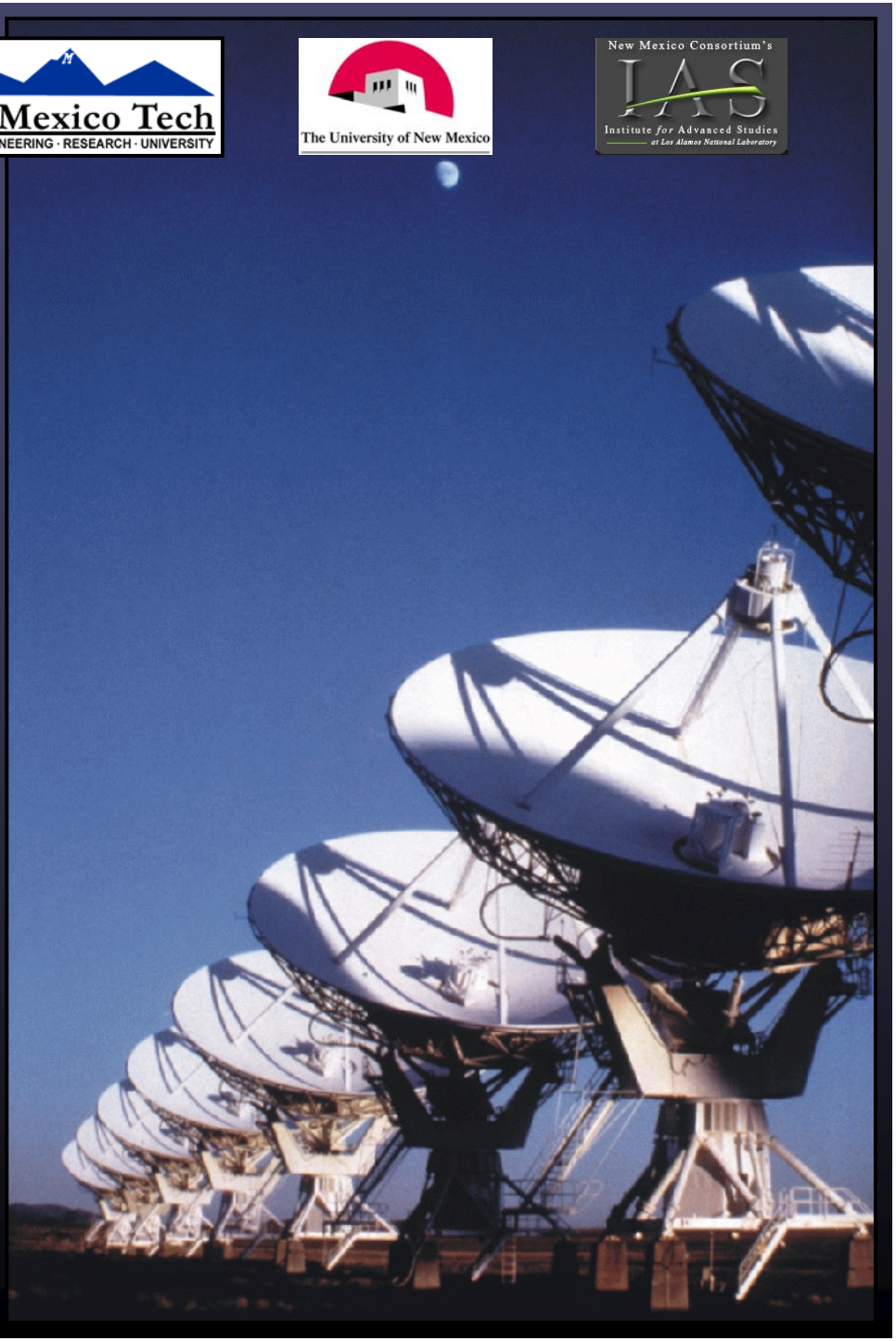
Extragalactic Science

Jim Condon



Eleventh Synthesis Imaging Workshop

Socorro, June 10-17, 2008

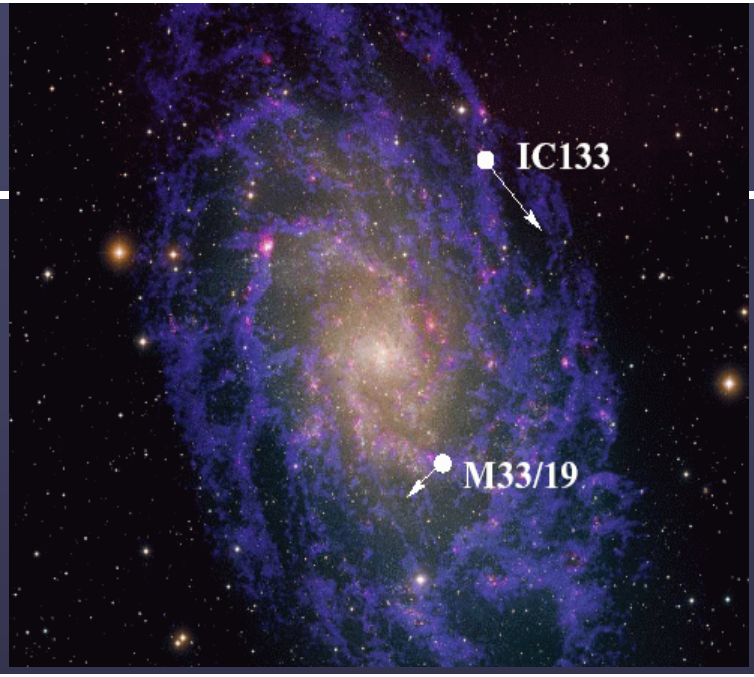
Why Synthesis Imaging?

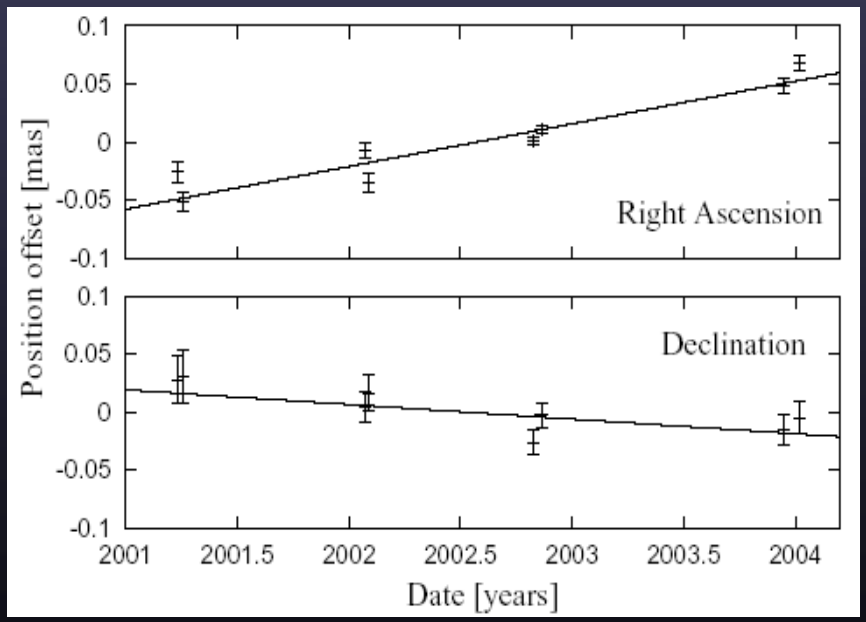
Angular resolution can be specified by the observer (to reduce “confusion,” match angular scales of the source or multiwavelength data -- but trade off surface-brightness sensitivity)

Extremely accurate absolute astrometry (high angular resolution, clocks instead of rulers, no plane-parallel refraction)

High dynamic range via deconvolution and self-calibration “fixing” telescope

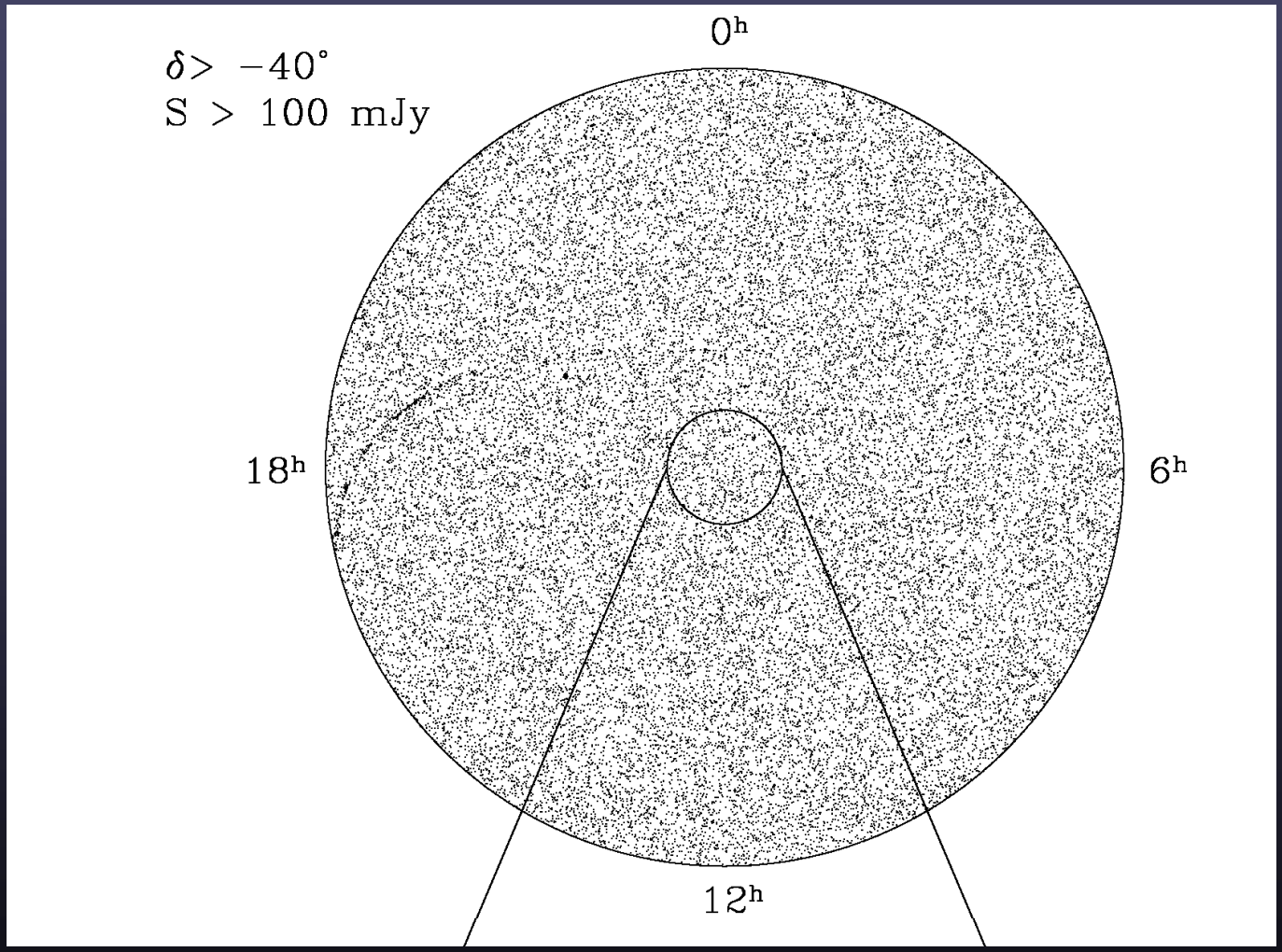
High sensitivity via long integrations, suppression of “baseline” errors and RFI



