Cosmology and the origin of structure

Rocky I: The universe observed

Rocky II: The growth of cosmological structure

Rocky III: Inflation and the origin of perturbations

Rocky IV: Dark matter and dark energy

Academic Training Lectures

Rocky Kolb

Fermilab, University of Chicago, & CERN

Seeds of structure

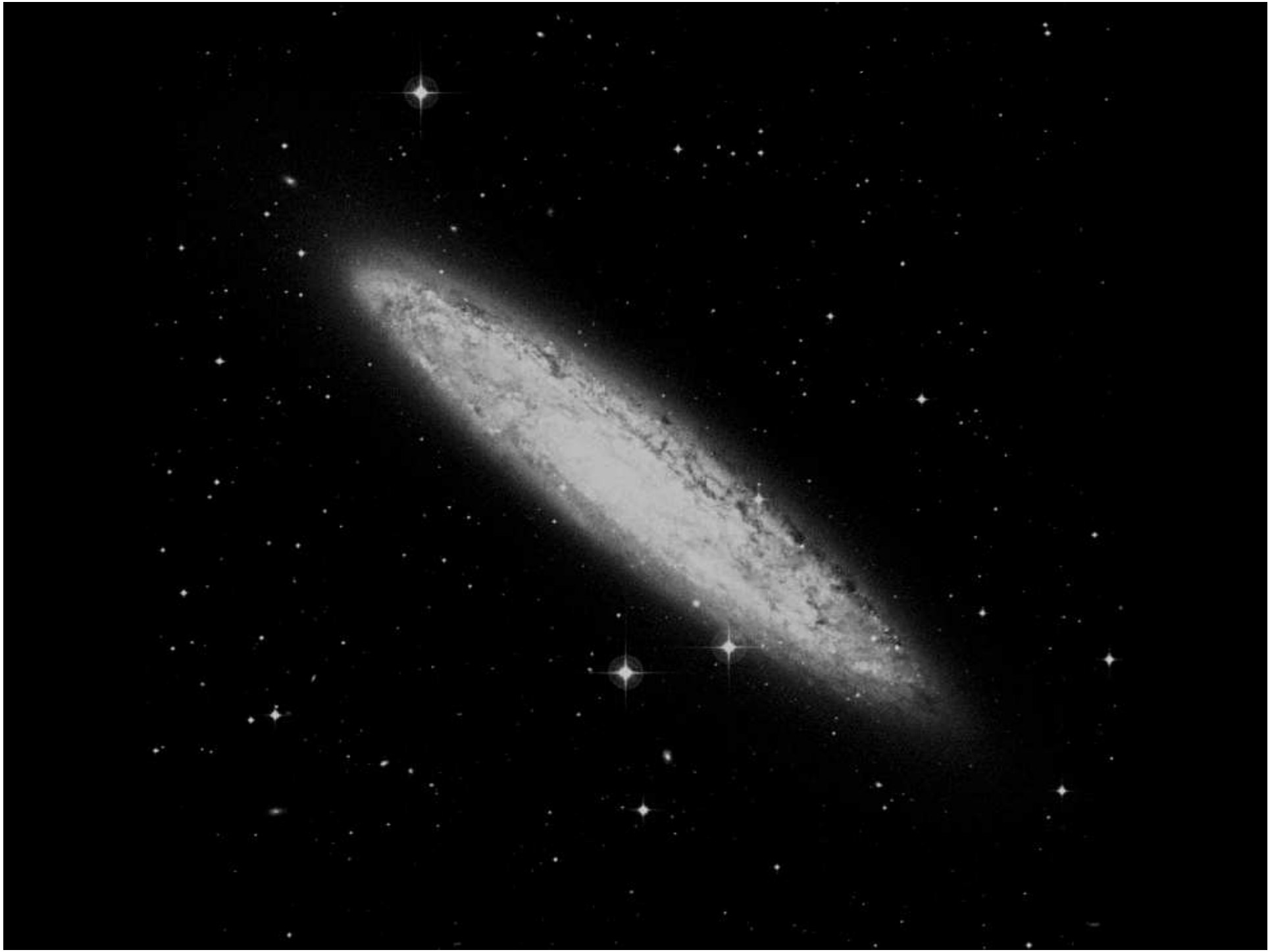
origin of small initial perturbations

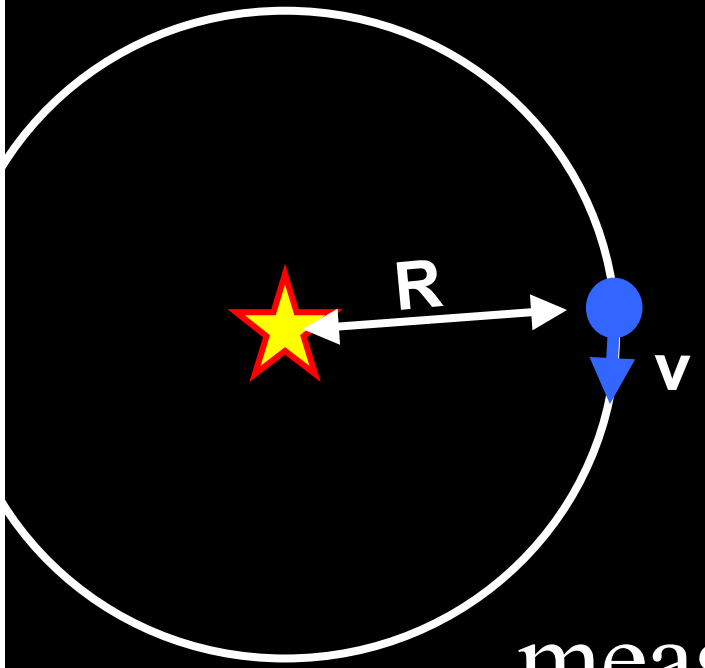
nature of the damn little black dots

time

Missing Pieces

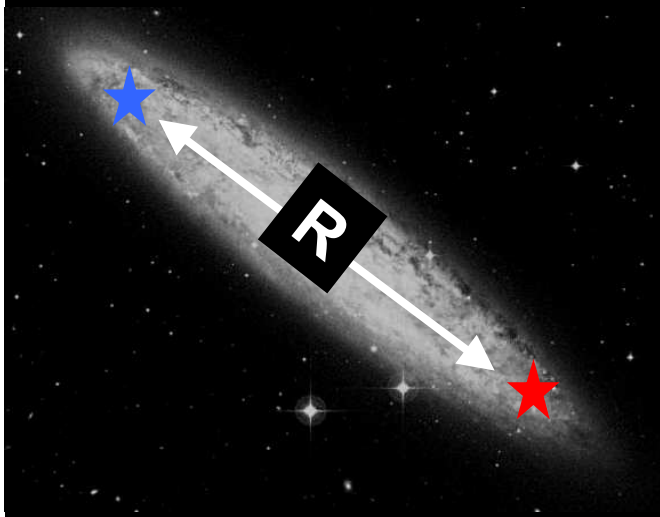
Dark Matter





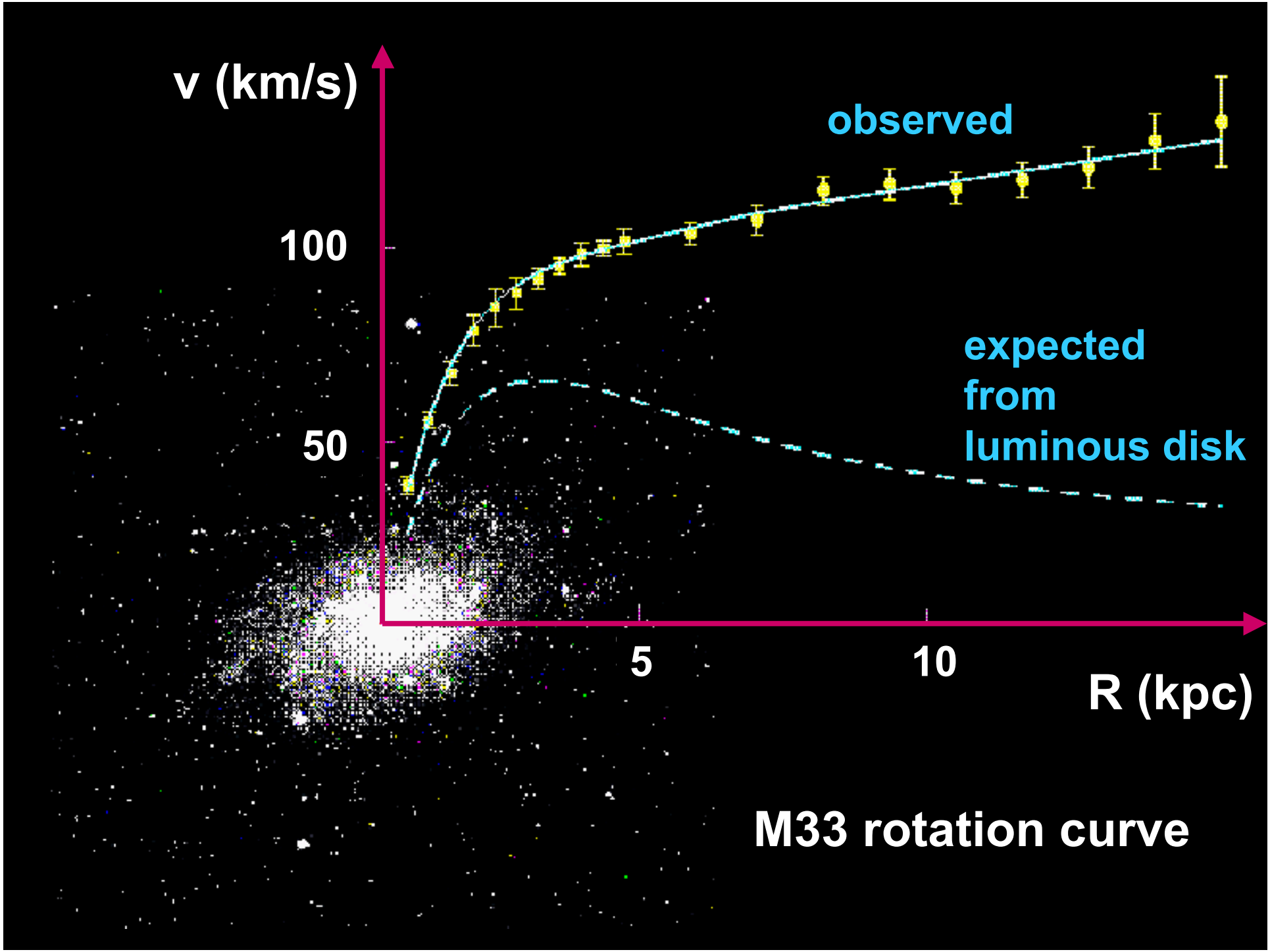
$$\frac{v^2}{R} = \frac{GM_{\odot}}{R^2}$$

