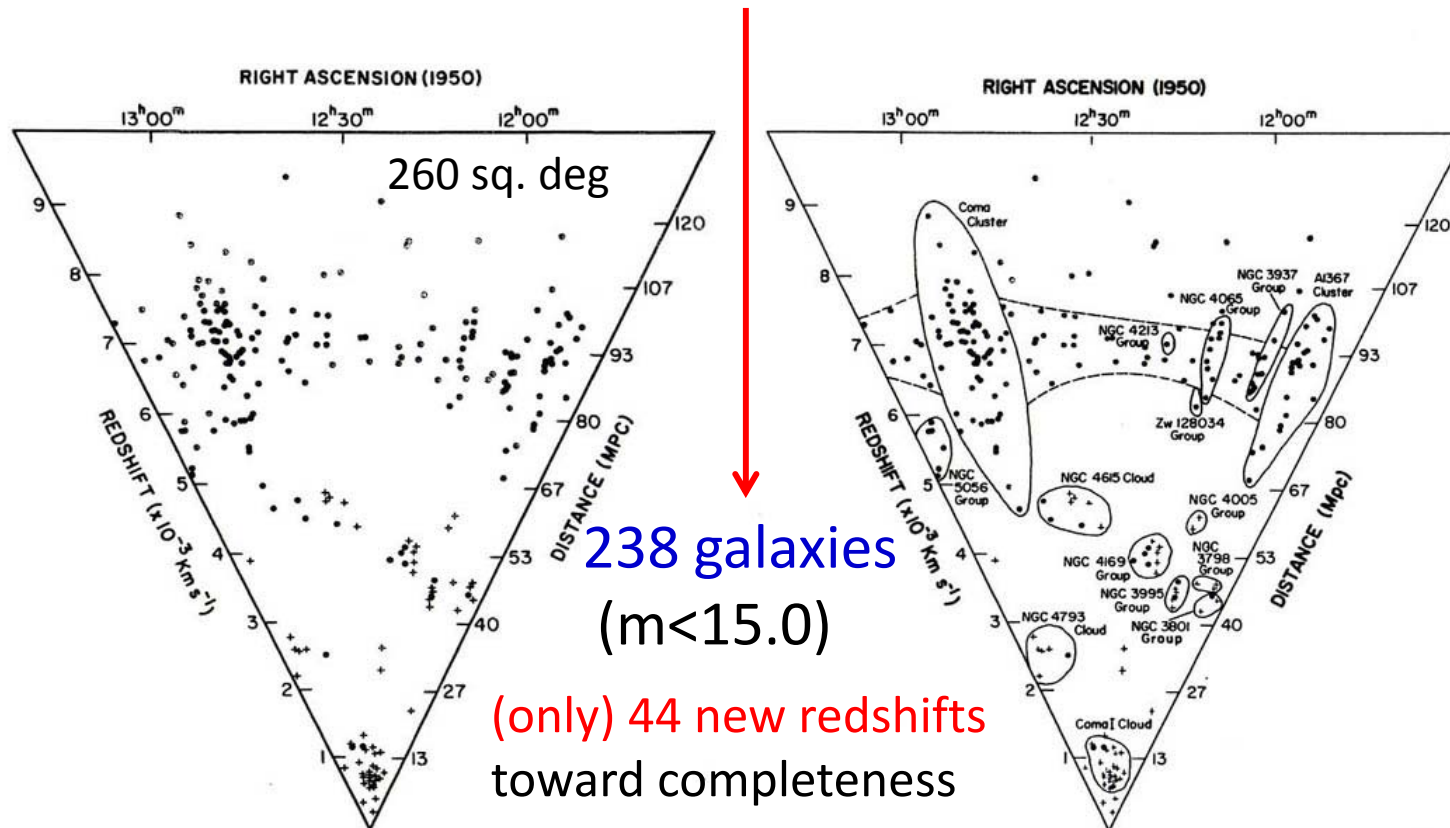
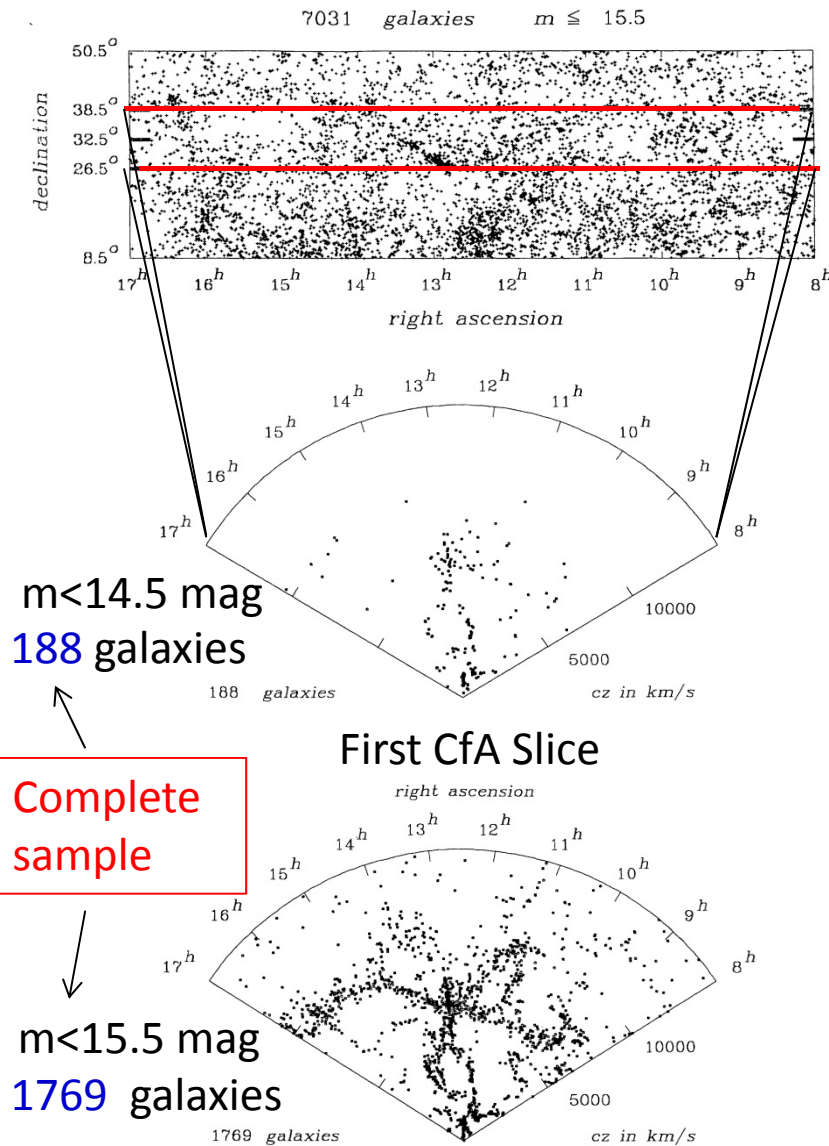


FIG. 2.—(a) (left panel) Wedge diagram for all galaxies in our sample. The Supercluster is clearly seen at an average redshift of approximately 7000 km s^{-1} . The distribution of foreground galaxies is very clumpy. Those galaxies with $V_0 < 5000 \text{ km s}^{-1}$ that are represented by crosses are too faint to be surveyed if they were at the distance of the Supercluster. The distance scale assumes $H_0 = 75 \text{ km s}^{-1} \text{ Mpc}^{-1}$, and the angular size of the survey has been magnified by approximately 2 times. (b) (right panel) An interpretive form of the wedge diagram.

