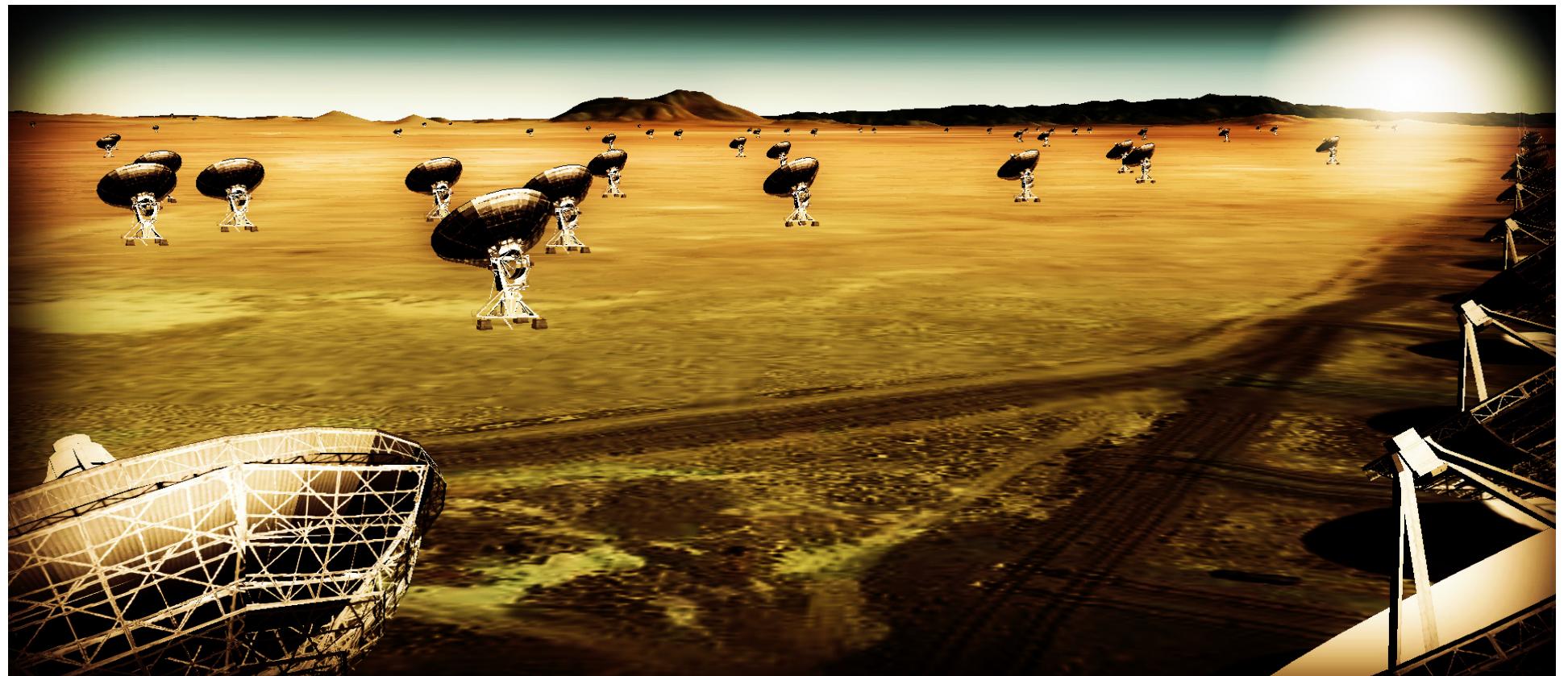
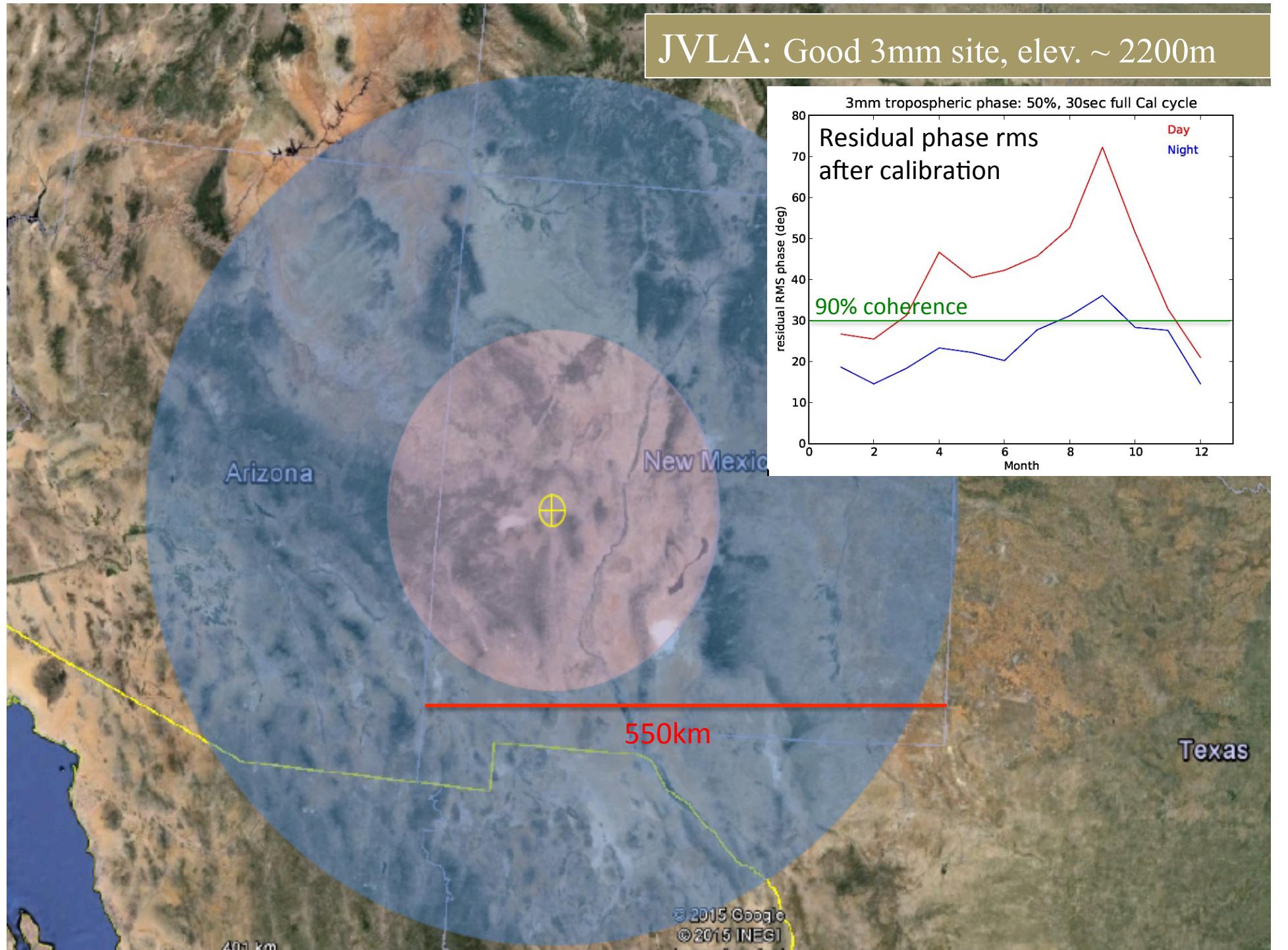


