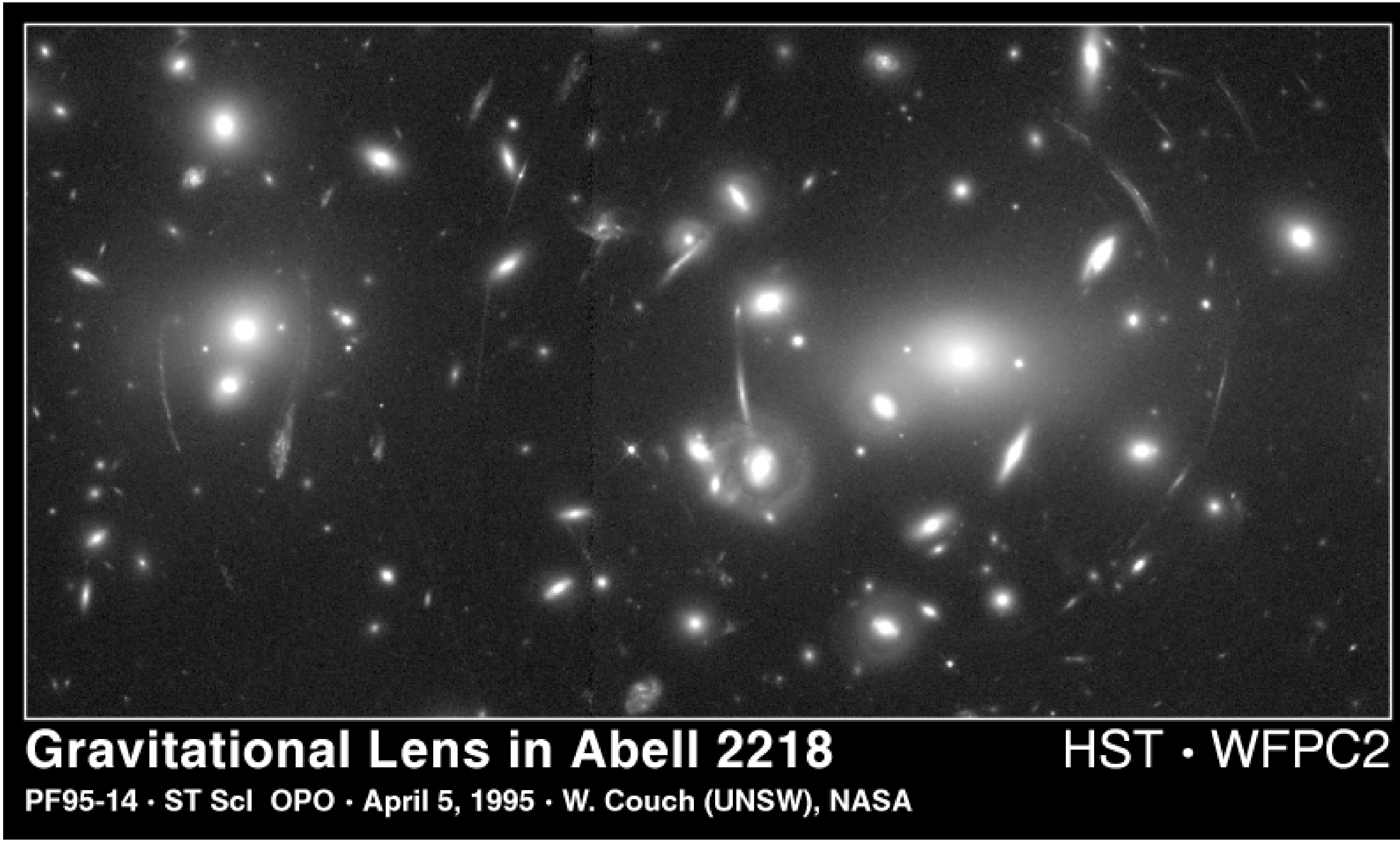
Cosmology 2004 – 2005
Part II

Prof. Guido Chincarini

The scope of these lectures is to give to the student a feeling for modern problems in cosmology, understand the basic concepts and give to him some tools to work with. Often I will deal with a rough approximation in deriving equations and numerical solutions. That is to facilitate the comprehension. The student can refer to advanced textbooks and articles to refine his/her computational capabilities.

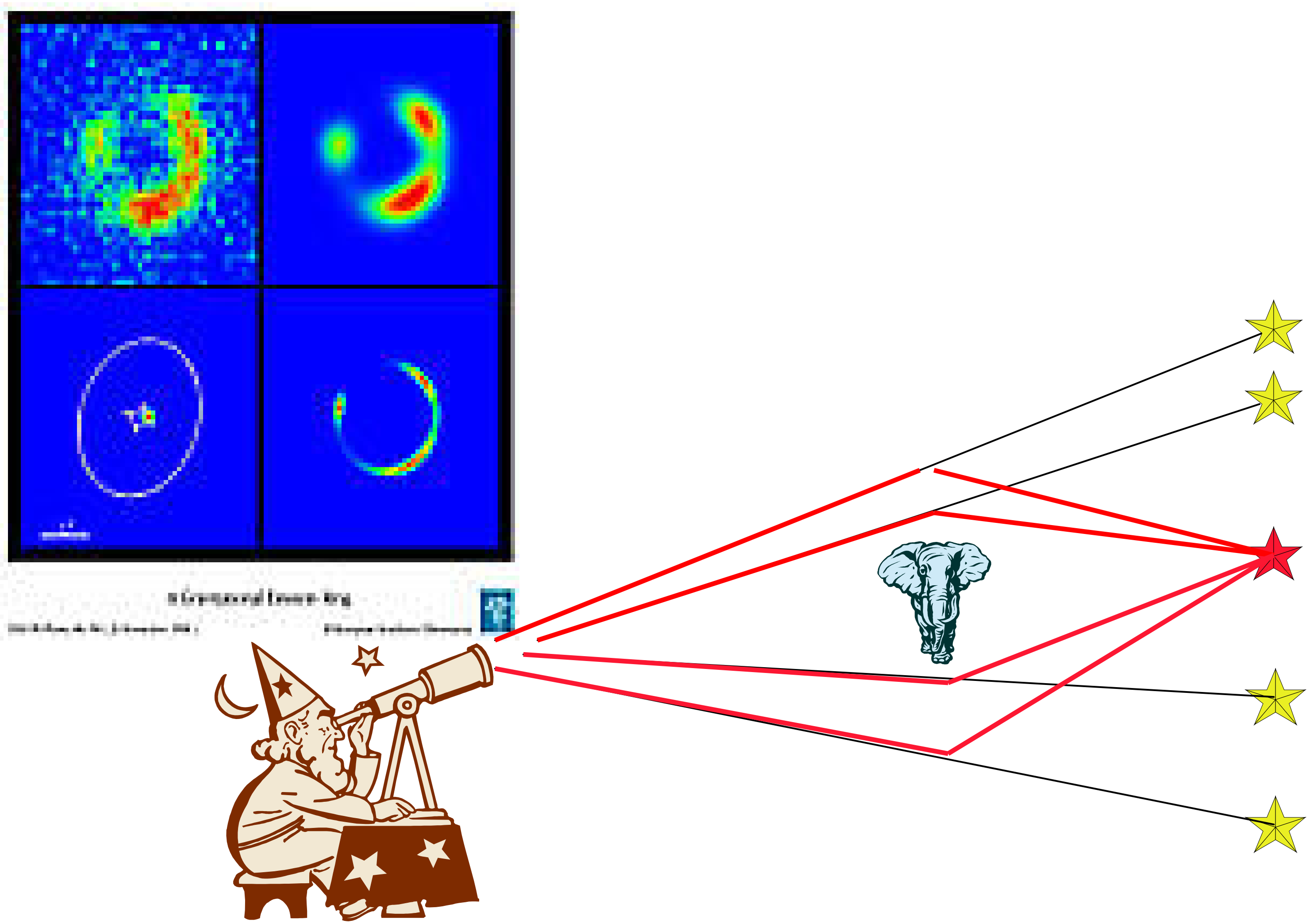
The Introduction give a general overview of the state of the art referring to basic matters and problems which are being studied now days. I will then, before getting to the world models, revisit the Luminosity Function of galaxies in its more general meaning in order to give to the students a good grasp on this fundamental distribution function and ideas on where our knowledge could and/or need to be improved.


Gravitational Lens in Abell 2218
HST • WFPC2
PF95-14 • ST ScI OPO • April 5, 1995 • W. Couch (UNSW), NASA

