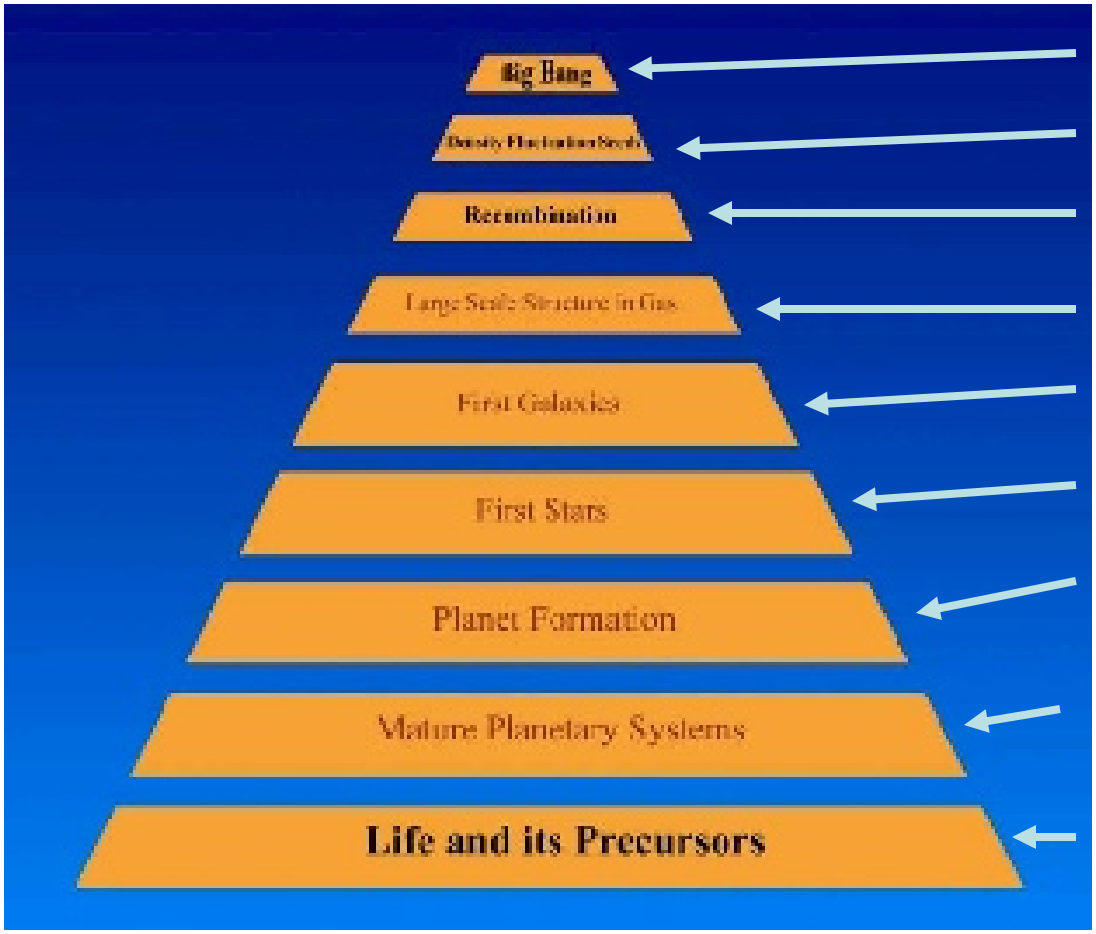
Science Opportunities and Future Radio Telescopes: II.

Strong Gravity, Cradle of Life, Milky Way & Local Group

Mark Reid: Harvard-Smithsonian CfA

“Big Questions” Need Pan-chromatic Data



Big Bang:

Density fluctuation seeds: CMB

Recombination: CMB

Dark Ages: 21 cm HI

First Galaxies: EoR,BHs,Starbursts

First stars:

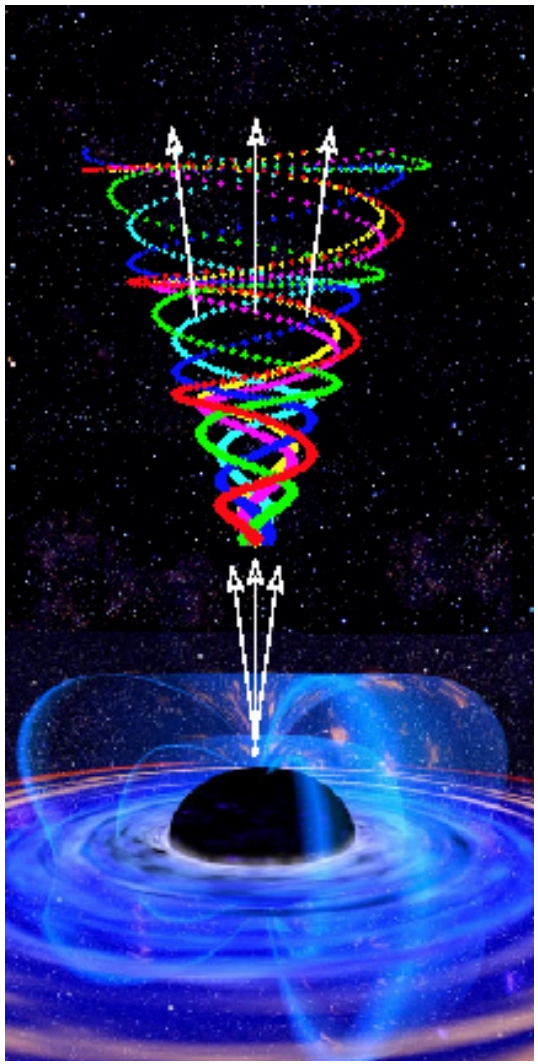
Star/Planet formation: dust, molecules, free-free

Mature Planetary Systems: Ours; extrasolar Jupiters

Life & Precursors: complex molecules, SETI

From “Frontier Science Enabled by a Giant Segmented Mirror Telescope”
GSMT Science Working Group, June 2003 ([sic] they left out galaxy evolution!)

Strong Gravity: Imaging Super Massive Black Holes



What does the environment of a SMBH look like?

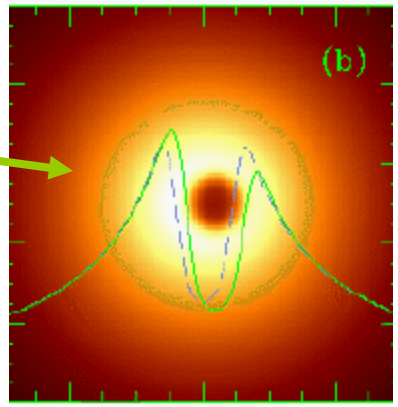
How do cosmic accelerators work?