THE VERY LARGE ARRAY

THE NEXT GENERATION

- 10x Effective Area JVLA, ALMA
- Frequency Range: 1 – 115 GHz
- 10x Resolution w. 50% to few km + 50% to 300km + VLBI





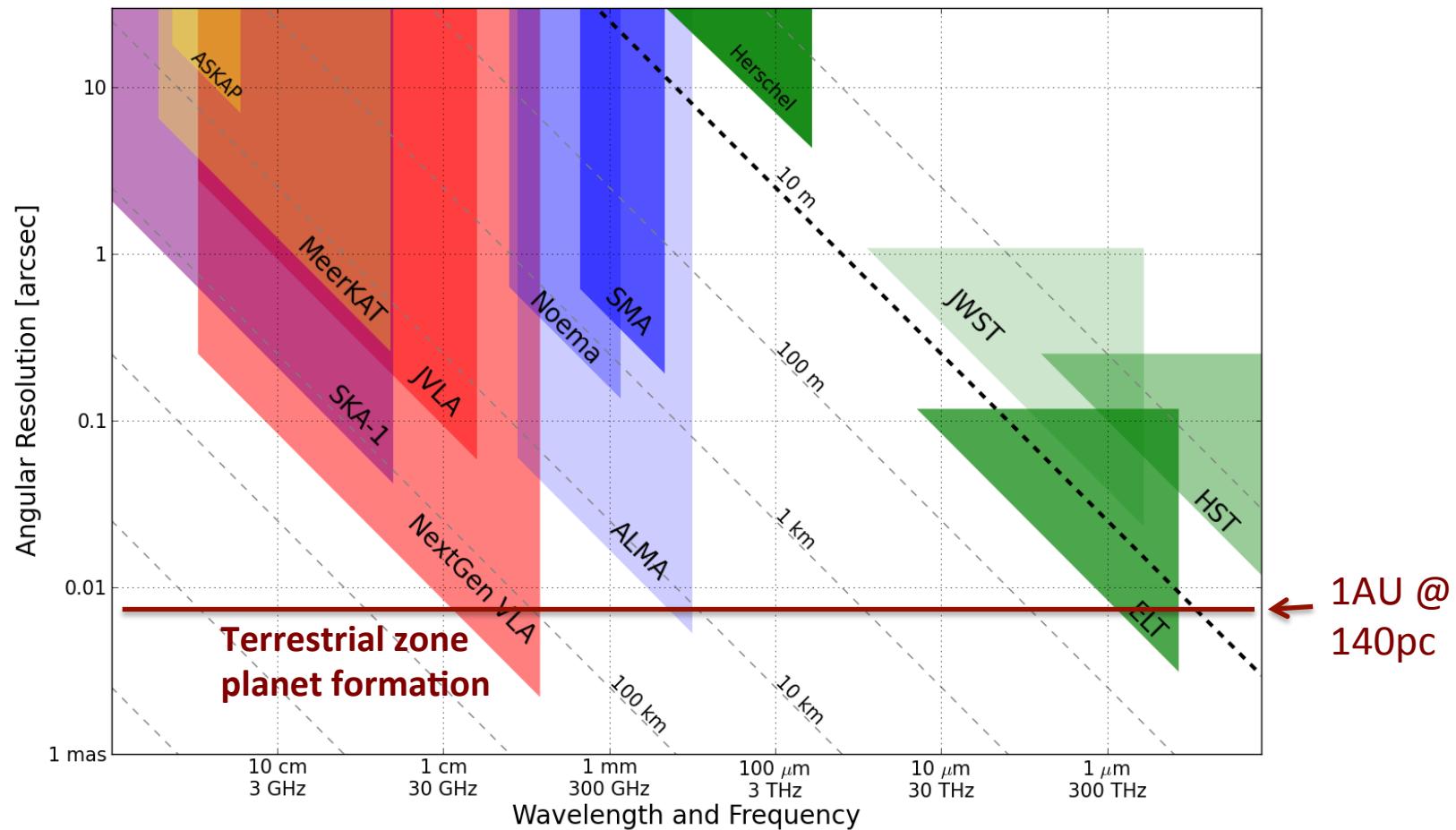
Process to date <https://science.nrao.edu/futures/ngvla>

- AAS Community Day January 2015
- Science working group reports October 2015
 - Circle of Life (Isella, Moullet, Hull)
 - Galaxy ecosystems (Murphy, Leroy)
 - Galaxy assembly (Lacy, Casey, Hodge)
 - Time domain, Cosmology, Physics (Bower, Demorest)
- Technical meetings
 - April 2015 Pasadena: Antennas, Receivers, Correlator
 - December 2015 Socorro: Operations, Post-processing, LO/IF
- Future
 - AAS Community Day January 4 2015
 - Key Use Cases → science requirements → telescope specs (small grants?)
 - Third Technical meeting ?