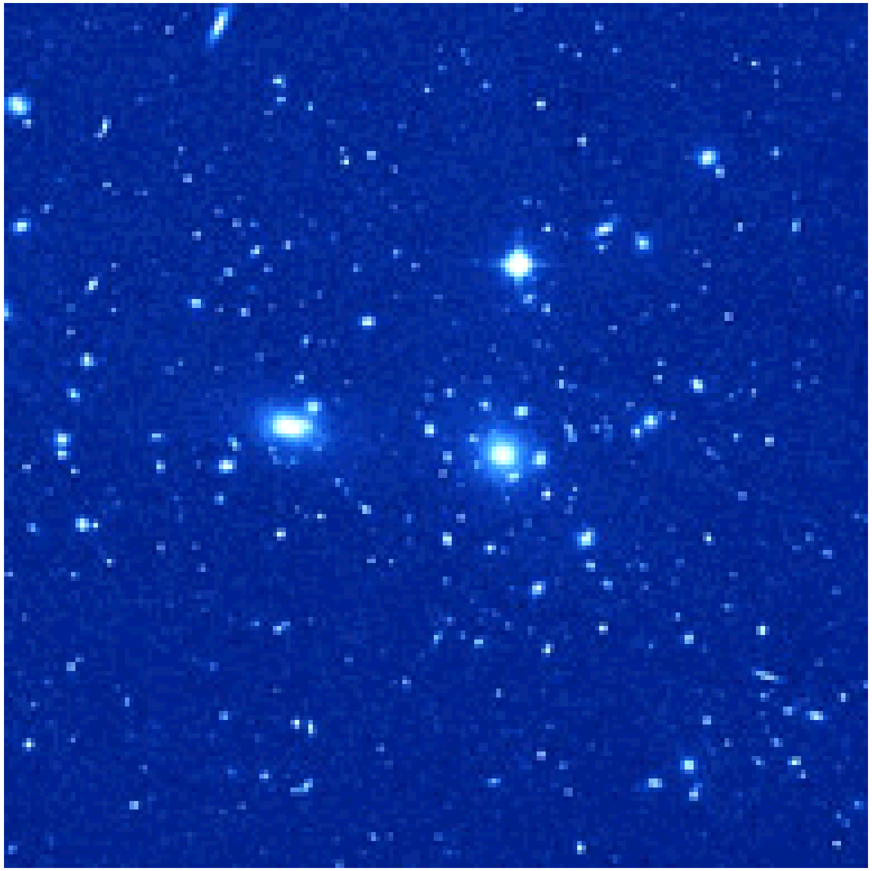
Basic Properties of Clusters

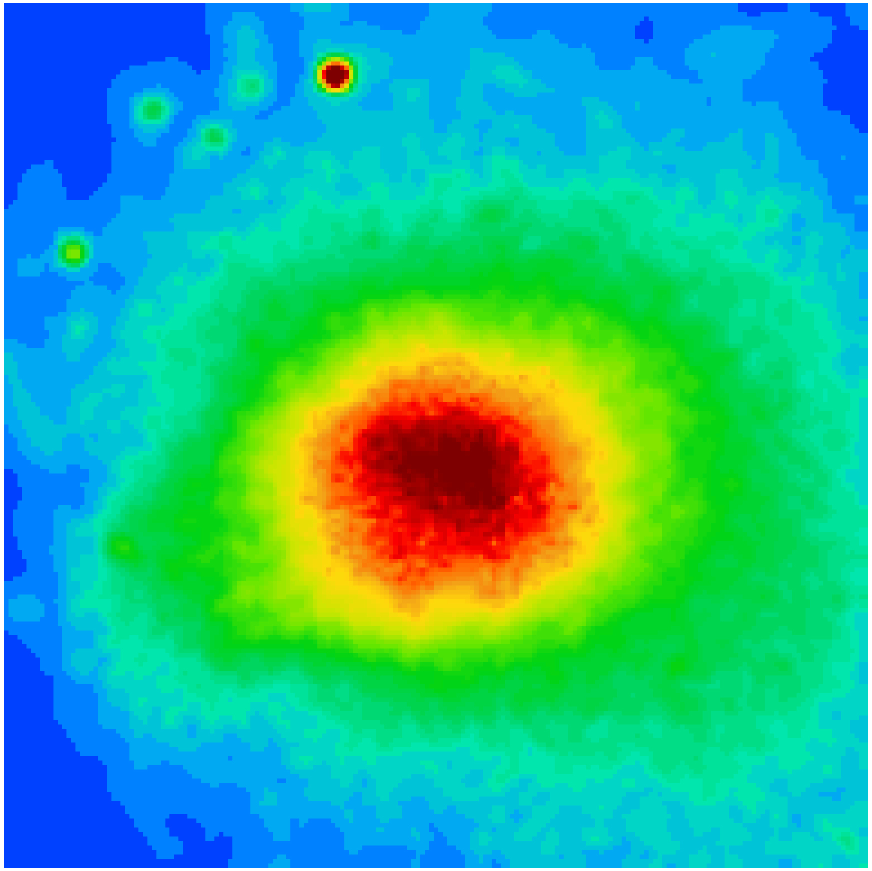
Property	Indicative values
Richness	30 – 300 galaxies between m_3 and m_3+2 in 1.5h^{-1}Mpc radius
Morphology	CD Clusters – Regular => Irregular
Population	E (35% to 15%), SO(45% to 35%), Sp(20% to 50%)
Line of sight vel. dispersion	In the range 1300 – 500, km/sec
Number counts profile	Projected: n®=no $(1+r^2/Rc^2)^{-3/2}$, Rc = core radius
Mass (within 1.5 h^{-1} Mpc)	10^{14} – 2 10^{15} h^{-1} $M_\odot$
Luminosity (r ≤1.5 h^{-1} Mpc)	In B filter: 5 10^{11} – 5 10^{12} h^{-2} $L_\odot$
X-ray gas S.B. profile	$[1+r^2/Rc^2]^{-3\beta+1/2}$
β	$\sigma_r/(kT_x/\mu m_p)$
Central density – (n_e core)	~ 10^{-3} $h^{1/2}$ cm^{-3}
X-ray Temperature	~2 to 14 keV, 2 10^7 – 10^8 K
X-ray Luminosity	~10^{42} – 10^{45} h^{-2} erg s^{-1}
Mass o f the gas & M_{gas}/M_{gal}	10^{13} – 10^{14} $M_\odot$ $h^{-2.5}$, 0.05 – 0.2 $h^{-1.5}$ (♍1.5 h^{-1} Mpc)
Cluster Number density	10^{-6} – 10^{-7} h^3 Mpc^{-3} [rich clusters]
Iron Aundance	0.2 – 0.5 solar

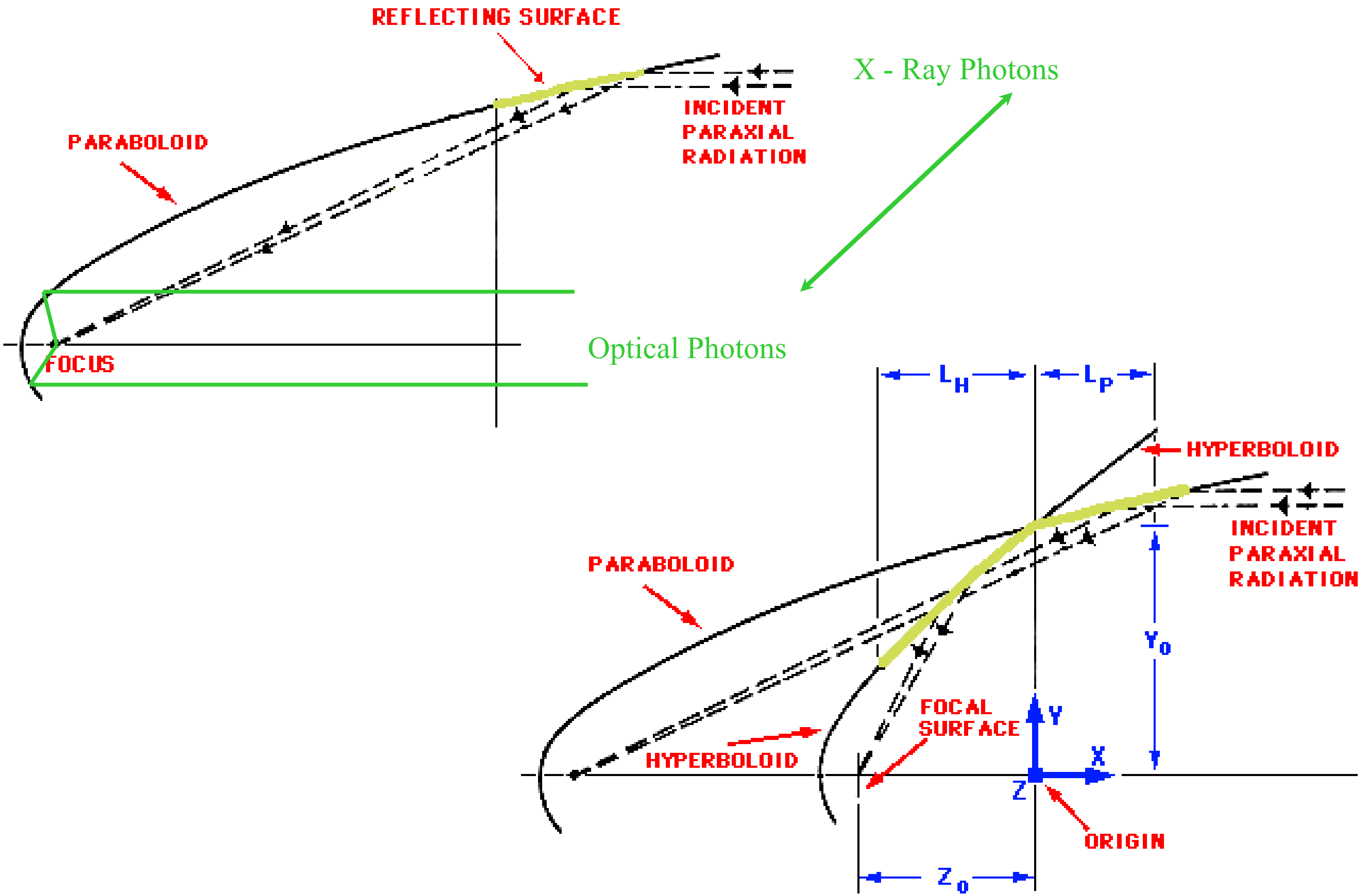
Distant Galaxy with Gravitational Lens - Einstein Ring - A way to Map Matter



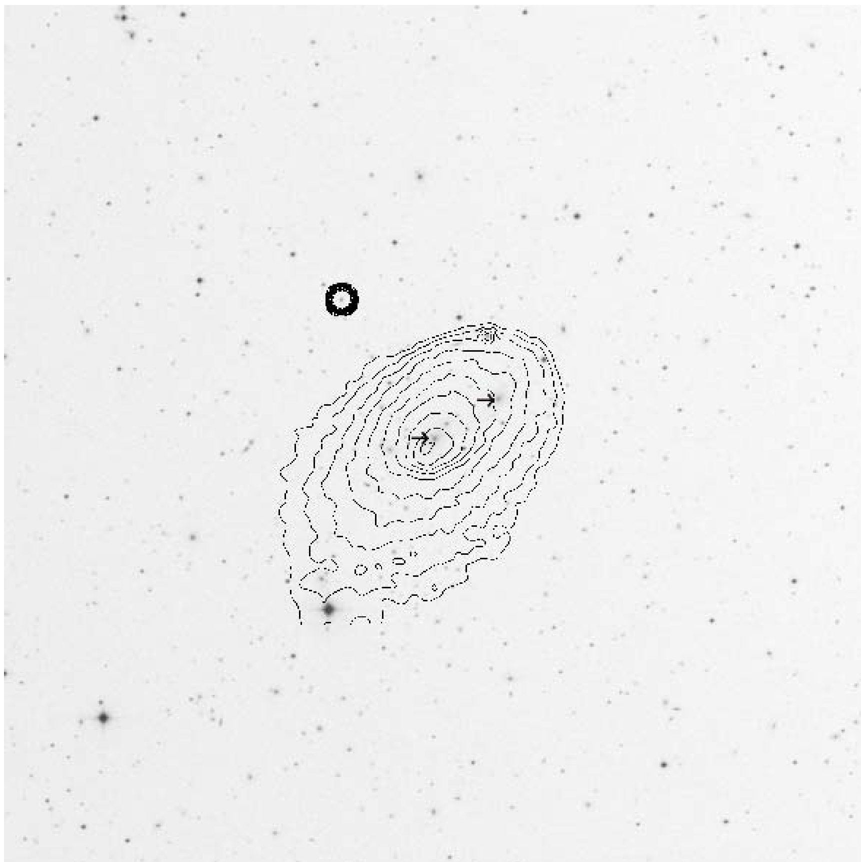
The Coma Cluster of Galaxies - PSS & CHANDRA