Gregory & Thompson 1978, ApJ, 222, 784

CfA Survey



$m < 15.5$ mag
7031 galaxies

CGCG+UGC

CfA-I (1977-1982)

2401 galaxies ($m < 14.5$)
over 8700 deg² ($b > 40$, $\delta > 0$)

CfA-II (1984-1995)

~18000 galaxies ($m < 15.5$)
over 9700 deg²

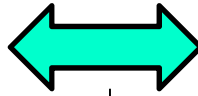
Motivation for wider
and deeper surveys

IRASz: IARS Point Source Catalog Redshift Survey
SPS: Supergalactic Plane Survey
SAPM: Stromlo-APM Redshift Survey
SSRS2: Southern Sky Redshift Survey II
CFRS: Canada-France Redshift Survey
ORS: Optical Redshift Survey
LCRS: Las Campanas Redshift Survey
ESP: ESO Slice Project
CNOc2: Canadian Network for Obs.'l Cosmology
Field Galaxy Redshift Survey

Geller et al. 1987, IAUS, 124, 301

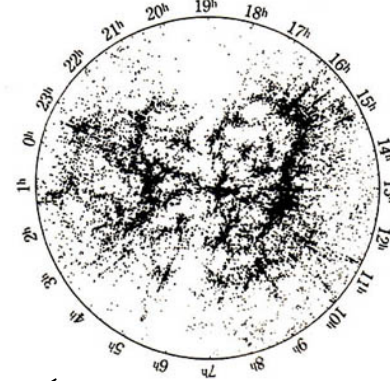
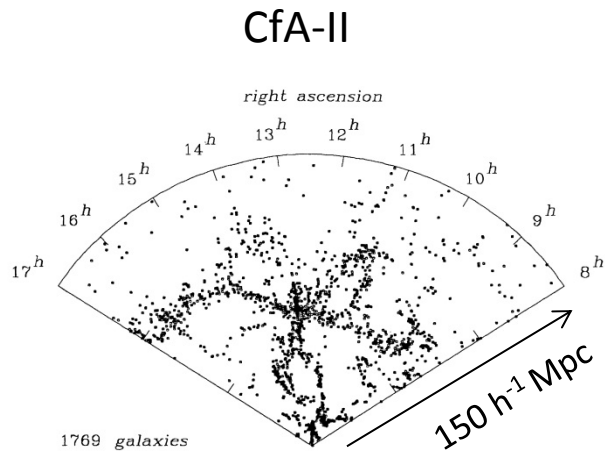
wide survey
 $m_B < \sim 16$ mag

~ 1990

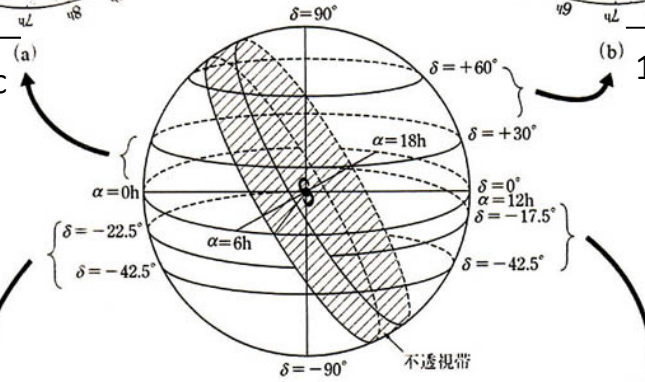


~ 2000

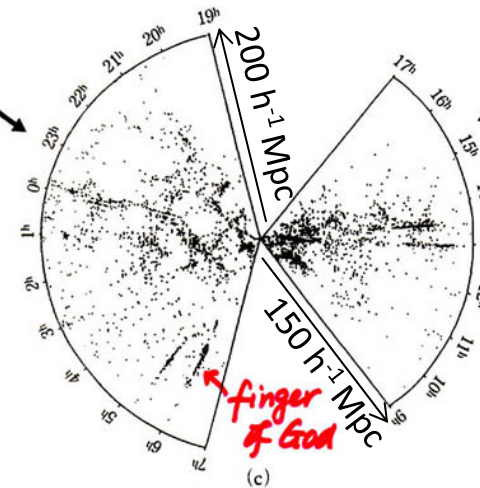
wide survey
 $m_B < \sim 16$ mag



$150 h^{-1} \text{ Mpc}$



$150 h^{-1} \text{ Mpc}$



(c)

1. Early Photometric Surveys
2. Early Redshift Surveys
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Modern Wide Surveys

Imaging Survey + Spectroscopic (Redshift) Survey

Photometric Catalog

Input catalog

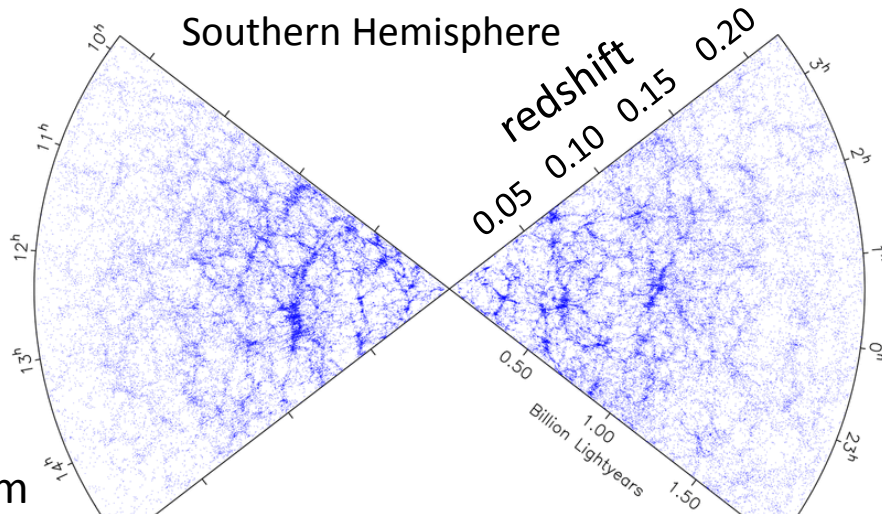
$m_B < \sim 19$ mag



$m_B < \sim 16$ mag

2dF Galaxy Redshift Survey (2dFGRS)

(photographic photometry and)
redshifts of **220,000 galaxies**



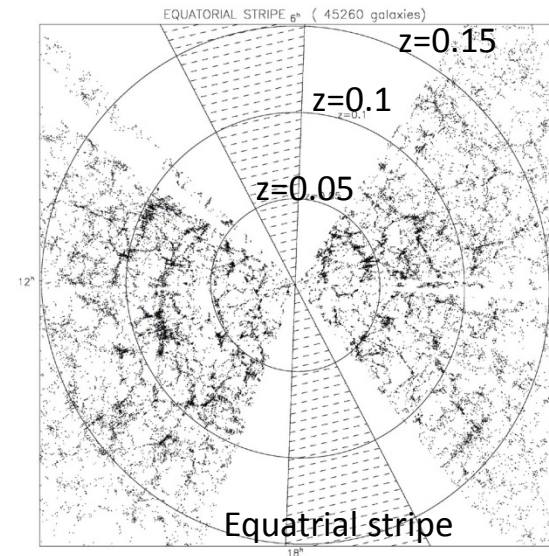
Started in 1997, completed in 2001
Final Data Release - 30 June 2003

APM (photographic) Galaxy Survey
was used as the input catalog

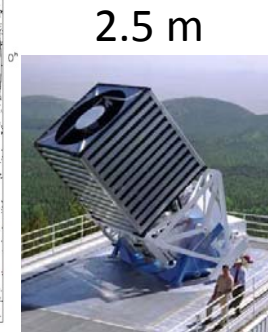


Sloan Digital Sky Survey (SDSS)

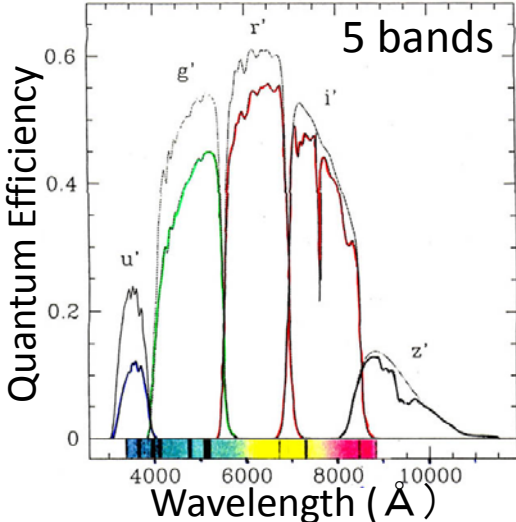
5-band Photometry: **3.57×10^8 objects**
redshifts: **930,000 galaxies**, **$\sim 100,000$ quasars**, and **460,000 stars**.