Killer Gap

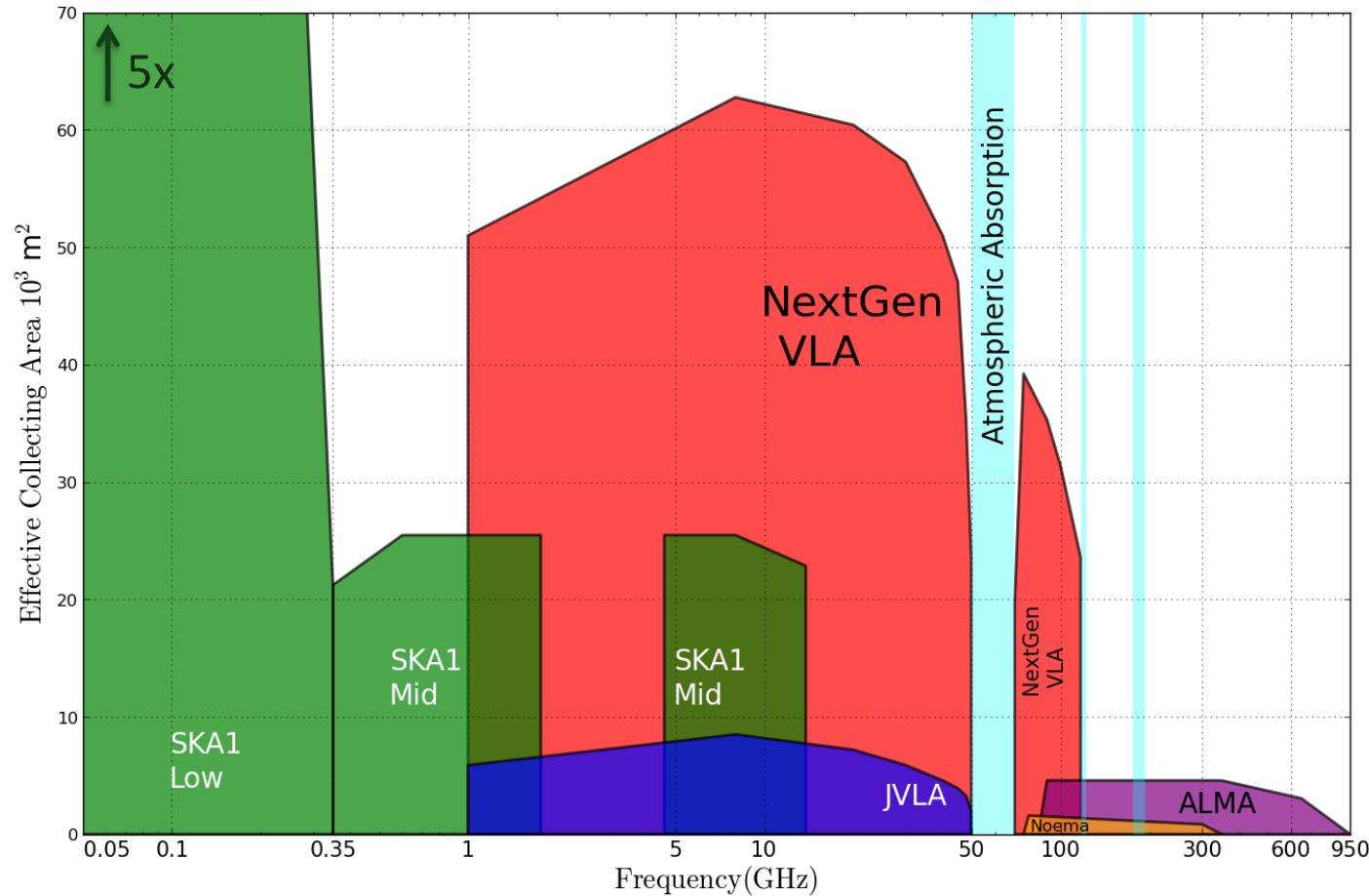
Thermal imaging on mas scales at $\lambda \sim 0.3\text{cm}$ to 3cm



- Resolution $\sim 10\text{mas}$ @ 1cm (300km)
- Synergy w. ALMA, future ELTs, NGST

Killer Gap

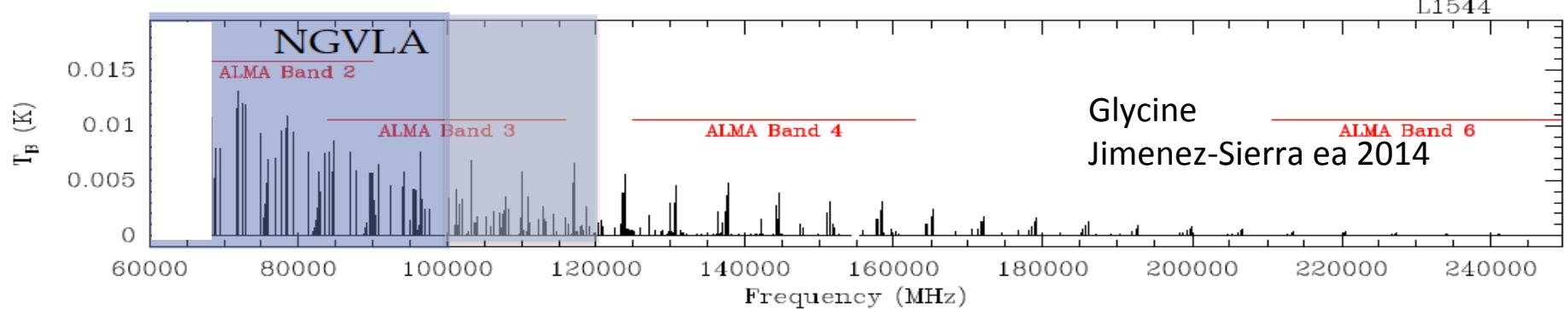
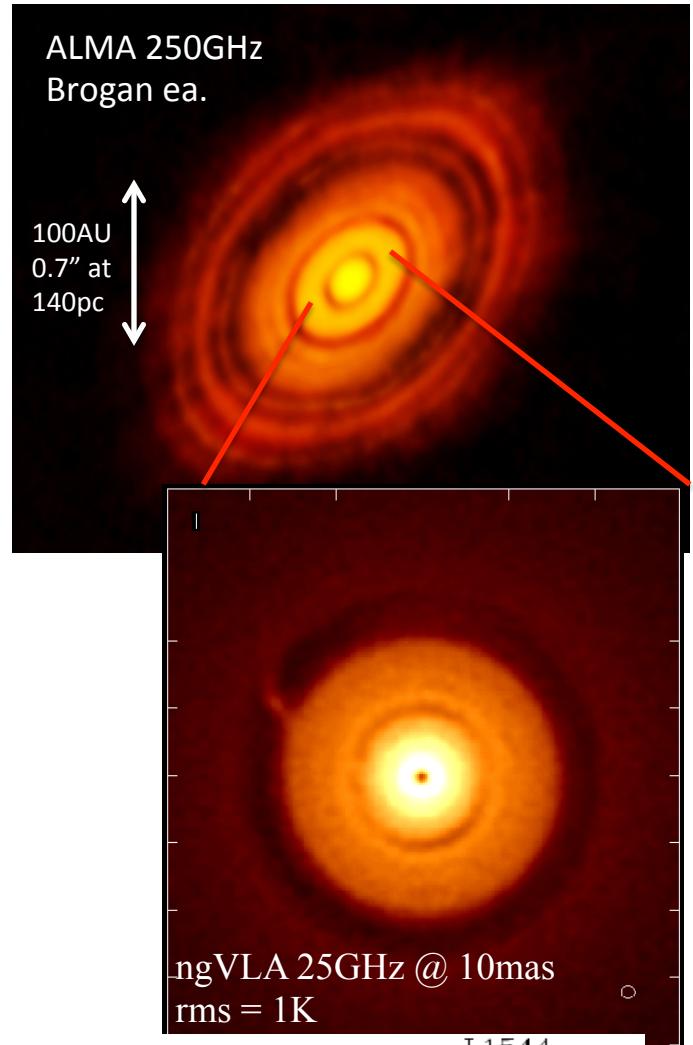
Thermal imaging on mas scales at $\lambda \sim 0.3\text{cm}$ to 3cm