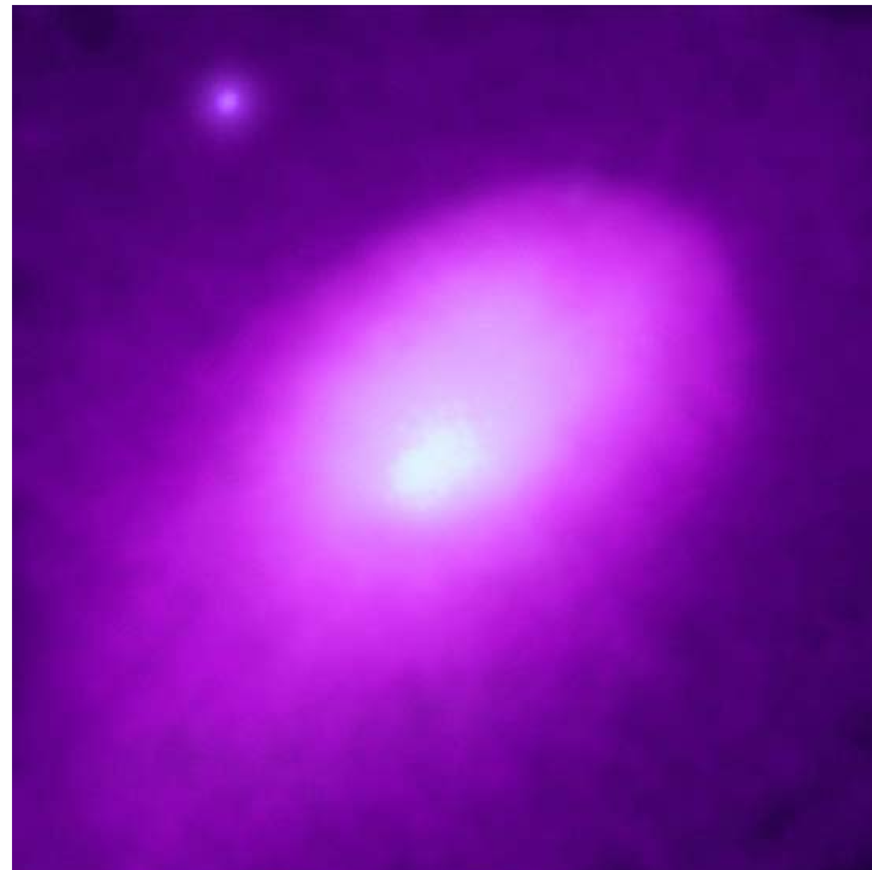


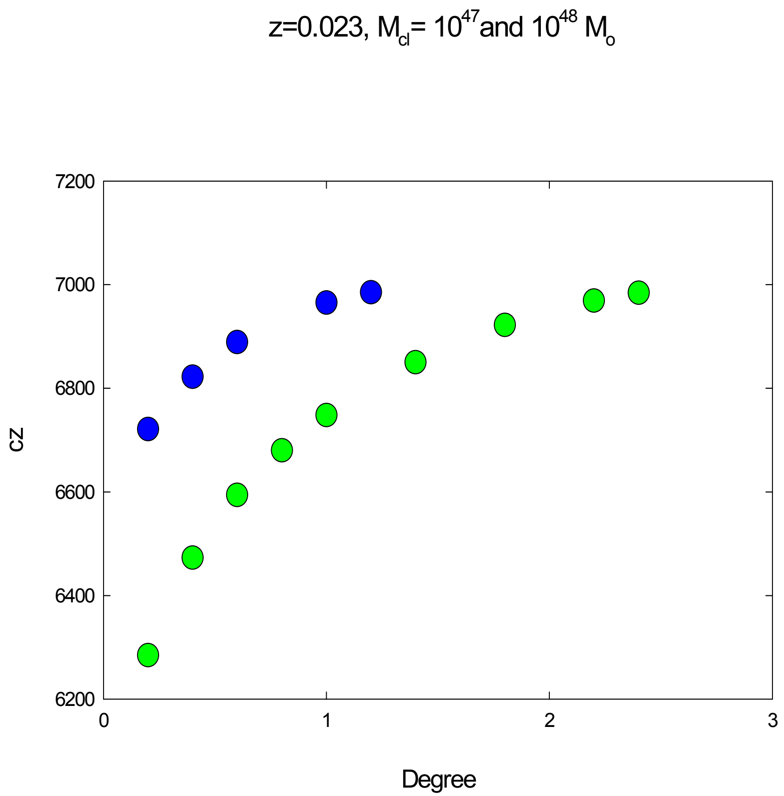


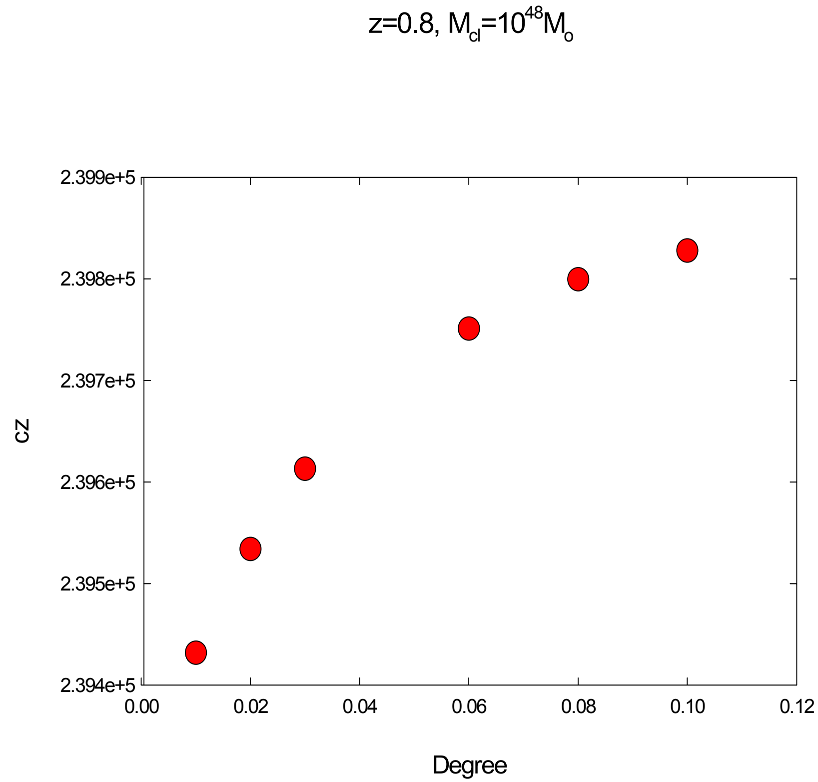

REFLECTING SURFACE
X - Ray Photons
INCIDENT
PARAXIAL
RADIATION
PARABOLOID
FOCUS
Optical Photons
L_H
L_P
HYPERBOLOID
INCIDENT
PARAXIAL
RADIATION
PARABOLOID
Y_0
FOCAL
SURFACE
Y
X
Z
HYPERBOLOID
ORIGIN
Z_0

Merger of two sub_clusters. The sub-clusters are embedded within Abell 2142. The subclusters might have collided two or three times in the past few billion years. The bright source in the upper left quadrant is an active galaxy belonging to the cluster. White 50 million Degrees, Magenta 50 Million Degrees to 100.






z=0.023, M_cl= 10^47 and 10^48 M_o
7200
7000
6800
6600
6400
6200
cz
0
1
2
3
Degree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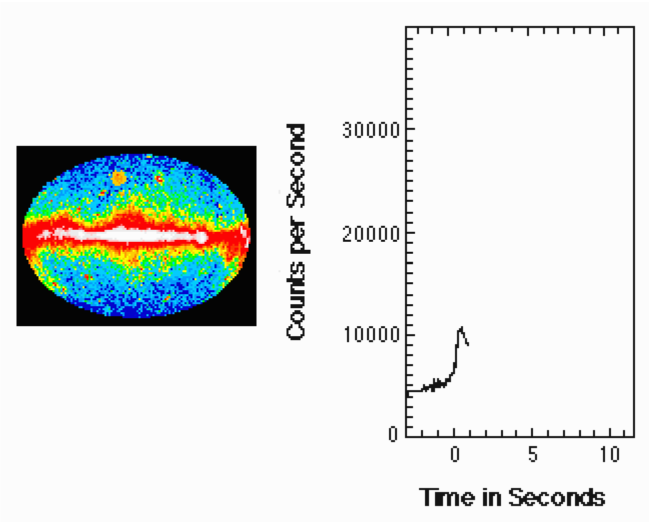
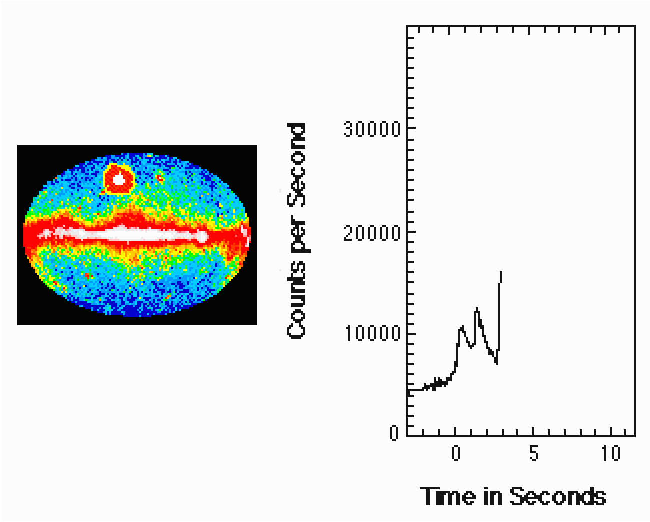
2.399e+5
2.398e+5
2.397e+5
2.396e+5
2.395e+5
2.394e+5
cz
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Degree


Counts per Second
30000
20000
10000
0
0
5
10
Time in Seconds


Counts per Second
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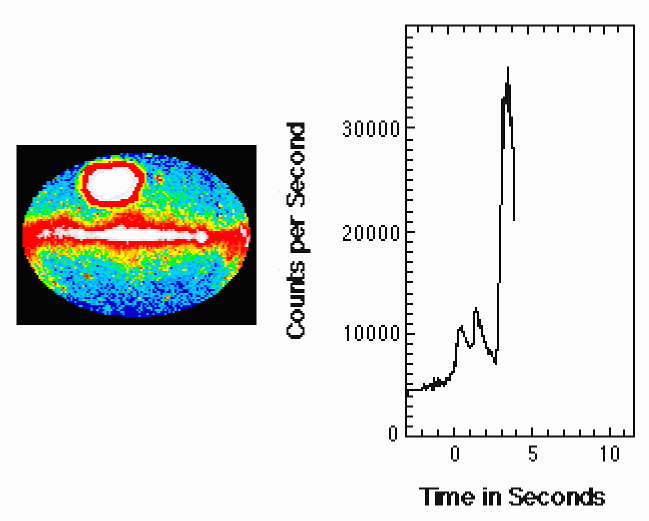
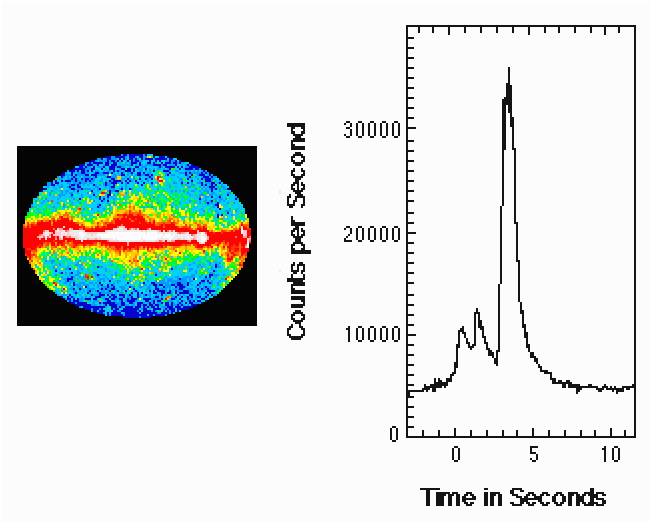
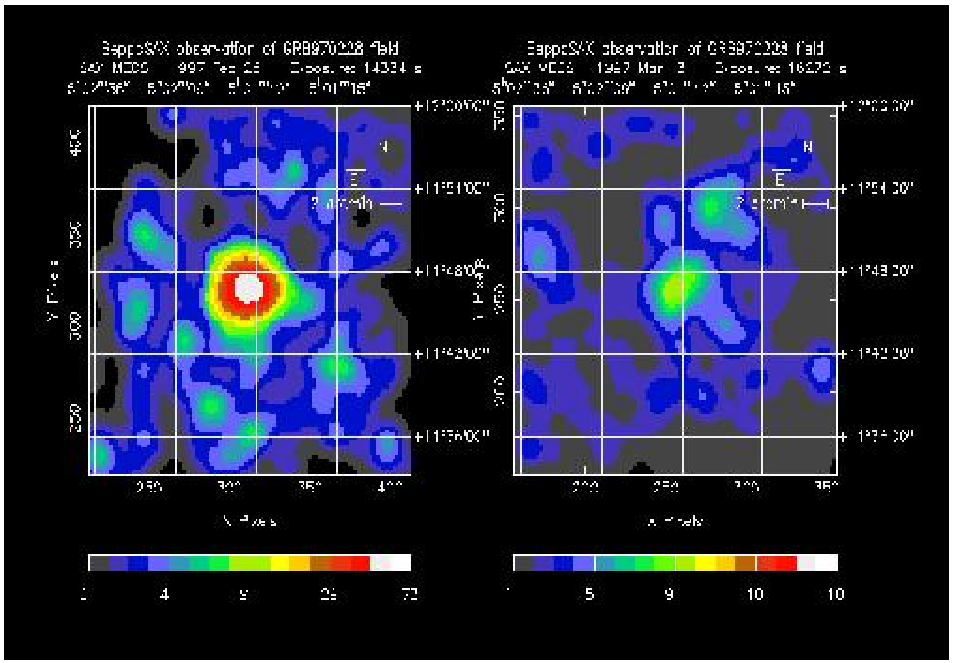
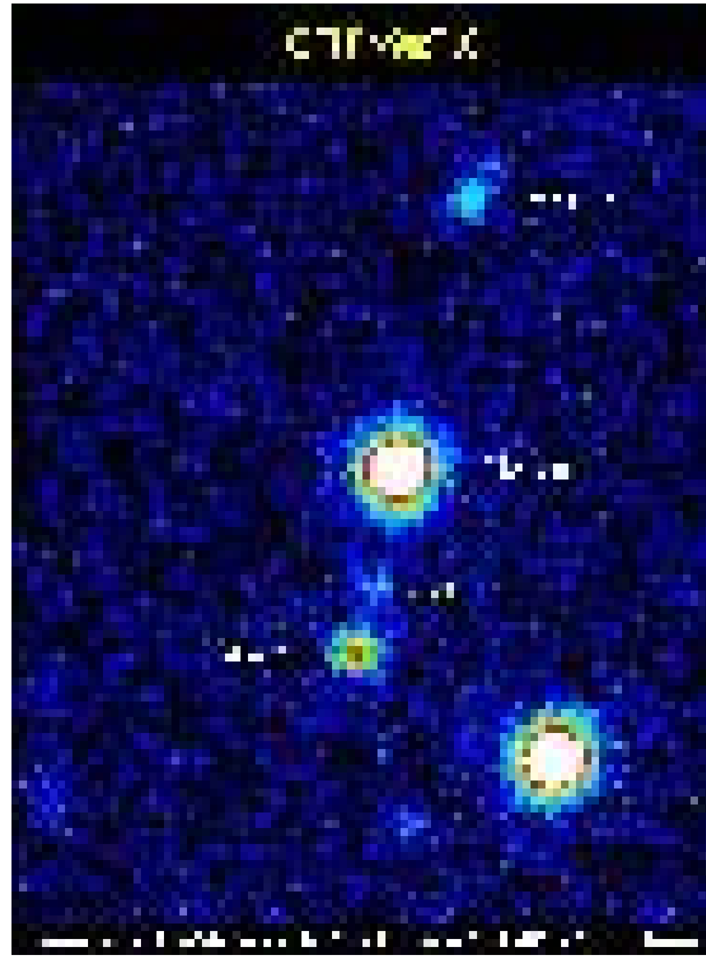
20000
10000
0
0
5
10
Time in Seconds


