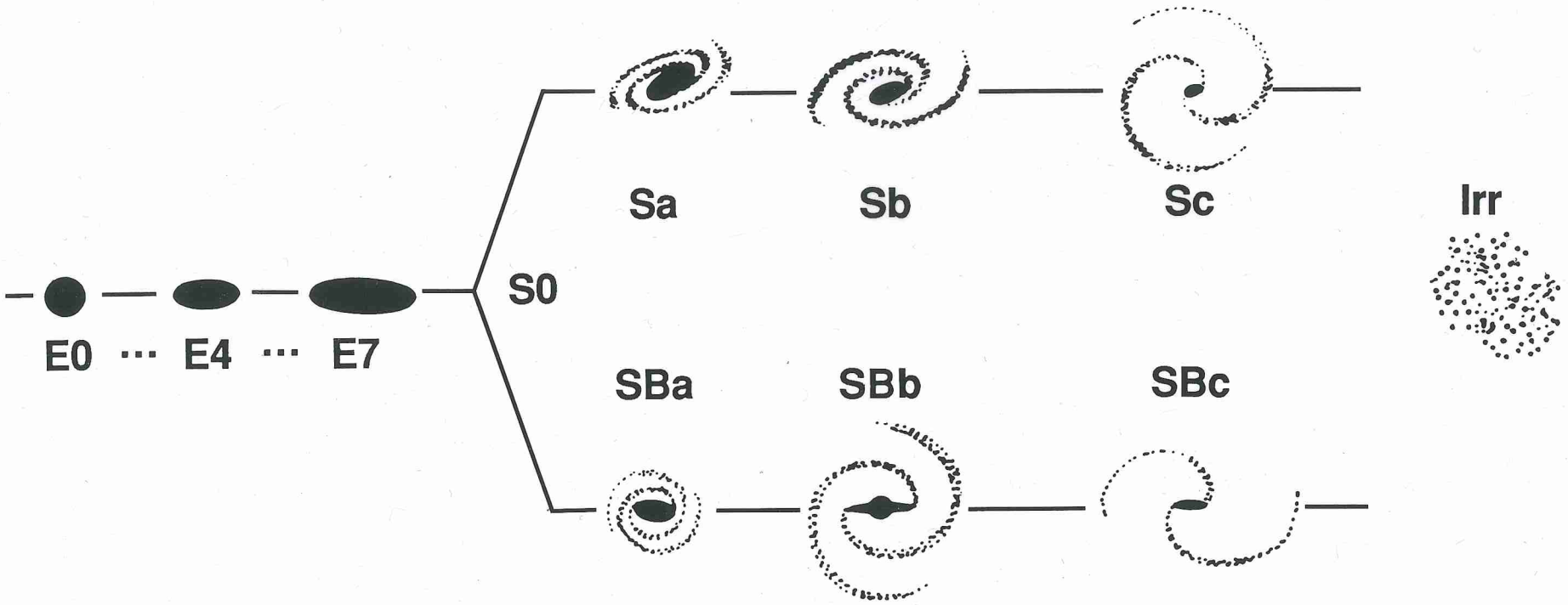
GALAXIES

- DISCOVERY/IDENTIFICATION AS SEPARATE STELLAR SYSTEMS : HUBBLE IN 1920 ✱ VIA DISTANCE TO ANDROMEDA NEBULA FROM CEPHEID VARIABLES ('ISLAND UNIVERSES')
- CLASSIFICATION (1ST STEP TO UNDERSTANDING)
  - SPIRAL, BARRED SPIRAL
  - ELLIPTICAL
  - IRREGULAR
  - PECULIAR

HUBBLE'S TUNING FORK DIAGRAM



Tuning fork diagram of galaxy types

Seeds: Horizons, 1995 ed., Fig. 13–2; Foundations of Astronomy, 1994 ed., Fig. 16–2

GALAXY PROPERTIES (TABLE 16-1)

(IN GALACTIC UNITS)

	ELLIPTICAL	SPIRAL	IRREGULAR
MASS	0.0001 - 50	0.005 - 2	0.0005 - 0.15
DIAMETER	0.01 - 5	0.2 - 1.5	0.05 - 0.25
LUMINOSITY	0.00005 - 5	0.005 - 10	0.00005 - 0.1
GAS/DUST	V. LITTLE → ZERO	IN DISK	LOTS
ENVIRONMENT	RICH CLUSTERS	SMALL GROUPS DWARFS + GIANTS	LOW DENSITY REGIONS

OUR GALAXY

BARRED SPIRAL SBbc

WHY so difficult to classify?