Started in 2000, completed in 2008
7th Data Release 2009, ApJS, 182, 543



Sloan Digital Sky Survey (SDSS) Legacy Survey (2000-2008)

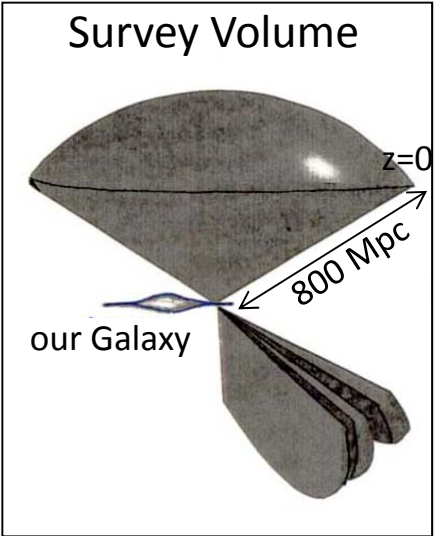


Imaging survey

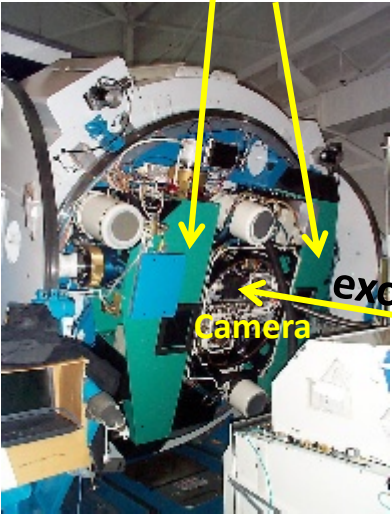
Proceeded in parallel



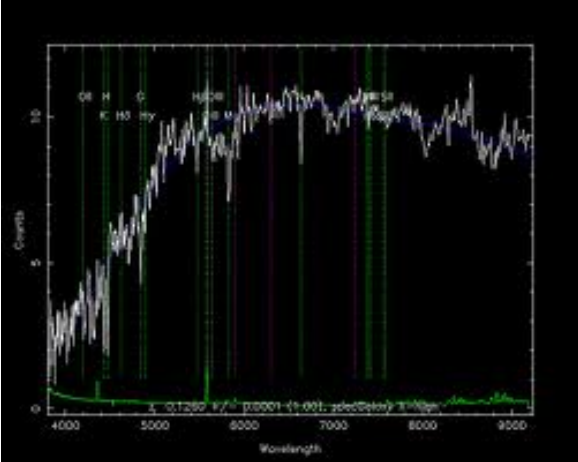
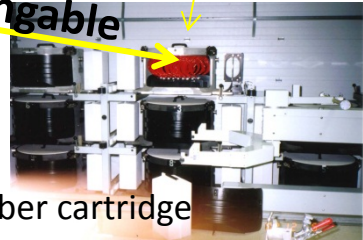
Spectroscopic Survey



Two 320-channel spectrographs



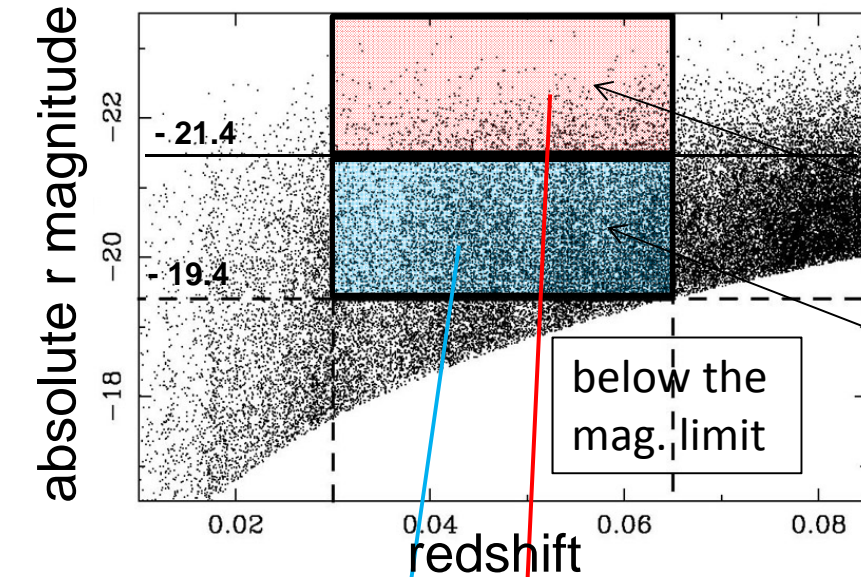
exchangable



1. Early Photometric Surveys
2. Early Redshift Surveys
3. Modern Surveys
- 4. Impacts of Modern Large Surveys**
5. Future Surveys

Impacts of a large survey (1)

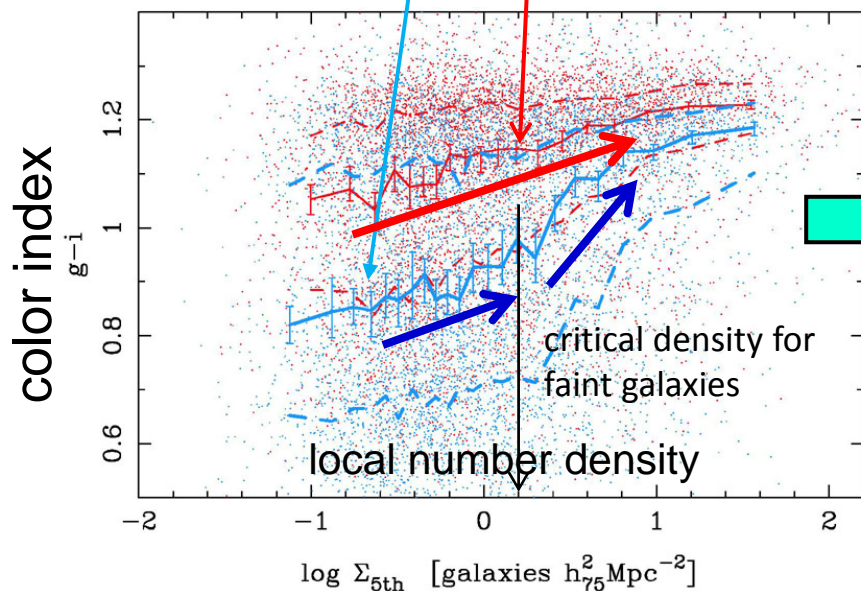
Tanaka, SO et al. 2004, AJ, 128, 2677



complete sample

bright complete sample
(volume-limited)

faint complete sample
(volume-limited)



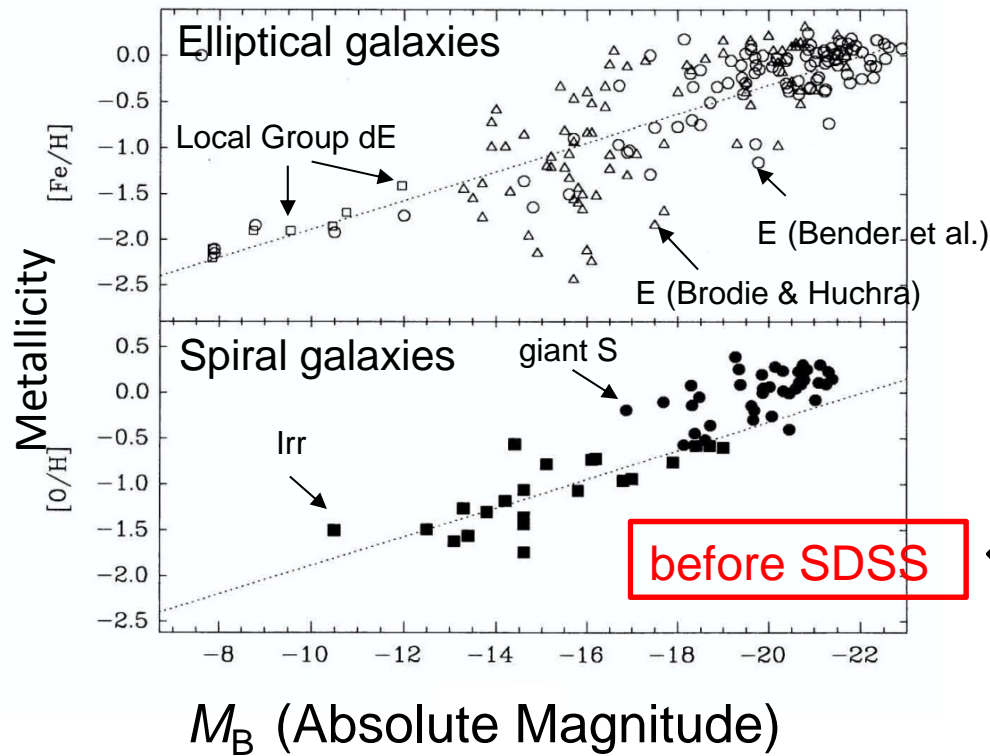
- Galaxies living in higher density regions are redder.
- However, the relation between local density and color is different for galaxies of different luminosities.
- The relation is more pronounced for faint galaxies than for bright galaxies.