Counts per Second
30000
20000
10000
0
0
5
10
Time in Seconds


Counts per Second
30000
20000
10000
0
0
5
10
Time in Seconds

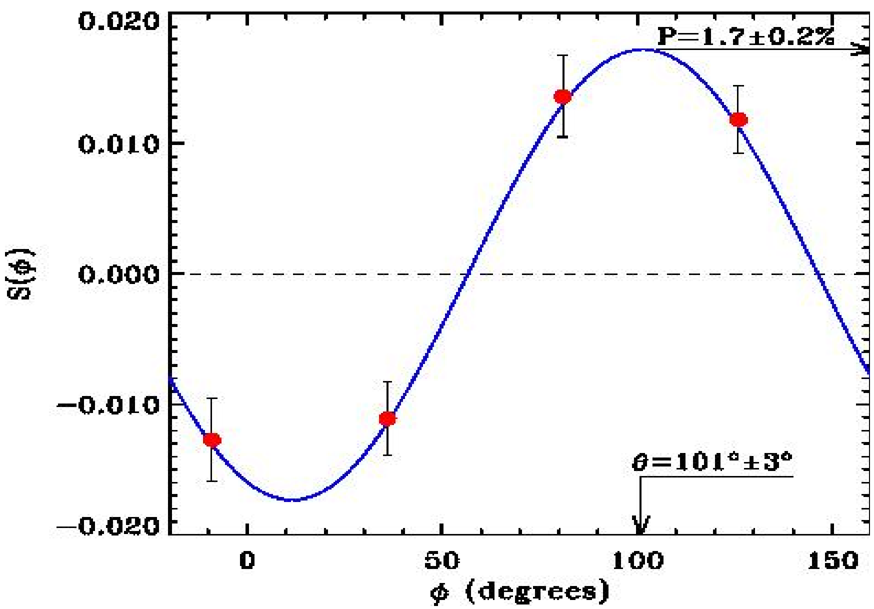
Gamma Ray Burst at z=1.6, GRB 990511



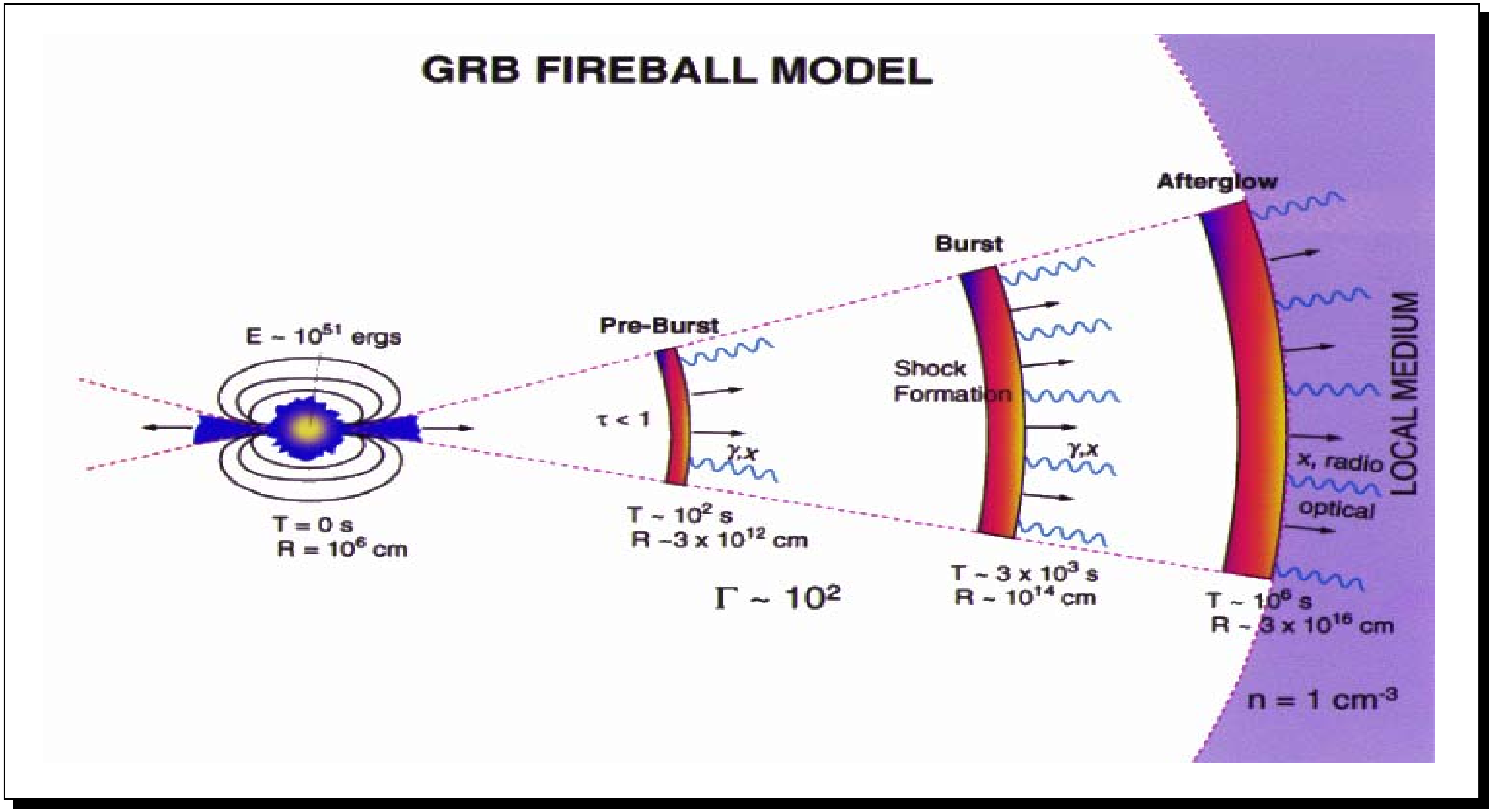


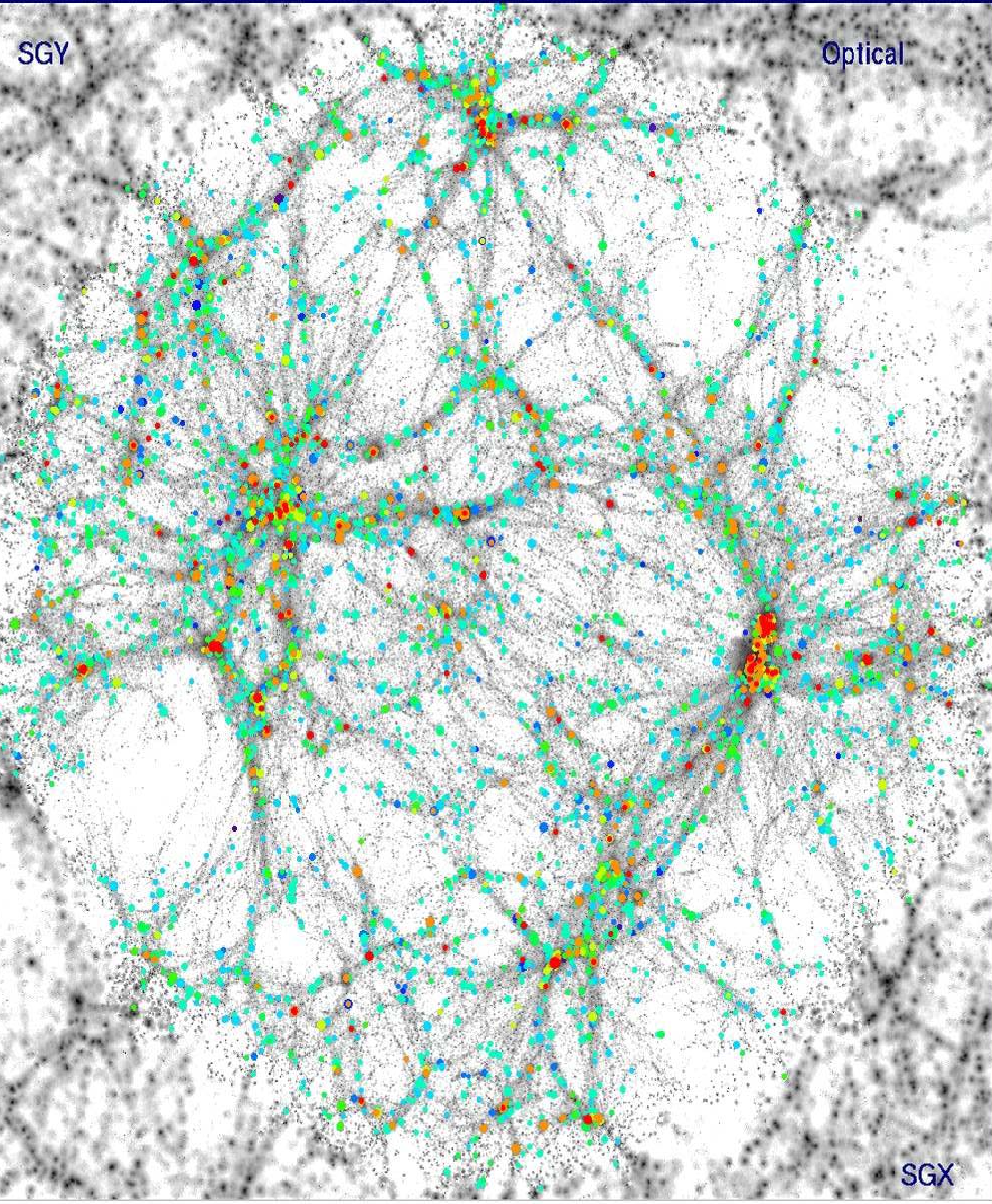
GRB Polarization

- Observing the afterglow of GRB990510 with the VLT soon (~ 18 h) after the burst detection, a small but significant amount of linear polarisation was detected in the optical (R) band, Covino et al.,Wijers et al. 1999. There are two major consequences of this observation: first, it is a confirmation of the synchrotron origin of the radiation, since synchrotron photons can be highly polarised. Second, associated with a somewhat anomalous steeping of the light-curve, it gives a strong indication for the fireball to be beamed.