measure v and R $\Rightarrow$ $M_{\odot}$



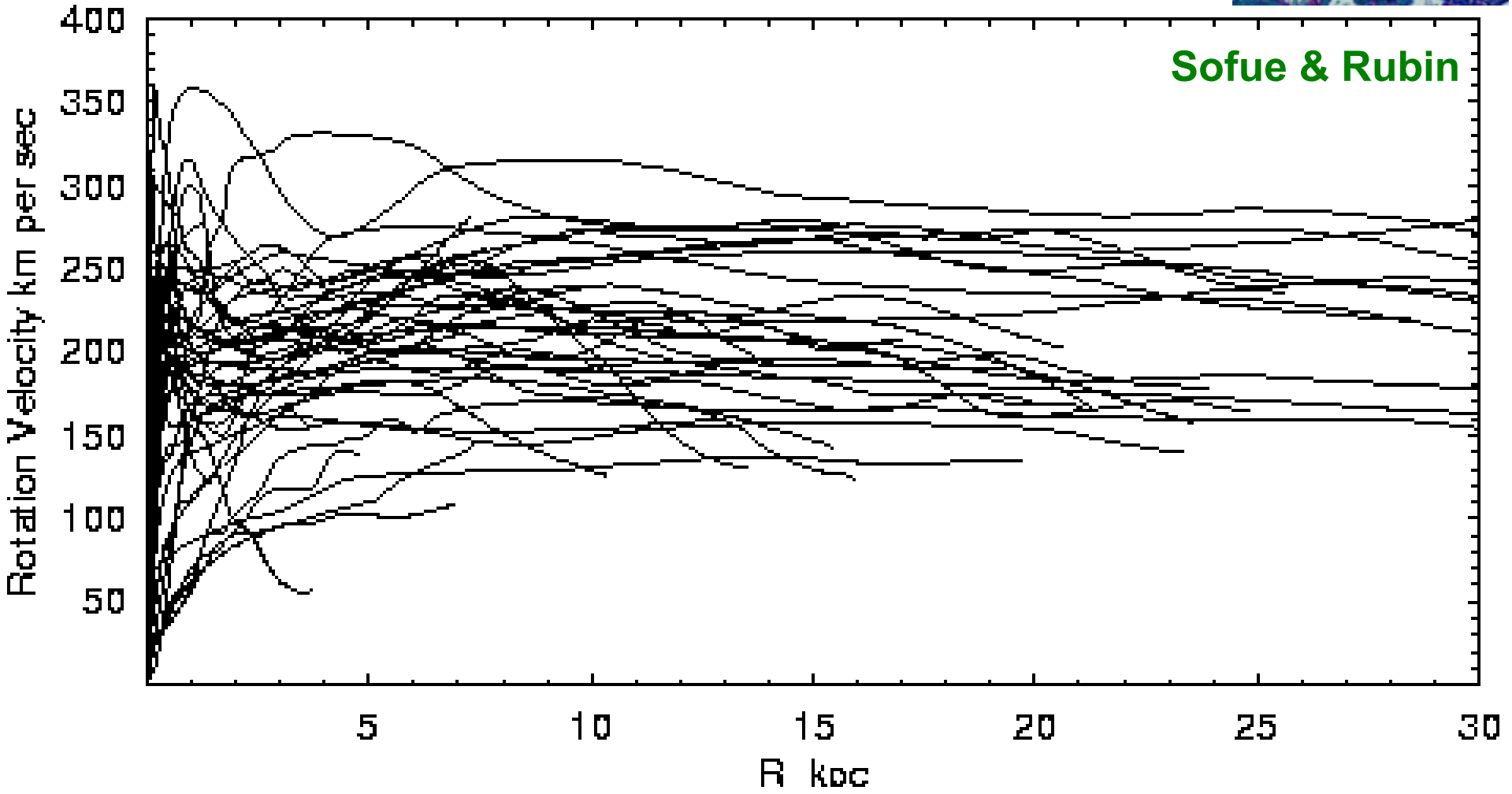
$$\frac{v^2}{R} = \frac{GM_{\text{GALAXY}}}{R^2}$$

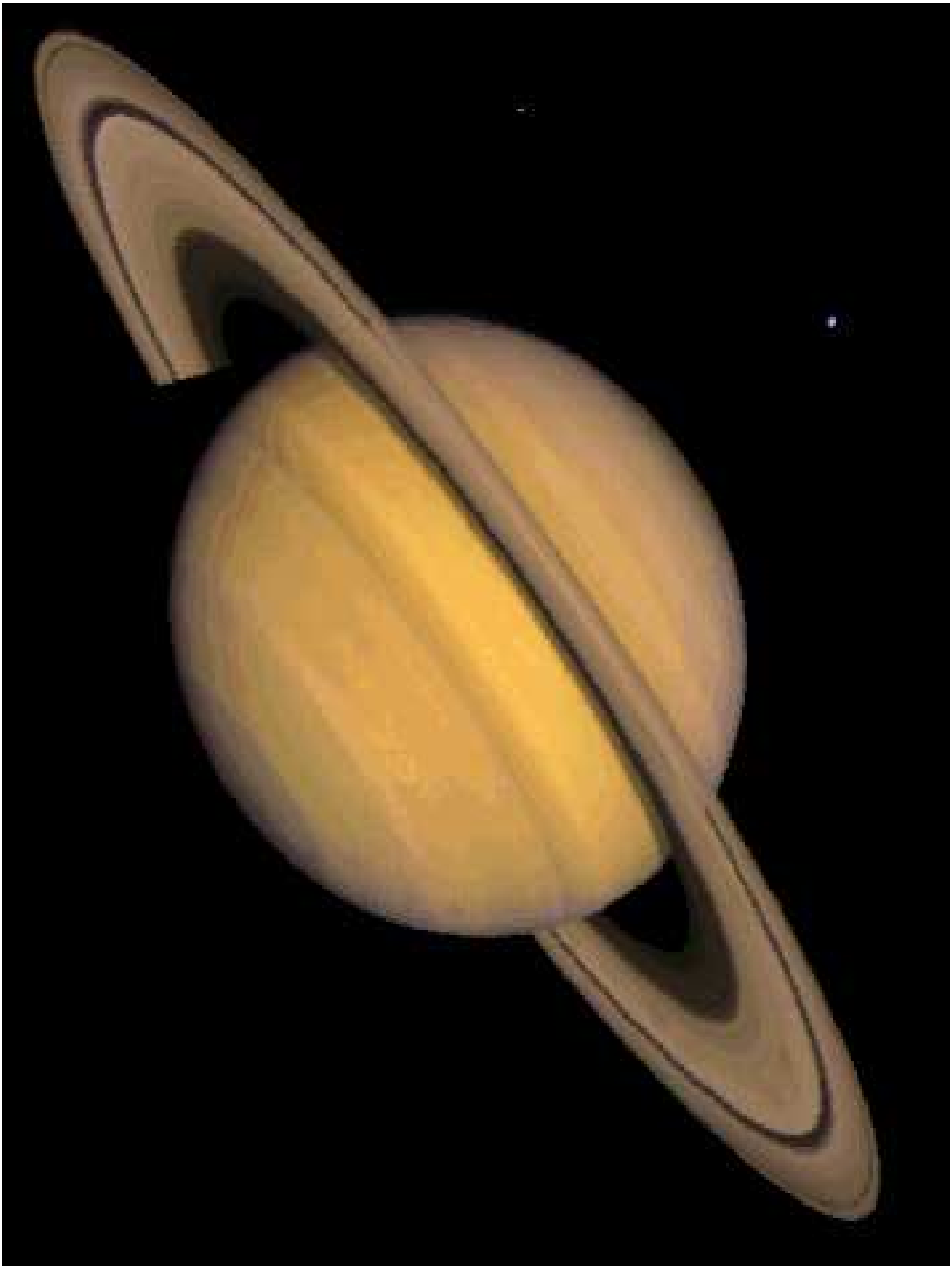
measure v and R $\Rightarrow$ M_{GALAXY}

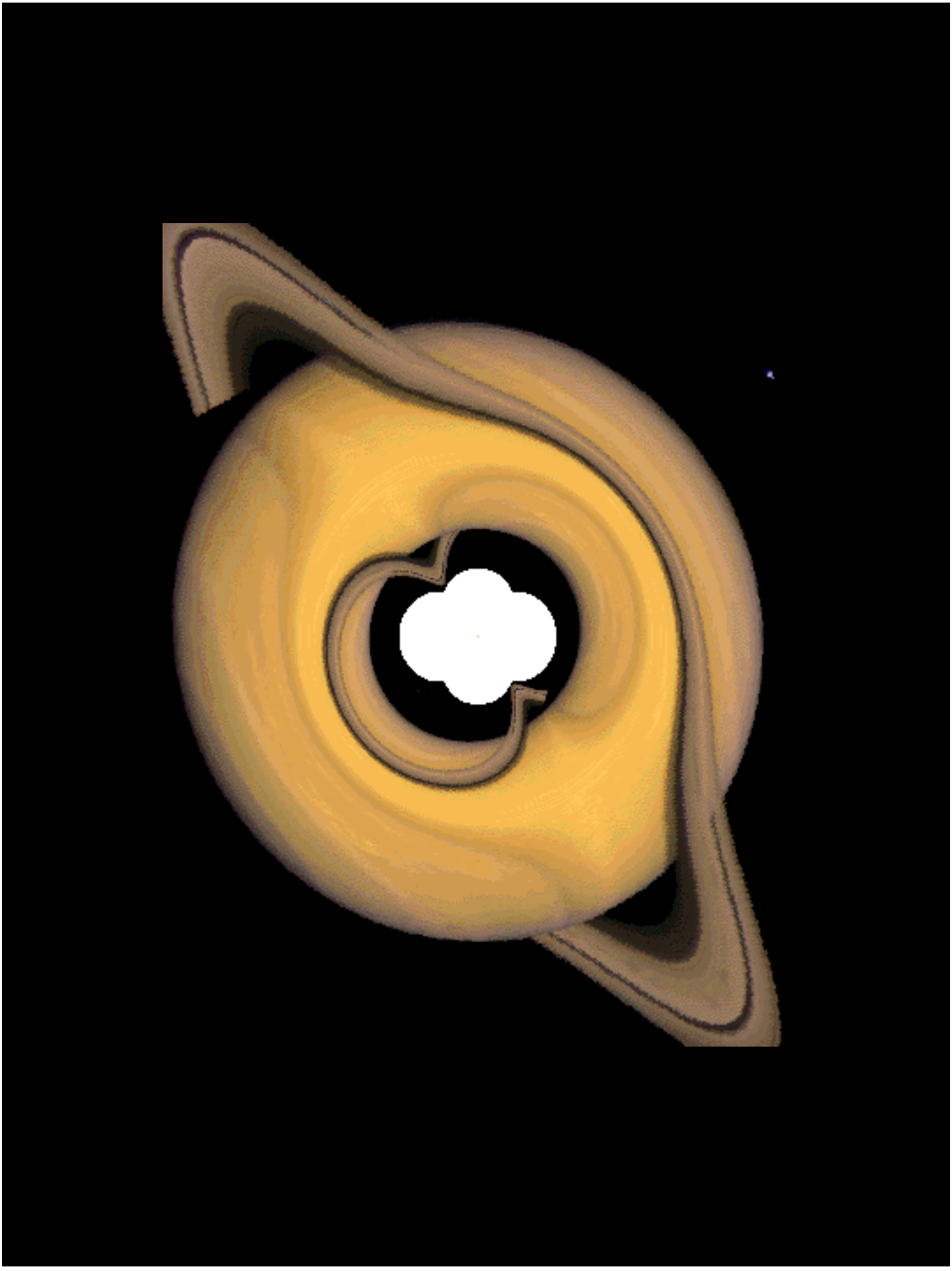

v (km/s)
observed
100
expected
from
luminous disk
50
5
10
R (kpc)
M33 rotation curve