Impacts of a large survey (2)

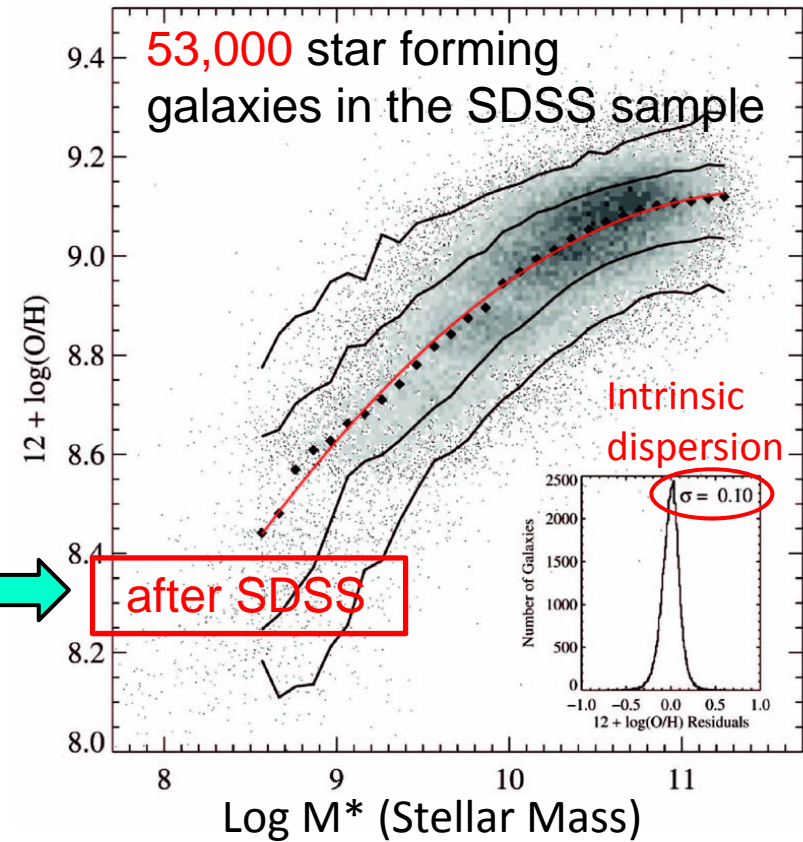
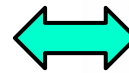
Large sample

- Small statistical error
- Accurate estimate of intrinsic dispersion

Luminosity (Mass) — Metallicity Relation



before SDSS

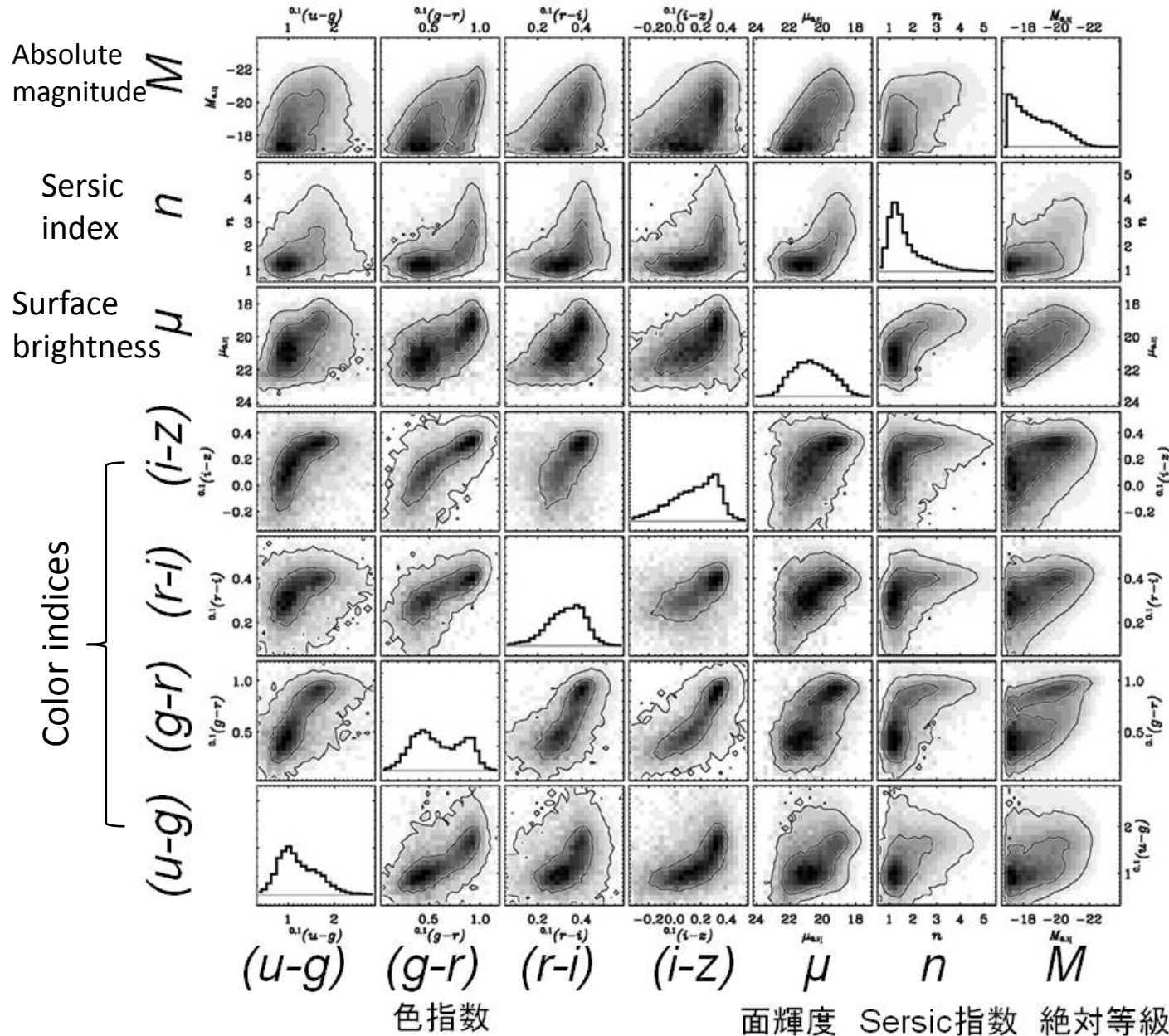


after SDSS

Zaritsky et al. 1994, ApJ, 420, 87

Tremonti et al. 2005, ApJ, 613, 898

Impacts of a large survey (3)



Global trend at a glance



Large sample
144,609 galaxies

Blanton et al. 2003,
ApJ, 594, 186

Impacts of a large survey (4)

	Discoveries!	
anticipated	before SDSS	after SDSS
quasars	<~15,000	~>80,000
High-z ($z>5$) quasars	None ($z_{\max}=4.897$)	~60 (DR5 catalog) + 13 $z>6$ quasars
L and T dwarfs	~20 (mostly from 2MASS, 1999)	71 (new from SDSS, 2006)
	Lensed QSOs	36 (25 new)