Imaging super massive black holes:

mm/sub-mm VLBI can directly image < 10 Rsch

for Sgr A*, M 87, & Cen A

See GR “shadow” of BH



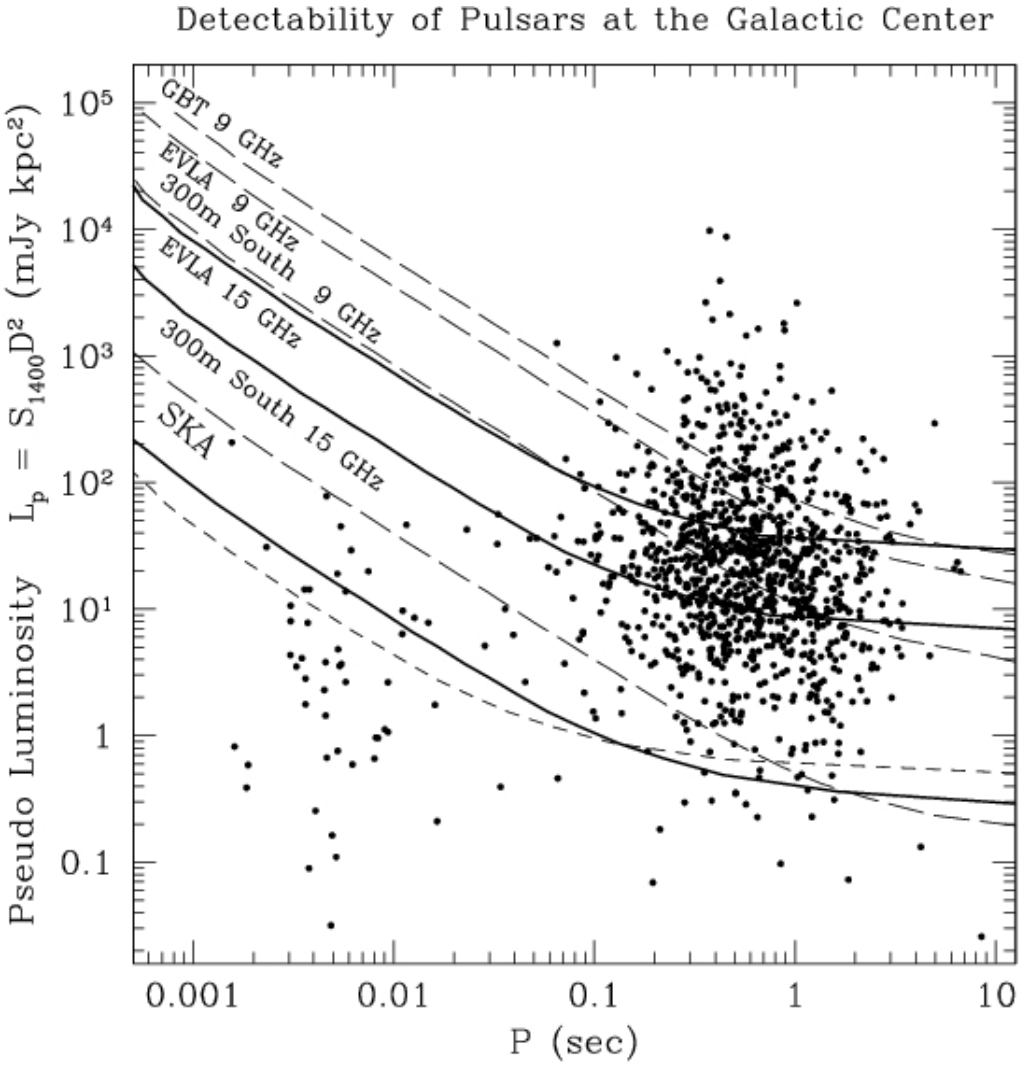
Synchrotron emission from

Accretion disk,

Magnetic connections (BH – disk),

Jet formation / acceleration

Pulsars



Estimated ~20,000 pulsars in MW beamed toward us

Measure parallax…

Tomography of ionized ISM

Understand formation routes

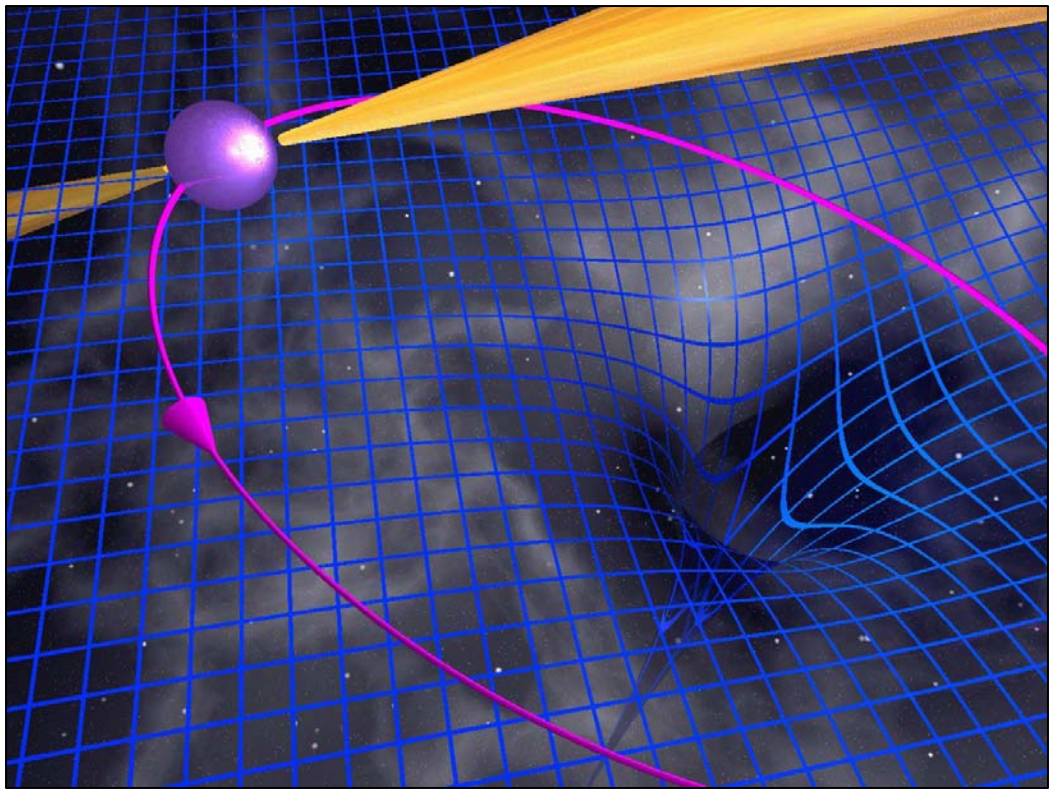
Discover pulsars orbiting Sgr A*
Stellar graveyard in Gal. Cen.?