Rotation curves

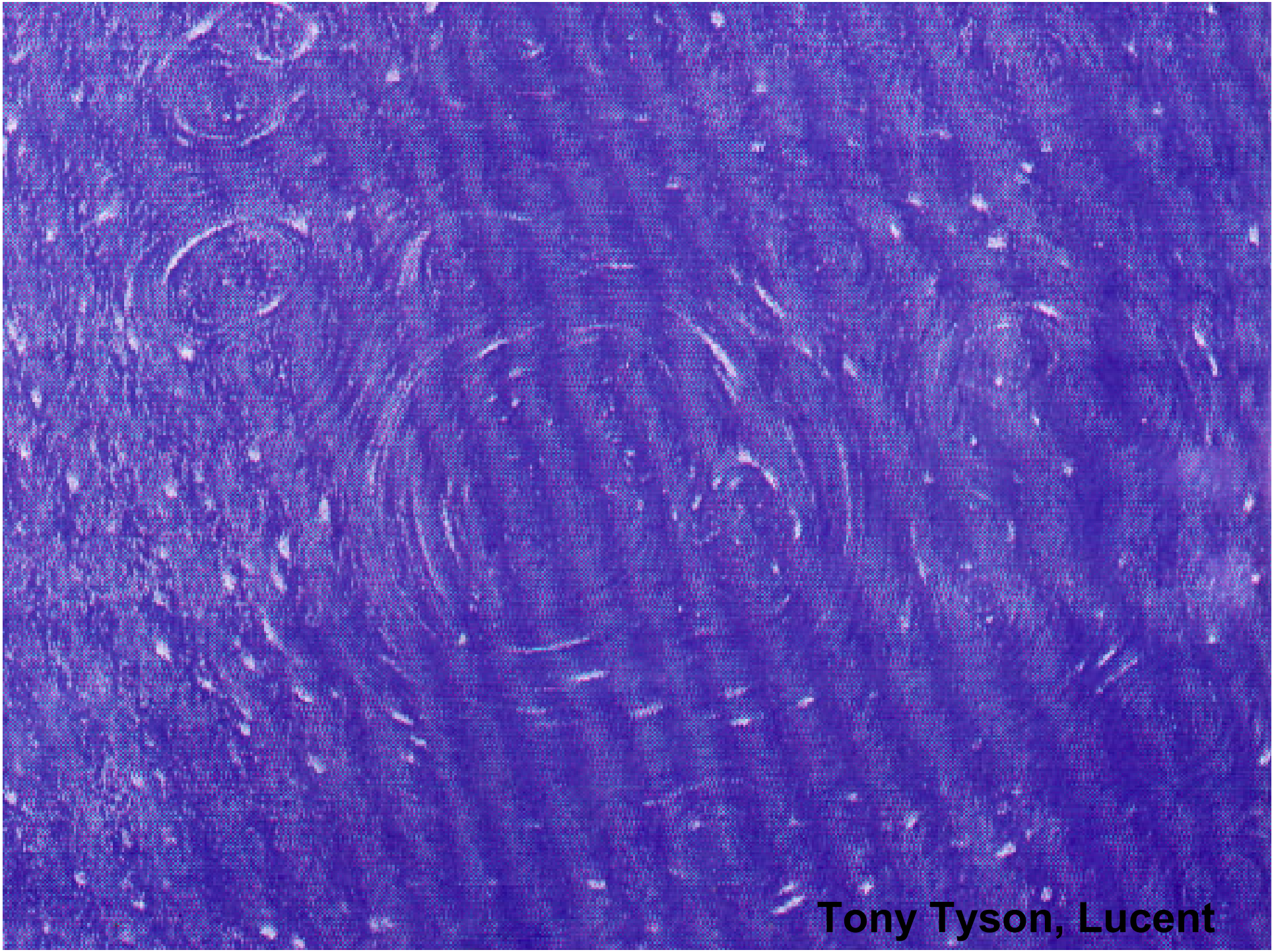
CO – central regions
Optical – disks
HI – outer disk & halo