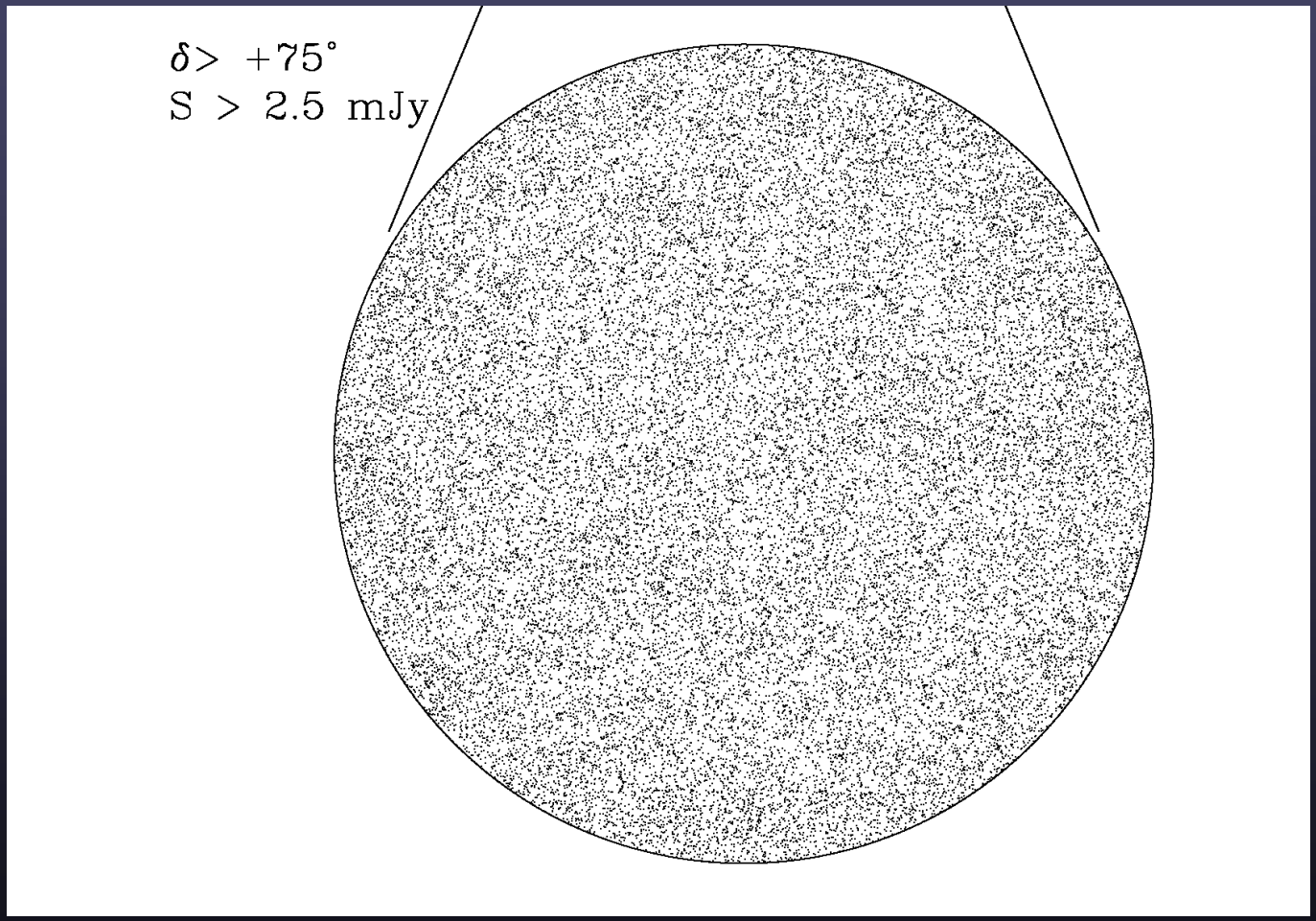


(Figures from Brunthaler et al. 2005, Science, 307, 1440)

Extragalactic Science: The radio continuum sky at 45 arcsec resolution — Where's our Galaxy?

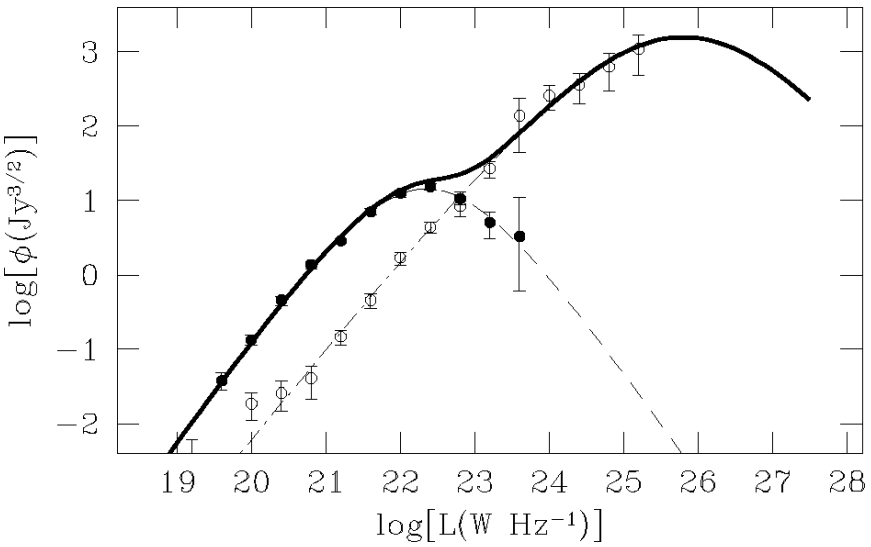


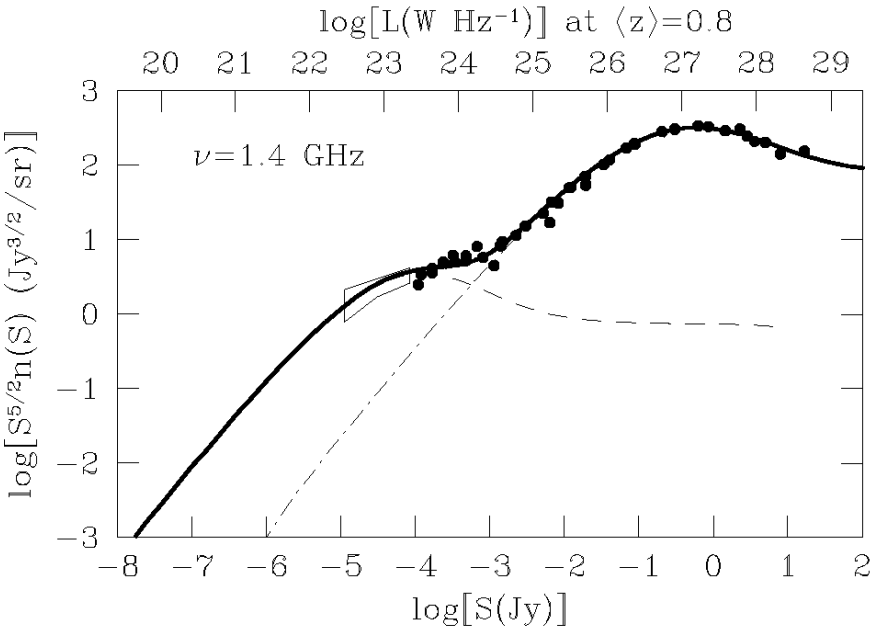
“It’s turtles all the way down”



Flux density versus luminosity of radio sources

- Evolution 10X in luminosity → few nearby sources, <z> ~ 1
- "shell" → L ∝ S
- AGNs at high L, S
- Star-forming galaxies at low L, S