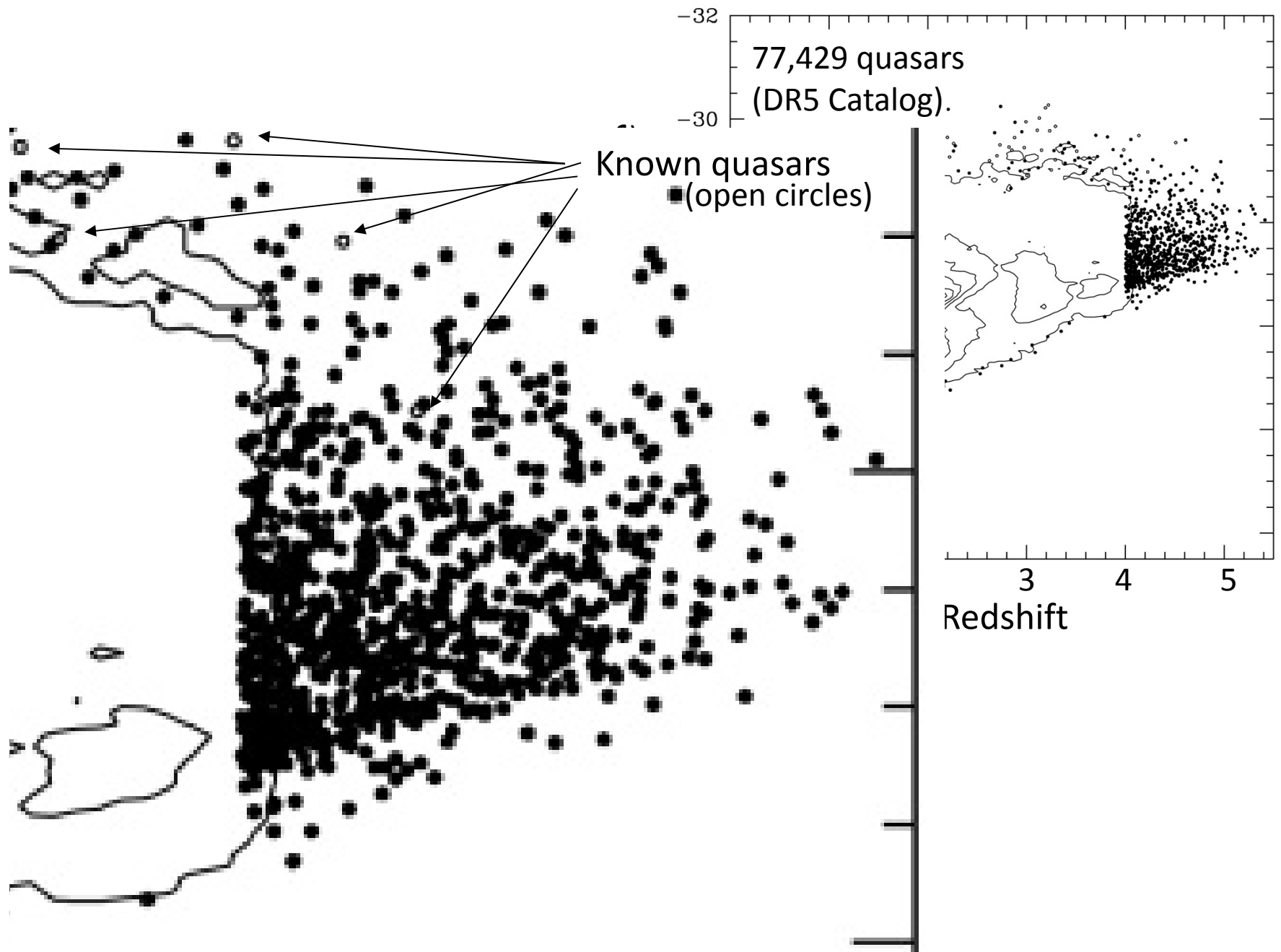
serendipitous

Green Peas

Actively star forming compact dwarf galaxies
Cardamone, C. 2009, MNRAS, 399, 1191

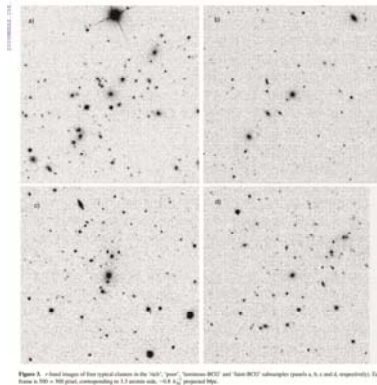
Actively star forming E galaxies

Fukugita et al. 2004, ApJ, 601, L127



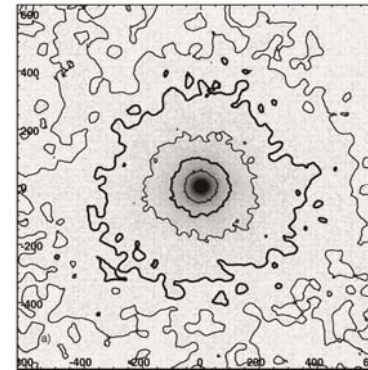
Impacts of a large survey (5)

Detection of Weak Signals!

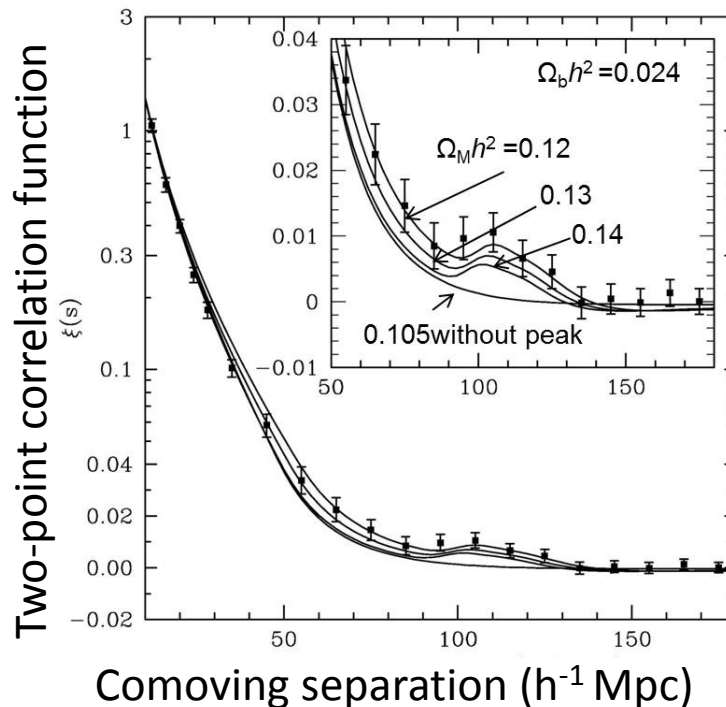


Stacking of **683**
clusters of galaxies
at $0.2 < z < 0.3$

Zibetti et al. 2005,
MNRAS, 358, 949



Detection of
diffuse
intracluster light



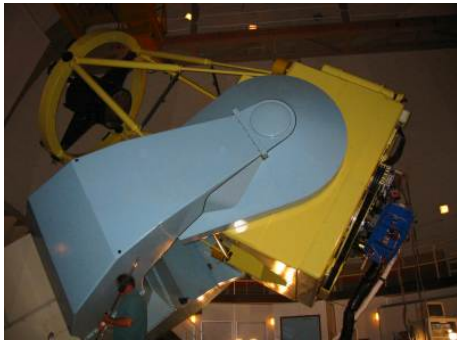
Detection of
the **Baryon Acoustic Peak**

46,748 luminous red galaxies in
 $0.72 h^{-3} \text{ Gpc}$ over 3816 deg^2
at $0.16 < z < 0.47$

Eisenstein et al. 2005, ApJ, 633, 560

Impacts of a large survey (6): Virgo Cluster

Las Campanas Survey: VCC (Virgo Cluster Catalog)