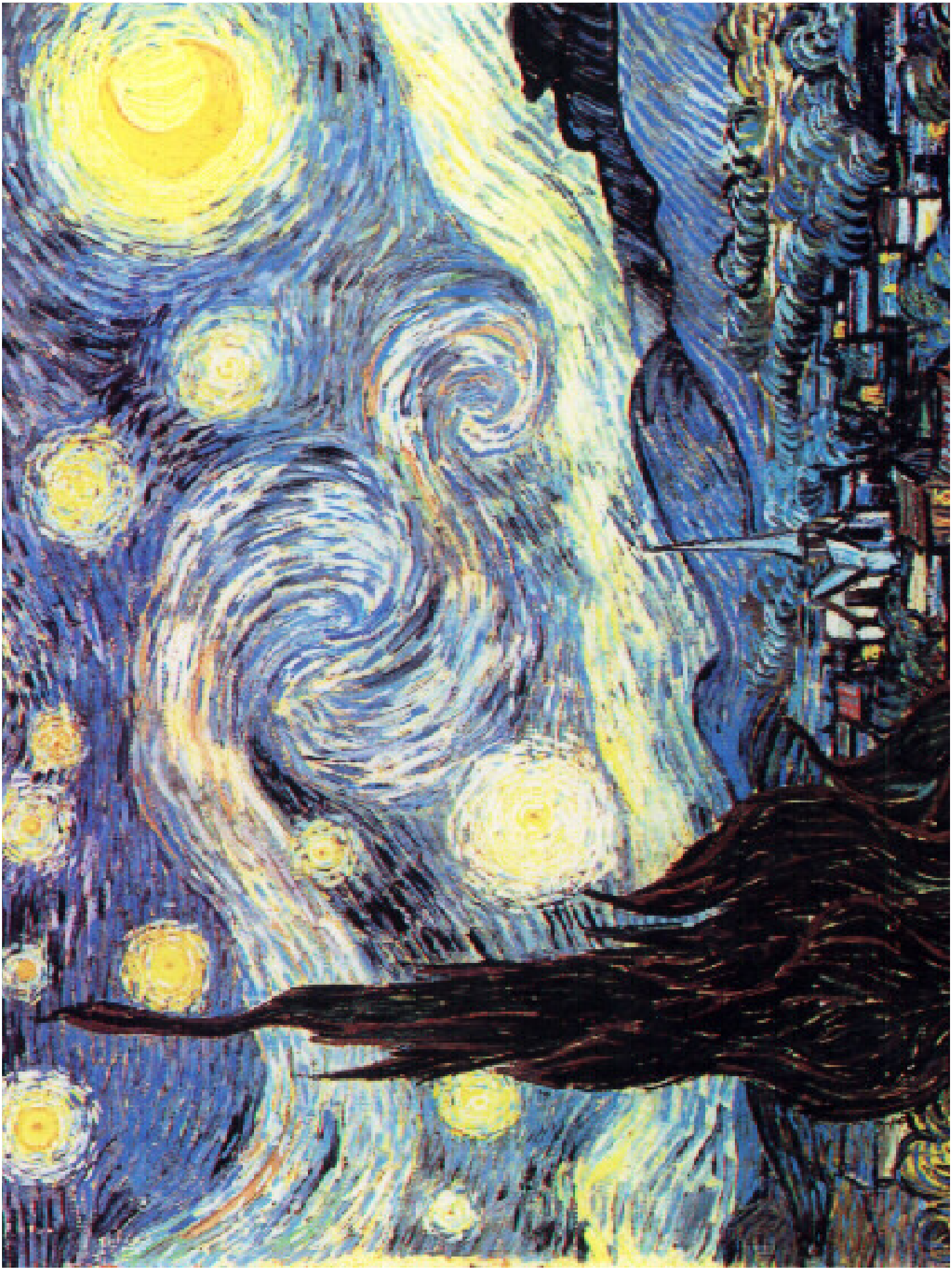




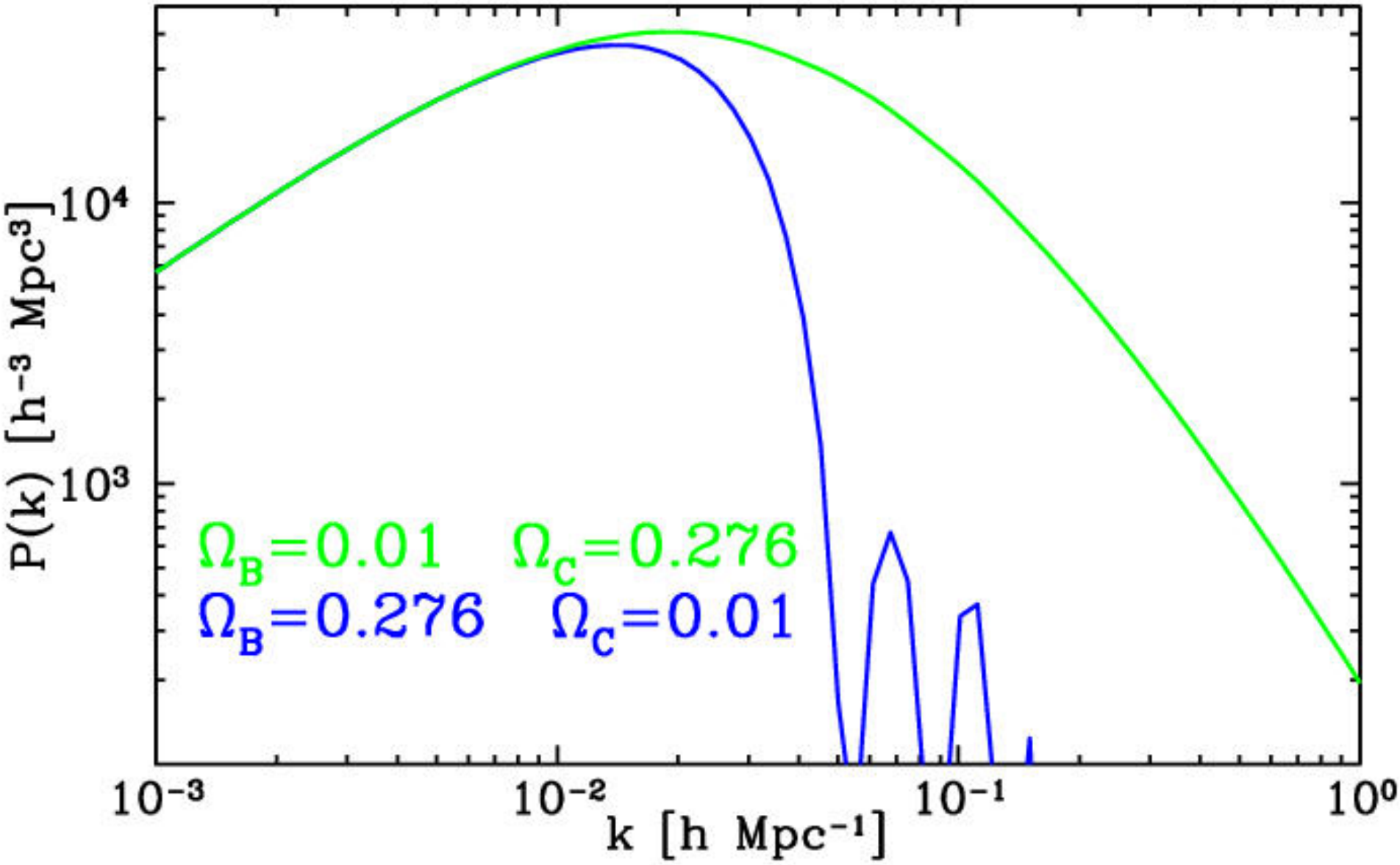


Gravitational Lens
Galaxy Cluster 0024+1654
Hubble Space Telescope • WFPC2


Tony Tyson, Lucent



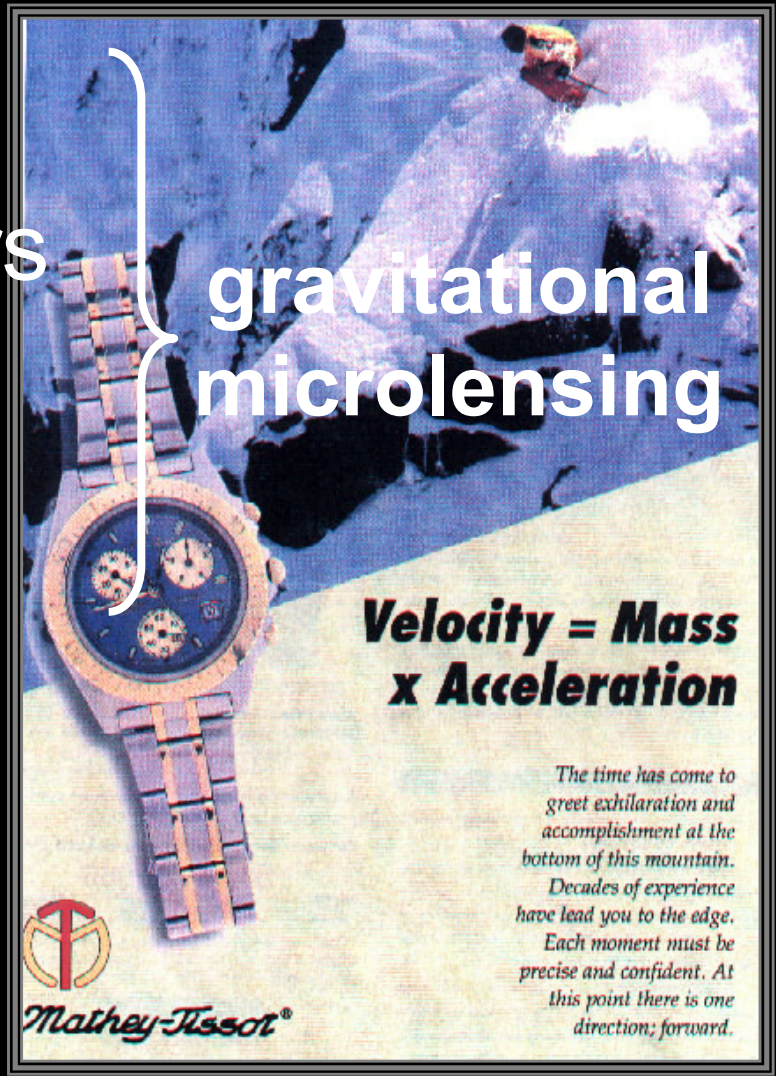
The evolved spectrum

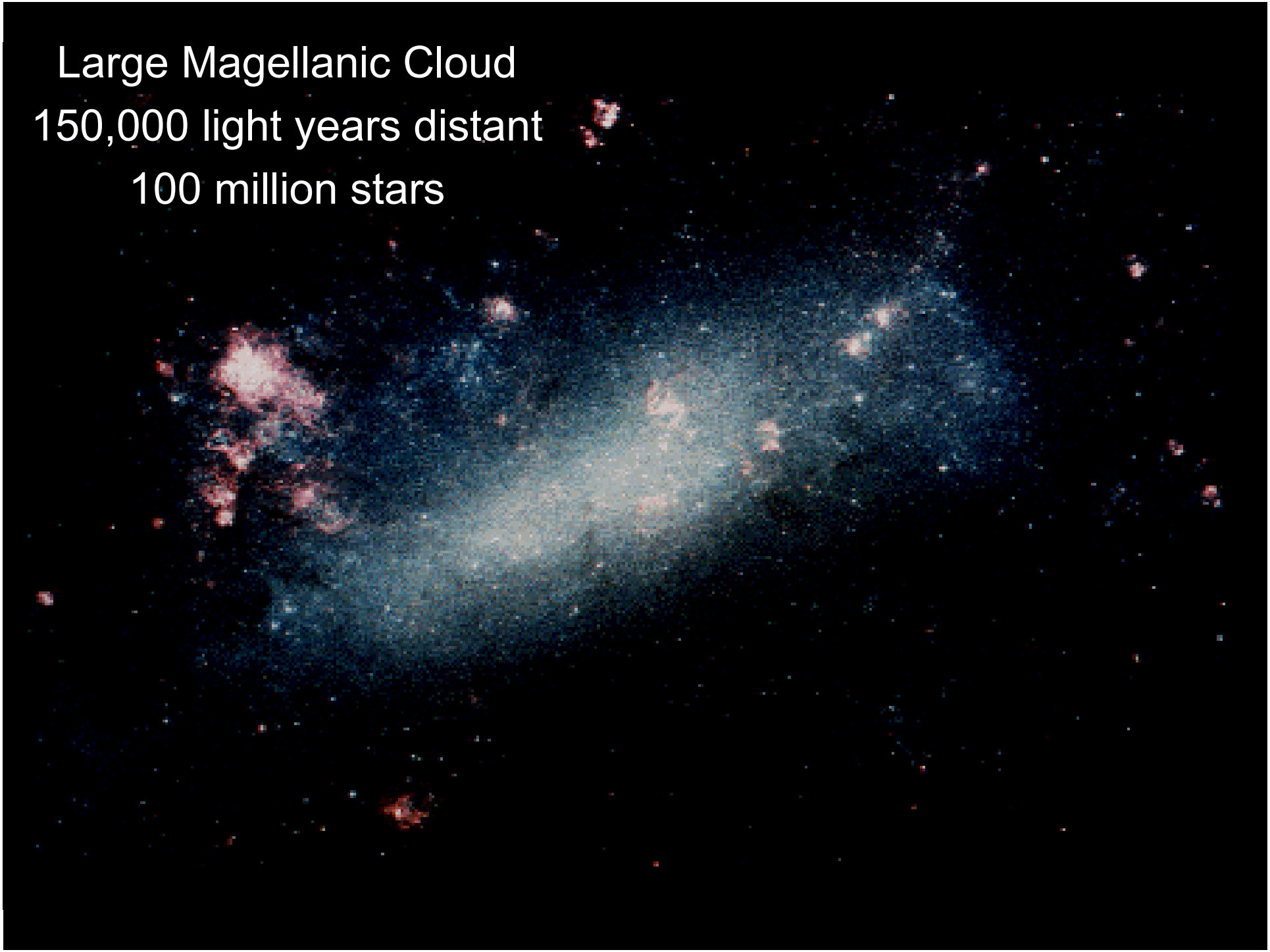


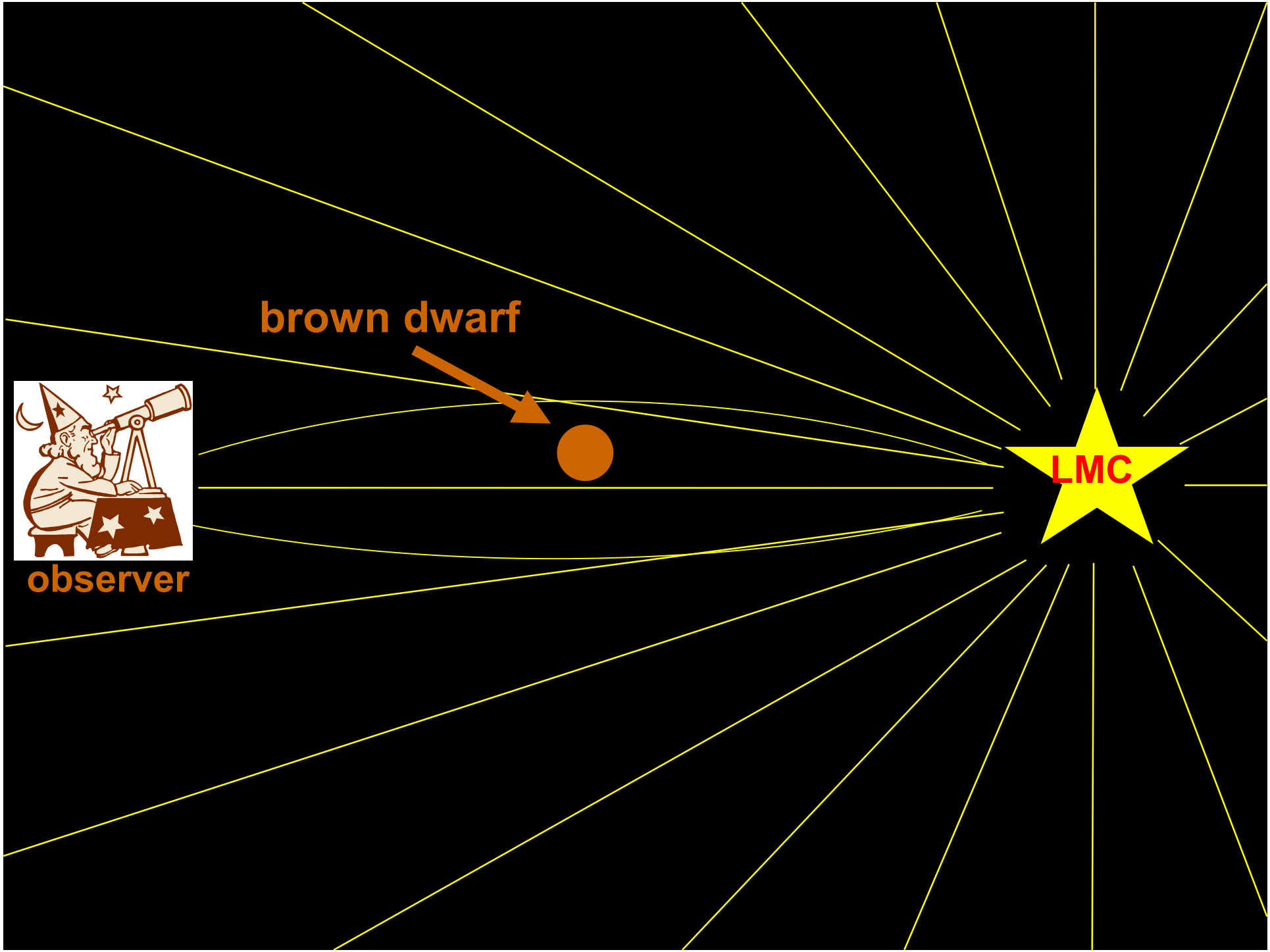
Most of the universe is dark!