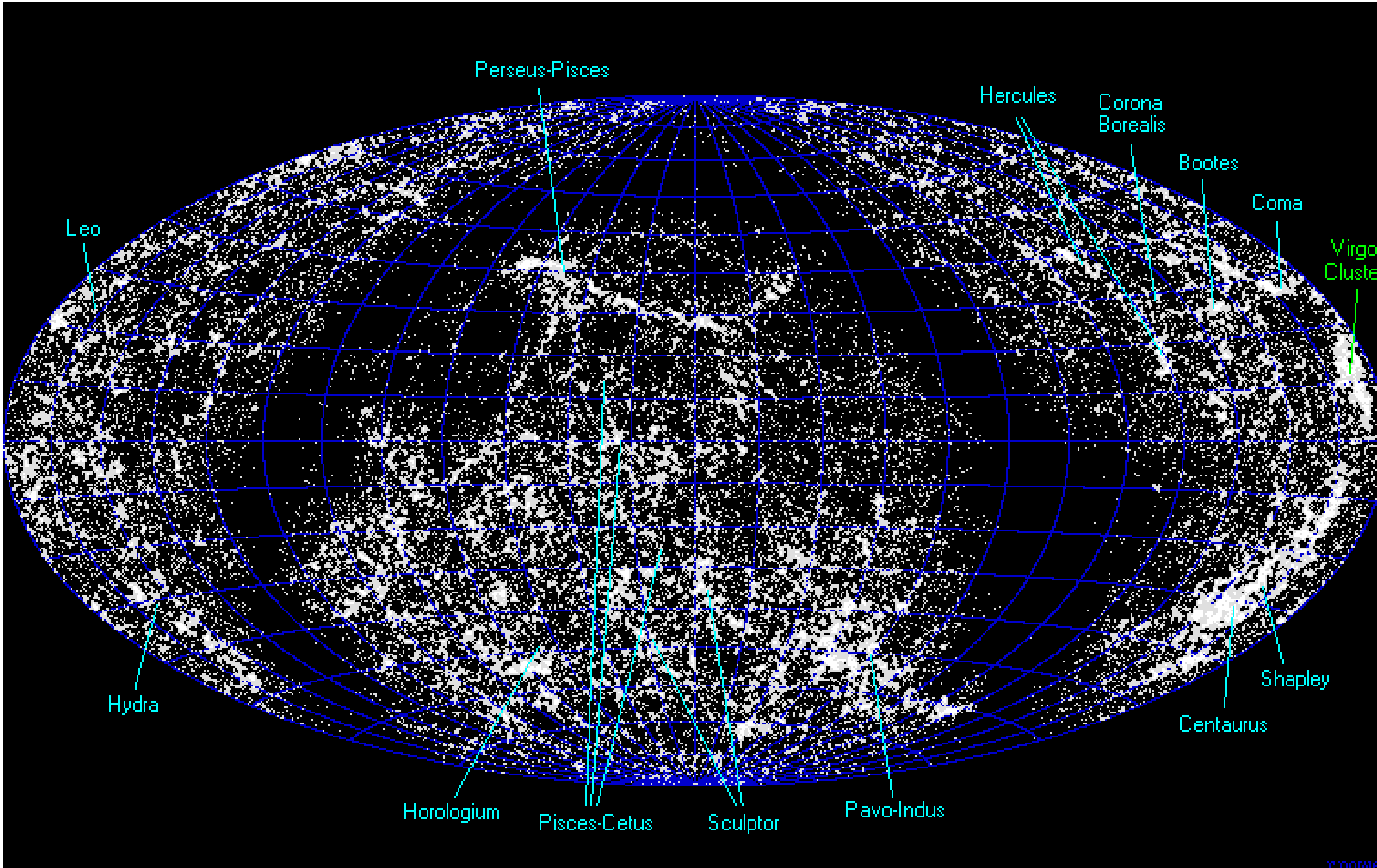


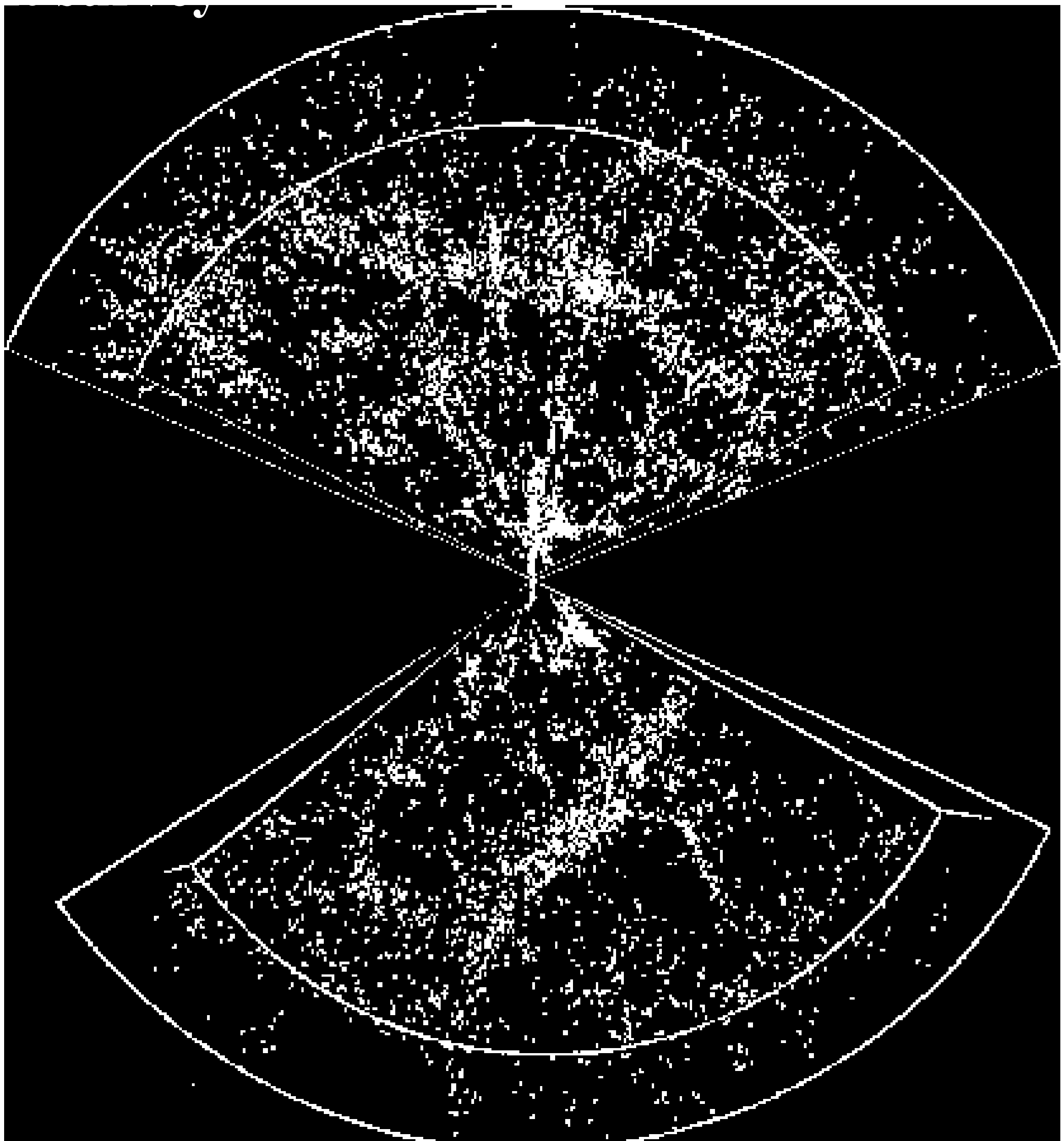
GRB Model

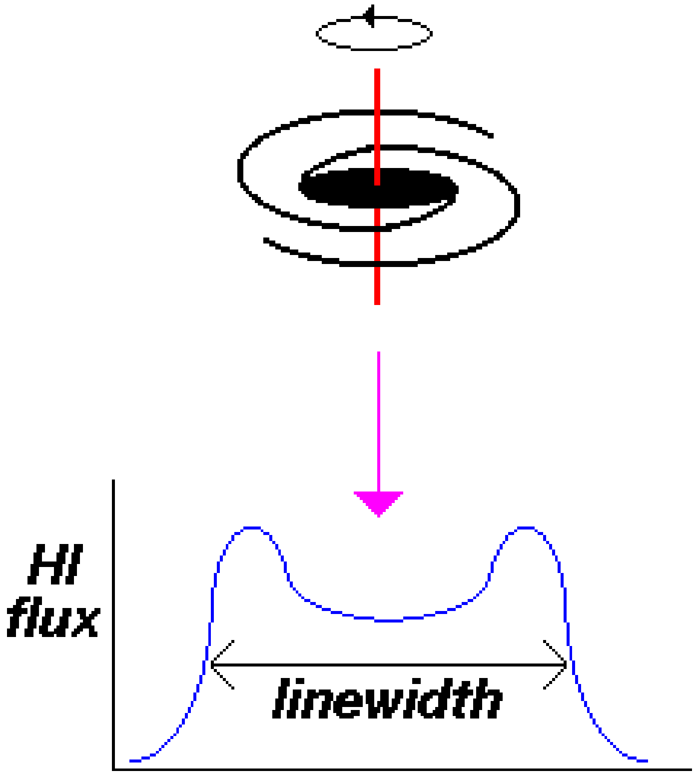

GRB FIREBALL MODEL
E ~ 10^51 ergs
T = 0 s
R = 10^6 cm
Pre-Burst
τ < 1
γ,x
T ~ 10^2 s
R ~3 x 10^12 cm
Γ ~ 10^2
Burst
Shock
Formation
γ,x
T ~ 3 x 10^3 s
R ~ 10^14 cm
Afterglow
x, radio
optical
T ~ 10^6 s
R ~ 3 x 10^16 cm
LOCAL MEDIUM
n = 1 cm^-3



CDM local universe (Λ=0.7, Ω=0.3, h=0.7)
onstrained within 8000 km/s by the IRAS 1.2 Jy survey
redits : Mathis, Lemson, Springel, Kauffmann, White and Dekel.


Perseus-Pisces
Hercules
Corona
Borealis
Bootes
Coma
Virgo
Cluster
Leo
Hydra
Horologium
Pisces-Cetus
Sculptor
Pavo-Indus
Shapley
Centaurus
r powell