Find many unusual cases (eg, strong gravity):

Plsr -- Plsr

Plsr -- BH

Tests of Strong Gravity

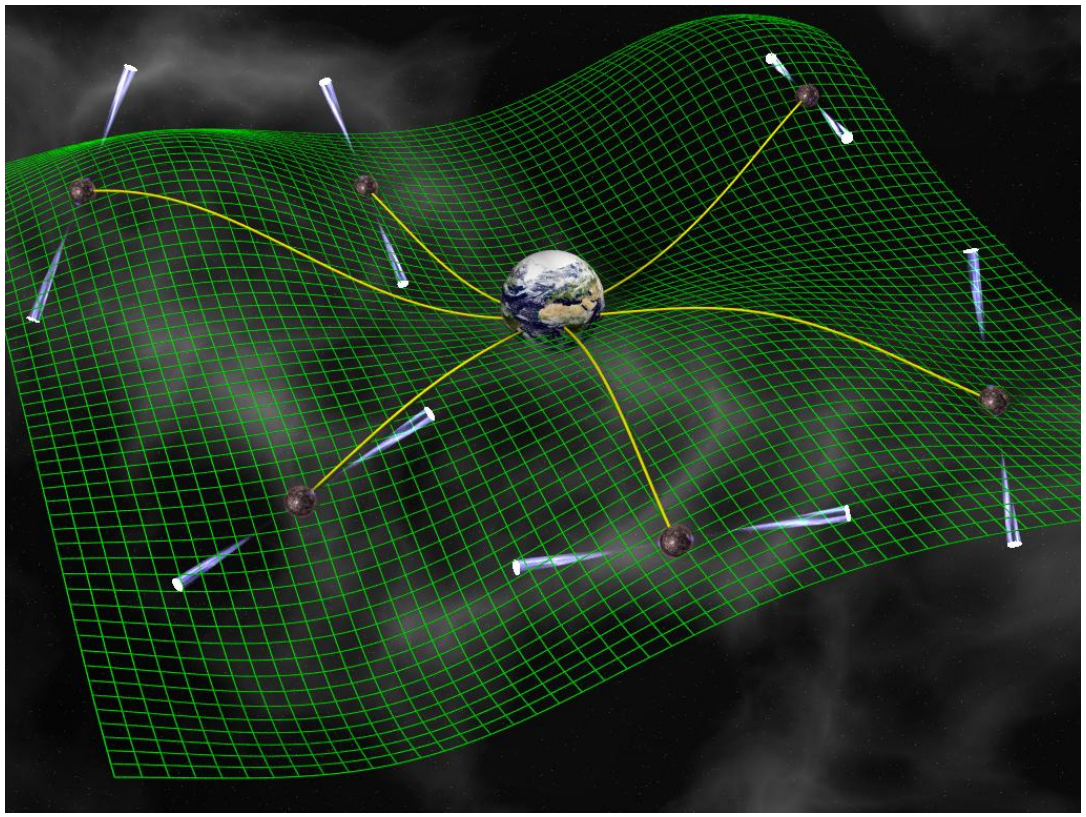


What happens in Strong Gravity?

Timing of Plsr – BH binaries

can uniquely test GR in strong gravity limit

Gravitation Wave Detection



What does the GW spectrum look like?

How do SMBHs merge?

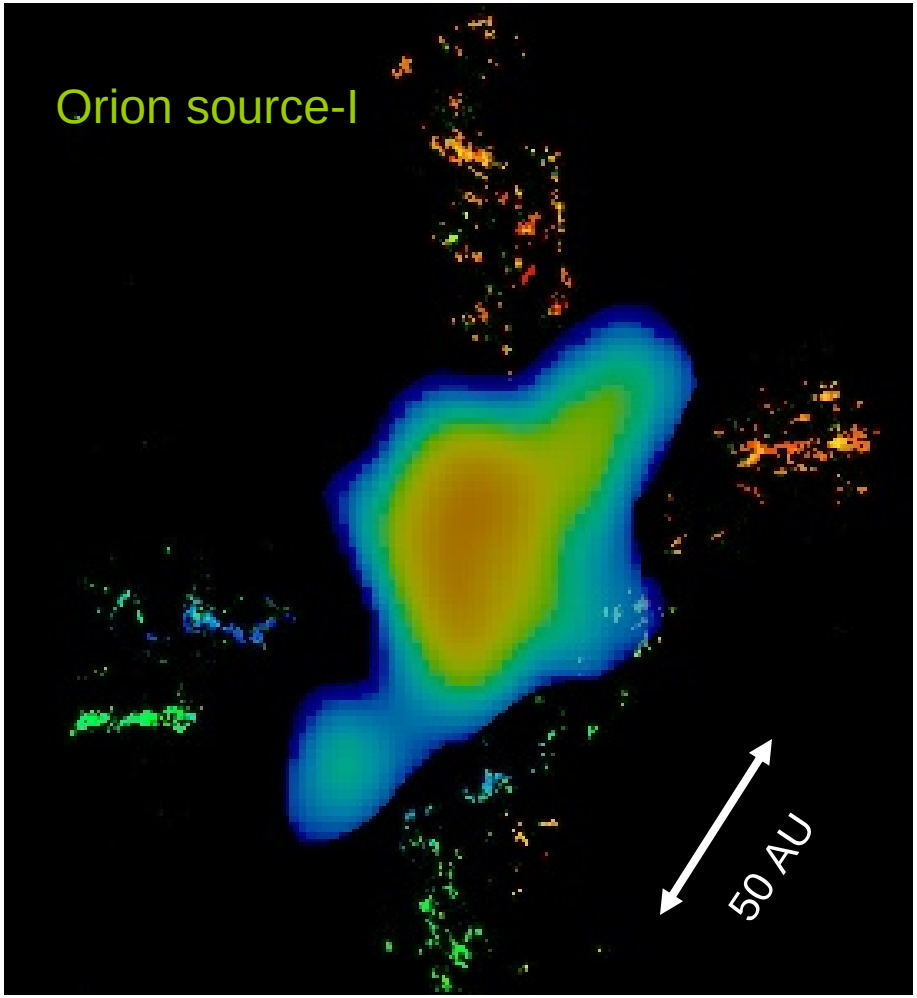
Stable milli-sec pulsars form a Pulsar Timing Array

Uniquely detect gravitation waves at nHz freq: SMBH binaries

Complements LIGO / LISA;

not sensitive to low frequencies

Cradle of Life



Greenhill, Reid, Menten & Chandler

How do stars of all masses form?

How do accretion disks work?