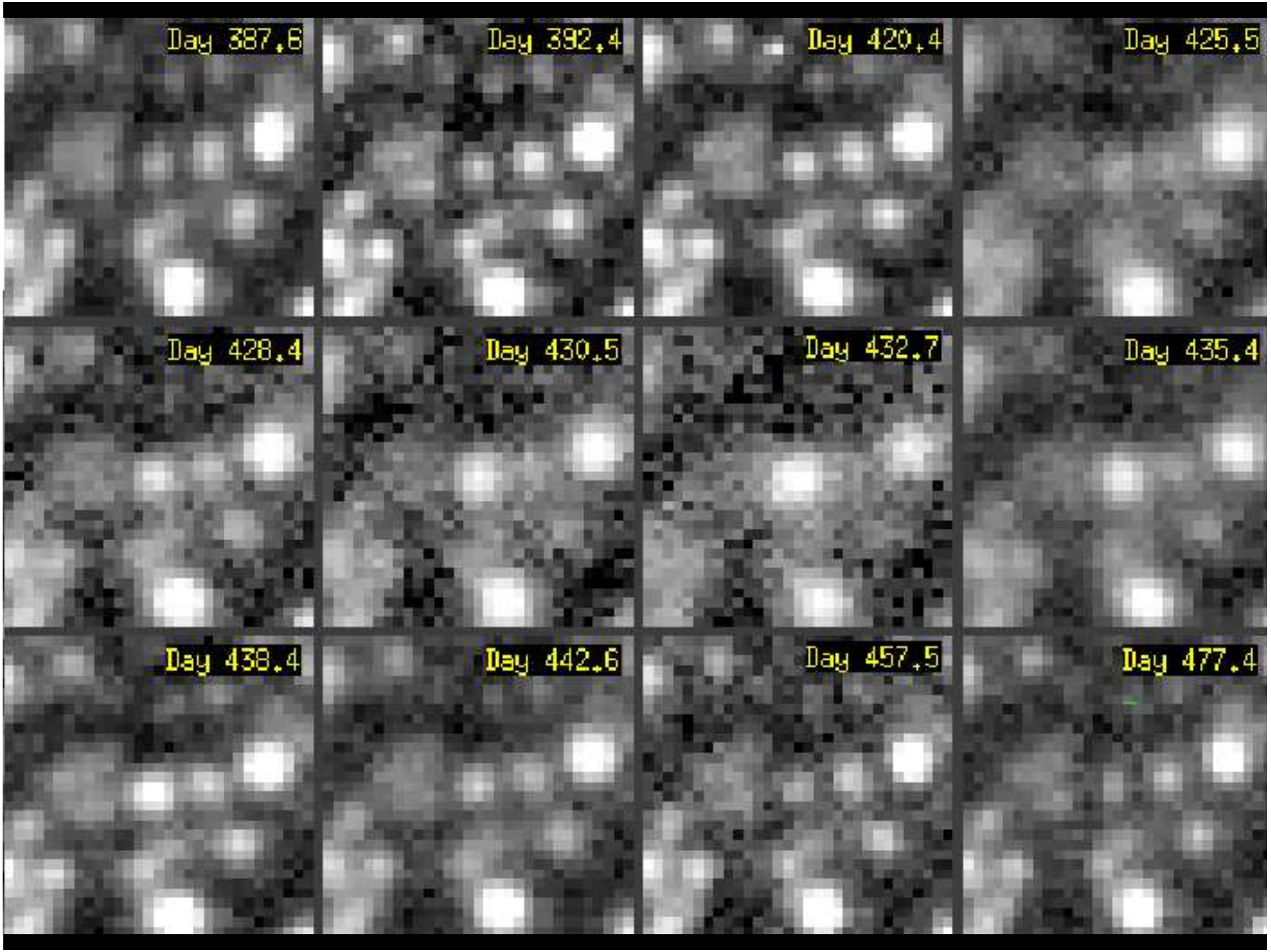
- Modified Newtonian dynamics
- Planets
- Mass disadvantaged stars