BARS may be temporary features
and may recur

IS HUBBLE SEQUENCE AN EVOLUTIONARY ONE?

① $E \rightarrow \begin{matrix} S \\ SB \end{matrix} > Irr$

- YOUNG STARS IN S, Irr NOT in E
- LOTS OF GAS IN S, Irr. 'NONE' in E

② $Irr \rightarrow \begin{matrix} S \\ SB \end{matrix} \rightarrow E$

- OLD STARS IN S, SB AS OLD AS STARS IN E

GALAXY EVOLUTION

- ACCRETION at EARLY TIMES
  - HUBBLE SPACE TELESCOPE
    - → VERY LARGE TELESCOPES

- COLLISIONS at recent & present TIMES

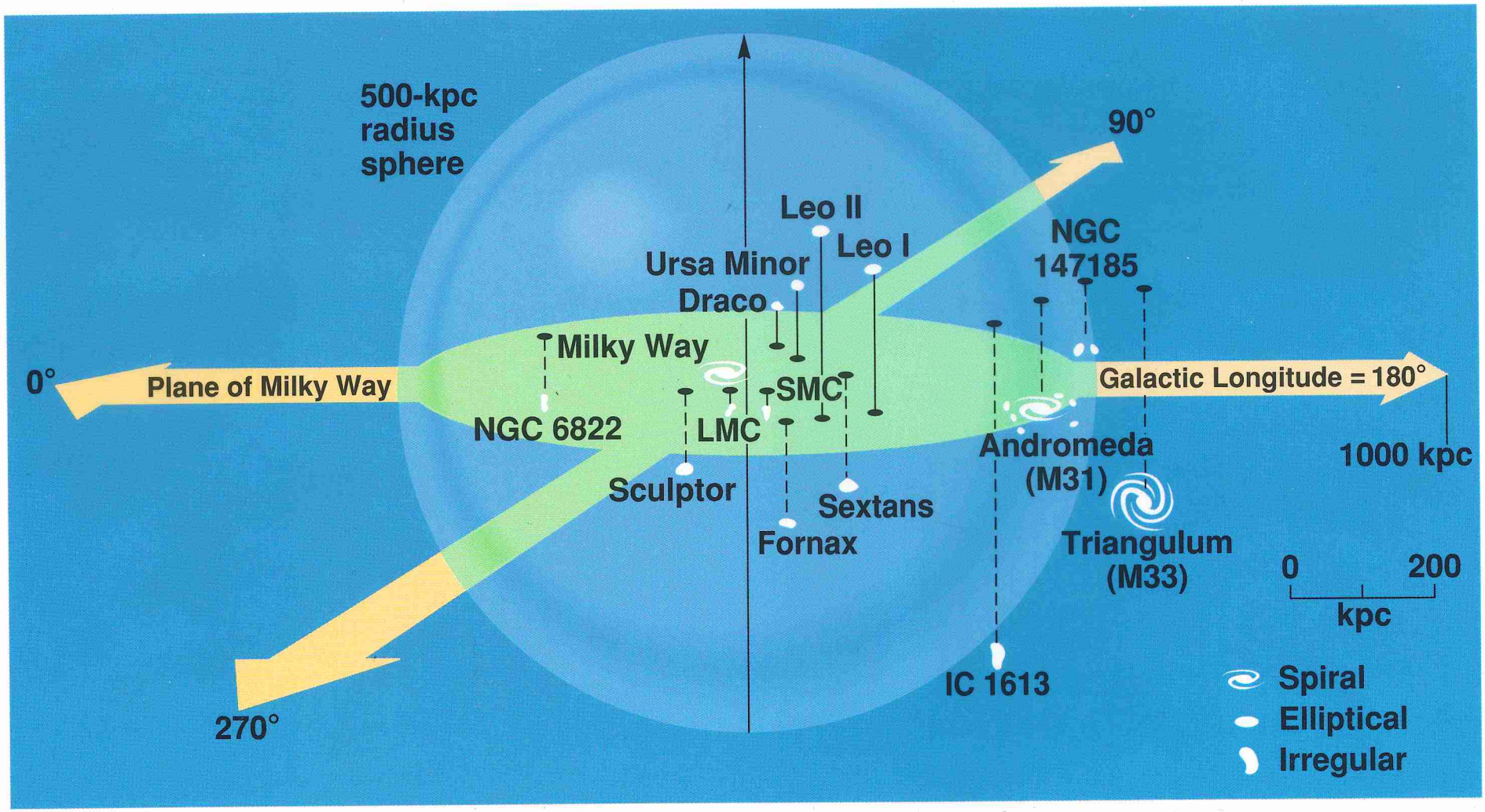
- GALAXY - GALAXY COLLISIONS
  - NOT RARE (see SEEDS)
  - COLLISIONS FACTOR IN GALAXY EVOLUTION
    - GALAXIES ARE LARGE (esp. with LARGE DARK MATTER HALOS)
    - AND RELATIVELY CLOSE TO EACH OTHER