2.5m du Pont Tel.
+ 50-cm pg. plates

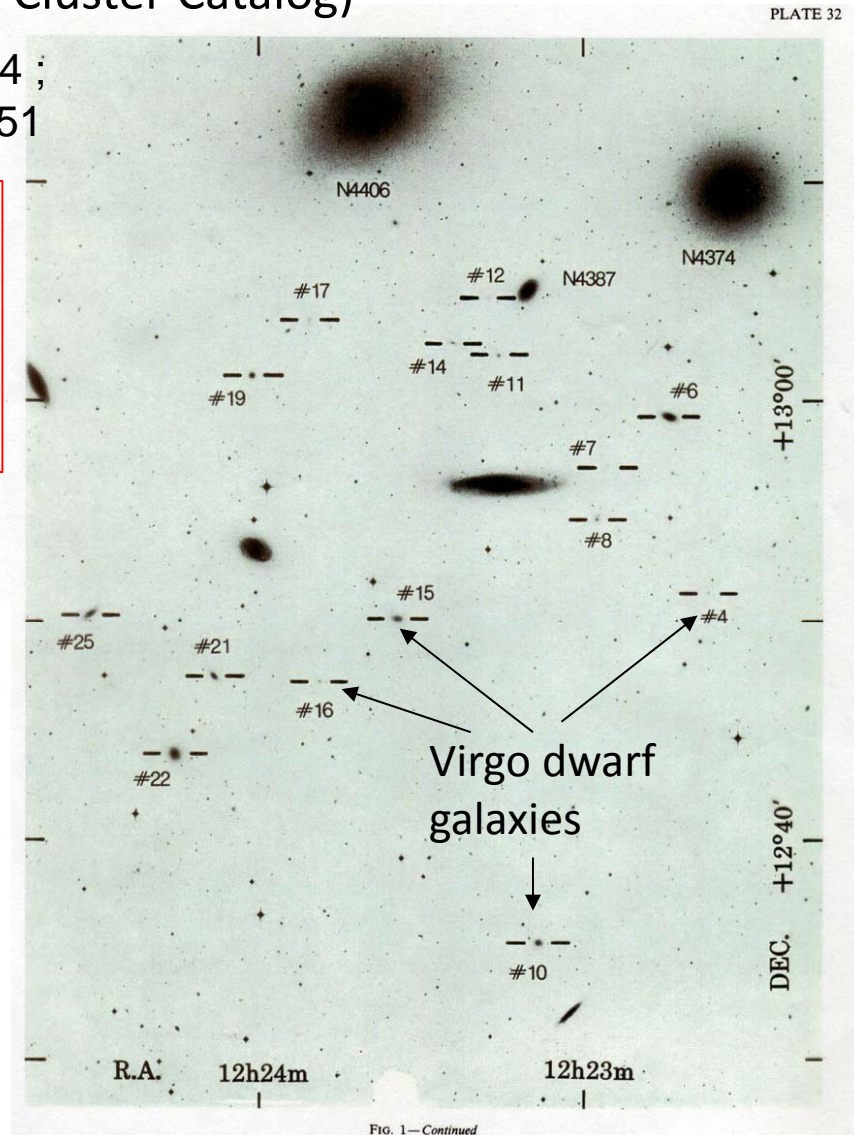
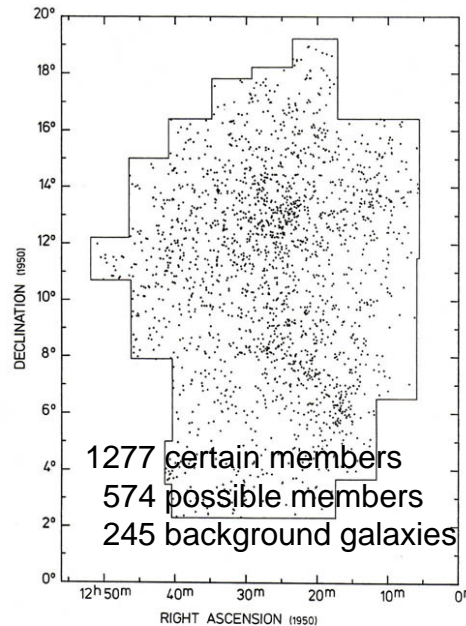
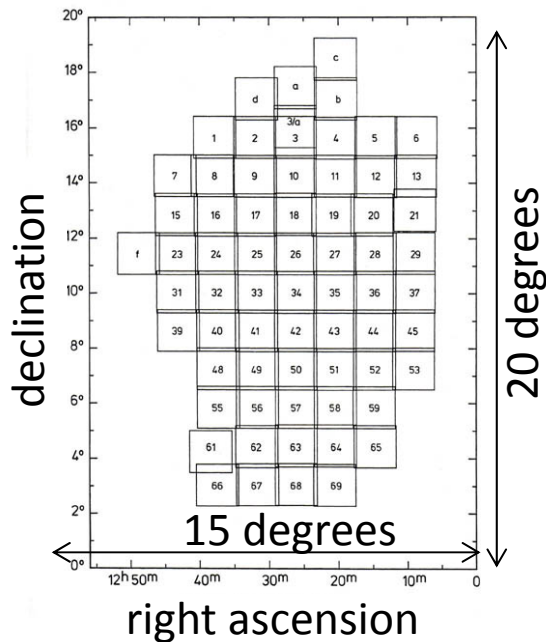
Binggeli et al. 1984, AJ, 89, 64 ;
1987, AJ, 94, 251



Study of dwarf galaxies beyond the Local Group

Virgo Cluster Catalog: VCC
2096 galaxies down to $B \sim 18$ mag

67 plates (1.5 deg FoV)



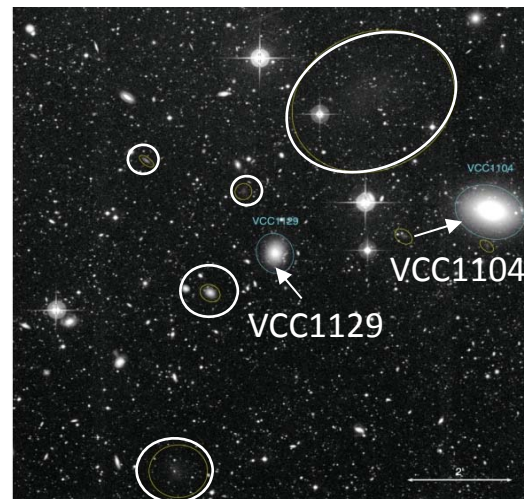
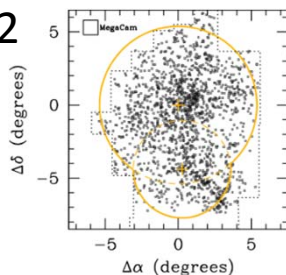
Ichikawa, Wakamatsu, SO 1986, ApJS, 60, 475

Next Generation Virgo Cluster Survey (NGVS)

Ferrarese et al. 2012, ApJS, 200, 4



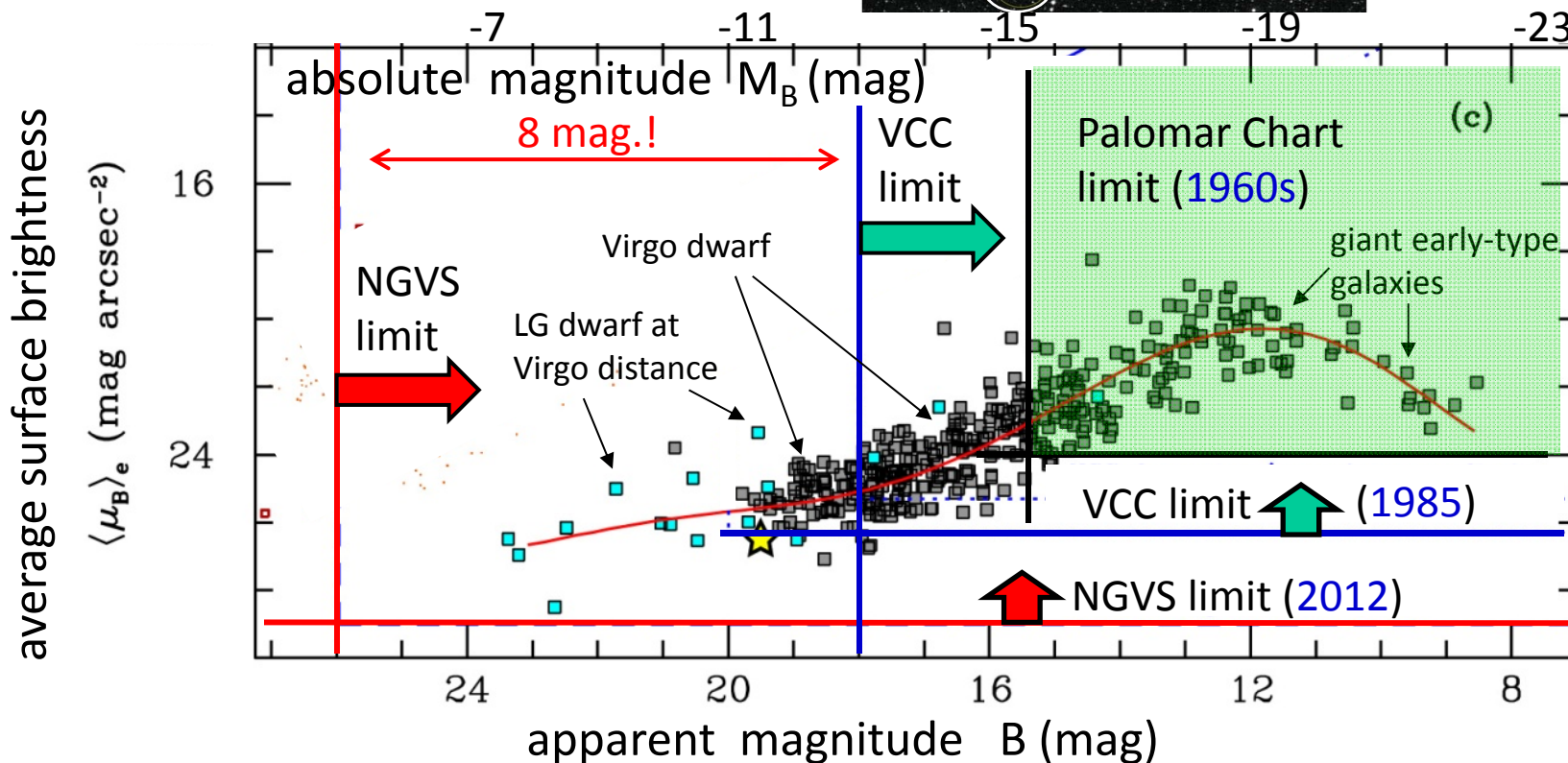
CFHT/MegaPrime,
~140 nights (2009-2012)
104 deg²



five SDSS bands

(point source)