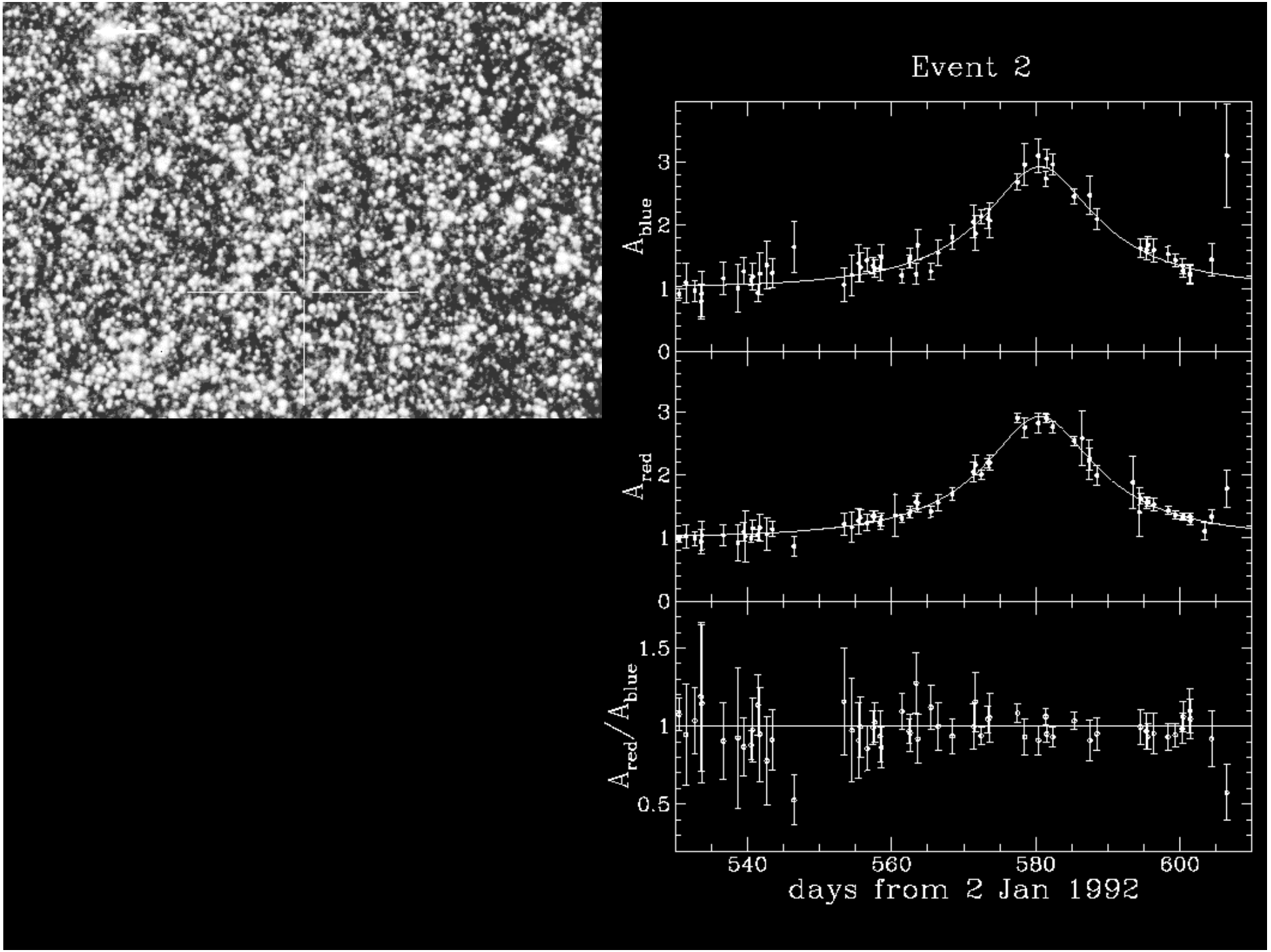
  brown red white
- Black holes



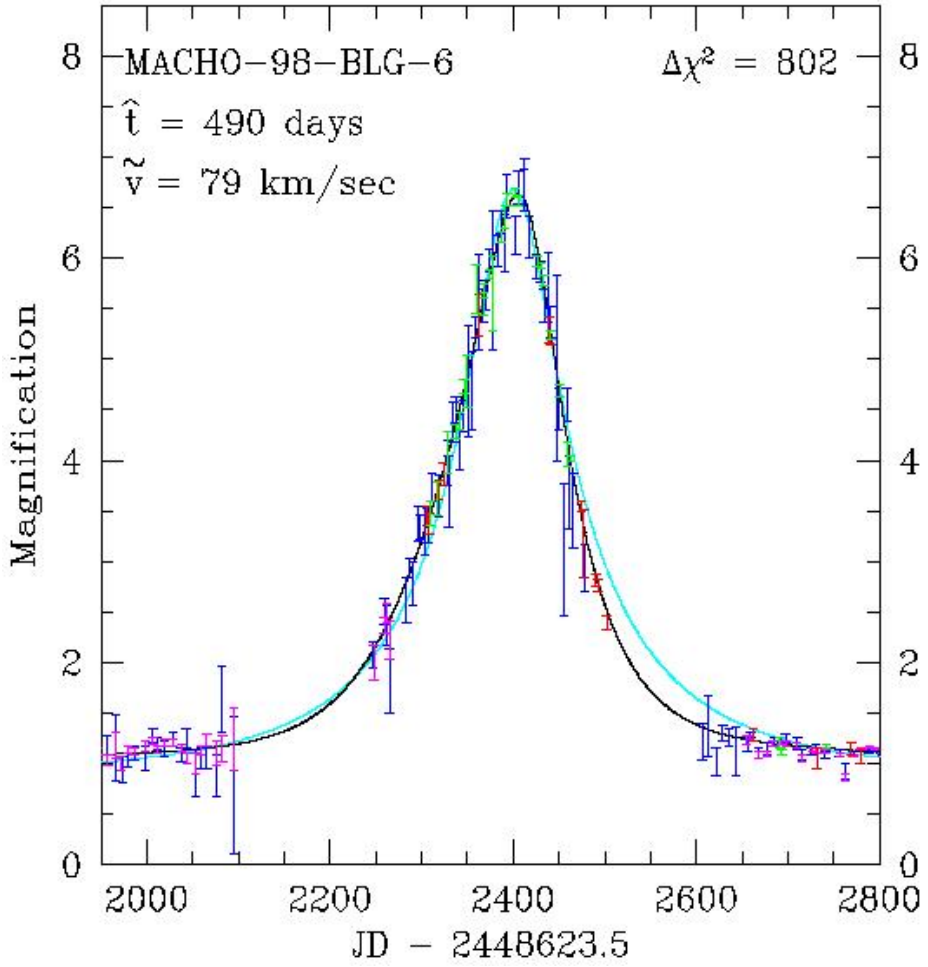

Large Magellanic Cloud
150,000 light years distant
100 million stars

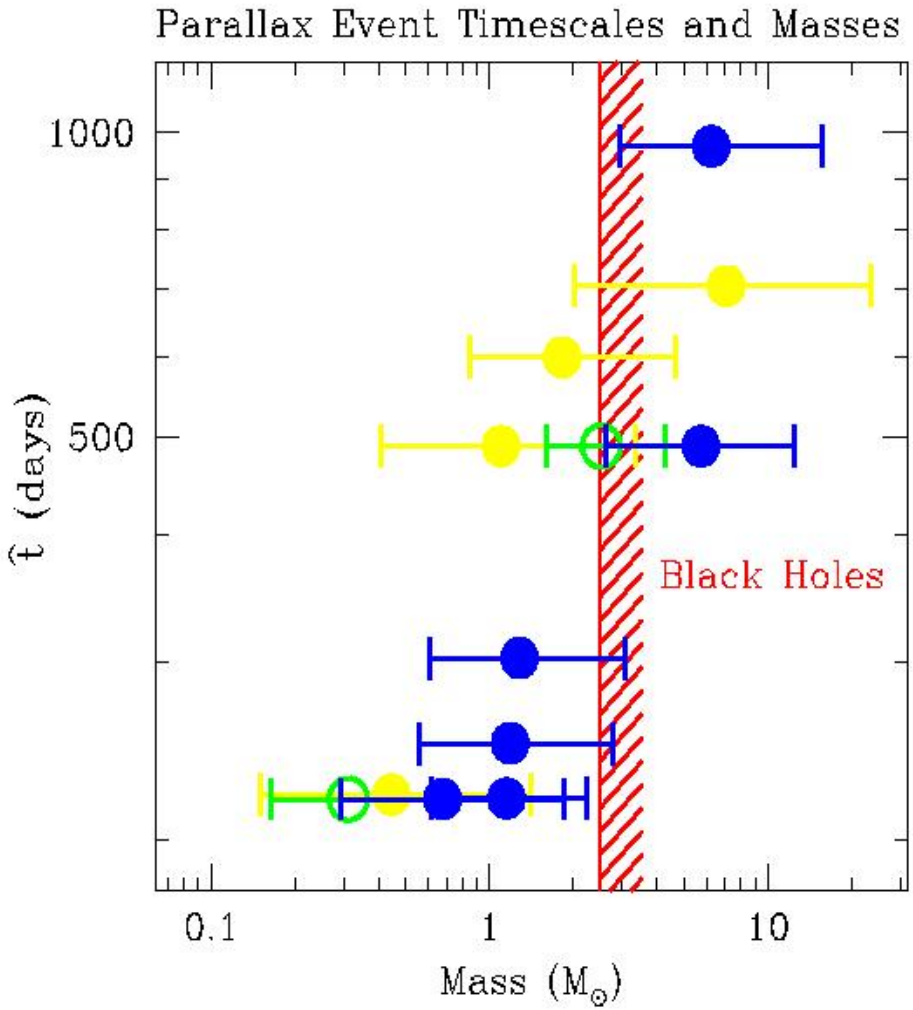

brown dwarf
LMC
observer


Day 387.6
Day 392.4
Day 420.4
Day 425.5
Day 428.4
Day 430.5
Day 432.7
Day 435.4
Day 438.4
Day 442.6
Day 457.5
Day 477.4


Event 2
A_{blue}
A_{red}
A_{red}/A_{blue}
0
1
2
3
0.5
1.5
540
560
580
600
days from 2 Jan 1992

Microlensing black-hole candidates





Bennett et al.
(also Mao et al.)

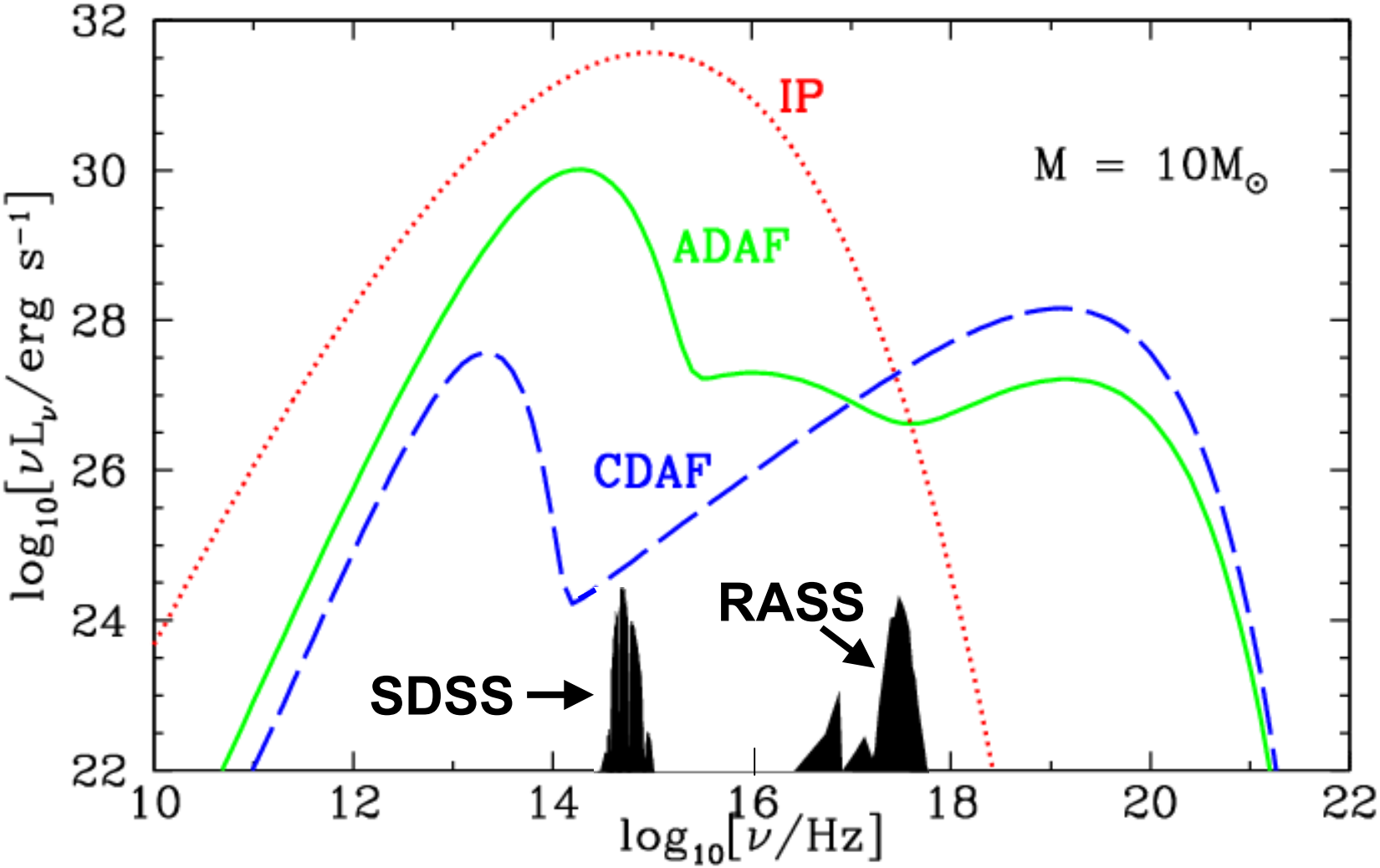
Stellar Mass Black Holes In the Solar Neighborhood

(with Jim Chisholm & Scott Dodelson)

Model spectral energy distributions:

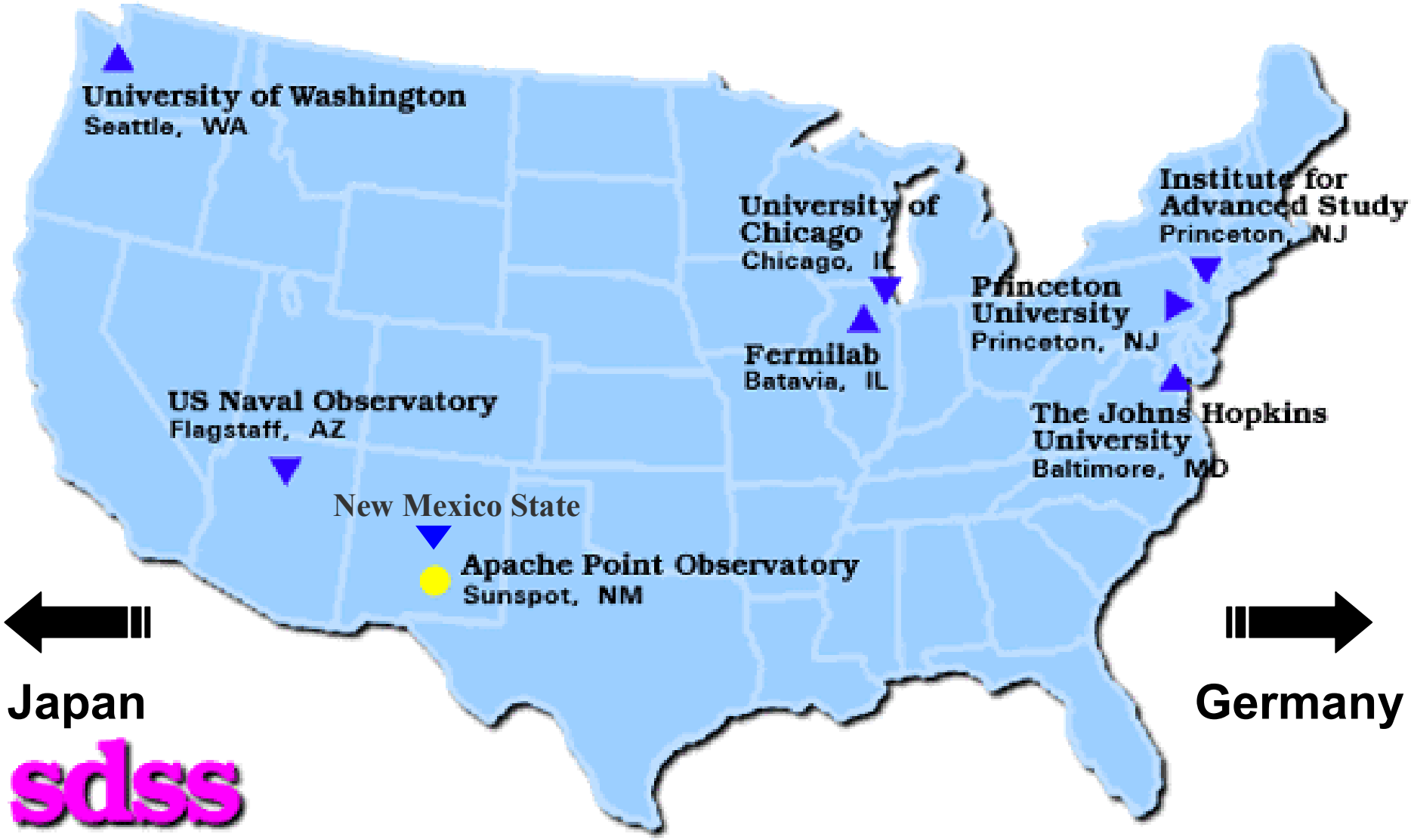
$$L = \int \frac{d\nu}{\nu} \nu L_\nu$$

$\nu L_\nu =$ spectral energy distribution (contribution per decade)