[STAR-STAR COLLISIONS IN A GALAXY V.V. RARE except IN NUCLEUS (perhaps)]

- MERGER OF 2 SPIRAL GALAXIES
  → ELLIPTICAL GALAXY
  - COLLISION SCRAMBLES DISKS INTO A QUASI-SPHERICAL DISTRIBUTION
  - COLLISION → GAS CLOUD COLLISIONS
    → BURST OF STAR FORMATION
    → CONSUMPTION/LOSS OF GAS
- DISK/SPIRAL GALAXIES FORMED STARS AFTER COLLAPSE THAT MADE THE GALAXY AND HAVE AVOIDED MAJOR COLLISIONS, HAVE ACCRETED DWARF GALAXIES

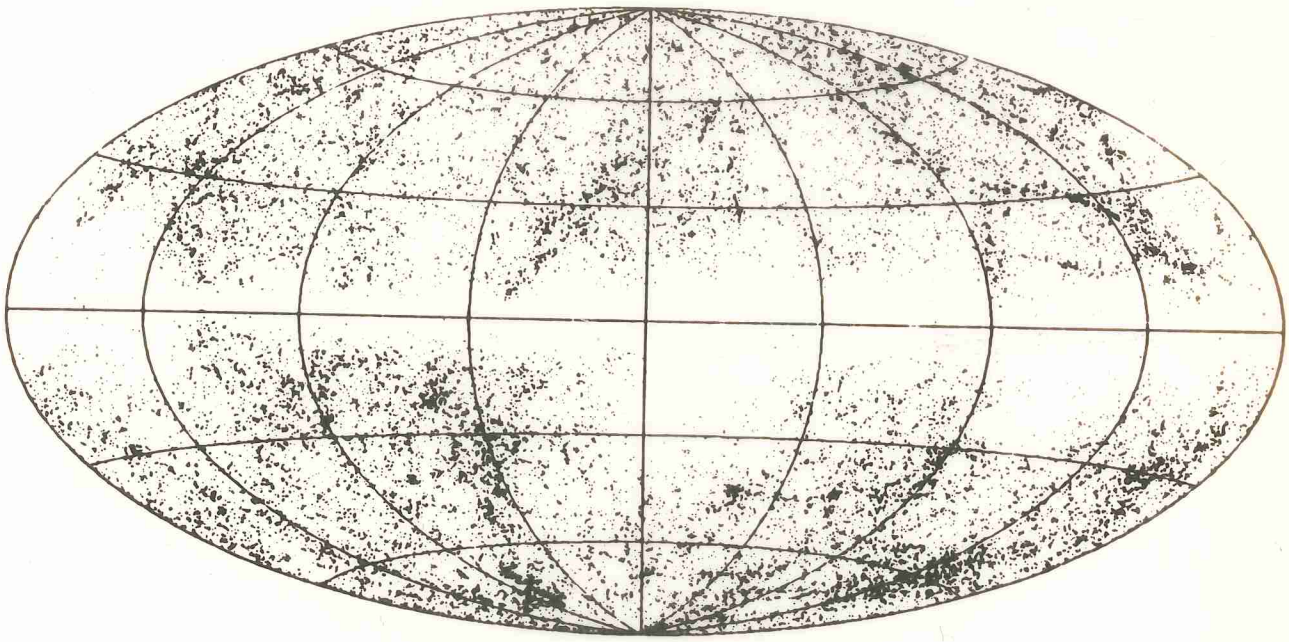
DISTRIBUTION OF GALAXIES

- ZONE OF AVOIDANCE
  → DUST IN OUR GALAXY!
- GALAXIES ARE CLUSTERED