- Sensitivity $\sim 100 \text{ nJy}$ @ 1cm, 10hr, BW = 20GHz
- $T_B \sim 1\text{K}$ @ 1cm, 10mas
- Molecular lines become prevalent above 15GHz

SWG1: Terrestrial zone planet formation imager

- Protoplanetary disks: Inner ~ 20 AU disk optically thick in mm/submm
- ngVLA cm: Grain growth and stratification from dust to pebbles to planets. Simulation:
 - Jupiter at 13AU, Saturn at 6AU: annual motions
 - Circumplanetary disks: planet accretion
- Pre-biotic molecules: rich spectra in 0.3cm to 3cm regime

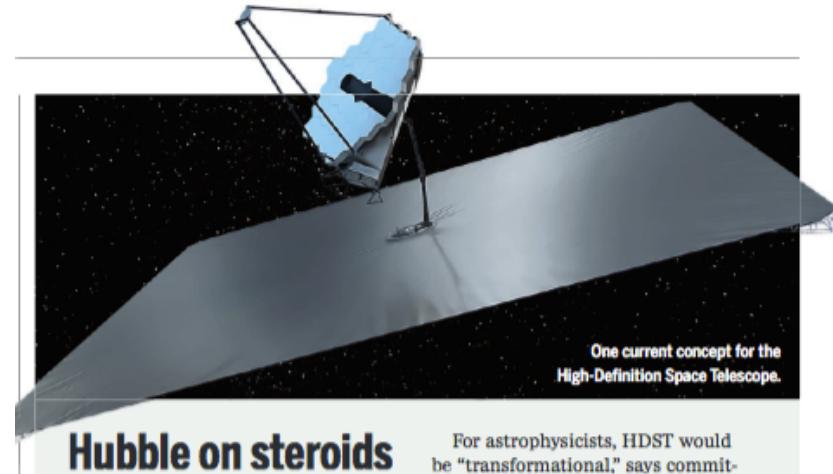


Next-Gen Synergy: Solar-system zone exoplanets

‘ALMA is to HST/Kepler as ngVLA is to HDST’

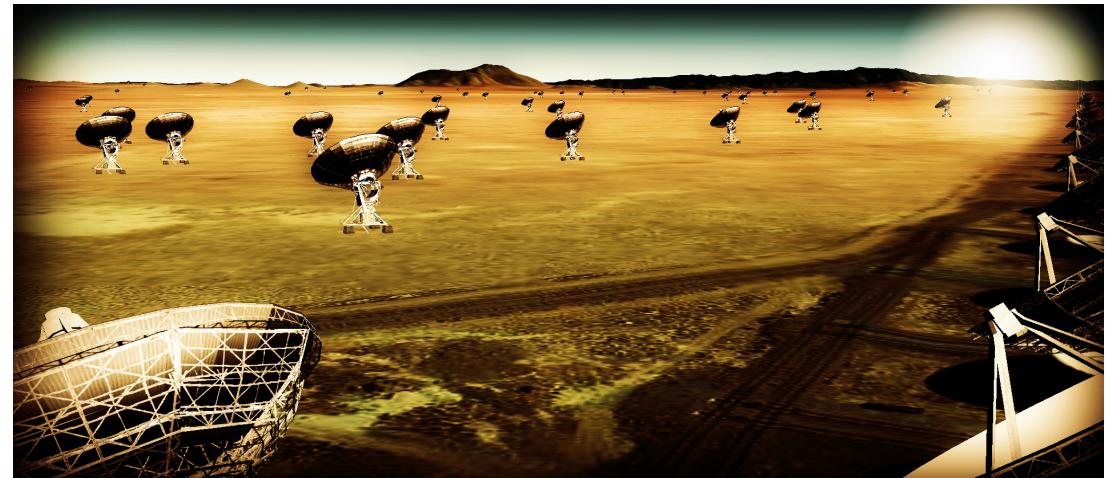
High Definition Space Telescope
Terrestrial planets: top science goal