Image accretion disks

How inflow / outflow works

Critical role of magnetic fields

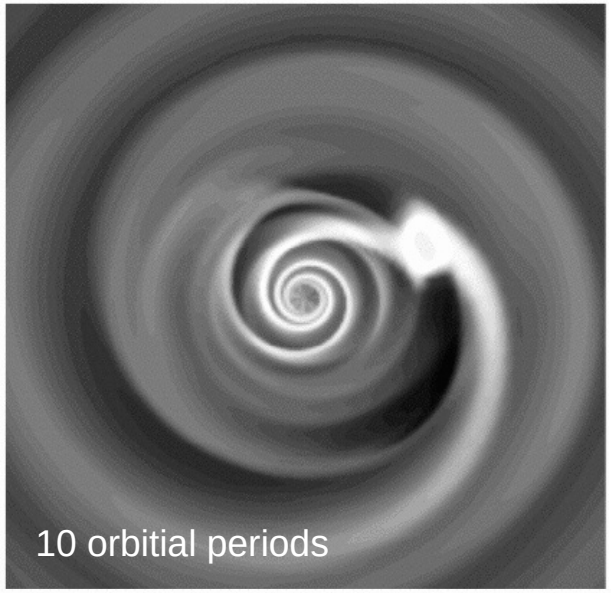
Transfer angular momentum

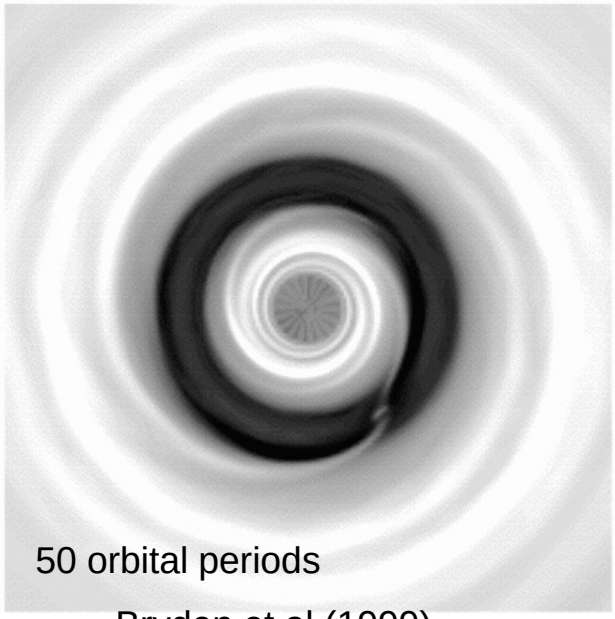
Deeply embedded:

IR totally extincted

Radio can see deep inside

Planet Formation





Bryden et al (1999)

How, where and when do giant planets form?

How, where and when do terrestrial planets form?

Do planets migrate?

Image protoplanetary disks into habitable zone

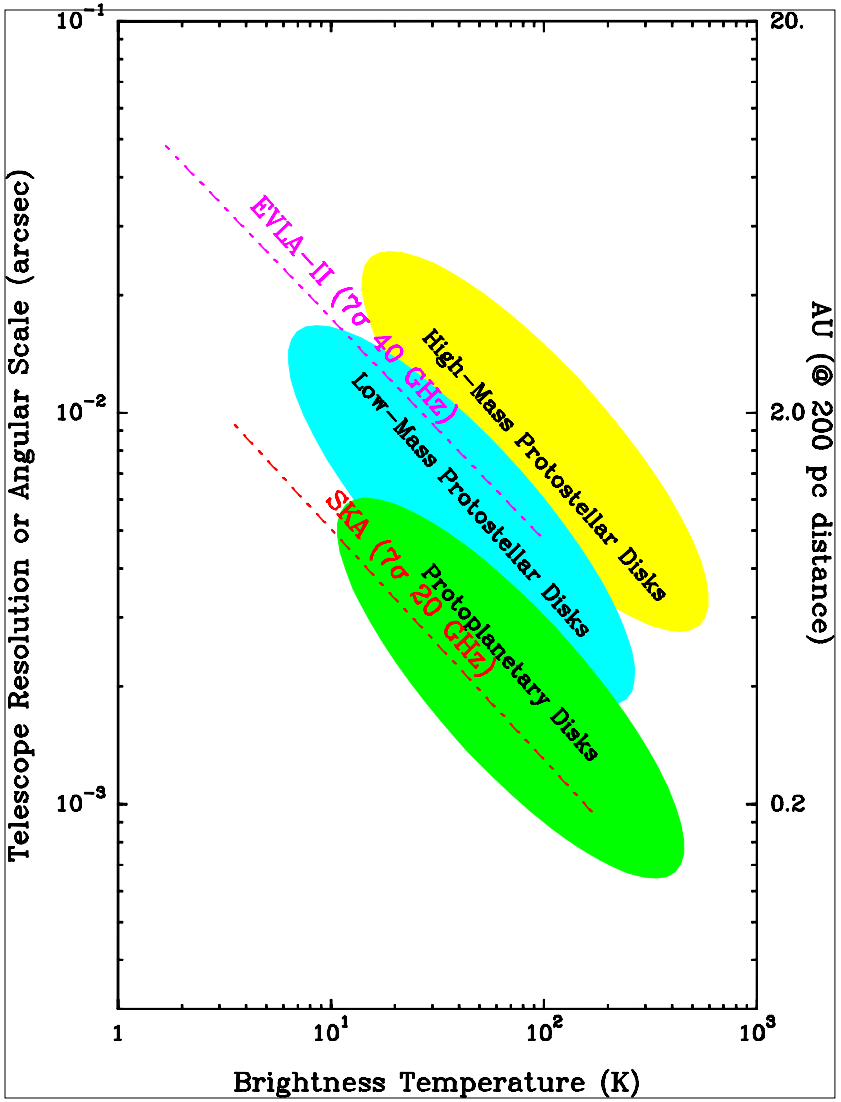
Need cm waves (avoid high optical depths, detect “pebbles”)

Need mas-resolution (sub-AU @ 200 pc)

Need excellent brightness sensitivity

Extremely dynamic processes, evolving on months to years – movie of protoplanetary disk

Future Telescopes Needed



Required image scales & brightness for

Proto-Stellar Disk: 0.1-0.01 Msun in 100 AU

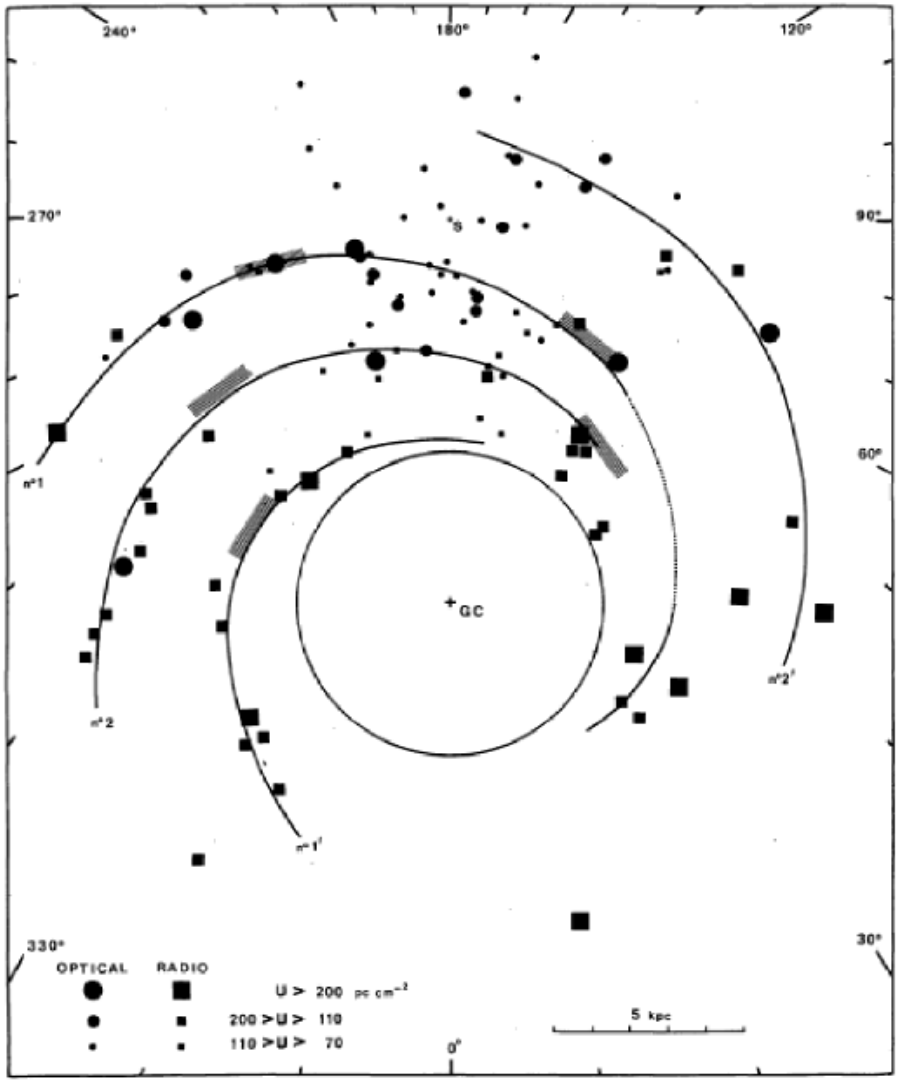
Proto-Planetary Disk: 0.001 Msun in 10 AU