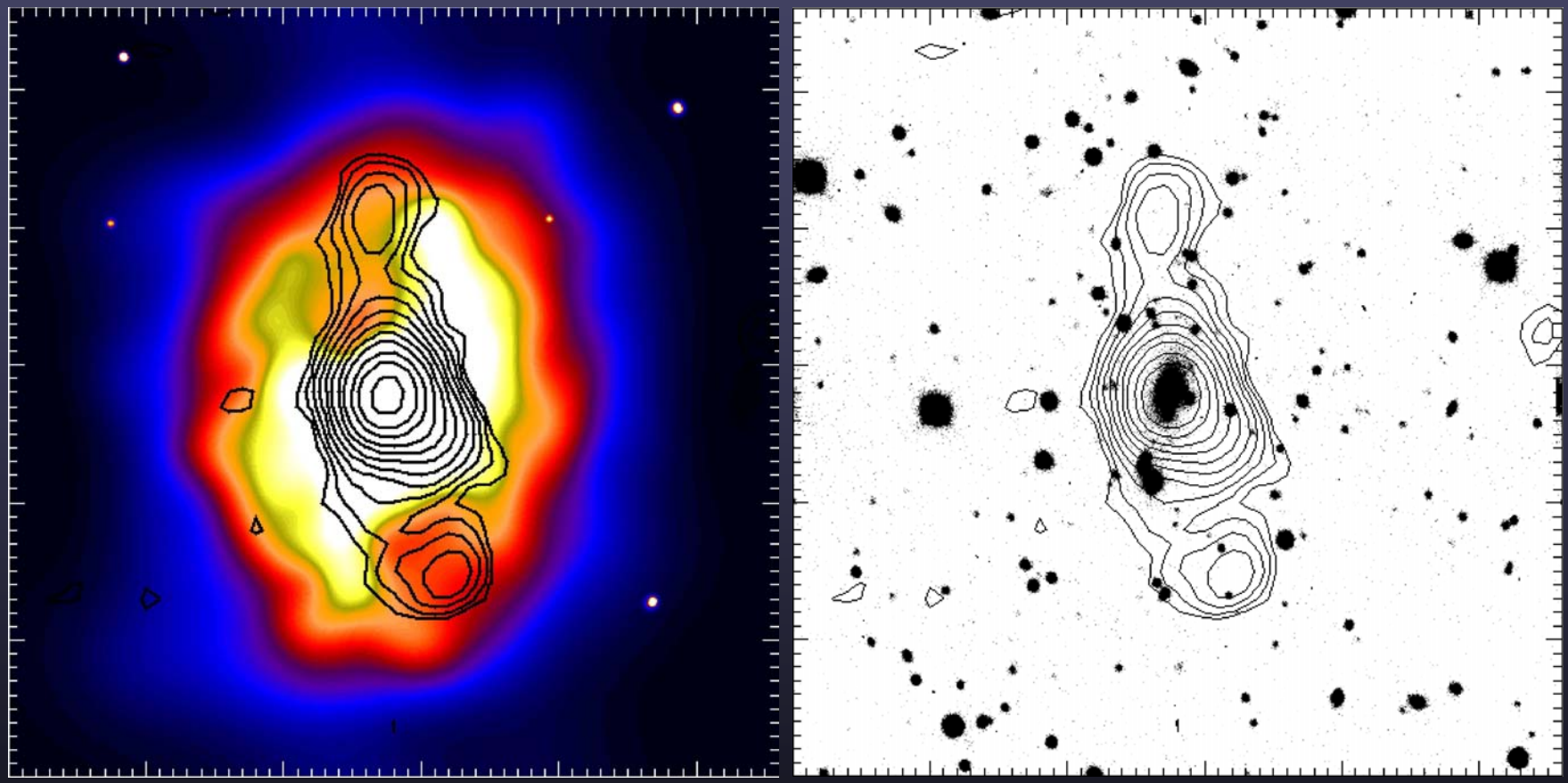




High Luminosity: Relativistic Jets and Lobes from AGN

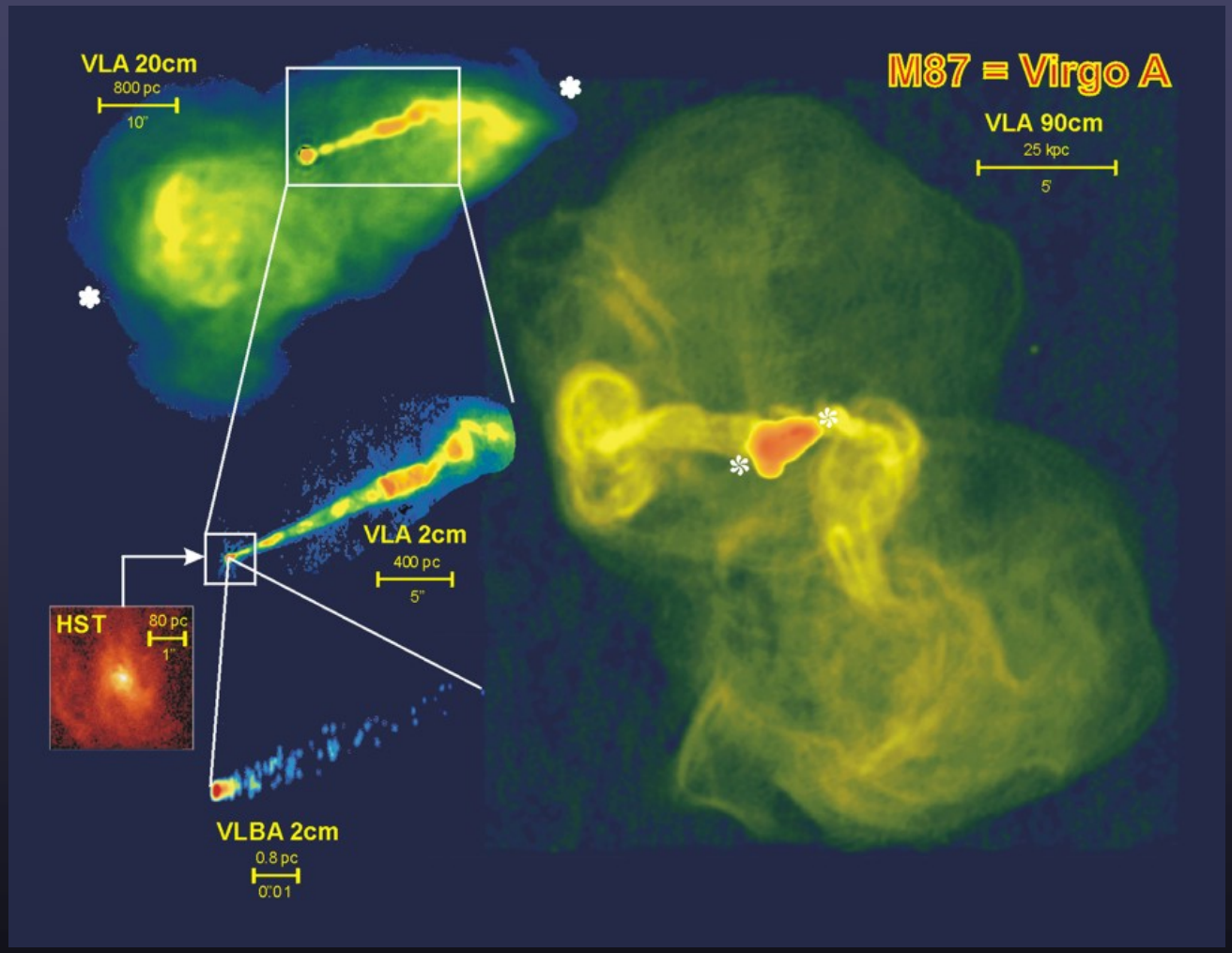
Centaurus A at radio (purple), optical, and X-ray wavelengths

Jet Energy via Radio Bubbles in Hot Cluster Gas

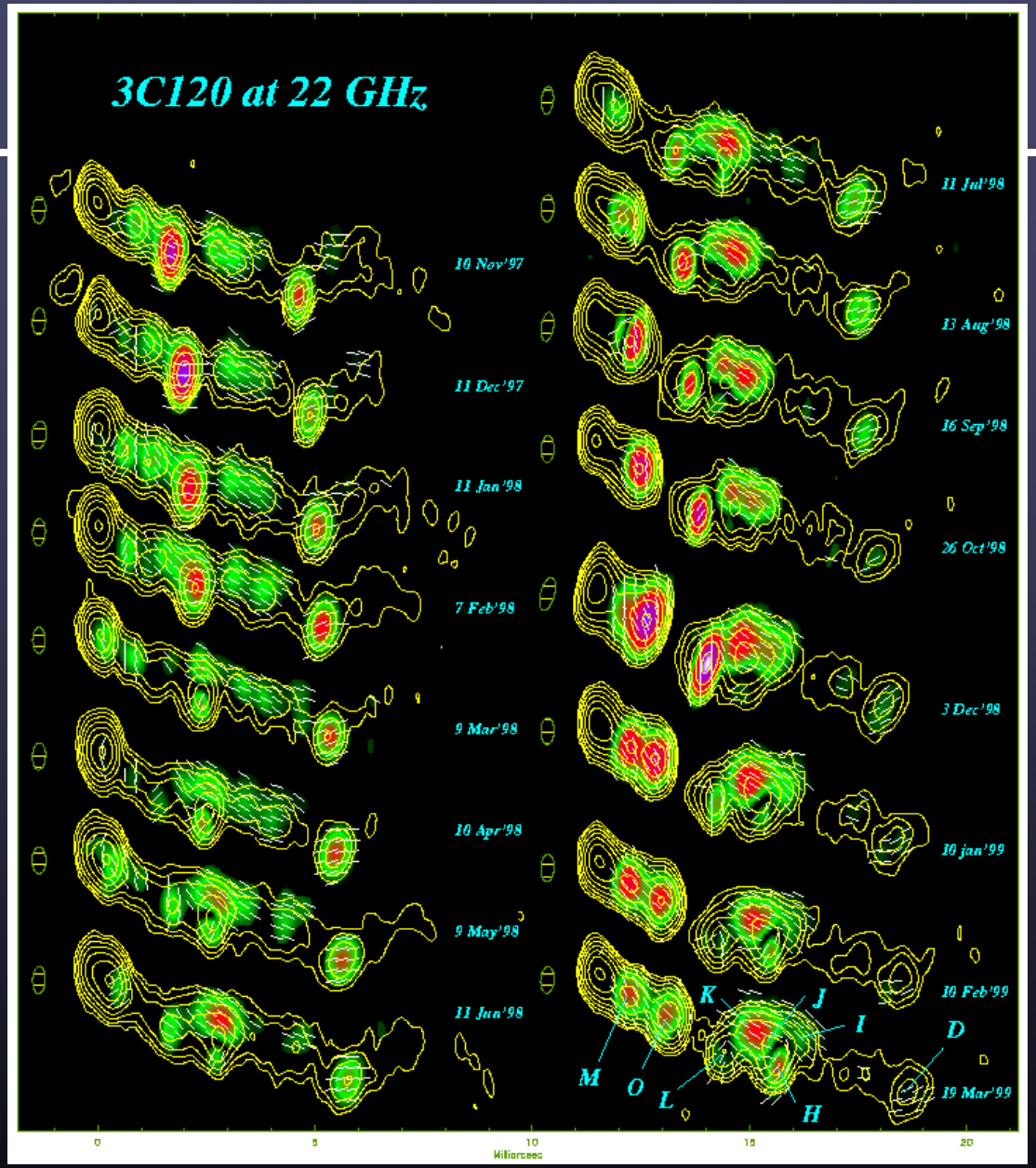


6 X 10^{61} ergs ~ 3 X 10^{7} solar masses X c^2 (McNamara et al. 2005, Nature, 433, 45)

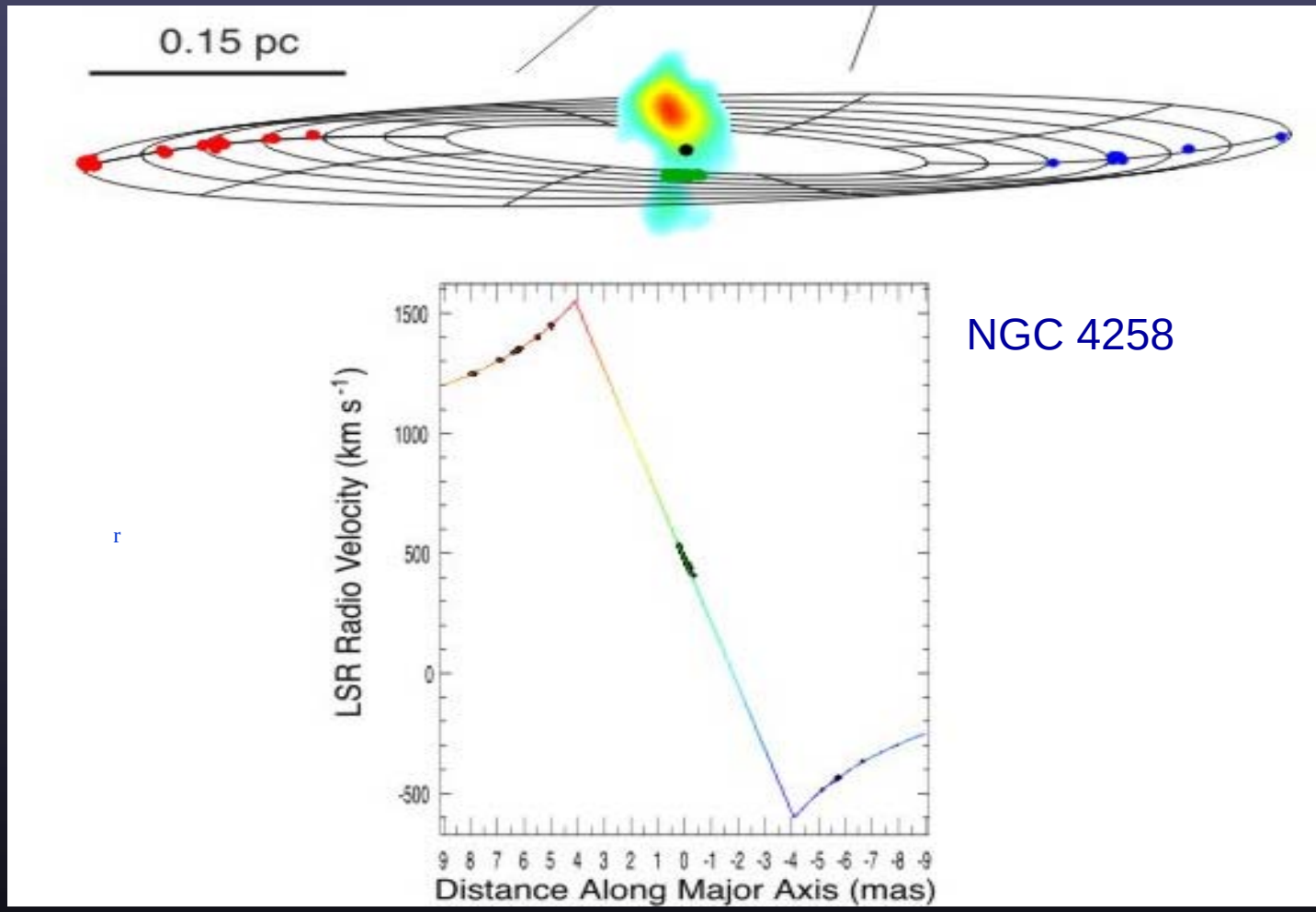
Resolution and Surface-brightness Sensitivity