  - LOCAL GROUP
    ~ 20^+ GALAXIES
    ~ 1 Mpc DIAMETER
    ~ MW + M31 ARE LARGEST
  - RICH CLUSTERS
    ~ VIRGO CLUSTER
    3Mpc DIAMETER @
    ~20 Mpc DISTANCE
    SEVERAL 1000 GALAXIES
  - SUPERCLUSTERS
    RICH + LOCAL GROUPS
    ~ OUR SUPERCLUSTER



Three-dimensional plot of Local Group of galaxies

Hartmann/Impey: The Cosmic Journey, 5th ed., Fig. 24-3; Hartmann: The Cosmic Voyage, 1992 ed., Fig. 24-1



LOCAL SUPERCLUSTER

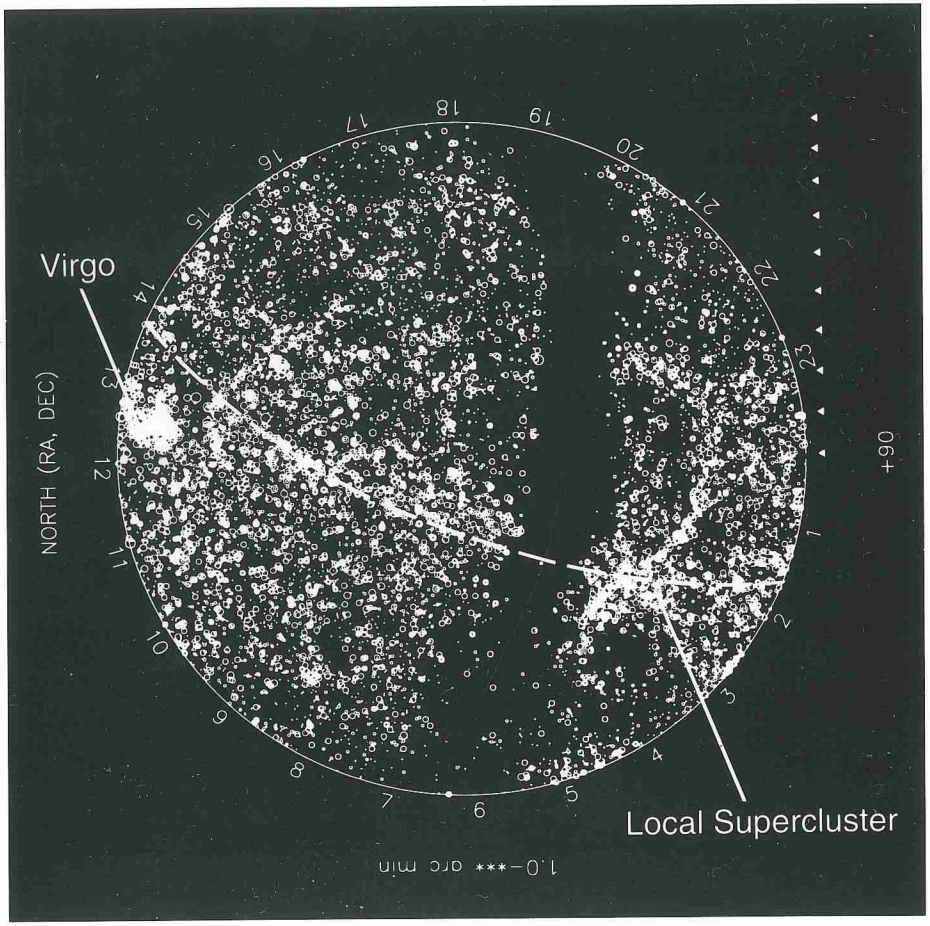
- CENTER in VIRGO
- ~40 Mpc in diameter
  ~10 Mpc in thickness