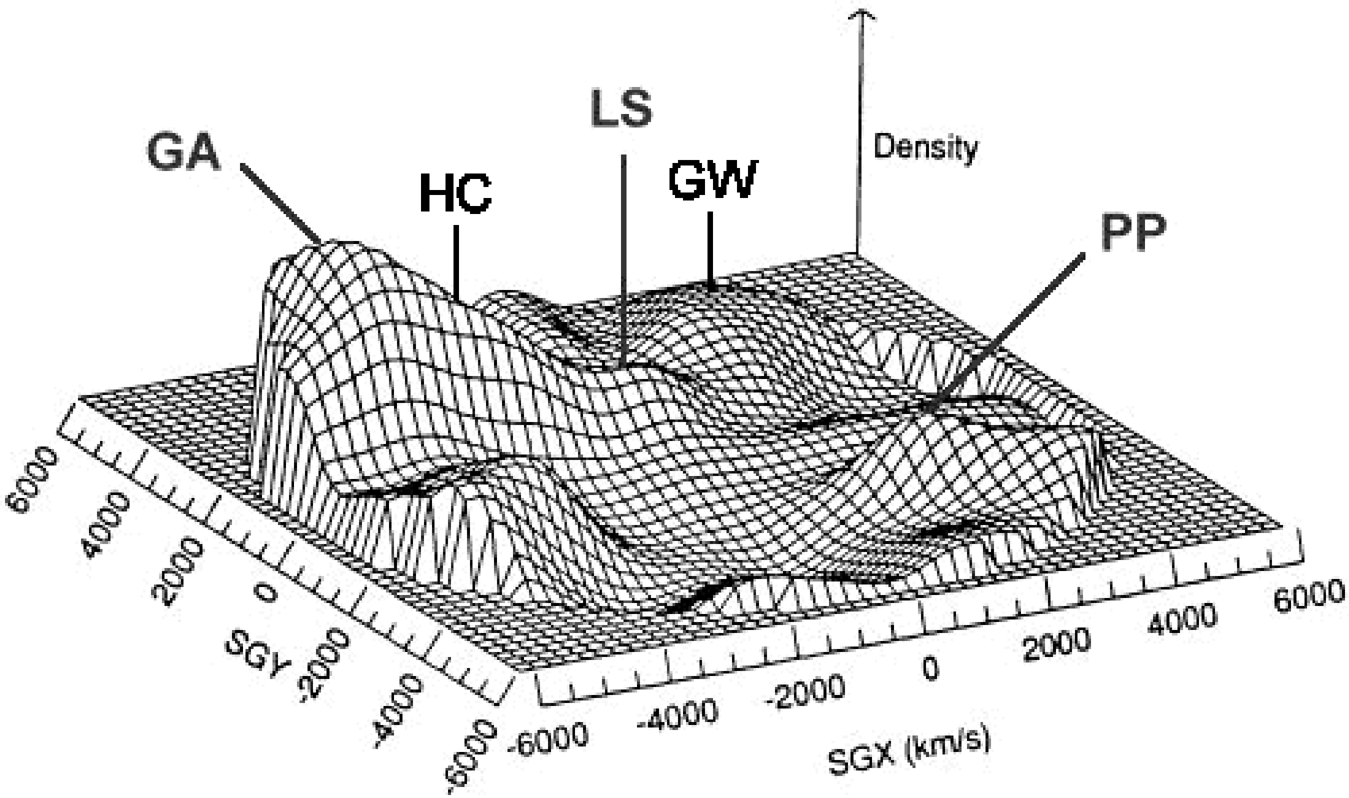


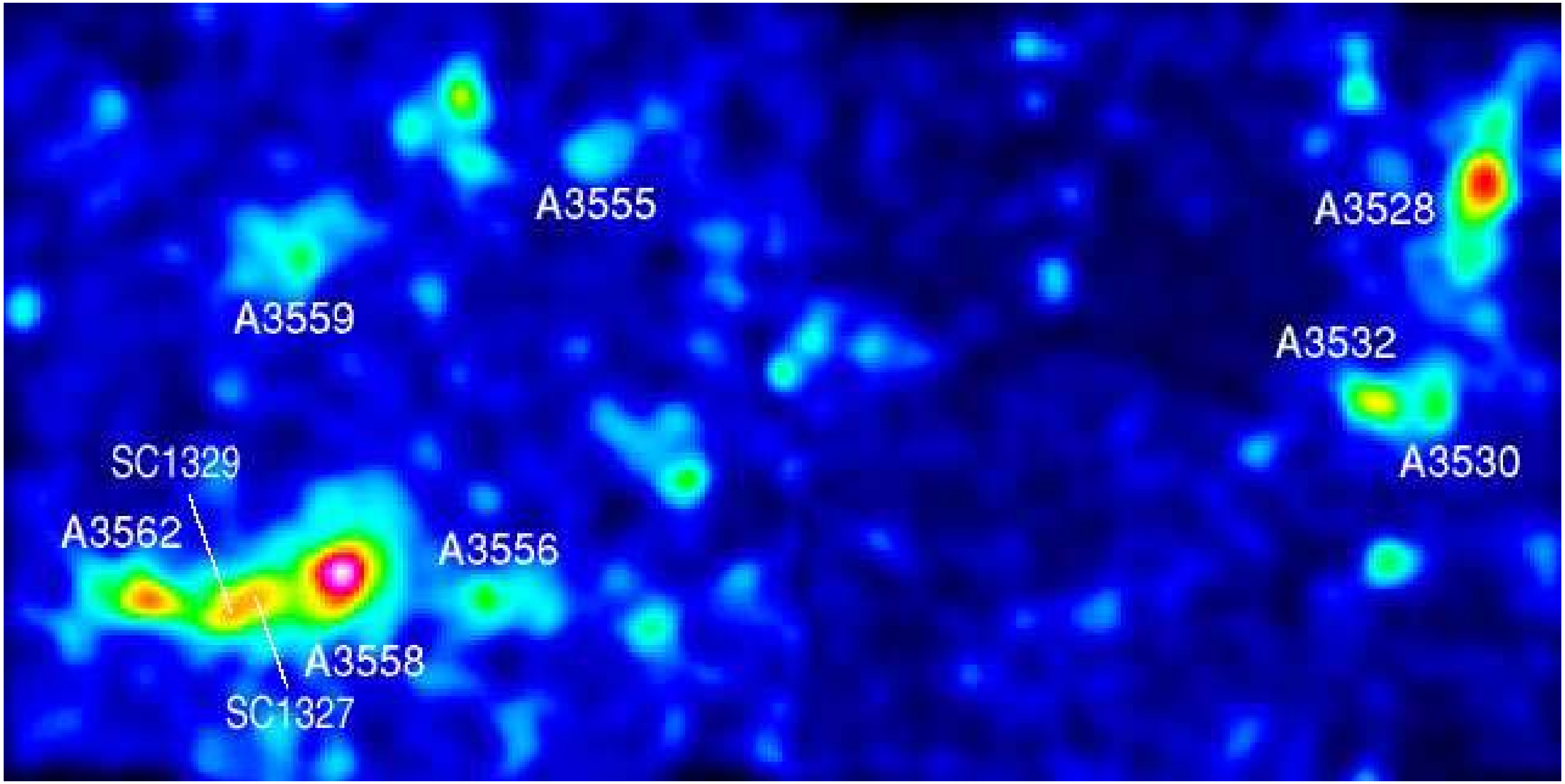


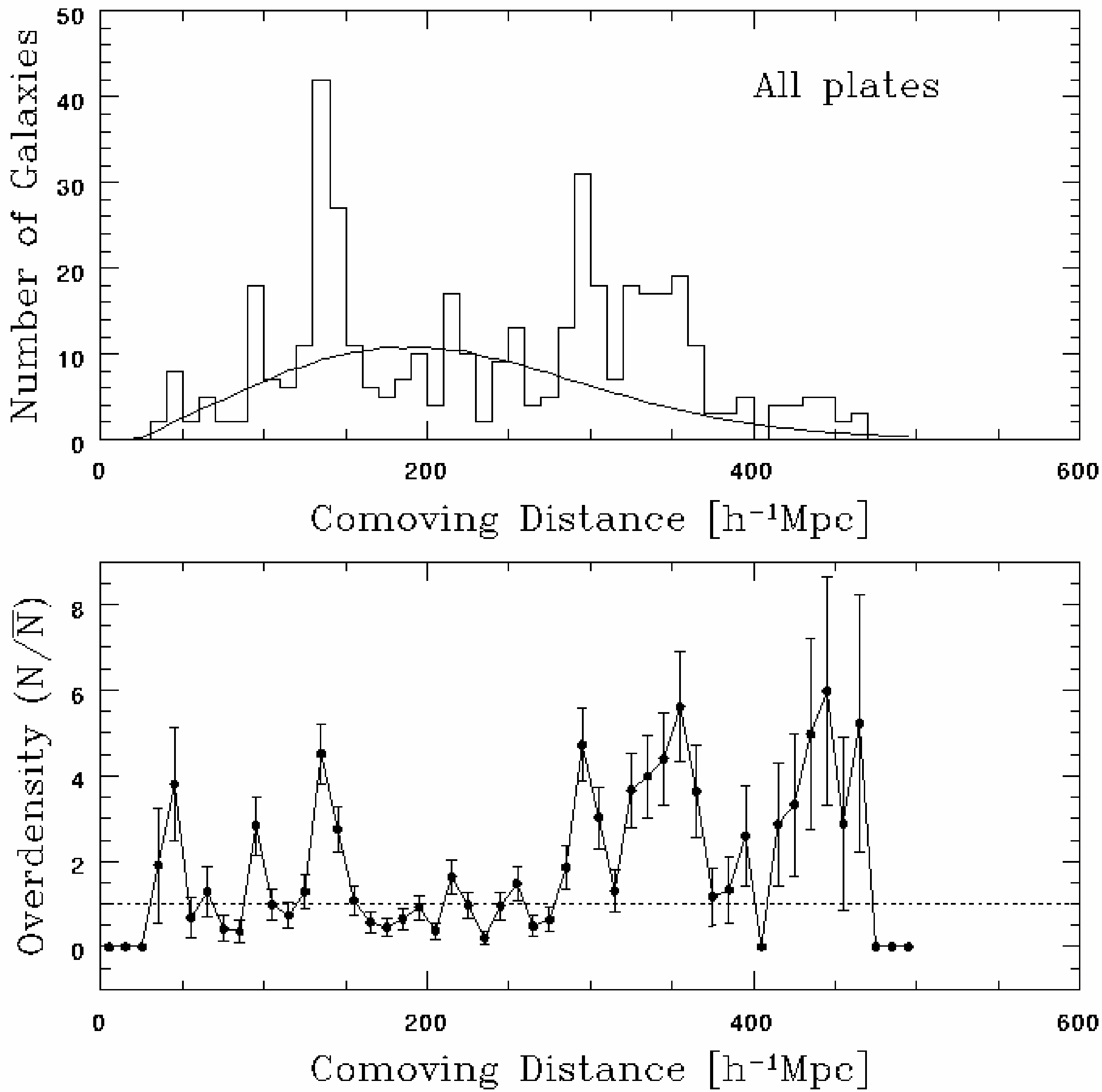
From distance indicators we have Dist

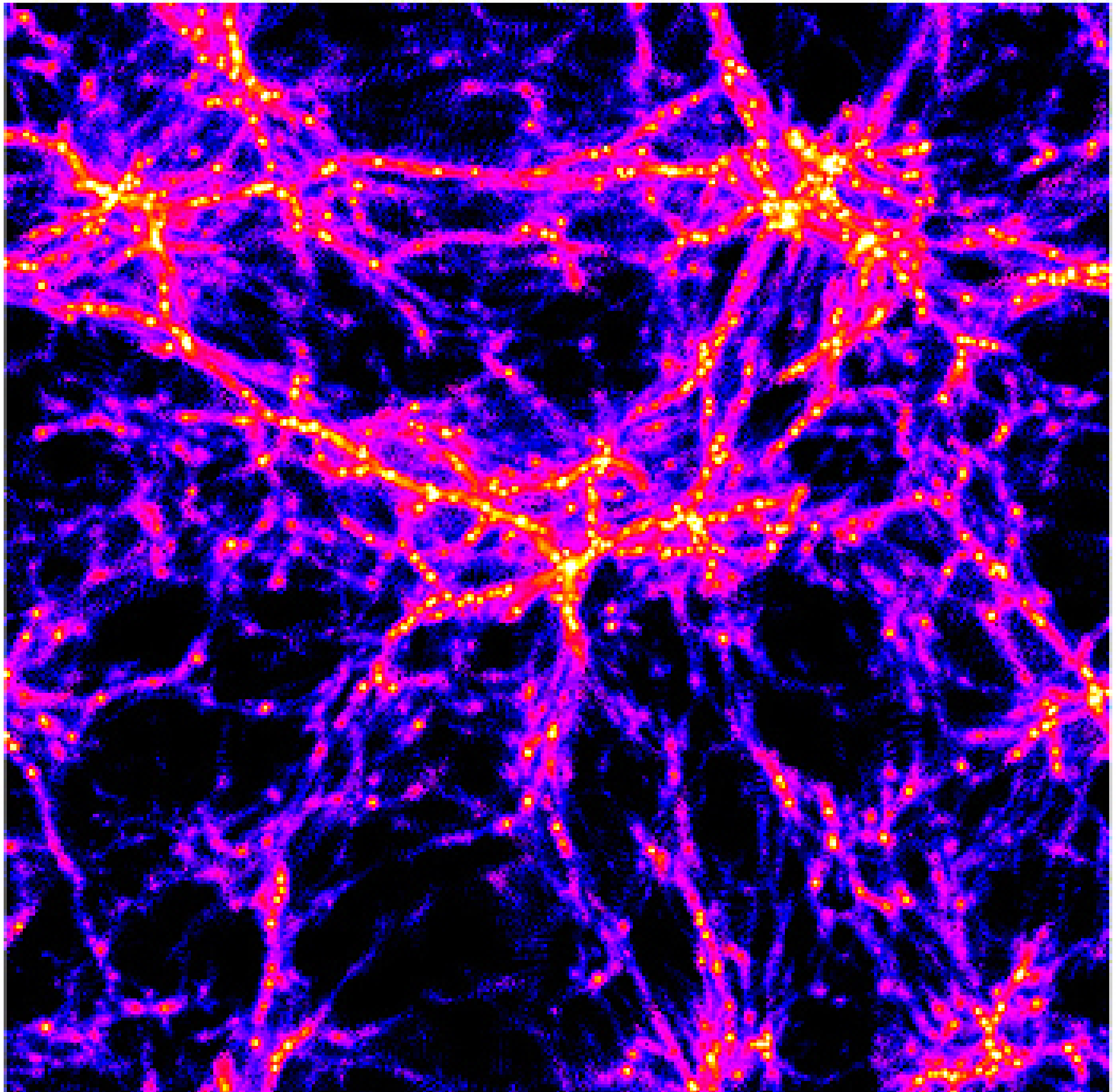
v_{pec} = cz - HDist

Great Attractor



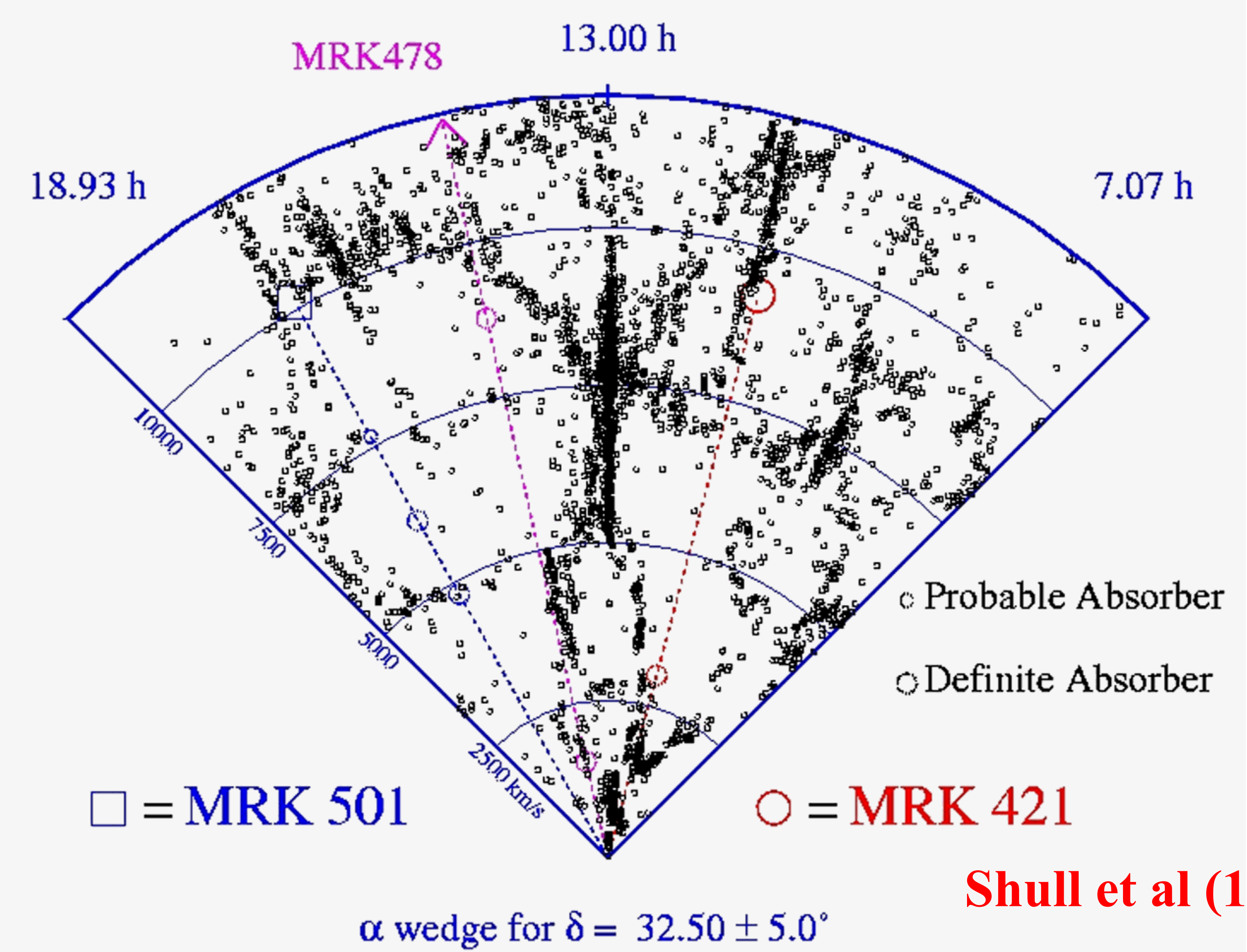

A3555
A3528
A3559
A3532
A3530
SC1329
A3562
A3556
A3558
SC1327


All plates
Number of Galaxies