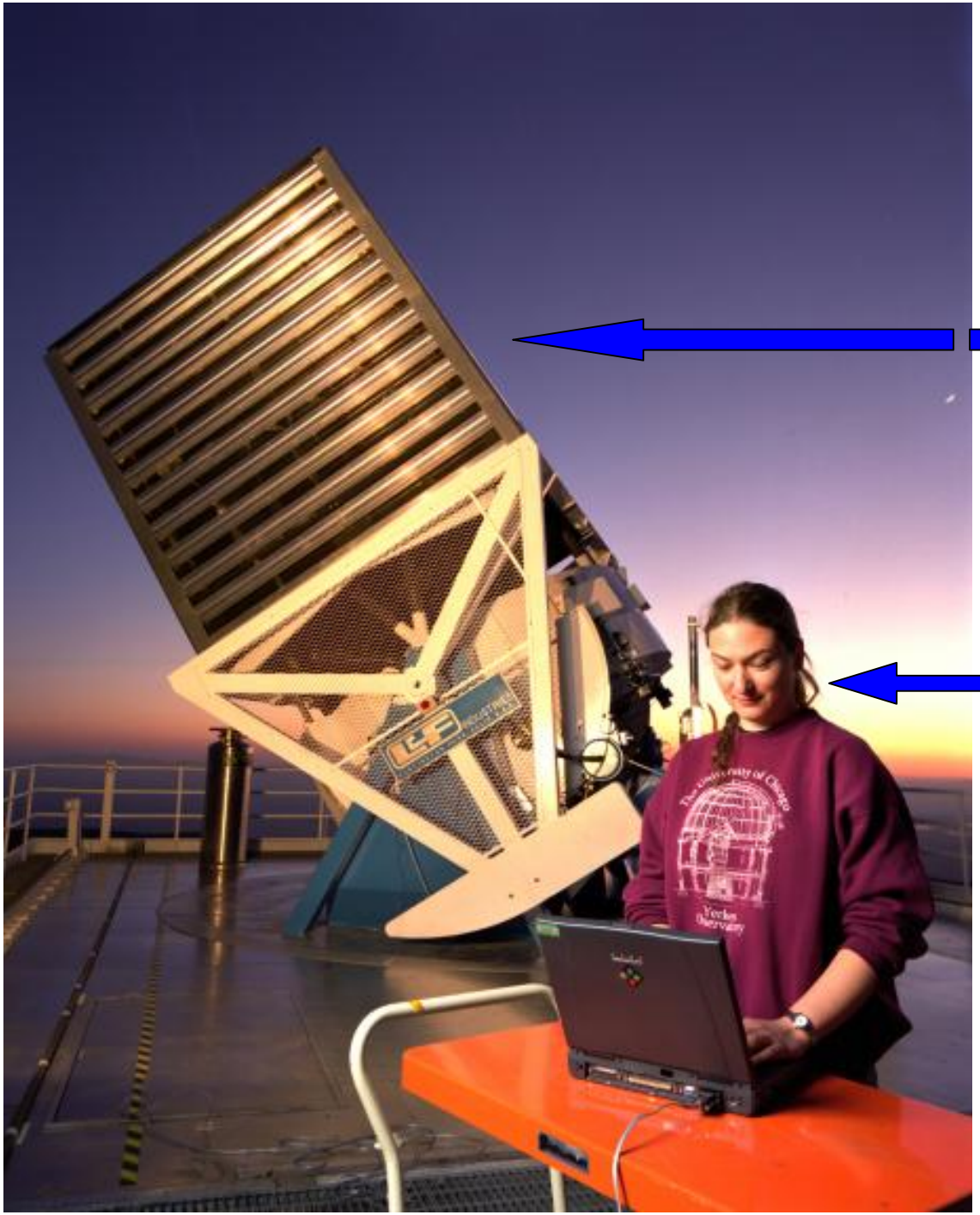


Sloan: a 2.5m telescope & instruments to

1. image the sky to 23rd mag in 5 colors (10^9 objects)
2. take the spectra of 10^6 objects (mostly extragalactic)