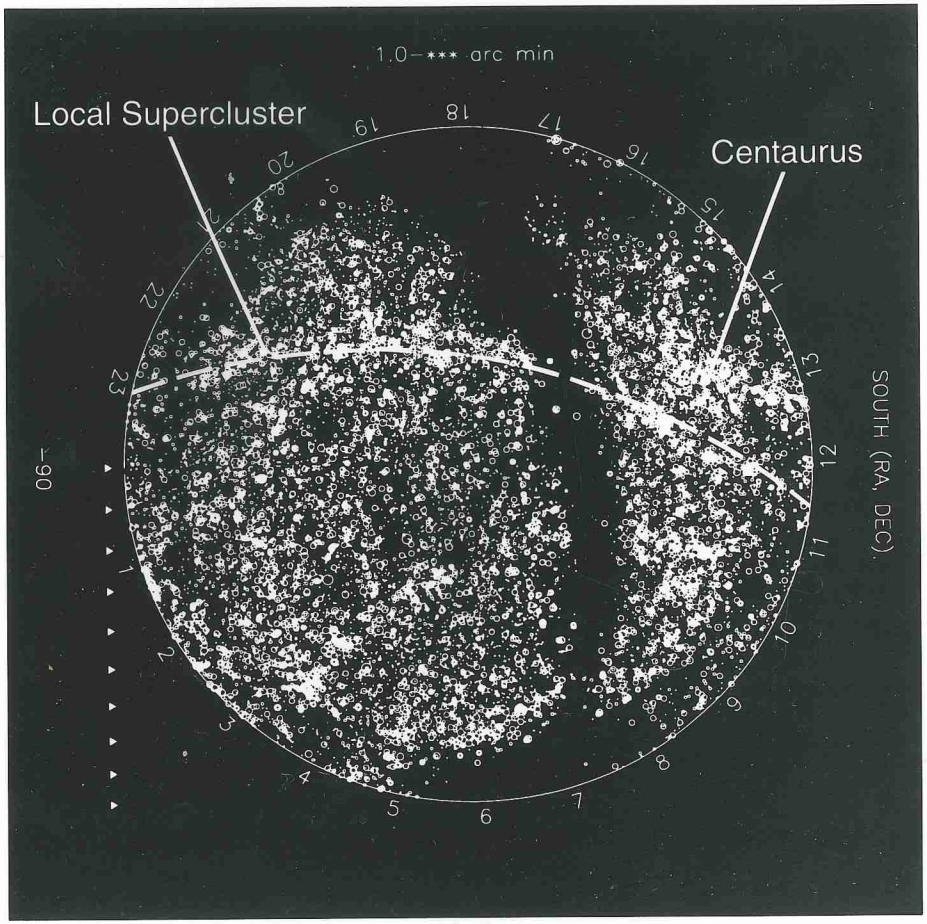
  ~50 CLUSTERS

  ~1000 GALAXIES

- WE ARE AT EDGE & ORBITING AT ~400 KM/S

- HUBBLE EXPANSION DISTORTION





Galaxies in the northern and southern skies