- Direct imaging of earth-like planets
- Search for atmospheric bio-signatures



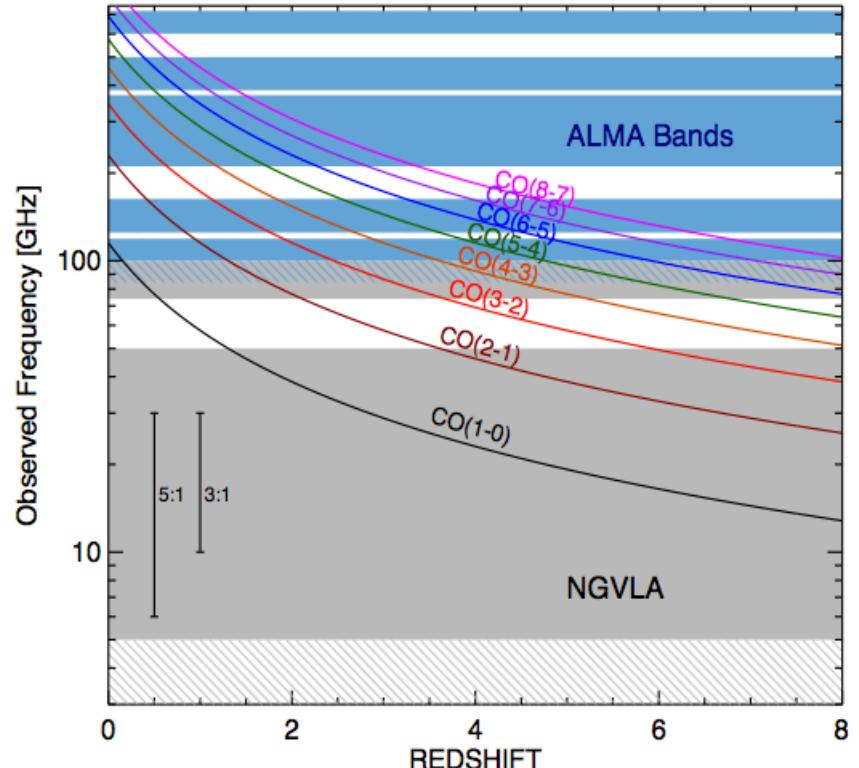
ngVLA

- Imaging *formation* of terrestrial planets
- Pre-biotic chemistry

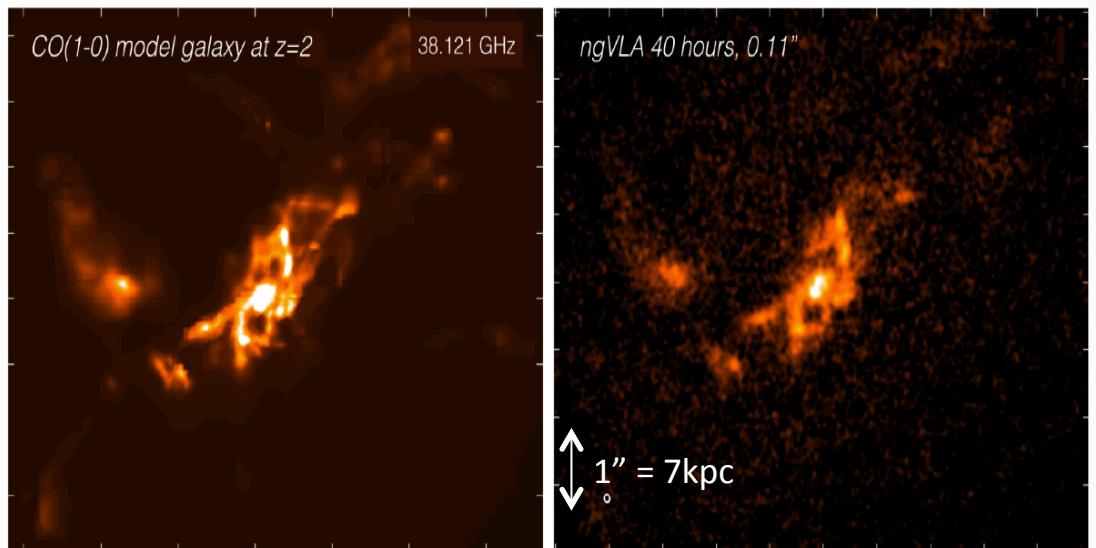


SWG3: Cool Gas History of the Universe – Tracing the fuel for star formation through cosmic time

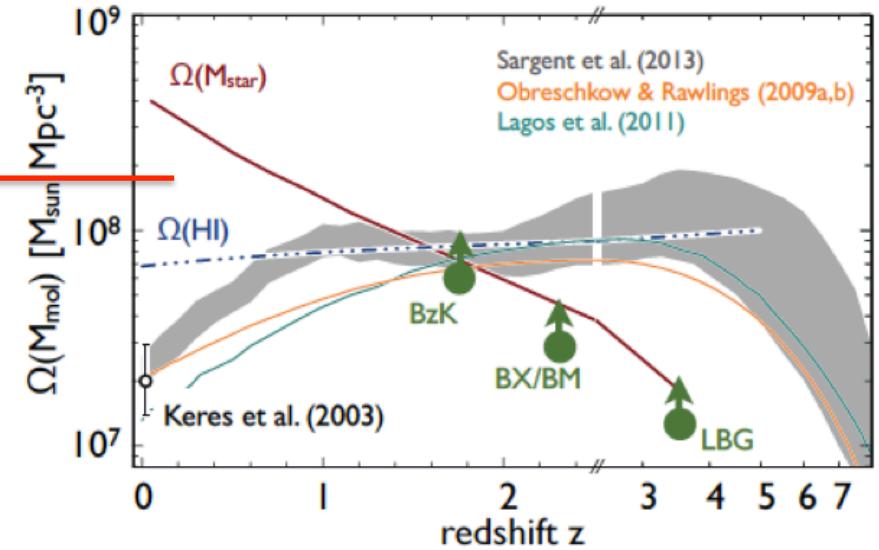
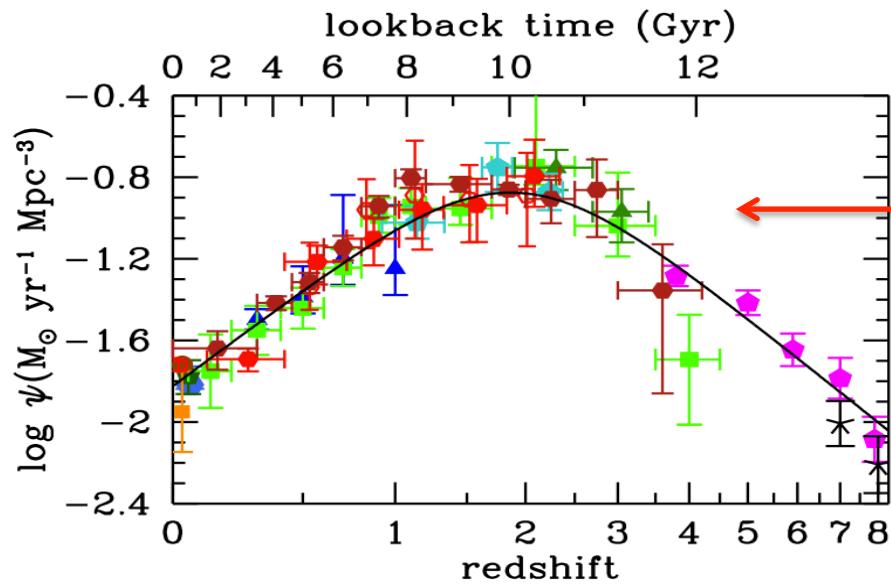
- Low order CO = molec. gas mass tracer
- 10x sens: $z > 1$ ‘main sequence’ galaxies in 1hr w. $M_{\text{gas}} \sim 10^9 M_{\odot}$
- Dense gas tracers (HCN, HCO+...)