Superluminal Motion in Compact Jets

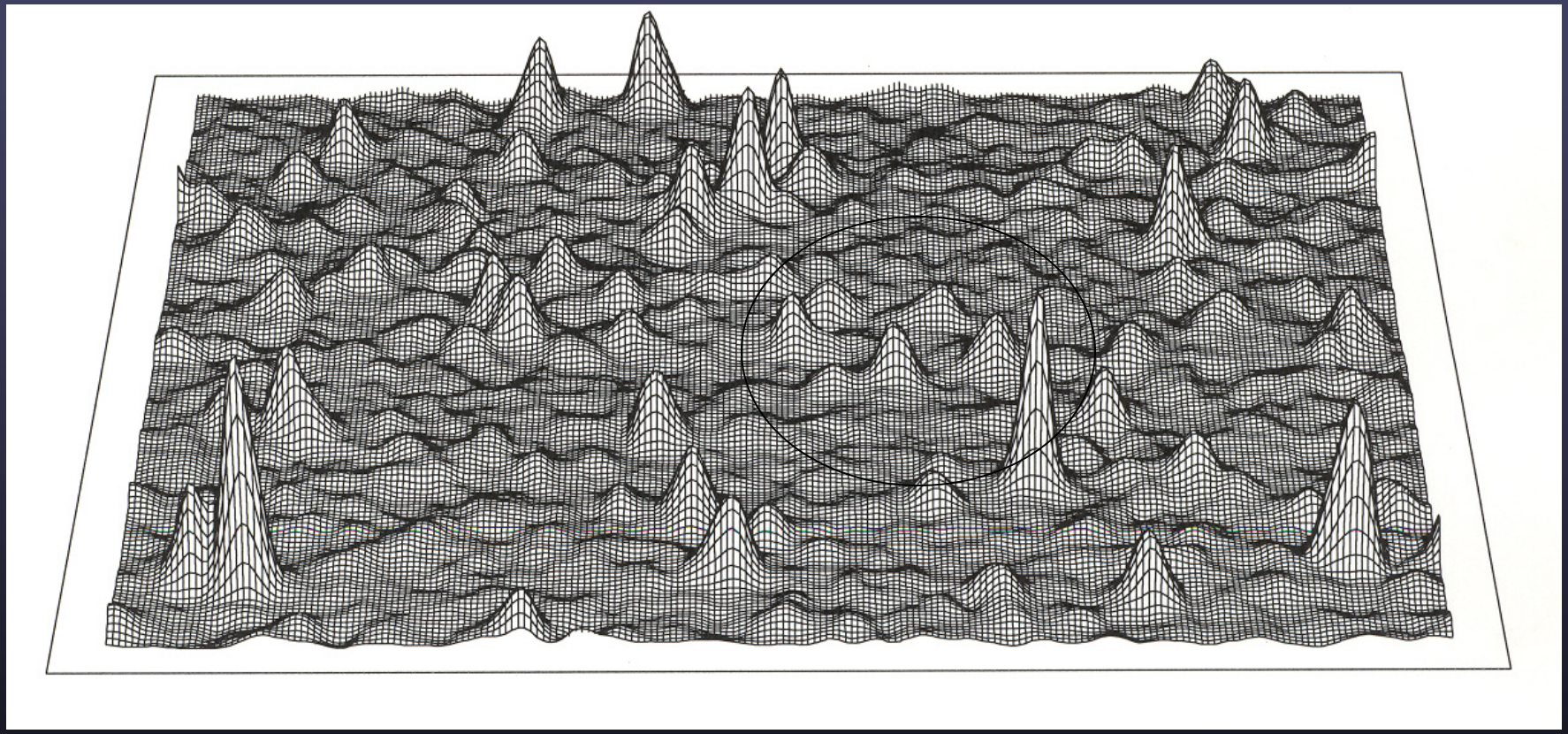


Resolving the circumnuclear disk in NGC 4258 and directly measuring the black-hole mass



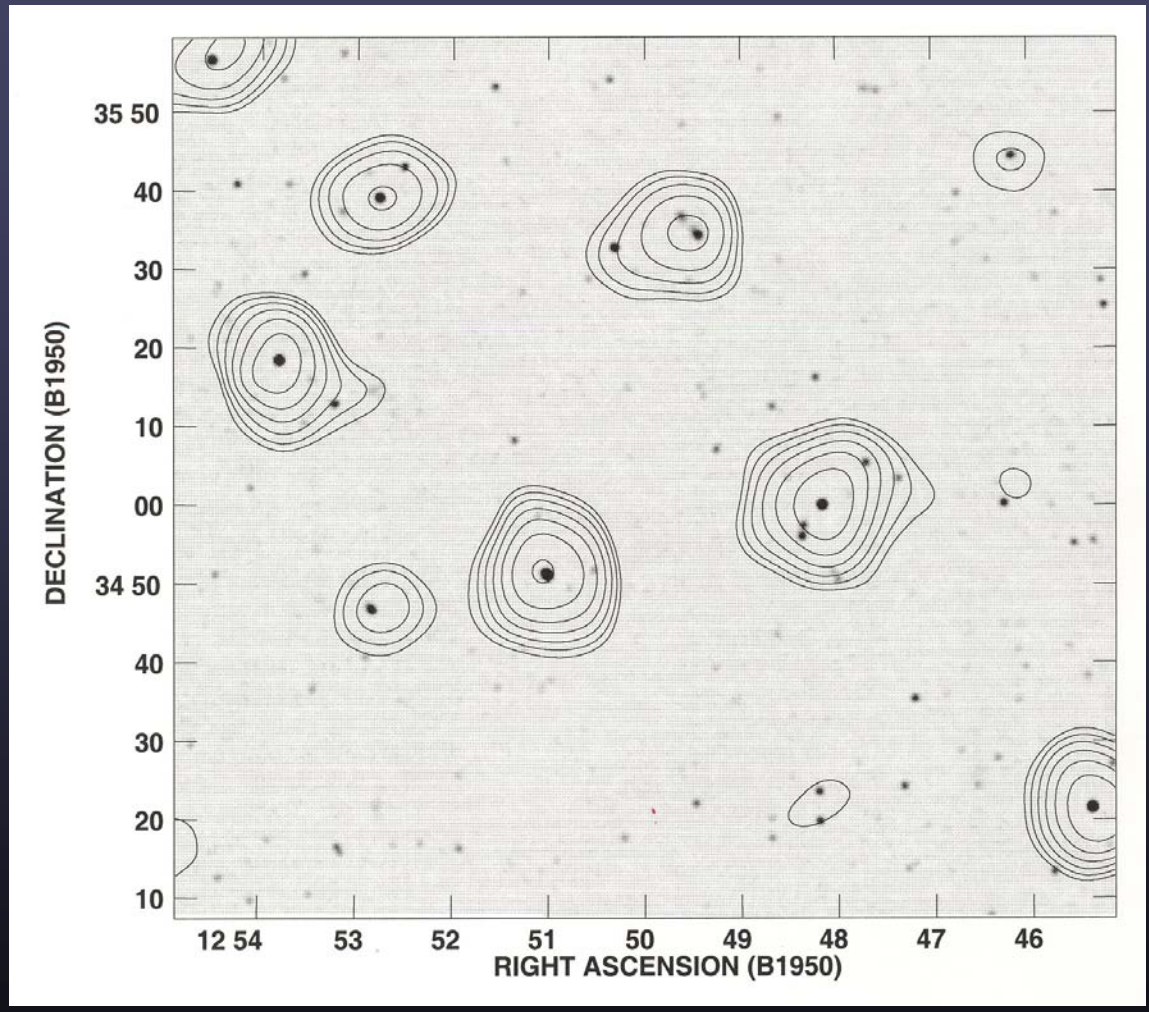
NGC 4258

Beating Confusion



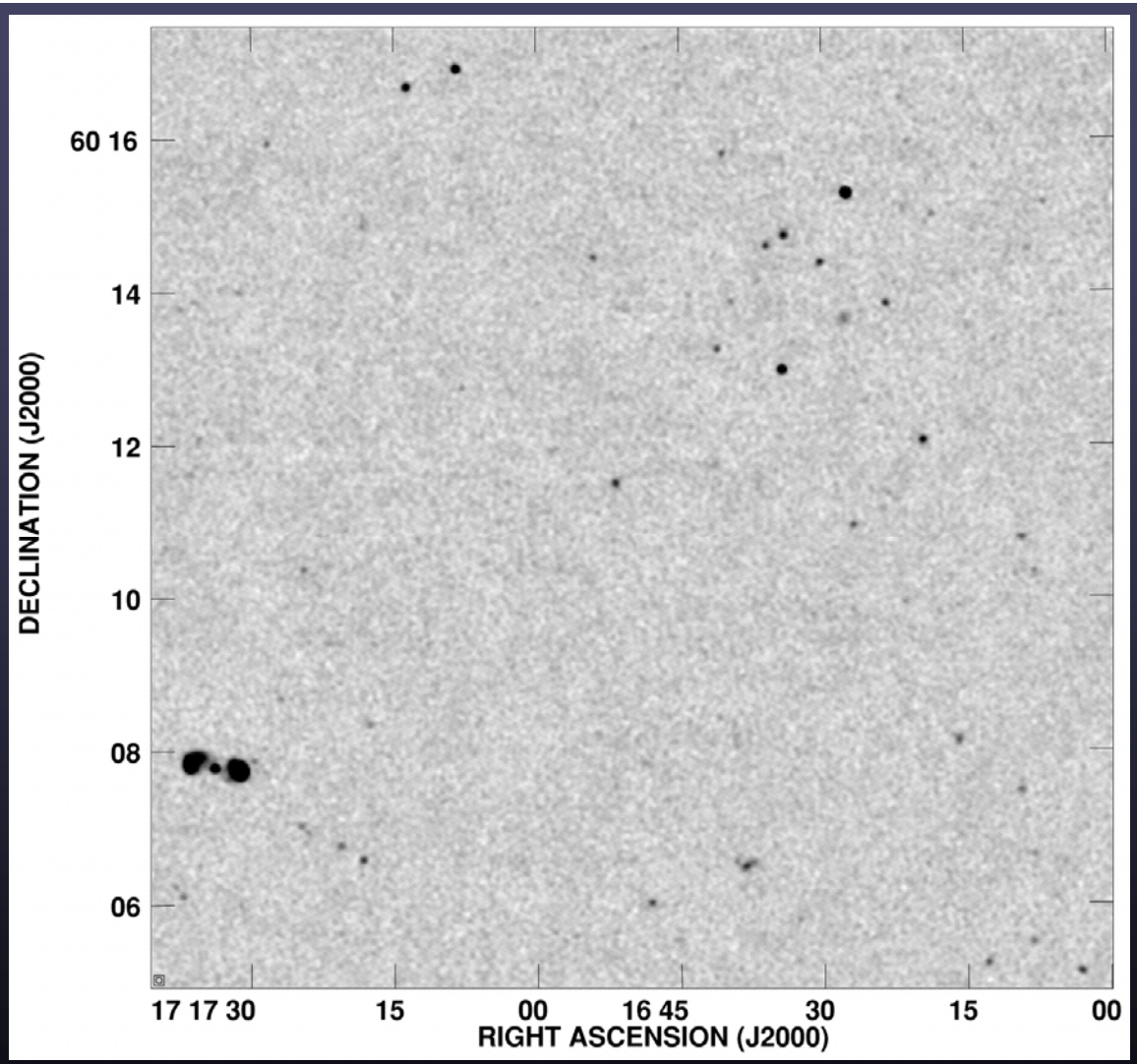
NVSS (45 arcsec) grayscale under GB 300-ft (12 arcmin) contours