Hartmann/Impey: The Cosmic Journey, 5th ed., Fig. 25-11

ANOTHER PIE CUT

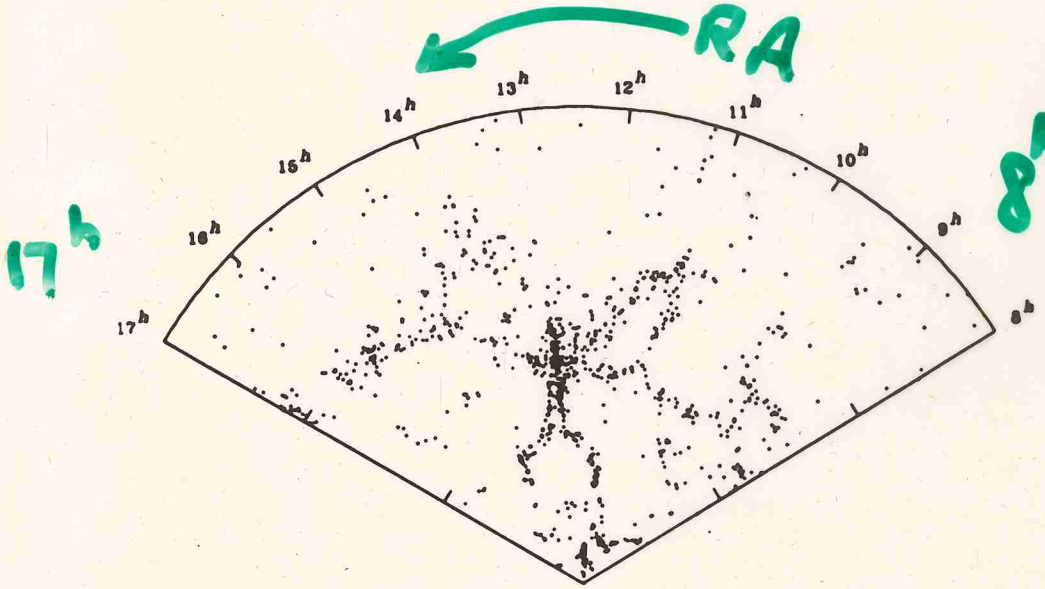
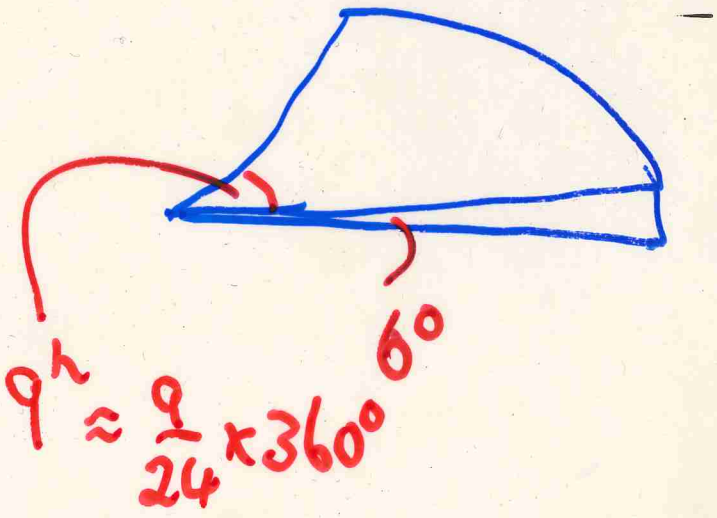
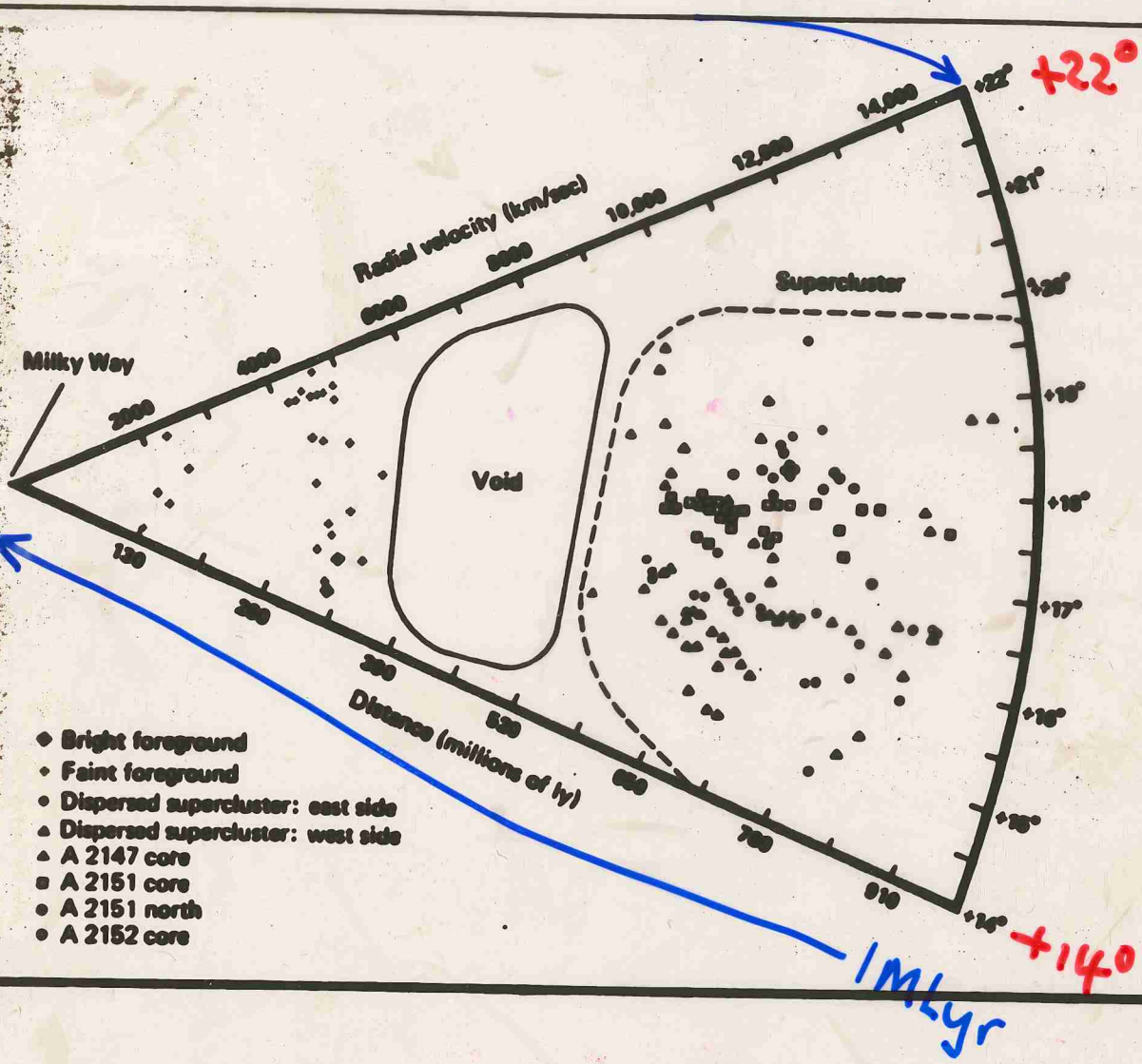