- Blind surveys: 100s galaxies/hr (vs. ~ 1 w. JVLA)
- Sub-kpc imaging: large scale gas dynamics
- Synergy w. ALMA: Gas excitation, dust + SF laws



Next-Gen Synergy: Cosmic Gas to Stars Cycle



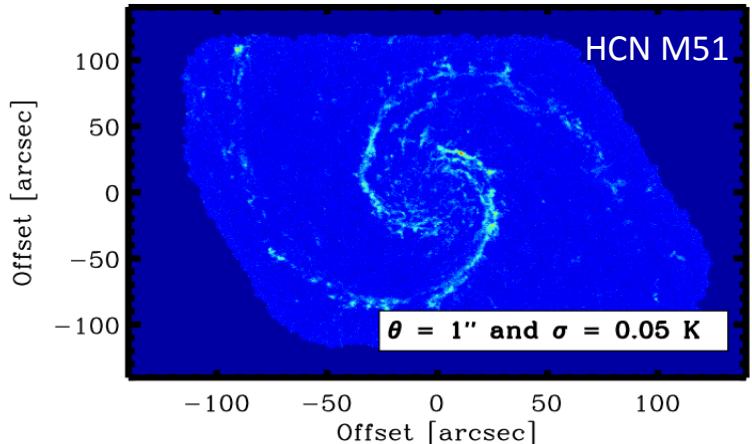
JWST/TMT: stars and star formation



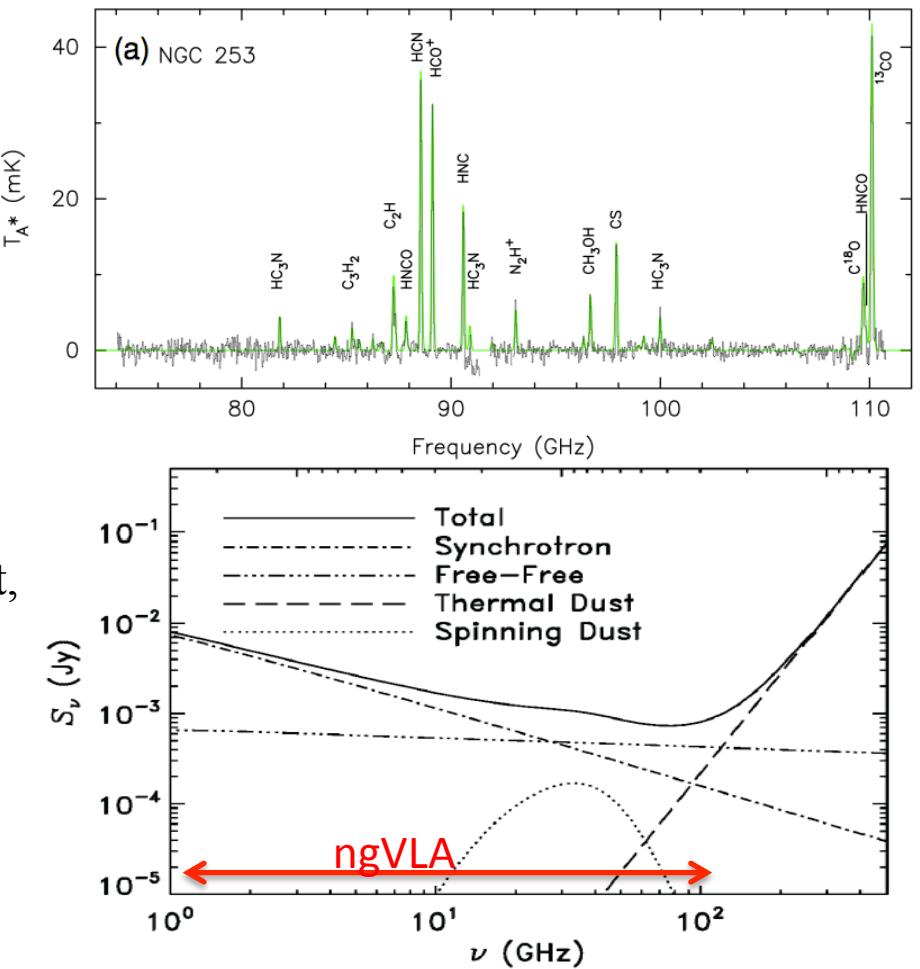
ngVLA: cold gas driving cosmic star formation



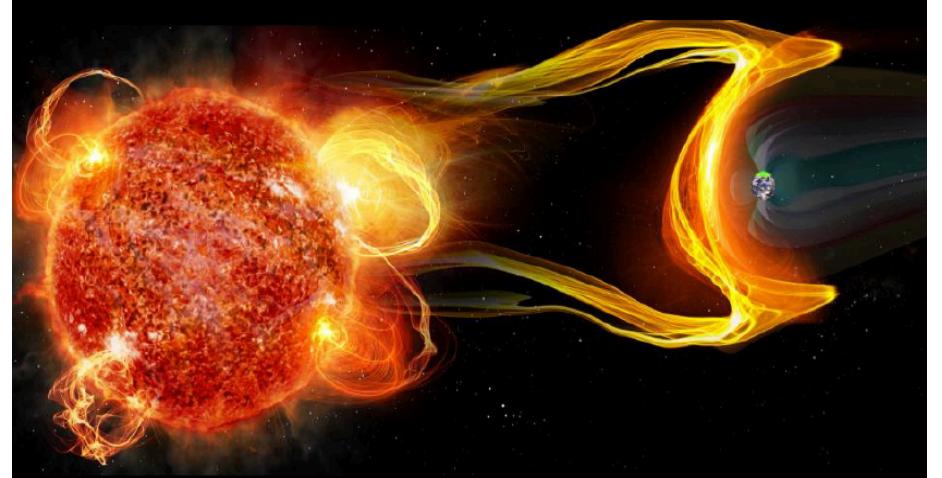
SWG2: wide field imaging 10x faster
than ALMA – MW/Local group science
out to Virgo!