"RMS" confusion
$\sigma_c \approx 0.2\ \nu^{-0.7}\ \theta^2$
where
σ is in mJy/beam,
ν is in GHz, and
θ is in arcmin

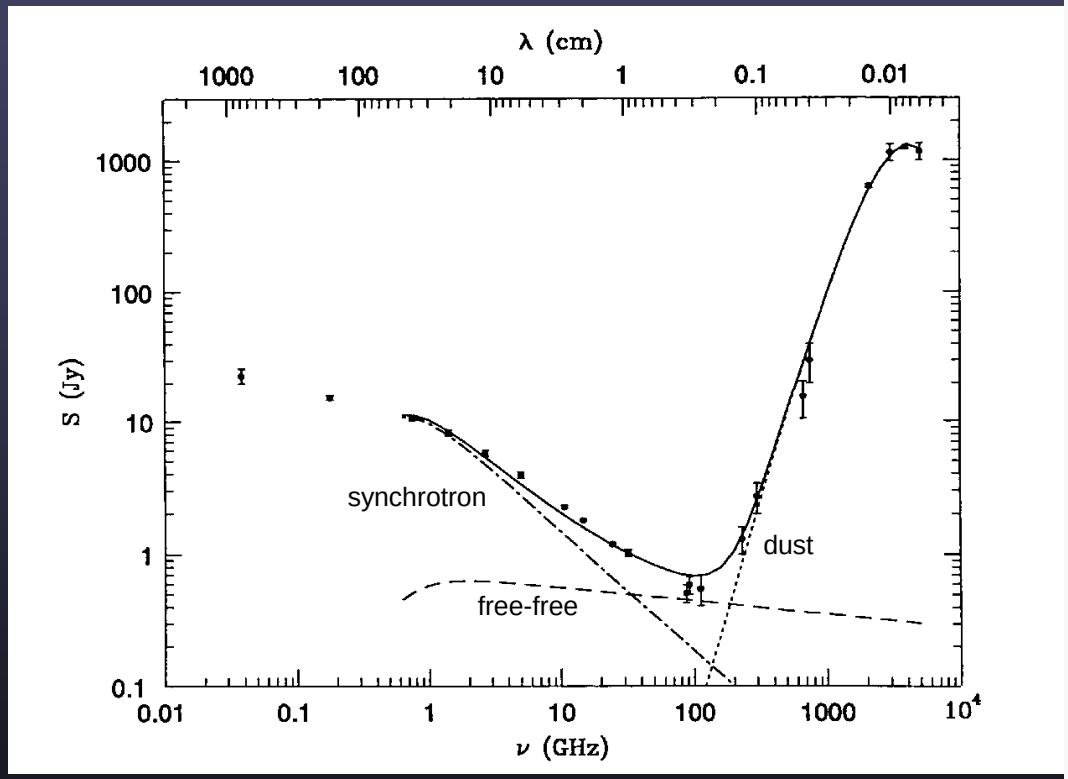


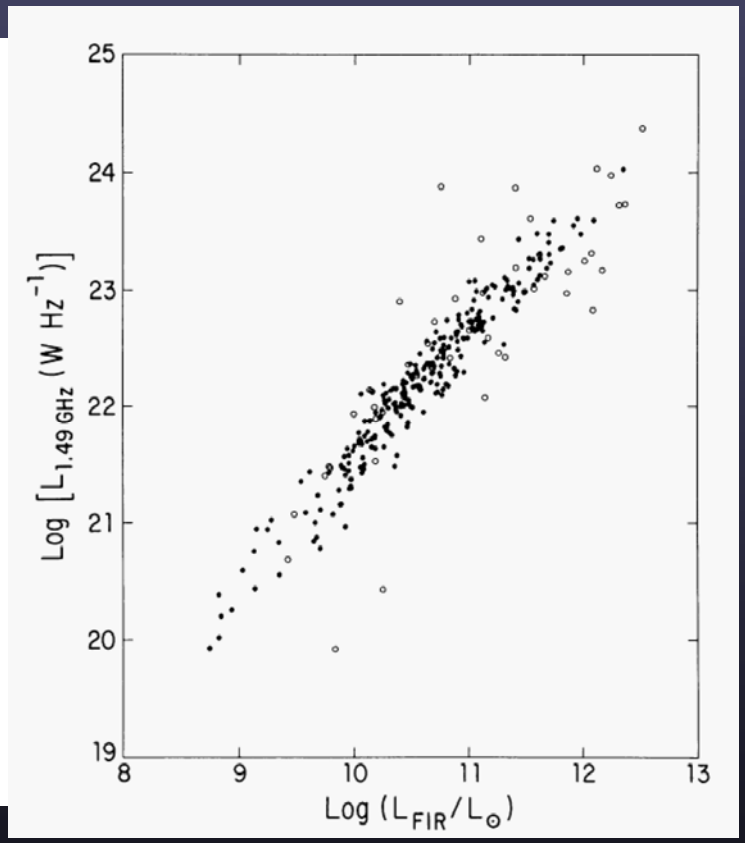
Low Luminosity: AGN+Starbursts

θ = 5 arcsec
σ = 23 mJy/beam
(σ_c ~ 1 mJy/beam)