Figure 29–12 The wedge shows velocity versus angle across our sky (right ascension) in a strip (declination) 6° across. All 1061 galaxies in the strip brighter than magnitude 15.5 are plotted. We see giant bubbles, like the suds in a kitchen sink. The Coma Cluster of galaxies is in the center, apparently at the intersection of several bubbles. (Valerie de Lapparent, Margaret J. Geller, and John P. Huchra, Harvard-Smithsonian Center for Astrophysics)



- VOIDS
- FILAMENTS

(1/200) speed of light



19.21

A slice of the Hercules supercluster. Shown here are the red shifts (and so distance, for H = 15 km/sec/Mly) and positions in the sky for the galaxies in the supercluster, which contains a number of clusters (labeled Abell 2147, 2151, and 2152). The Milky Way lies at the vertex of this pie diagram. Note the void in front of the supercluster. (Adapted from a diagram by M. Tarenghi, W. Tifft, G. Chincarini, H. Rood, and L. Thompson, Astrophysical Journal, vol. 234 (1979), p. 793)

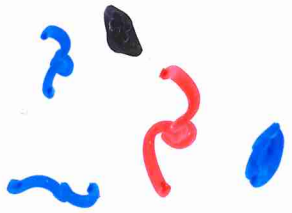
PIE-CUT

USES REDSHIFT (EXP. VELY) TO GET DISTANCE

- VOIDS !
- SUPERCLUSTER (HERCULES)

STRUCTURE AT GREATER DISTANCES ?

GALAXY CLUSTERS : 1ST EVIDENCE OF DARK MATTER



- COLLECTION OF GALAXIES ALL AT VERY SIMILAR REDSHIFTS

- MEASURE RADIAL VELOCITIES

  → LARGE SPREAD IMPLYING GALAXIES ARE DISPERSING UNLESS MASS OF CLUSTER SUFFICIENTLY HIGH TO RESTRAIN GALAXYS' ESCAPE

  → MASS ESTIMATED FROM LUMINOSITY INADEQUATE ∴ ADD DARK MATTER, OR CLUSTER SHOULD HAVE DISPERSED.