- Spectral lines
 - Ground state transitions of primary astrochemical, dense gas tracers
 - Unprecedented view of Baryon Cycle
- Broad-Band Continuum
 - Synchrotron, free-free, cold (spinning?) dust, SZ effect
 - Obscuration free estimates of SFR
 - Physics of cosmic rays, ionized gas, dust, and hot gas around galaxies
- Synergy: FIR Explorer, TMT...



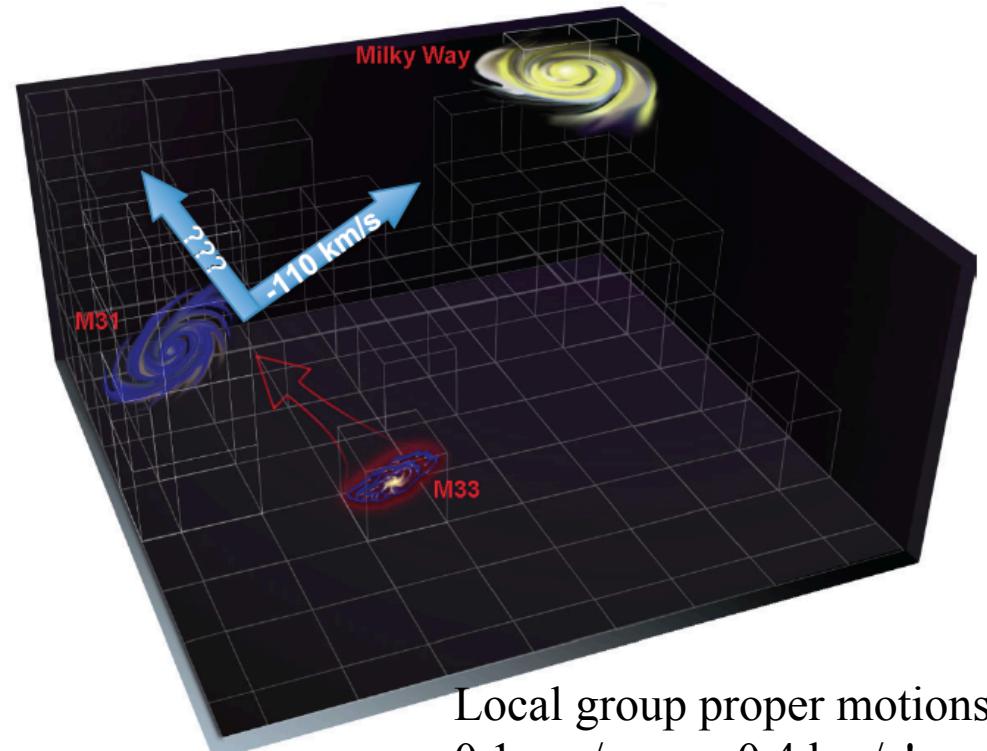
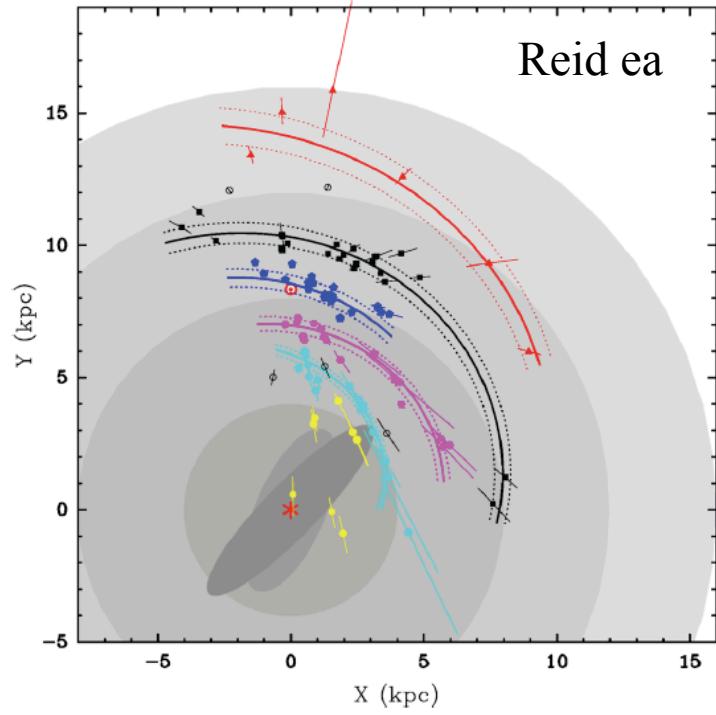
SWG4: Exploring the Time Domain – NGVLA most sensitive telescope to study broad-band temporal phenomena



- Explosive Universe (TDEs, GRBs, Blazars, GW/EM, FRBs?): high frequency peaks higher and earlier
- Exo-space weather: exo-planet environments and the development of life
 - Thermal stellar winds to $10^{-13} M_\odot/\text{yr}$
 - Brown dwarf Auroras: Star-planet magnetospheric interactions
- Synergy: LSST, LIGO, FERMI++...