Multi-wavelengths important to determine grain size vs radius & age

EVLA-II complements ALMA

SKA explores unique territory

Structure and Dark Matter in Milky Way



Georgelin & Georgelin (1976)

What does Milky Way look like in 3-D?

Is Spiral Density Wave paradigm correct?

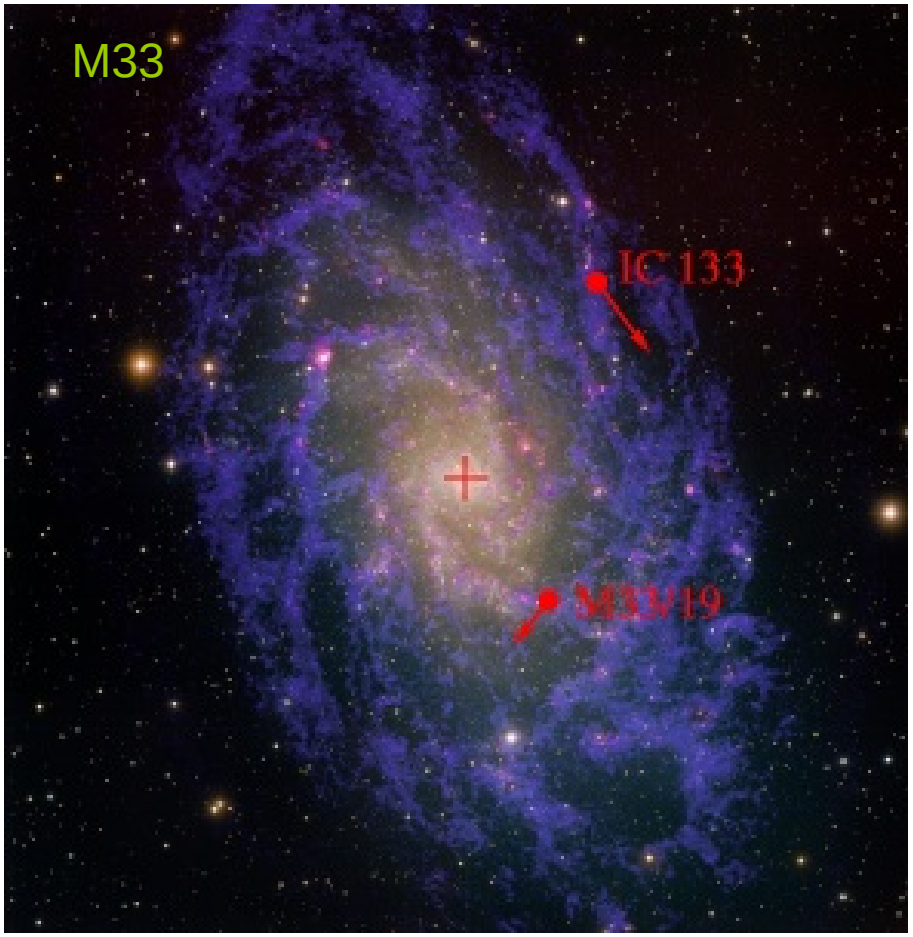
How is the Dark Matter halo distributed?

Little progress in 30 years!

Need Parallaxes and Proper Motions
(SIM/GAIA limited by optical extinction)

SKA detects weak sources, close calibs
Distances to Hyades / Pleides (<<1%)
Ro (1%)
thousand pulsars, stars (few %)

Mapping the Local Group



VLBA has measured proper motions of 2 masers in M33

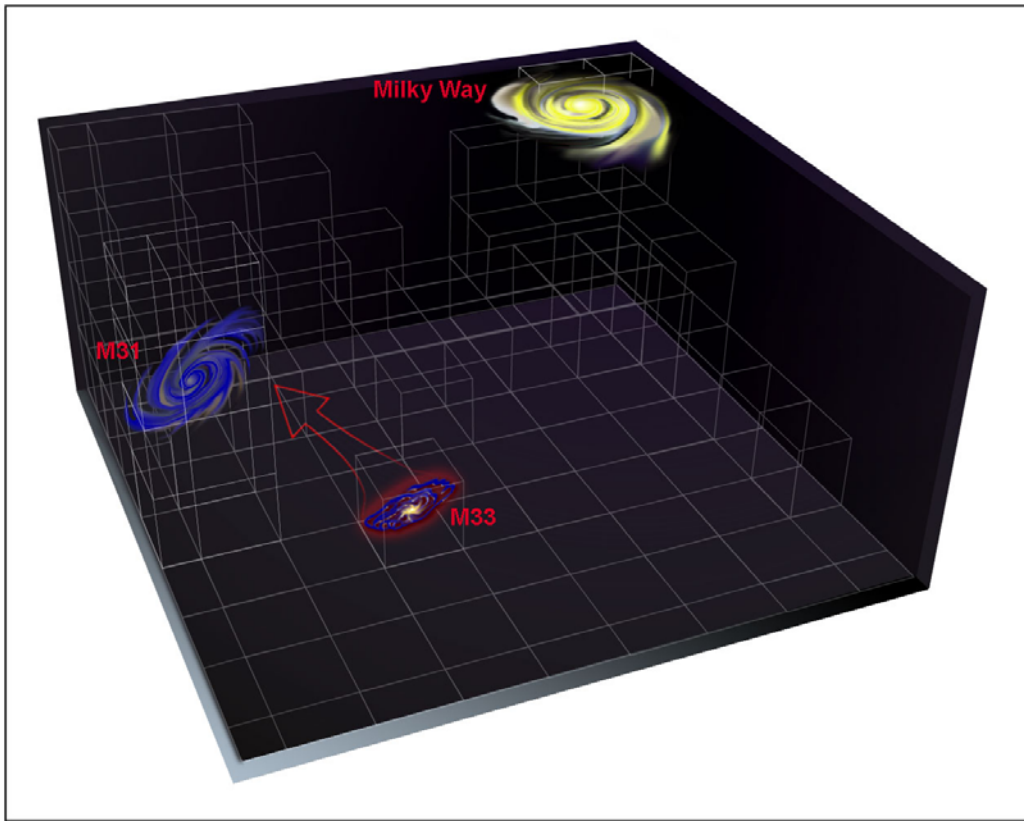
SKA-VLB could do entire Local Group

Proper Motions

Rotation Distances:

$$D = V_{rot} / (\mu \sin i) \sim +/- 5\%$$

Dark Matter in Local Group



What is the history and fate of the Local Group?