0
10
20
30
40
50
0
200
400
600
Comoving Distance [h⁻¹Mpc]
Overdensity (N/N̄)
0
2
4
6
8
0
200
400
600
Comoving Distance [h⁻¹Mpc]

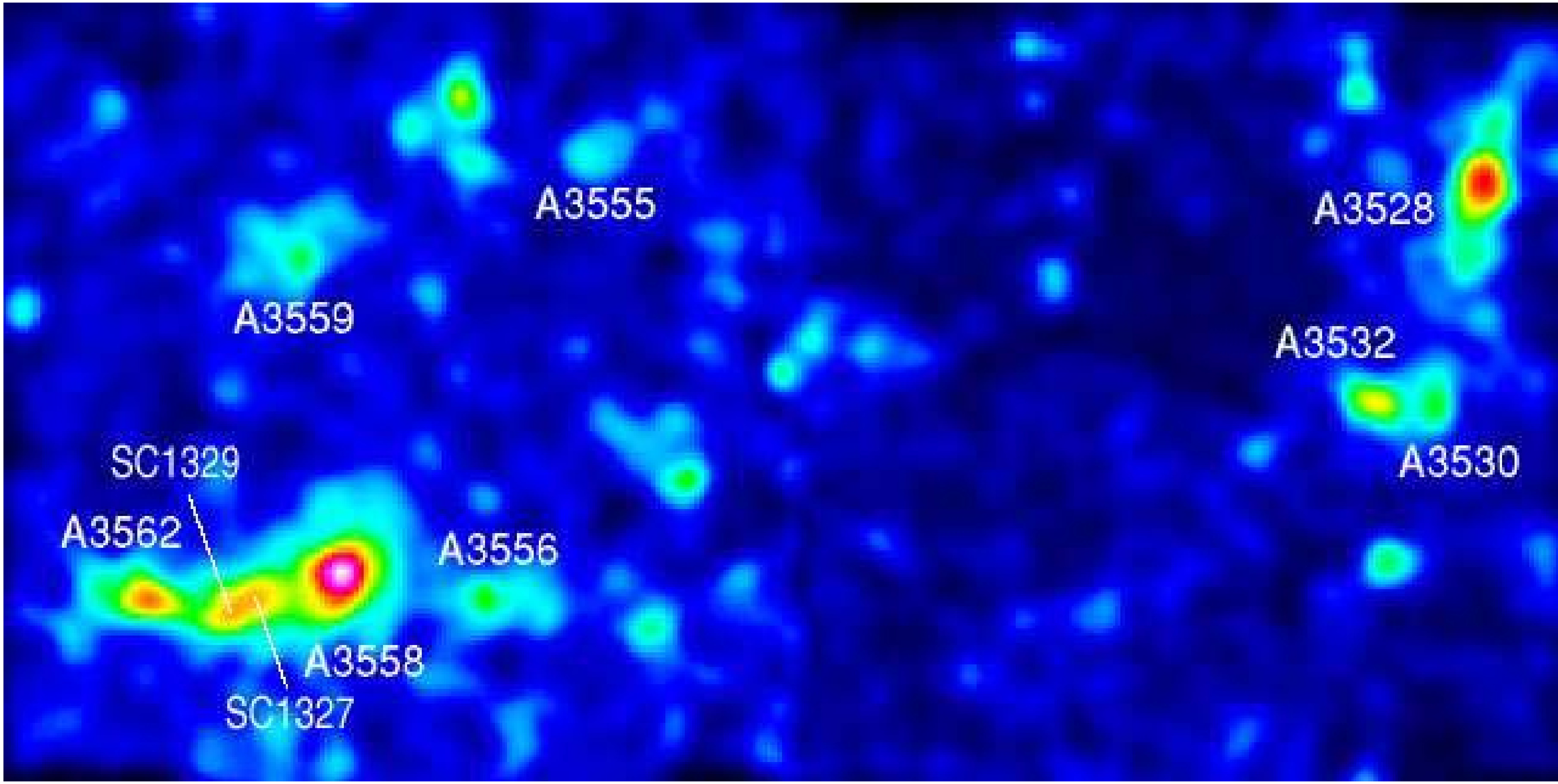


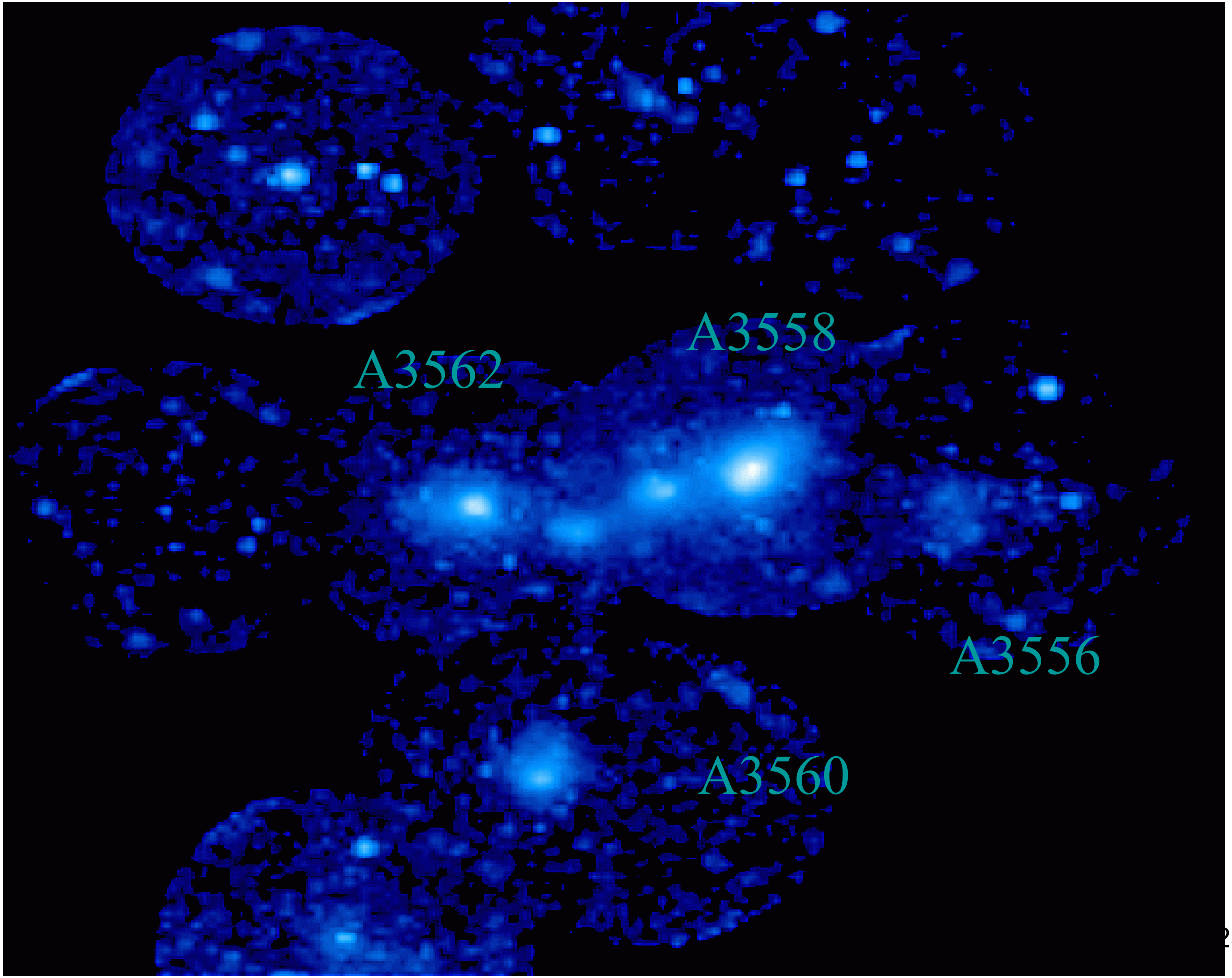
The Universe - Two Billion Years after the Big Bang
(Computer Animation - T. Theuns, MPA)

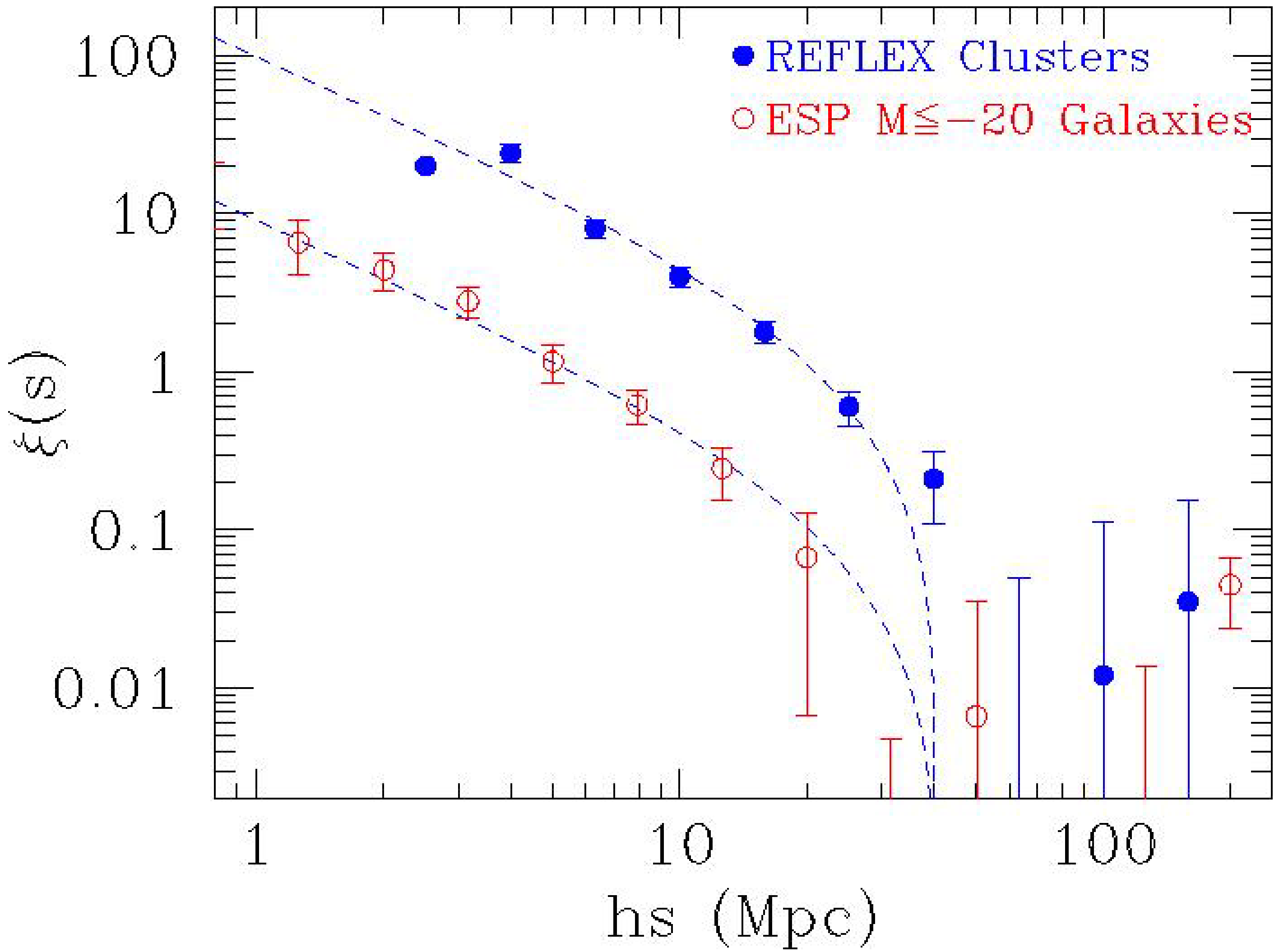
ESO PR Photo 19a/01 (18May 2001)