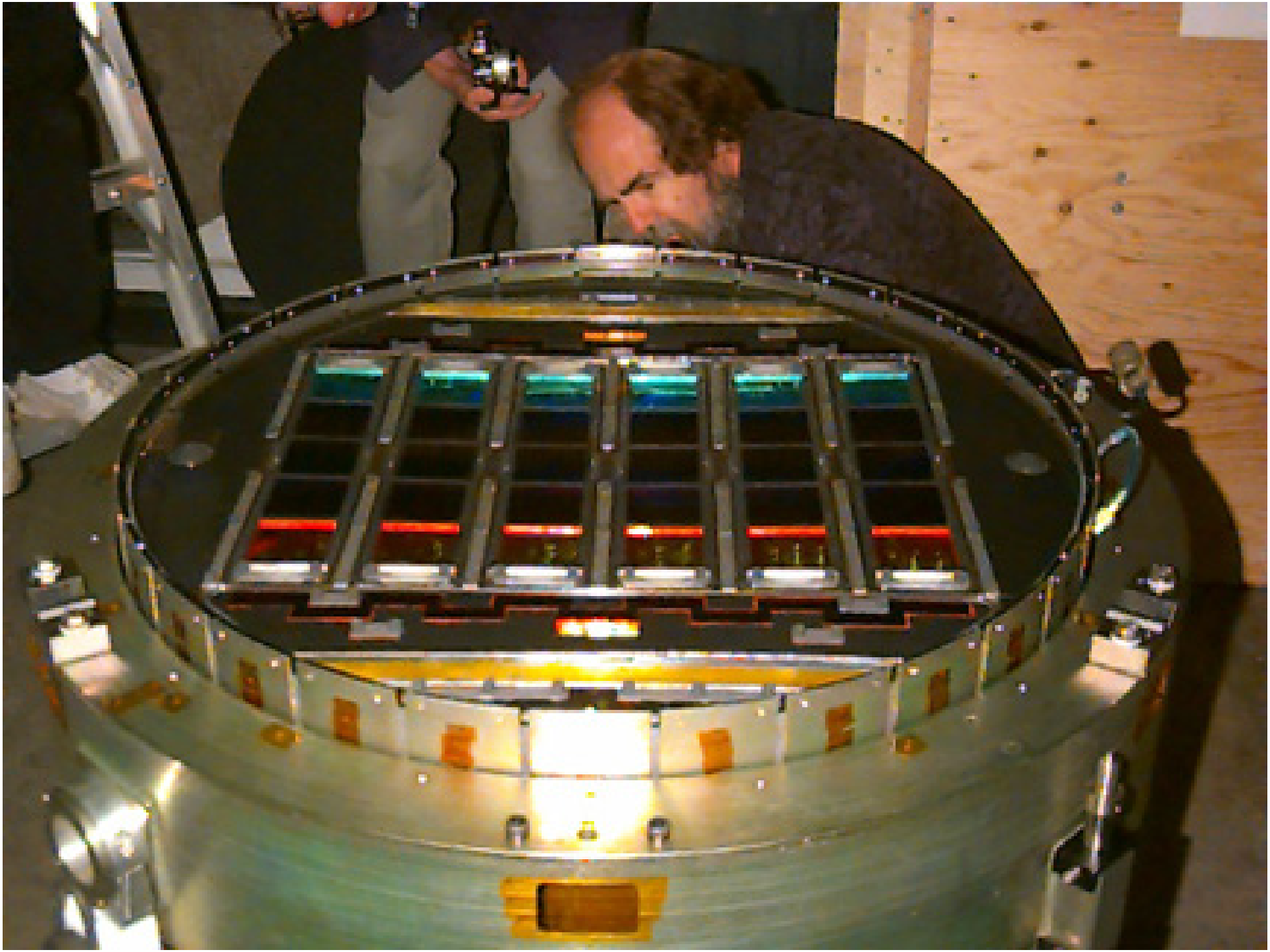


SDSS

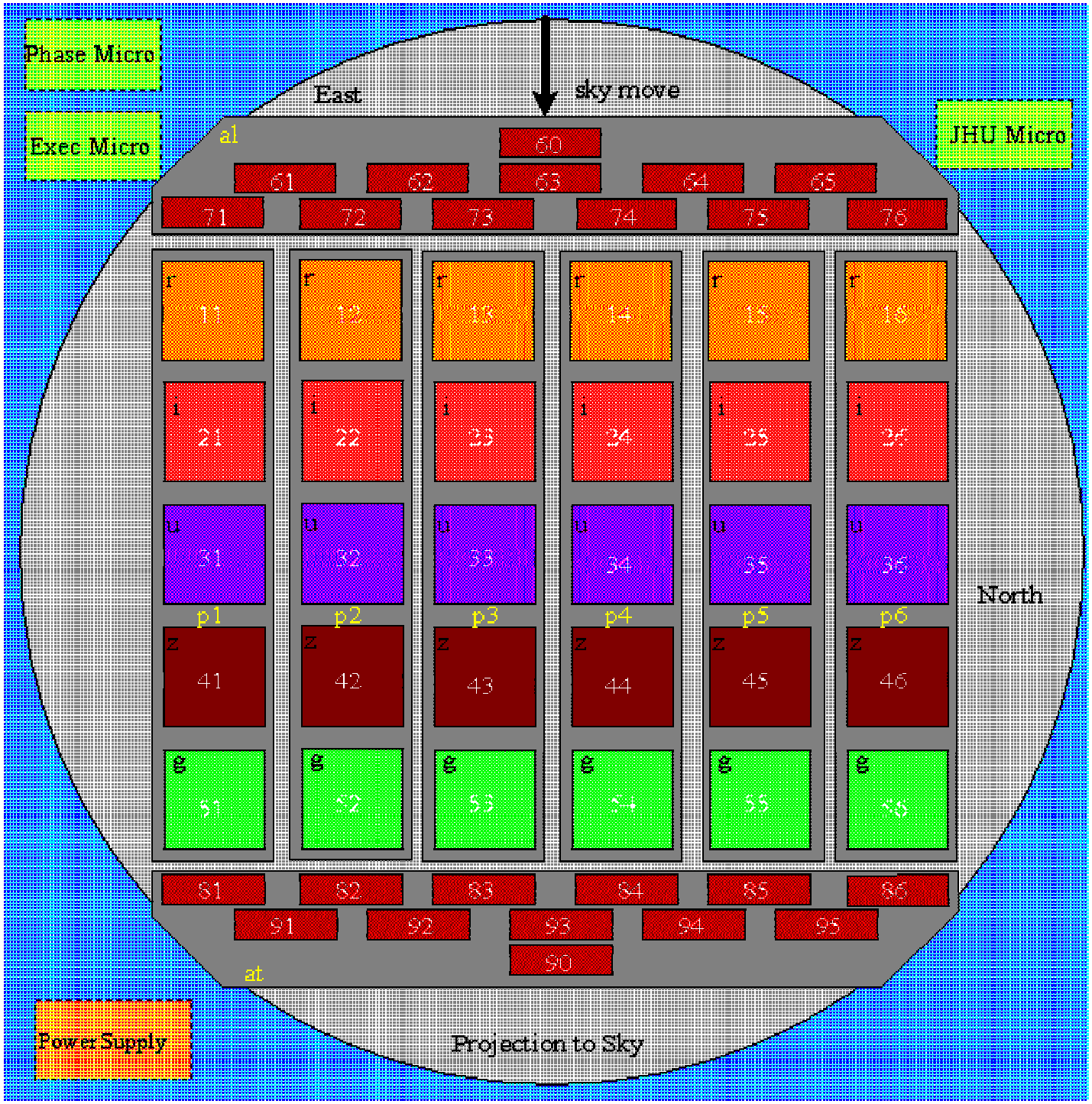


2.5 m telescope

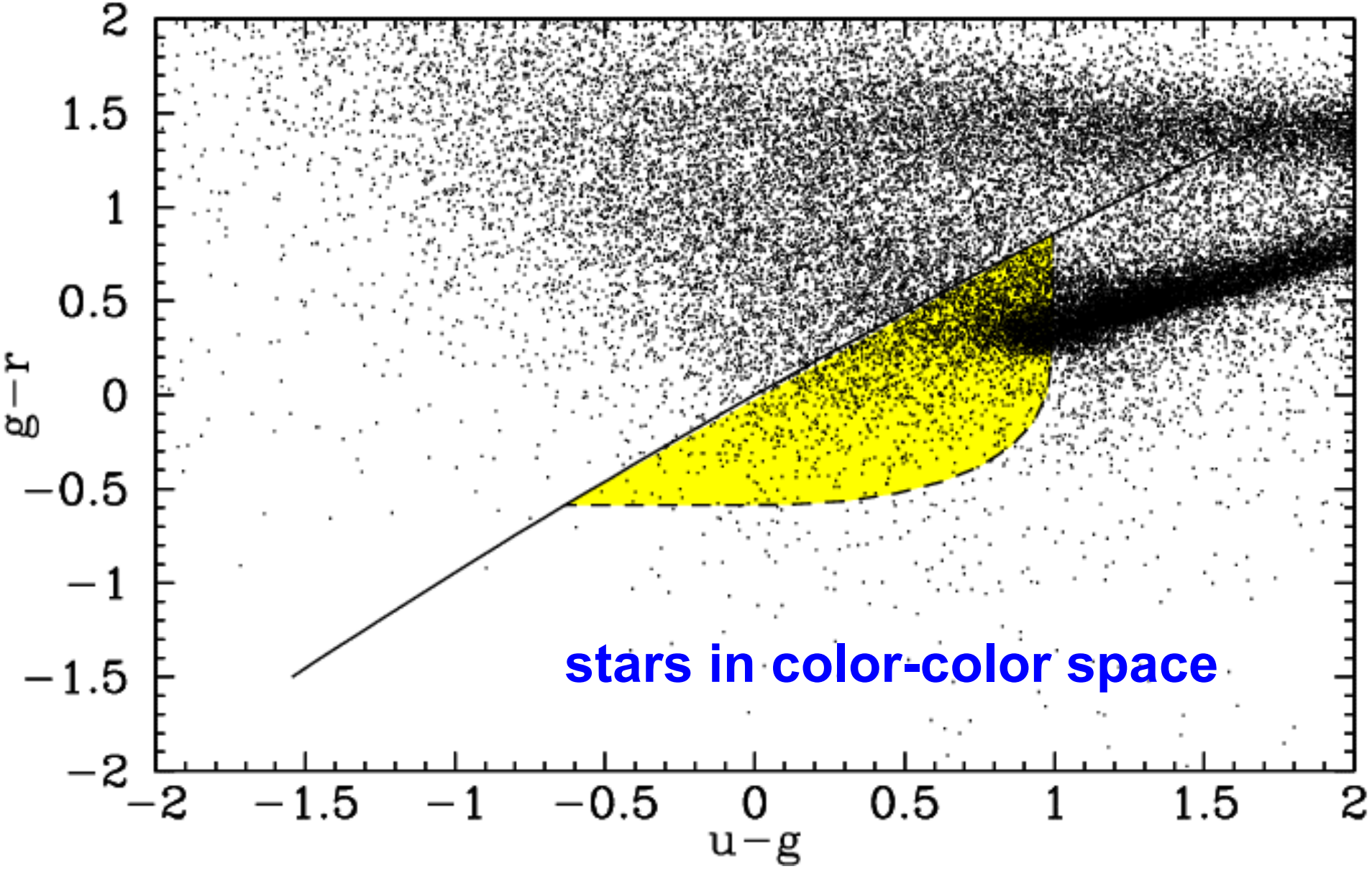
data acquisition system



SDSS camera


Phase Micro
Exec Micro
East
sky move
JHU Micro
a1
60
61
62
63
64
65
71
72
73
74
75
76
r
11
12
13
14
15
16
i
21
22
23
24
25
26
u
31
32
33
34
35
36
p1
p2
p3
p4
p5
p6
z
41
42
43
44
45
46
g
51
52
53
54
55
56
North
81
82
83
84
85
86
91
92
93
94
95
90
at
Power Supply
Projection to Sky

Color-color space

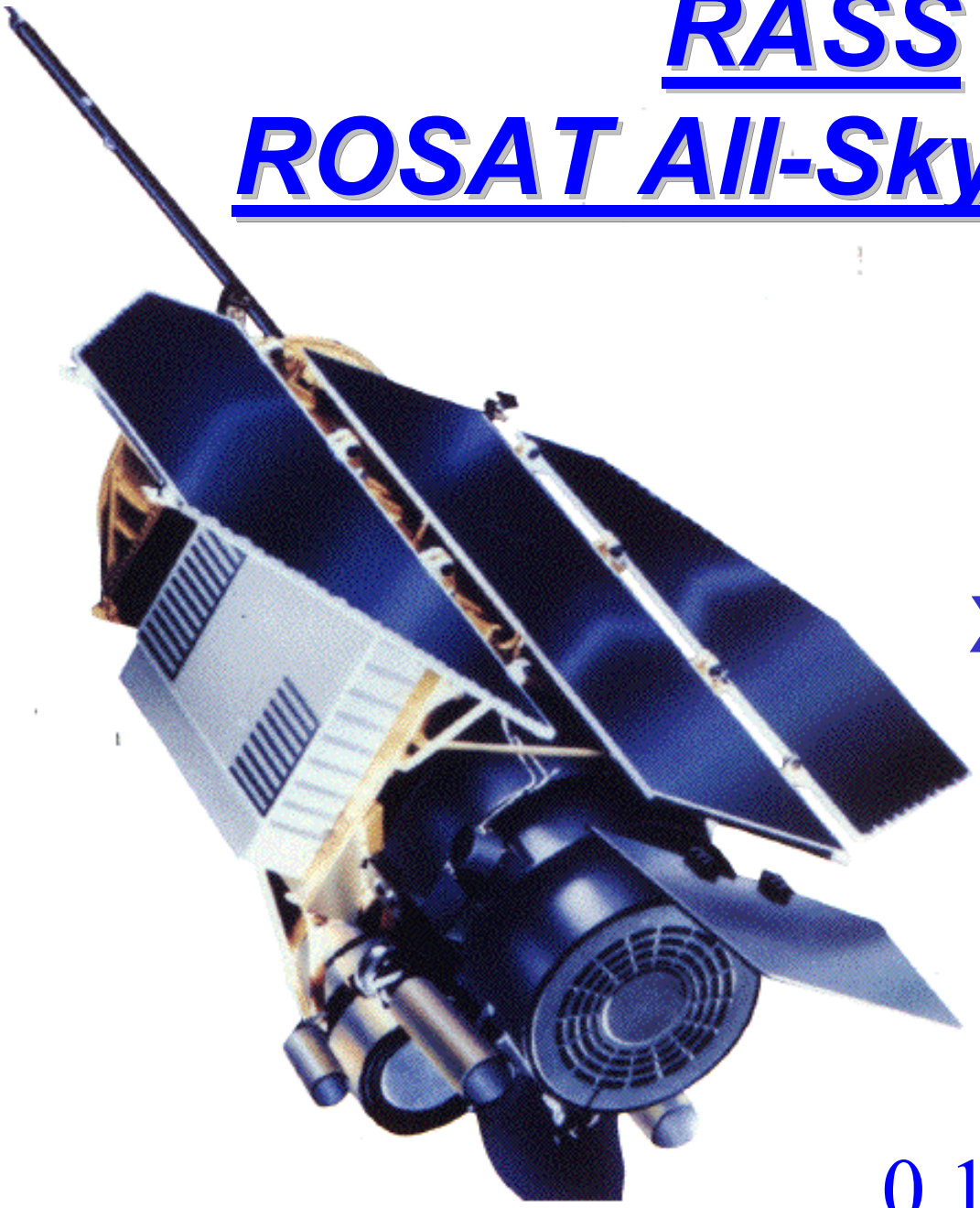


Color-color cut + RASS detection

SDSS Early Data Release = 3.7 million objects

SDSS color cut = 150,000

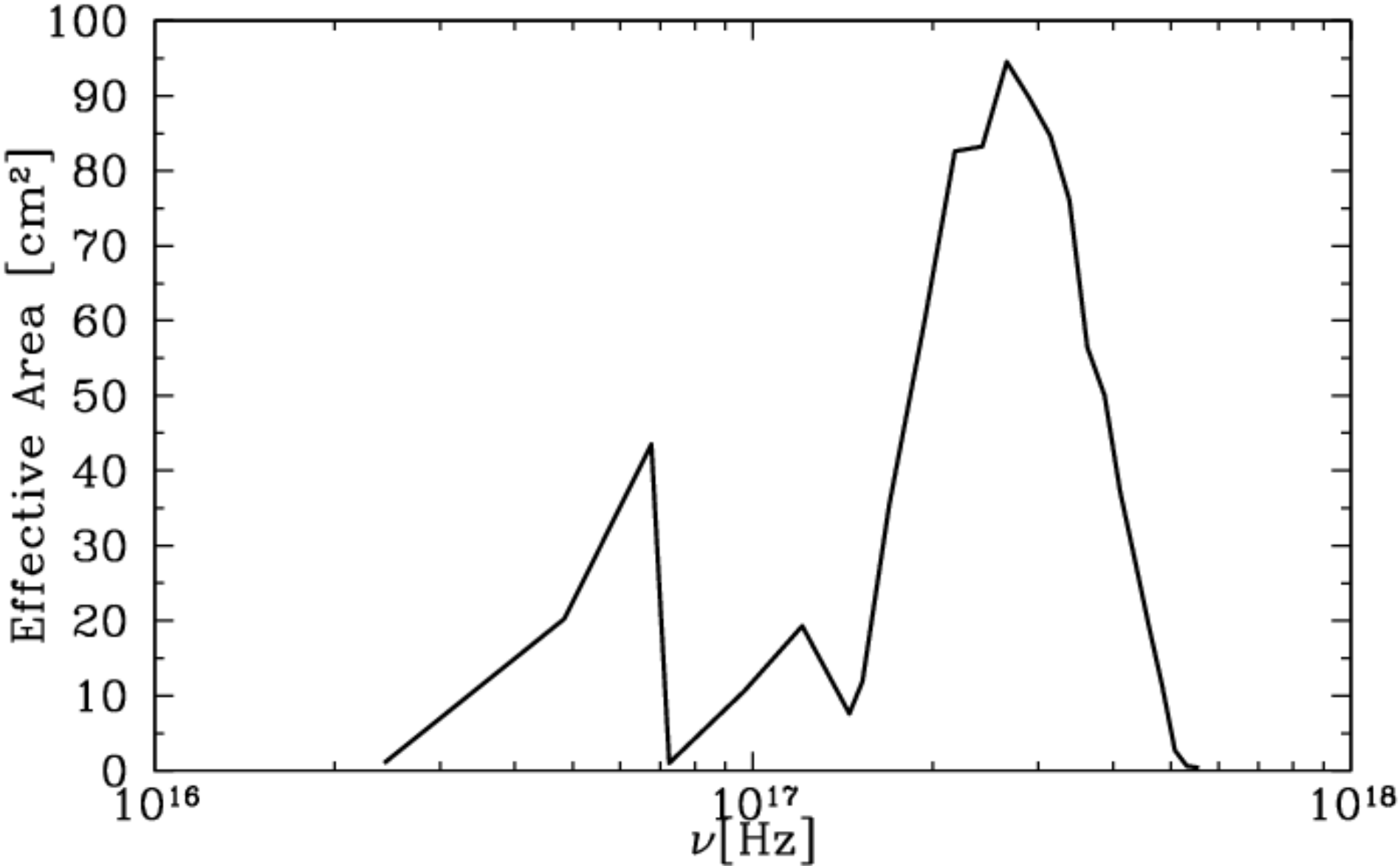
RASS
ROSAT All-Sky Survey



ROSAT
Röntgen Satellite
X-Ray Observatory
Germany/US/UK
1990-1999

$0.1\ \text{keV} \leq E \leq 2.4\ \text{keV}$

ROSAT effective area



Color-color cut + RASS detection

SDSS Early Data Release = 3.7 million objects

SDSS color cut = 150,000

SDSS + RASS = 47

47 is a manageable number
(can examine each individually)

7 targeted for spectroscopy by SDSS
(5 stars + 2 QSOs)

Can define measure of how far from stellar locus in
4 color-color spaces

Run 1339 Col 4 Field 75