How much Dark Matter is in halos?

How is the Dark Matter distributed?

Measure 3-D locations and motions;

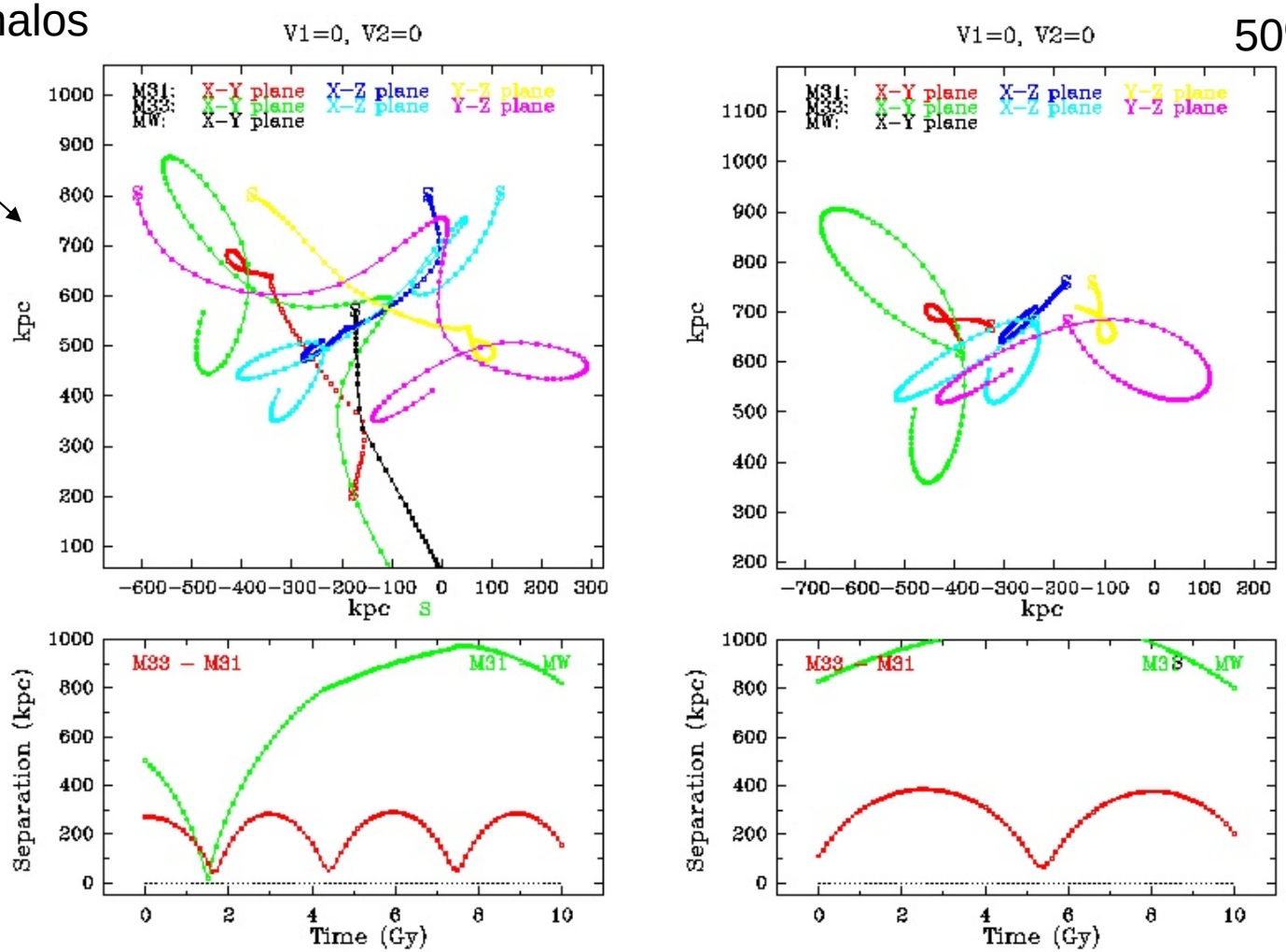
Model dark matter halos

N-body integrations yield history/future

Dark Matter in Local Group

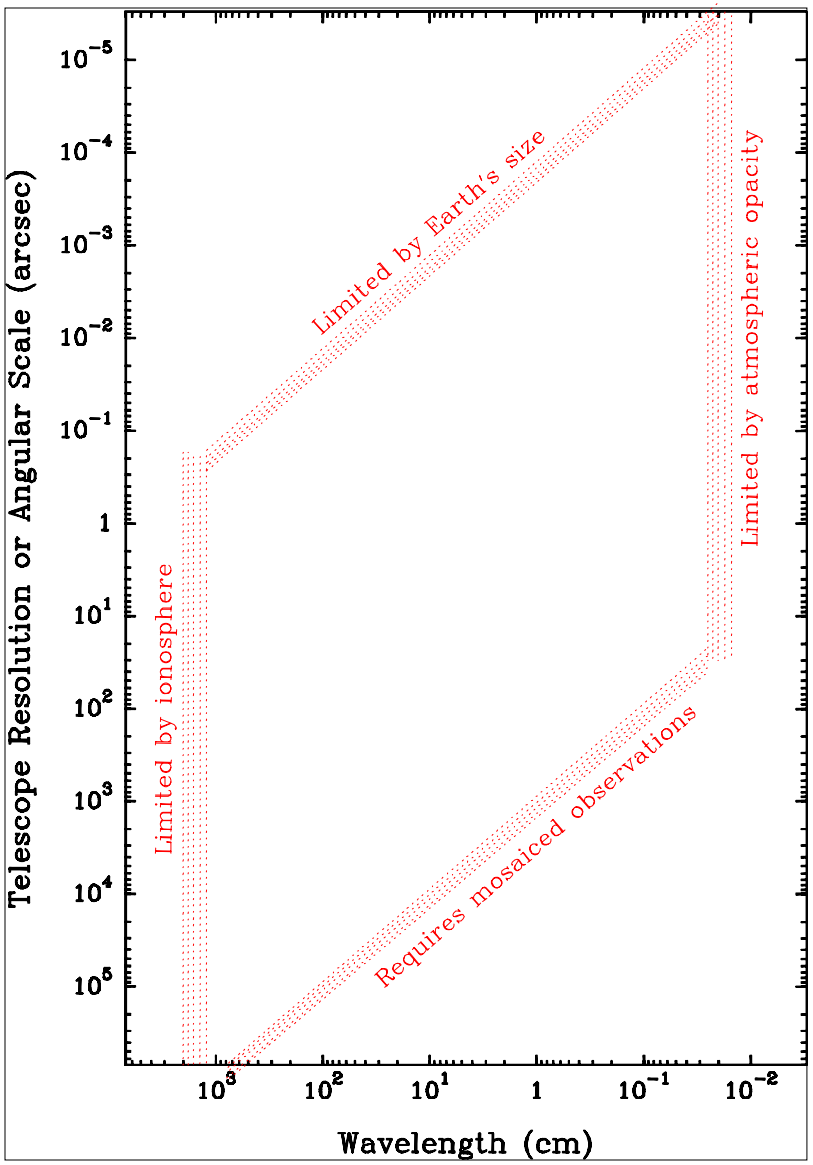
"full" DM halos