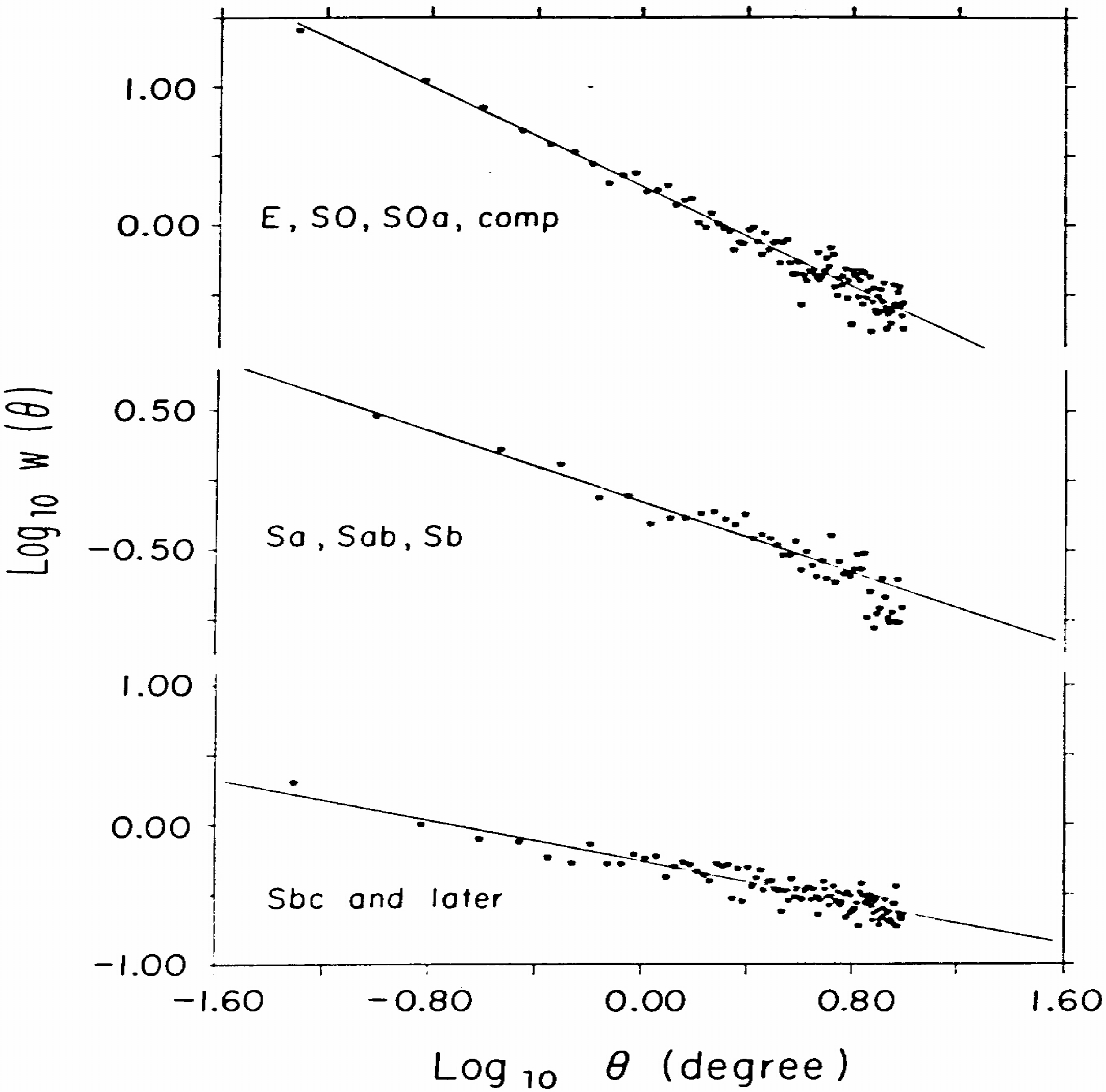


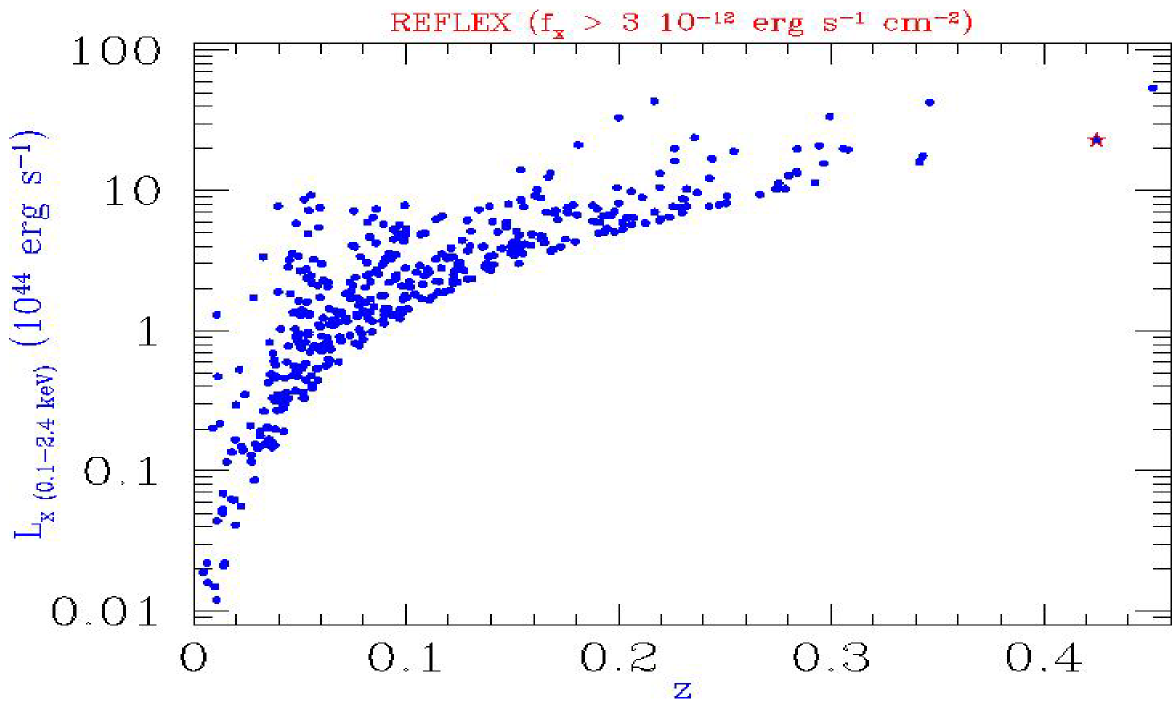
Shull et al (1999)

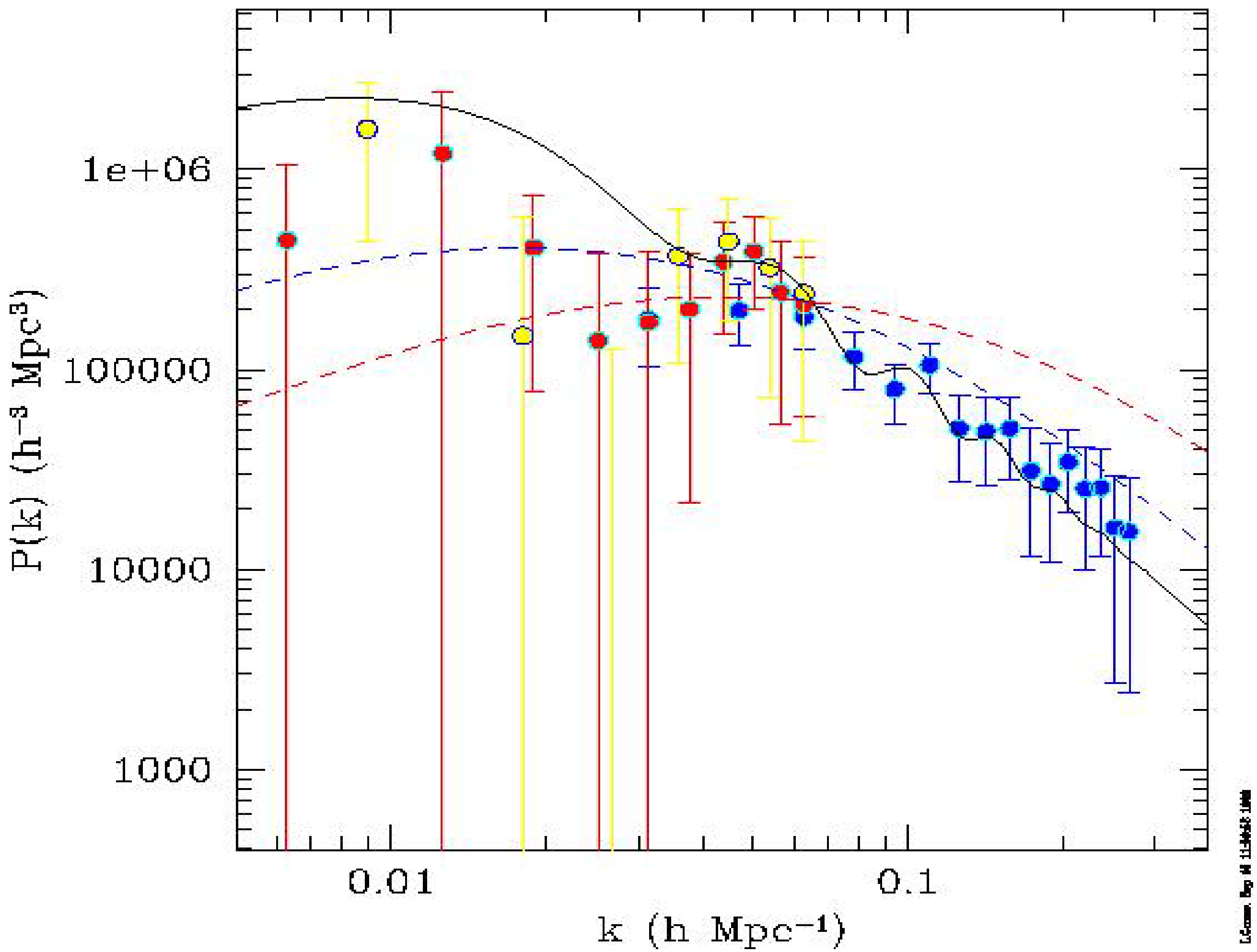

A3555
A3528
A3559
A3532
A3530
SC1329
A3562
A3556
A3558
SC1327


A3558
A3562
A3556
A3560


REFLEX Clusters
ESP M≦−20 Galaxies
100
10
1
0.1
0.01
ξ(s)
1
10
100
hs (Mpc)


1.00
0.00
E, SO, SOa, comp
0.50
-0.50
Sa, Sab, Sb
1.00
0.00
-1.00
Sbc and later
Log10 w (θ)
-1.60
-0.80
0.00
0.80
1.60
Log 10 θ (degree)


REFLEX (f_x > 3 10^{-12} erg s^{-1} cm^{-2})
$L_{X\,(0.1-2.4\ keV)}$ (10^{44} erg s^{-1})
100
10
1
0.1
0.01
0
0.1
0.2
0.3
0.4
z


1e+06
100000
10000
1000
P(k) (h^{-3} Mpc^3)
0.01
0.1
k (h Mpc^{-1})