$u^* = 25.9$ AB mag
 $g' = 25.7$ AB mag
 $r' = 25.2$ AB mag
 $i' = 24.9$ AB mag
 $z' = 24.6$ AB mag



1. Early Photometric Surveys
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- 5. Future Surveys**

Major Existing, **Upcoming** , and **Future** Surveys

SXDS: The Subaru/XMM-Newton Deep Survey

COSMOS: Cosmic Evolution Survey

CFHTLS: Canada-France-Hawaii Telescope Legacy Survey

NDWFS: The NOAO Deep Wide-Field Survey

BCS: Blanco Cosmology Survey

Stripe82: SDSS Legacy Survey Stripe82

RCS2: Red Sequence Cluster Survey 2

VST-ATLAS: VLT Survey Telescope (2.6m tel)

PS1/PS2: Pan-STARRS 1&2 Telescopes

KIDS: Kilo degree Survey (VST)

HSC: Hyper Suprime-Cam Survey

DES: Dark Energy Survey (DECam+Blanco 4m)

Skymapper: Skymapper Southern Sky Survey

Euclid: Euclid Satellite

LSST: Large Synoptic Survey Telescope

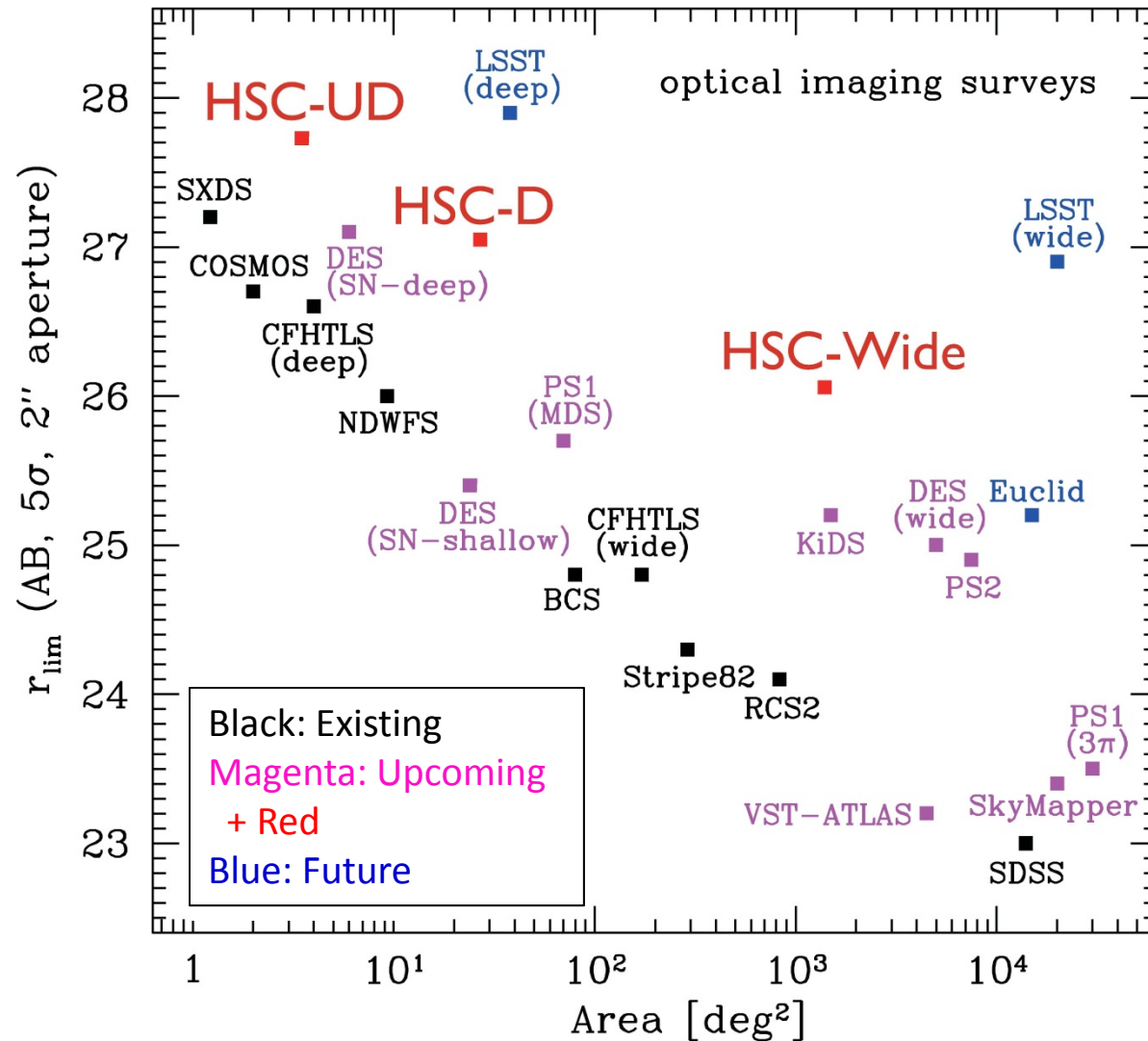
Black: Existing

Magenta: Upcoming

+ Red

Blue: Future

Major Existing, Upcoming, and Future Surveys

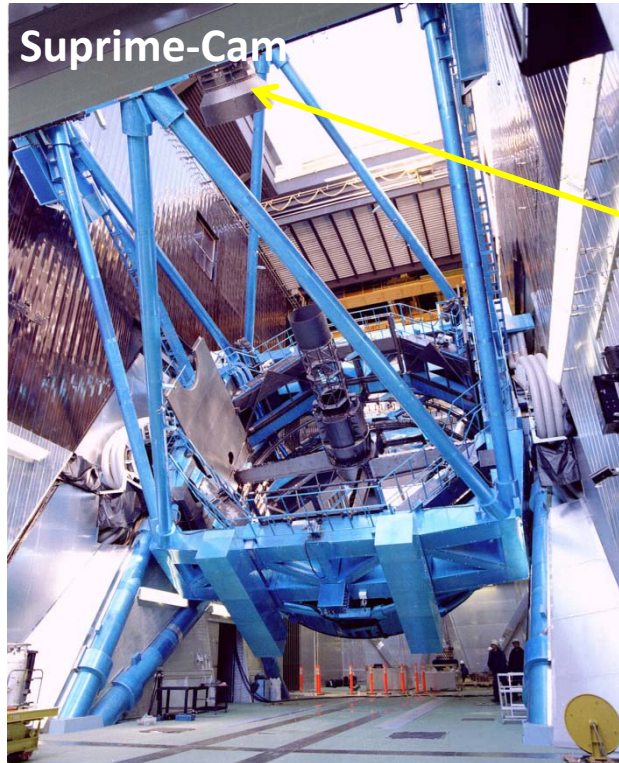


HSC=Hyper Sprime-Cam
on Subaru Telescope

(Credit: M.Takada, HSC survey team)