50% DM halo



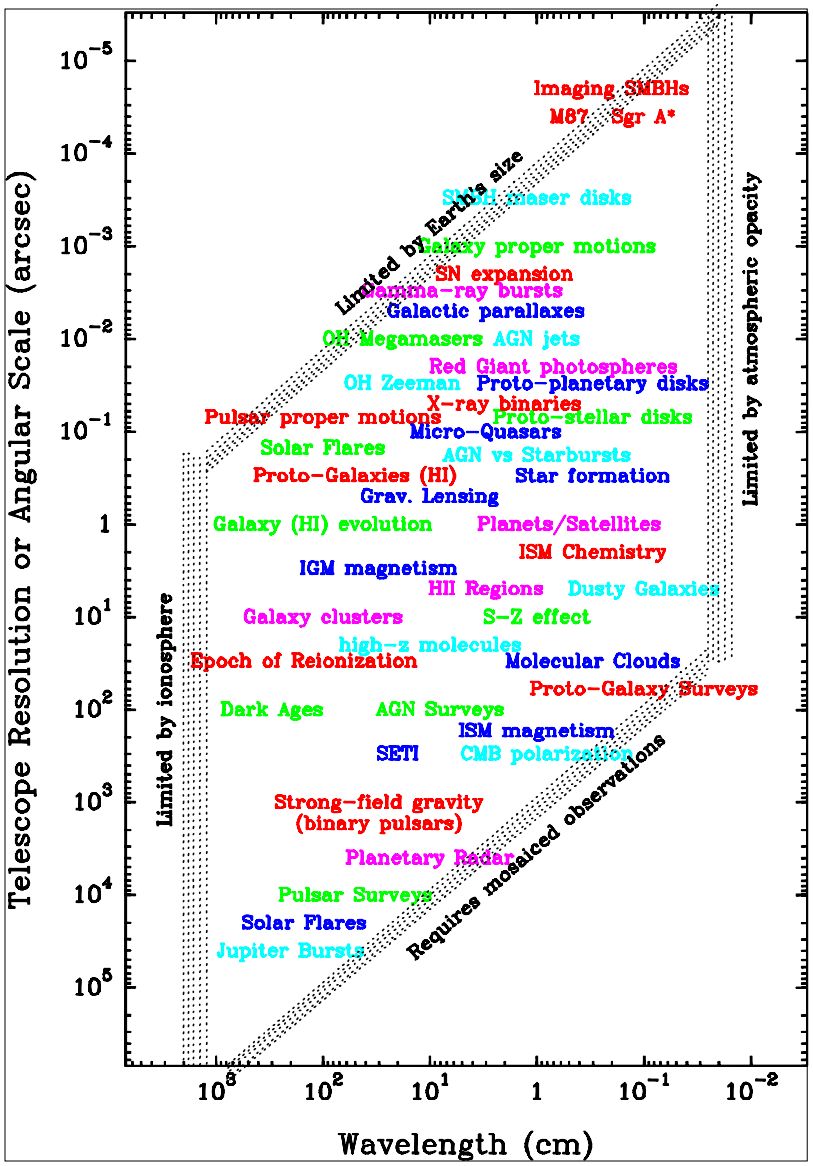
N-body calculations: sensitive to dark matter halos

Science with Current and Future National Radio Telescopes



Constraints on radio observations

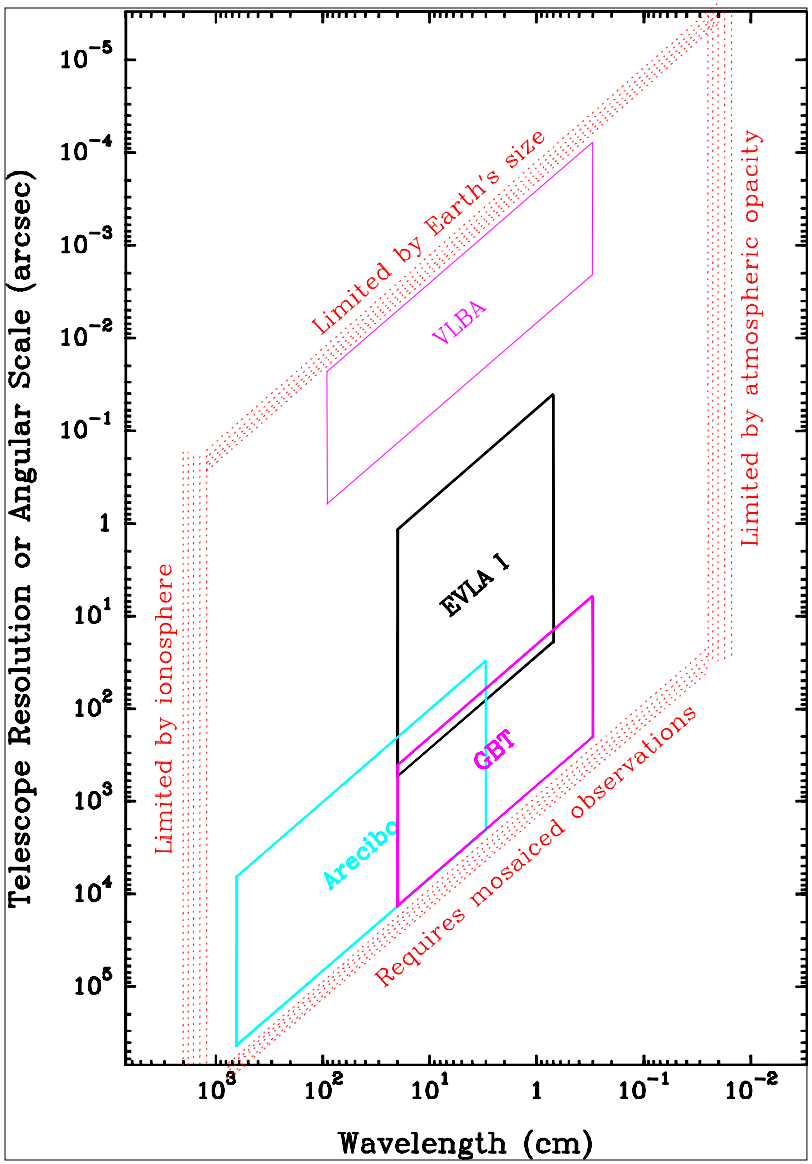
Science with Current and Future Radio Telescopes