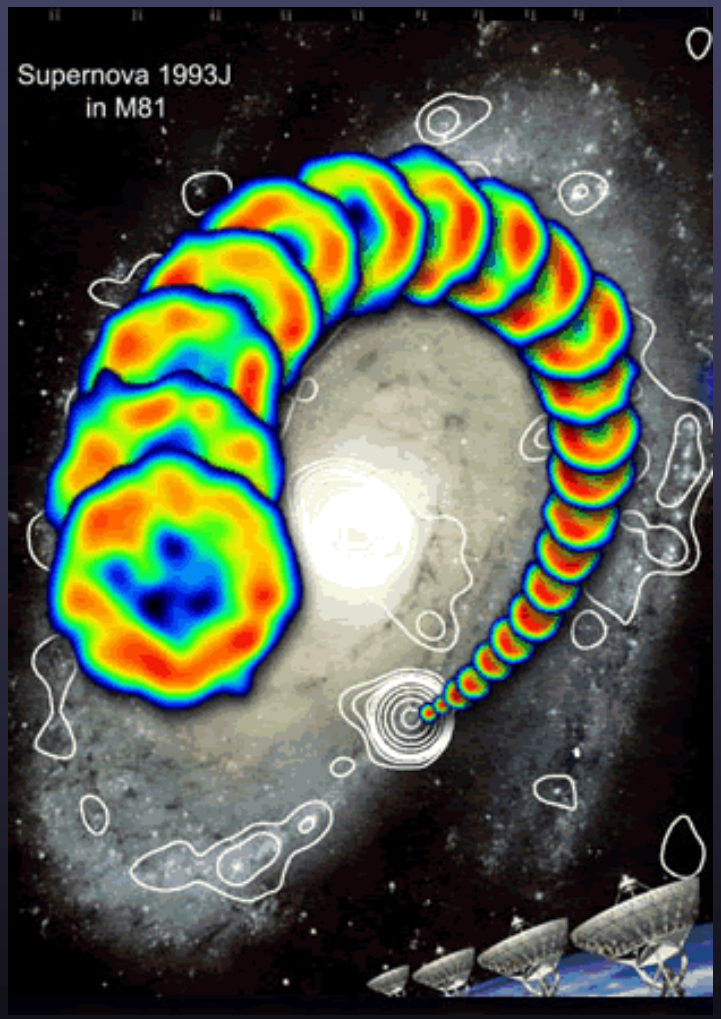


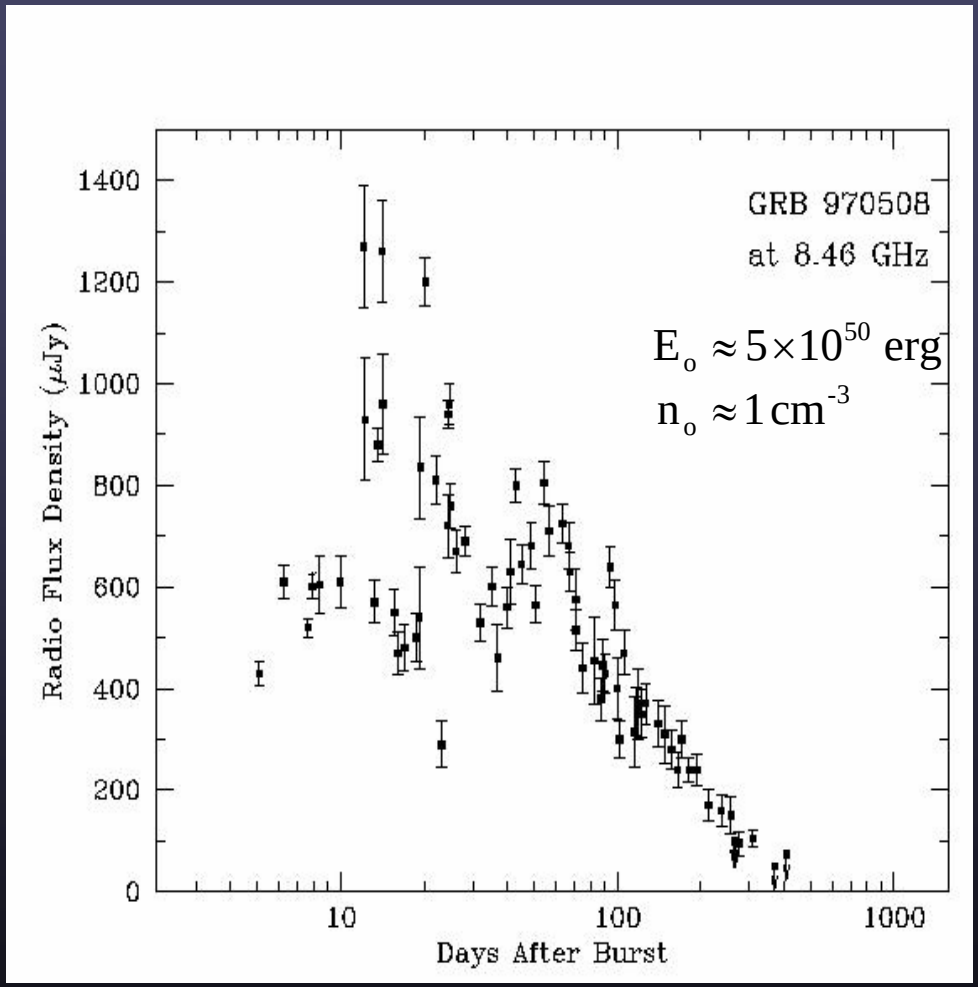
Low Luminosity: Star-forming Galaxies



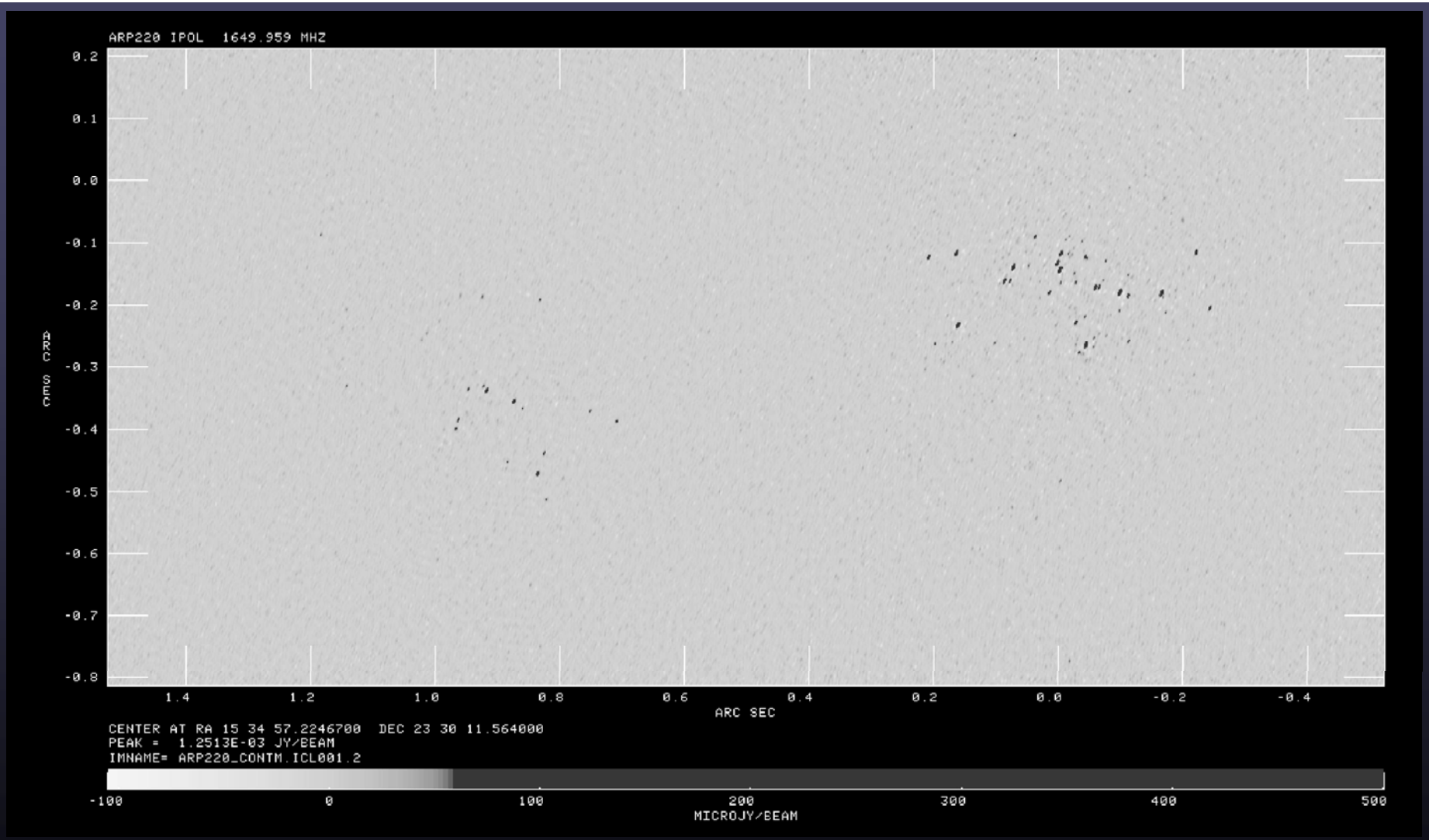


SNe and GRBs


Supernova 1993J
in M81

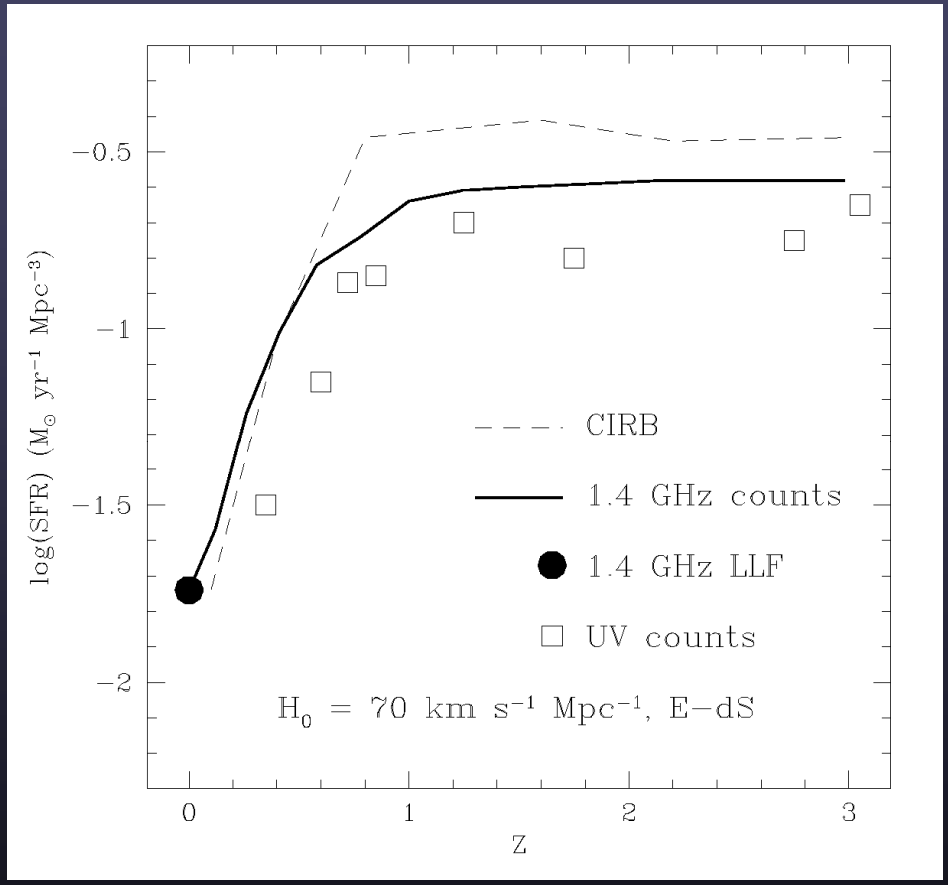

GRB 970508
at 8.46 GHz
$E_o \approx 5\times10^{50}$ erg
$n_o \approx 1\,cm^{-3}$
Radio Flux Density (μJy)
Days After Burst
0
200
400
600
800
1000
1200
1400
10
100
1000