Hyper Suprime-Cam (HSC) on Subaru Telescope

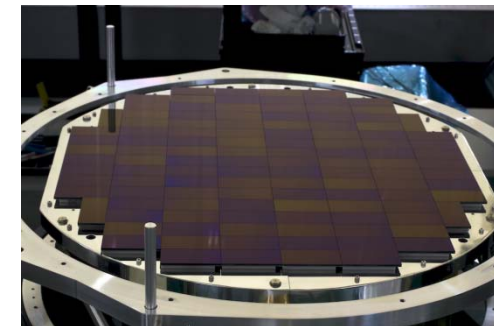
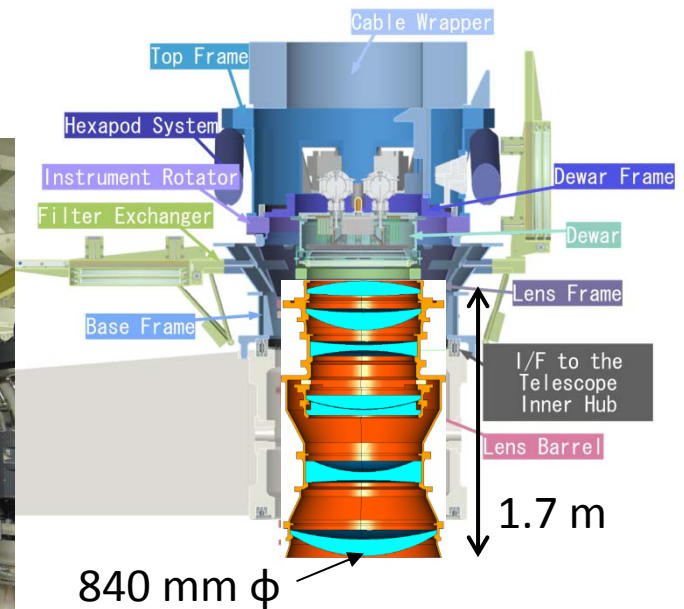
Japan/Princeton/Taiwan Collaboration
with Mitsubishi/Canon/Hamamatsu



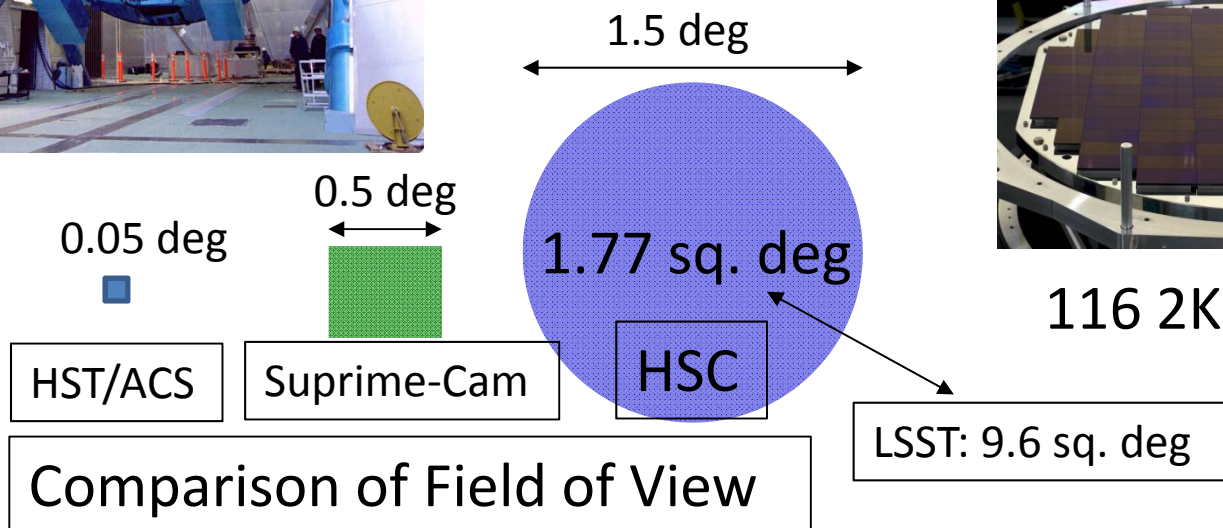
Suprime-Cam



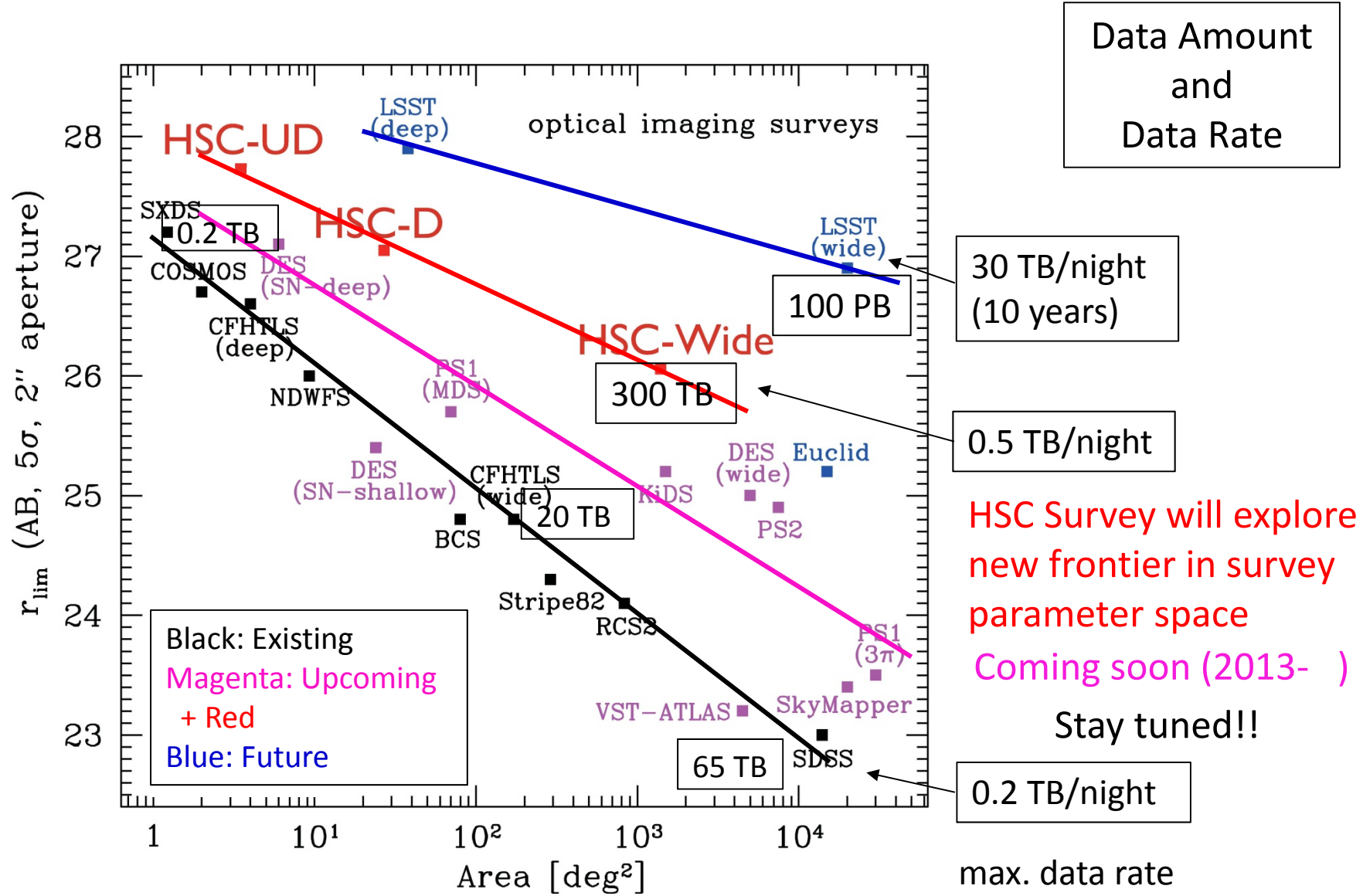
Hyper Suprime-Cam



116 2Kx4K CCDs



Major Existing, Upcoming, and Future Surveys



HSC Survey will explore new frontier in survey parameter space

Coming soon (2013-)

Stay tuned!!

(Credit: M.Takada, HSC survey team)

Summary

- Essential factors of galaxy surveys
Completeness, Homogeneity, Wide sky coverage
- Innovative surveys/catalogs opened frontiers
SA/RSA catalog, Lick Count, POSS, CGCG, UGC, ...SDSS
- Impacts of large surveys
complete sample, small statistical error/weak signal
detection, discoveries (anticipated, serendipitous), ...
Next Generation Virgo Survey (NGVS)
- Upcoming and future surveys
data amount: 300TB-100PB,
data rate: (0.5TB-10TB)/night