Constraints on radio observations

Many significant science targets

Science with Current and Future Radio Telescopes

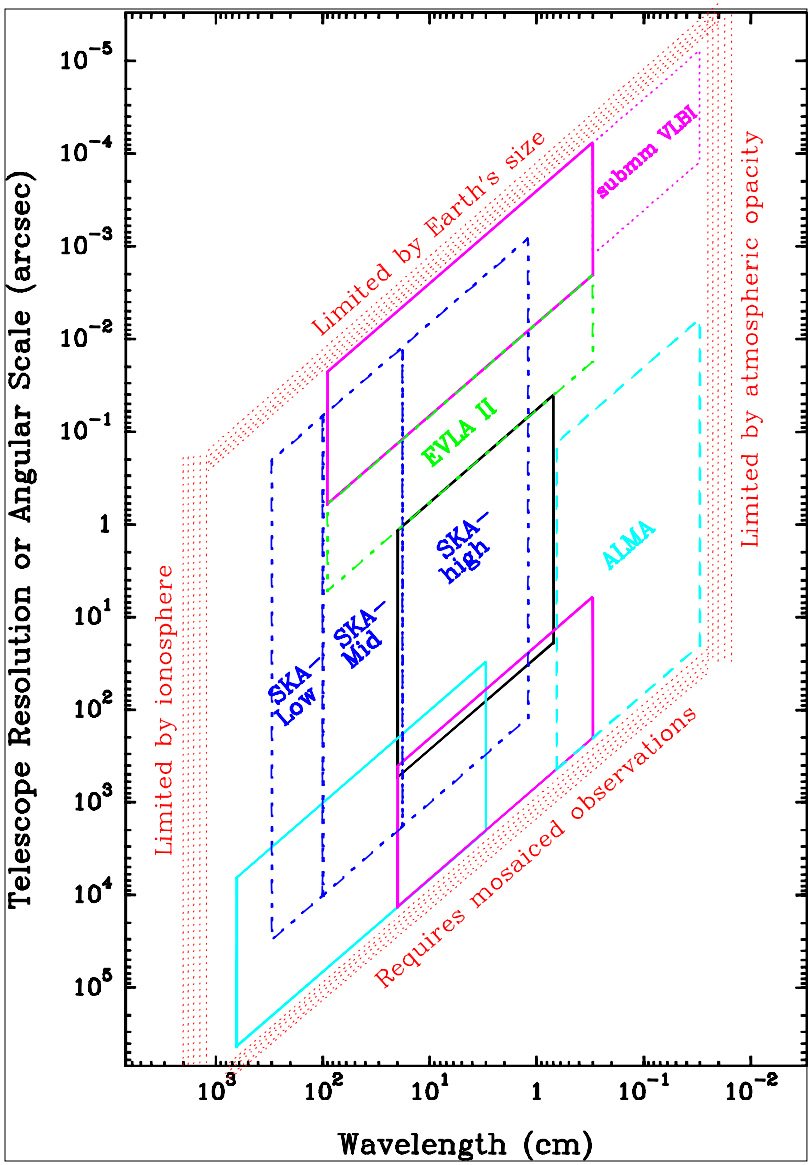


Constraints on radio observations

Many significant science targets

Current national facilities leave big gaps

Science with Current and Future Radio Telescopes



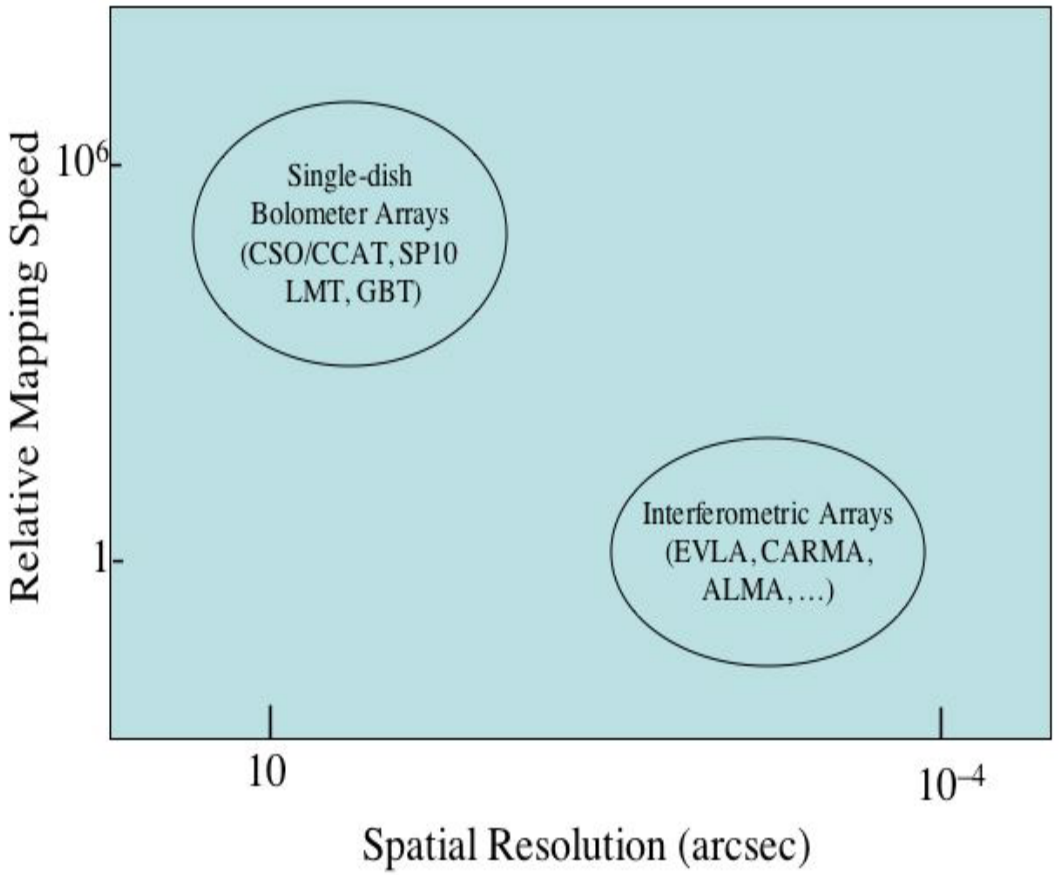
Constraints on radio observations

Many significant science targets

Current national facilities leave big gaps

New facilities needed

Other Important Observational Parameters



Also need single-dish telescopes with large receiver arrays