VLBA/HSA Image of the Starburst Nuclei in Arp 220

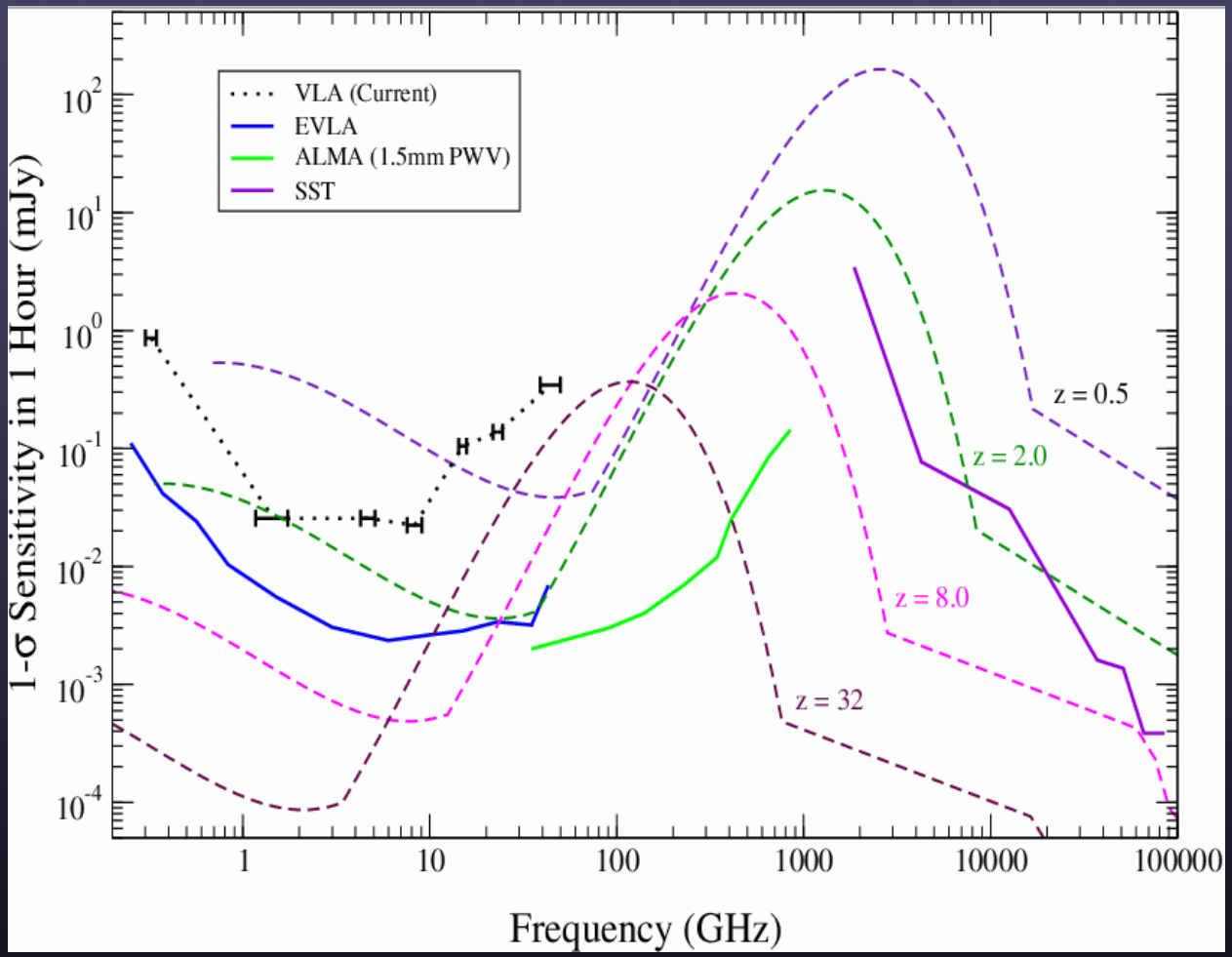


Evolution of star formation

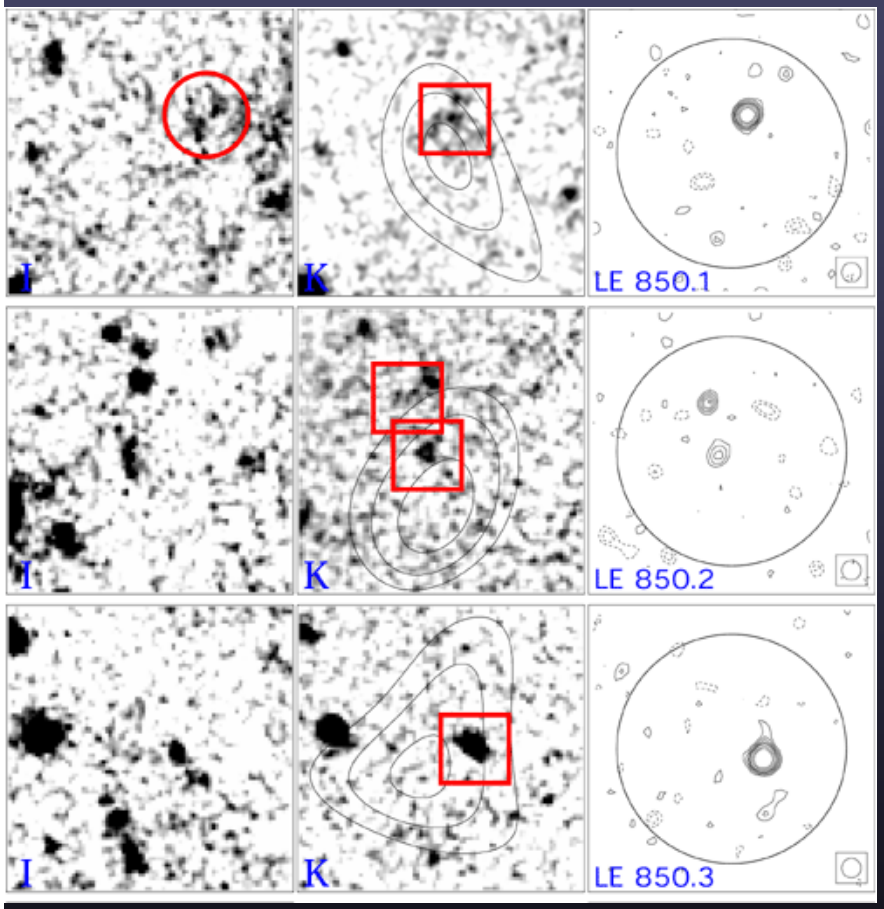
- Radio “Madau diagram”
- Free from dust extinction

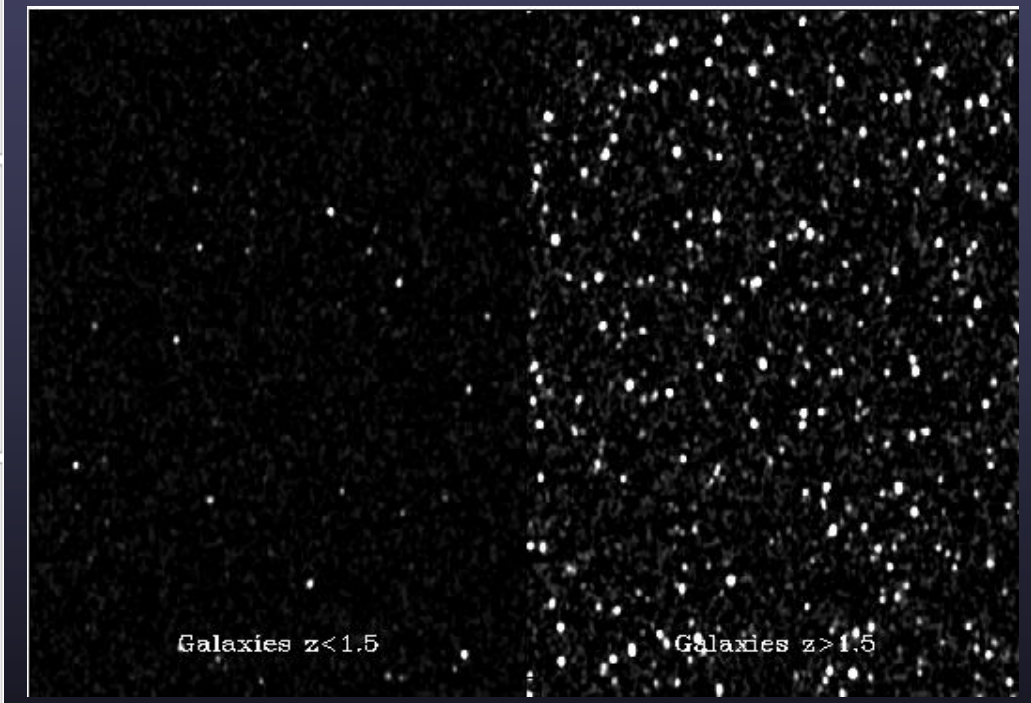


Star Formation at High Redshift

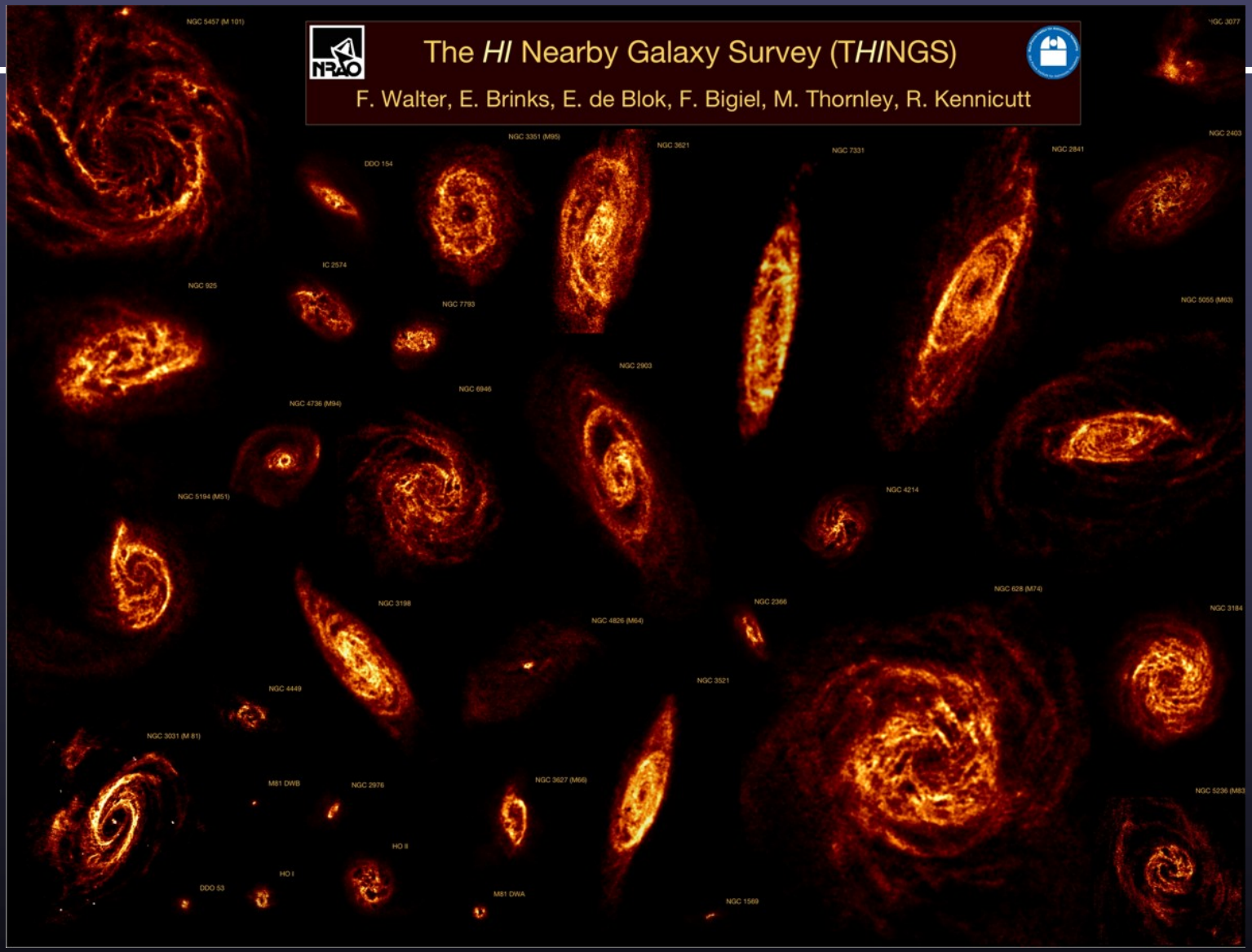


Primordial Starbursts

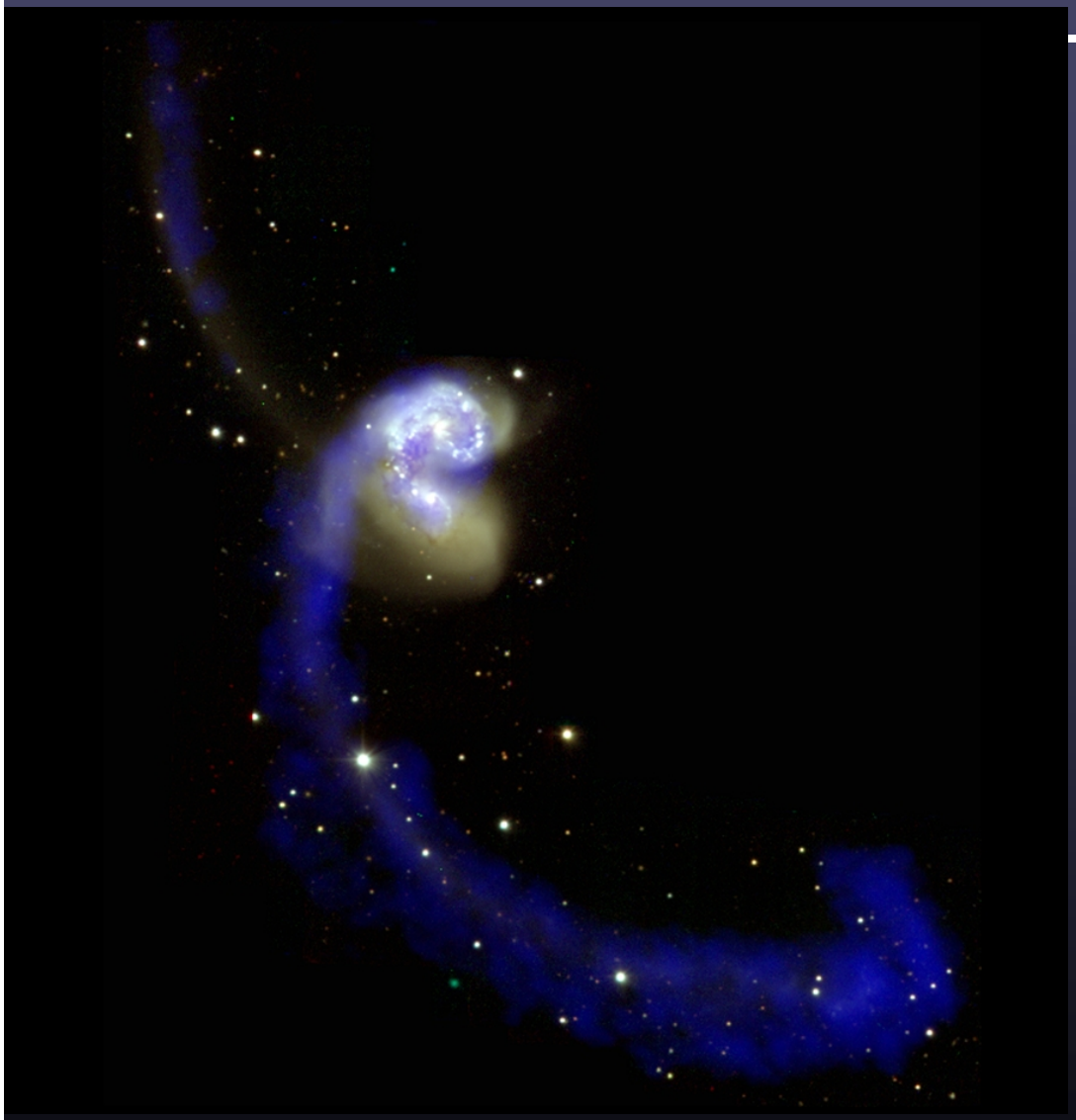




Radio Spectral Lines: Cold Gas

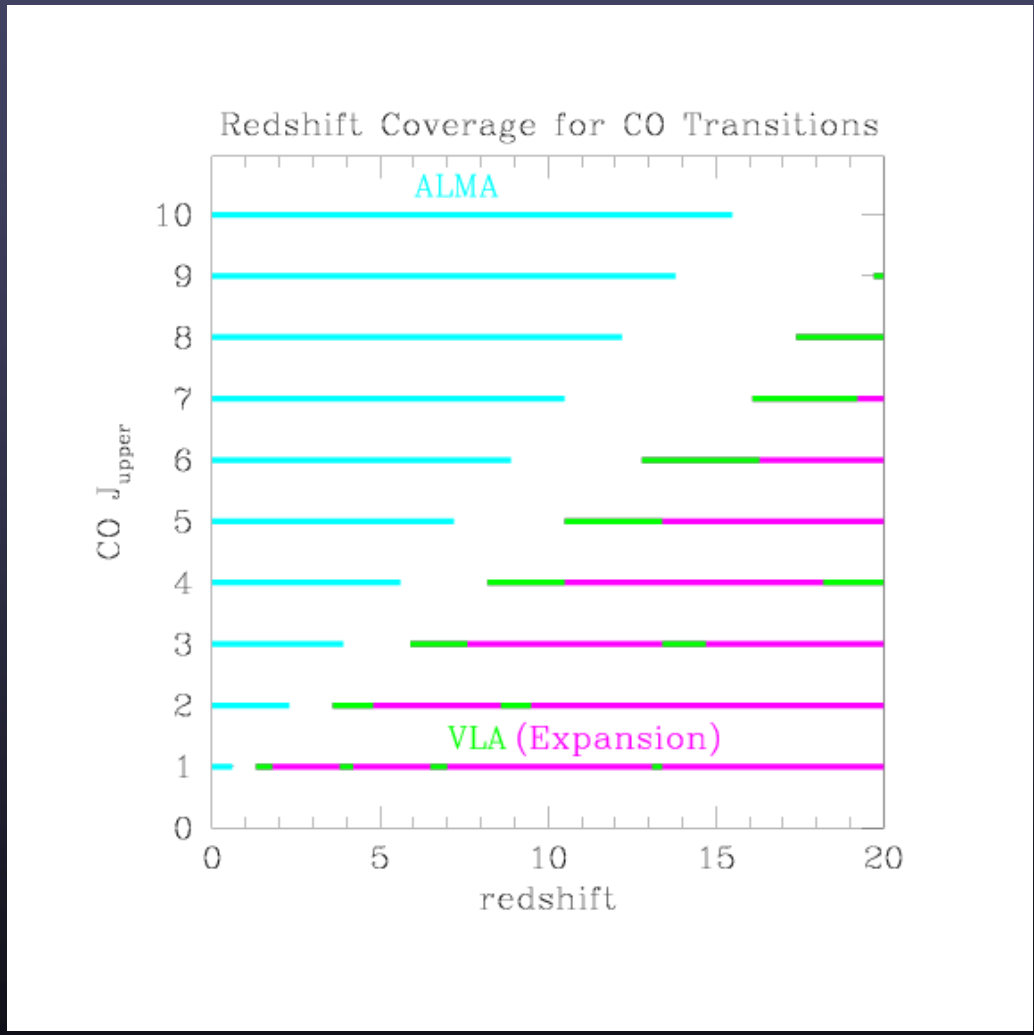


Crash Forensics



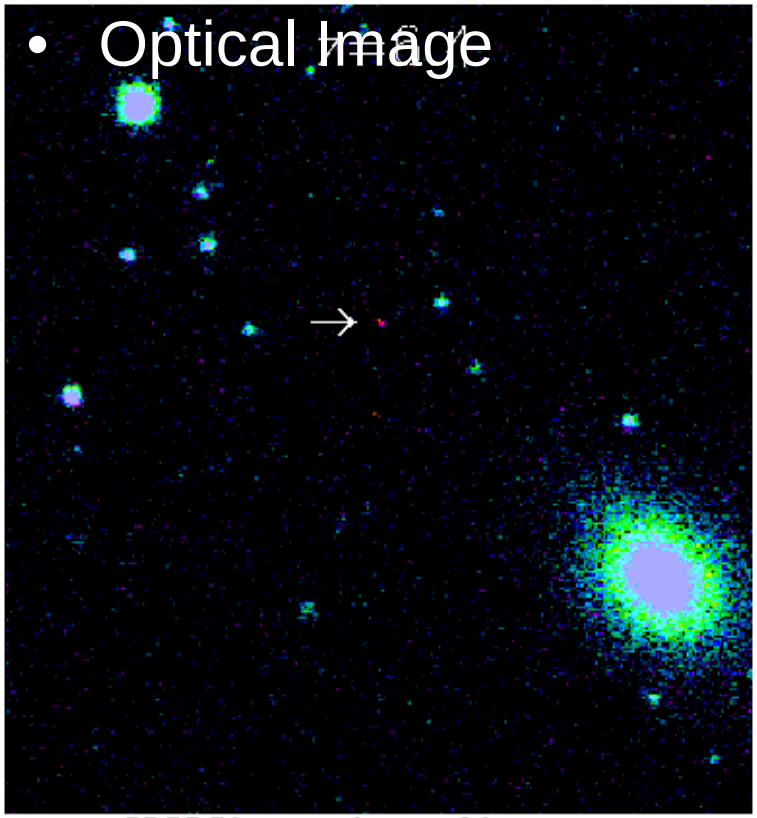
EVLA and ALMA

- Continuous frequency coverage from 1 GHz to 50 GHz
- Detect CO at almost any redshift
- Study excitation of star-forming gas in distant galaxies

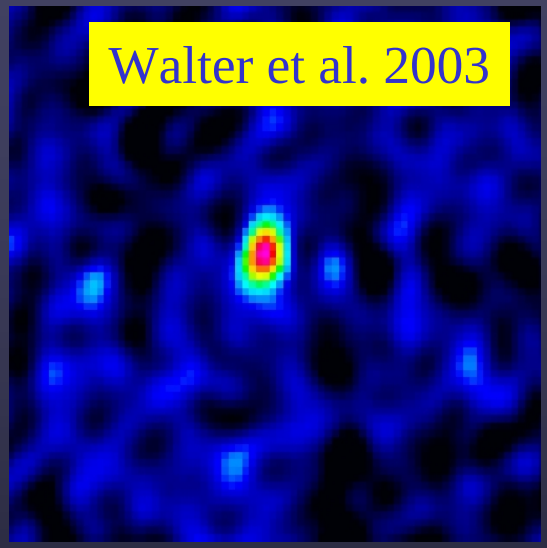


The Most Distant Quasar

- Optical Image

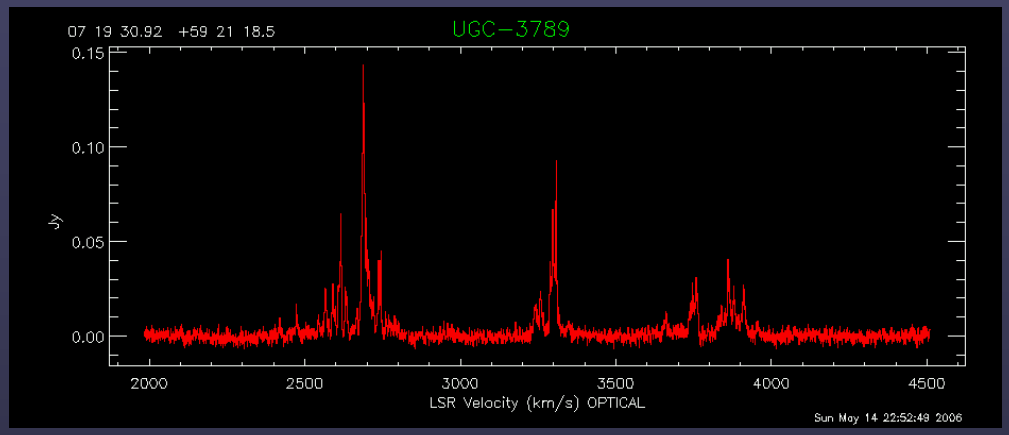


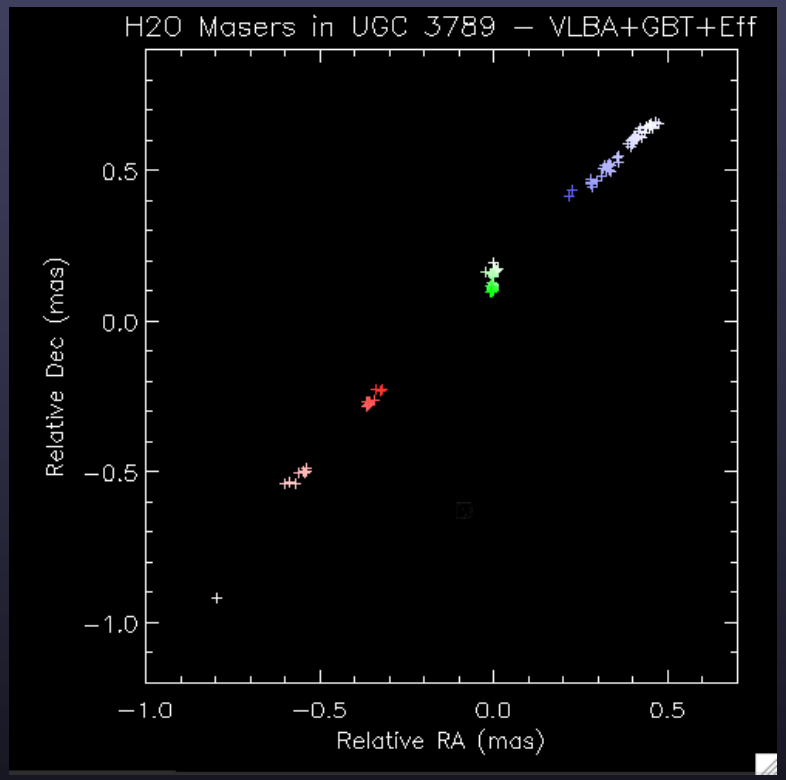
SDSS Discovery Image of J1148+5251:
Quasar is Red Dot Pointed Out by Arrow



- VLA image of CO (4-3) from the first known star formation
  - Redshifted to 46 GHz
- Artist's conception of disk of molecules and dust

Geometric Distances, H_0, and Dark Energy





Preliminary

Properties of UGC 3789 Maser Disk

R ~ 0.09 - 0.20 pc (0.40 - 0.87 mas)
V ~ 750 - 450 km/s
M_{bh} ~ 1.2 x 10^7 M_{sun}
a ~ 3.6 km s^{-1} yr^{-1} (mean value)

D ~ 51 Mpc (15%)
H_0 ~ 64 km s^{-1} Mpc^{-1}

The End...

...NOT!