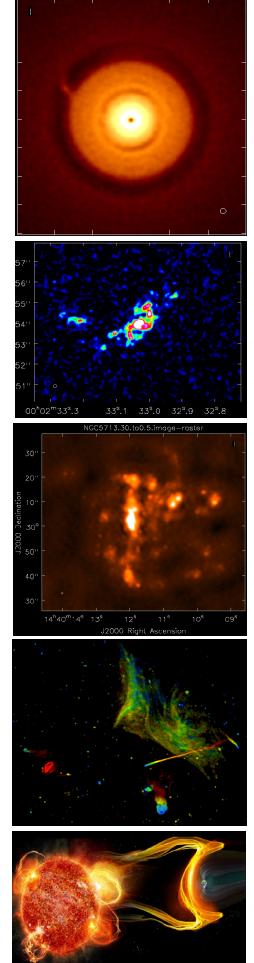
VLBI uas astrometry

- Local group cosmology: proper motions + parallax w. masers + AGN: 0.1 uas/yr => dark matter, fate MW, real-time cosmology: watch local Hubble expansion!
- Spiral structure of MW: masers in SF regions to far side of Galaxy



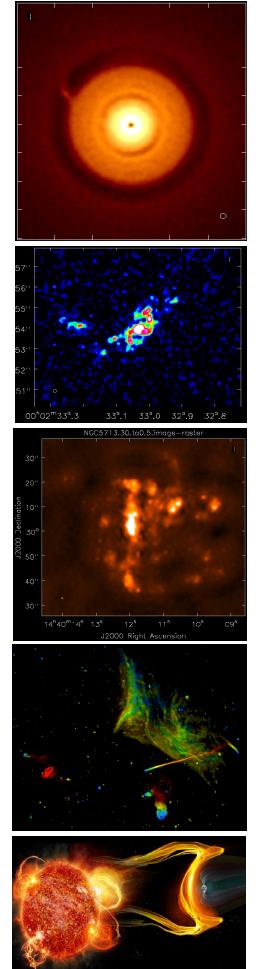
Local group proper motions
0.1 uas/year = 0.4 km/s!
(Darling)

Next steps: Requirements to Specifications

Goal	Science Requirement	Array Specification	
TPF	Optically thin	Freq ~ 15 to 50GHz	
	1AU at 130pc @ 30GHz	B ~ 300km	
	1K in 10hrs @ 10mas, 30GHz	$A_{\text{full}} \sim 300 \times 18\text{m}$; BW ~ 20GHz	
CGHU	CO 1-0 to z=8	Freq = 15 to 115GHz	
	$M_{\text{gas}} = 10^9 M_{\odot}$ at $z = 3$ in 1hr	$A_{\text{mid}} \sim 70\%$ to $B \sim 30\text{km}$	
	500pc resolution at $z = 3$ (60mas)	30km	
	Large volume surveys	Octave Band Ratio	
Baryon Cycle	$T_B < 0.2\text{K}$ (1hr, 10 km/s, 80GHz, 1'')	$A_{\text{core}} \sim 30\%$ to $B \sim 2\text{km}$	
	Continuum science	Octave BR; Linear pol to 0.1%	
Time Domain	Explosive follow-up (GRBs, GW/EM...)	Minute trigger response time	
	Blind discoveries (eg. FRBs)	millisec searches	
	Exo-space weather: 1uJy in 1min	Freq ~ 1 to 20GHz $A_{\text{full}} \sim 300 \times 18\text{m}$ Circular pol to few %	

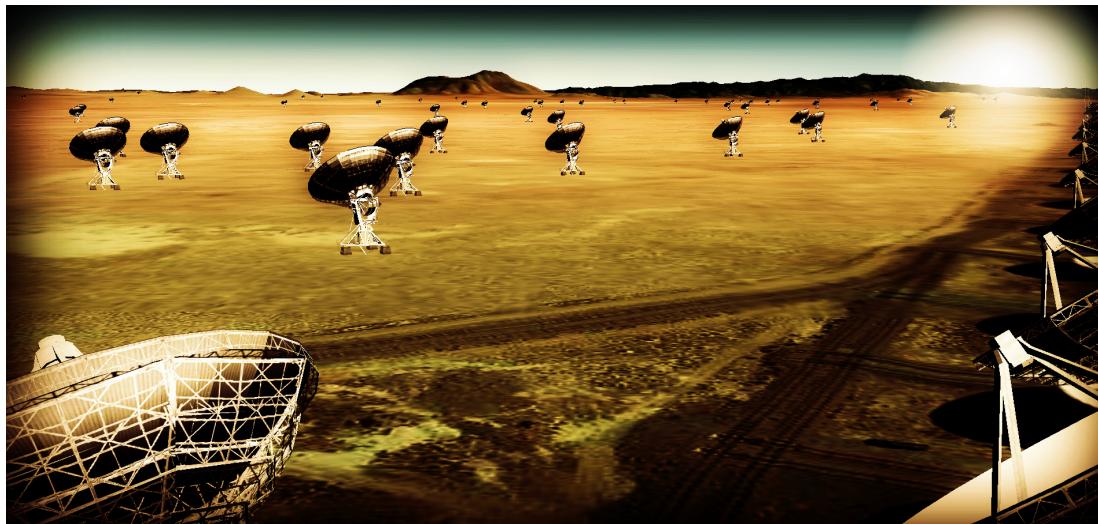
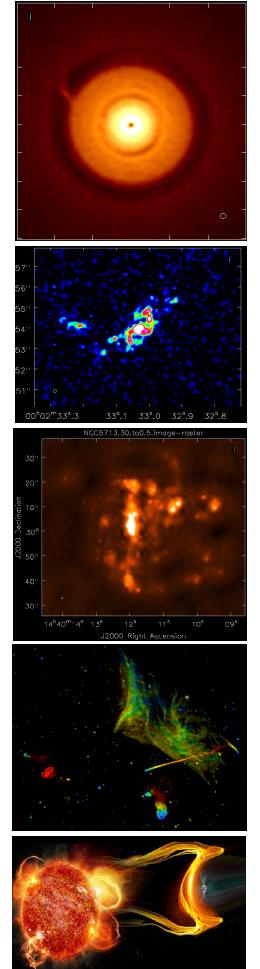
Next steps: Requirements to Specifications

- Antennas
 - 12m to 25m: FoV requirements
 - On vs. off axis: DNR requirements
- Configuration: need simulations
 - Balance: Core (1km) vs. mid (30km) vs. long (300km)
 - Some fraction reconfigurable
 - Need for large single dish + cameras or compact array
- Receivers
 - Band ratios: performance v. number
 - Low frequency limit
- Phase Calibration: testing at JVLA
- VLBI implementation: need simulations
 - New stations vs. ‘ad hoc’



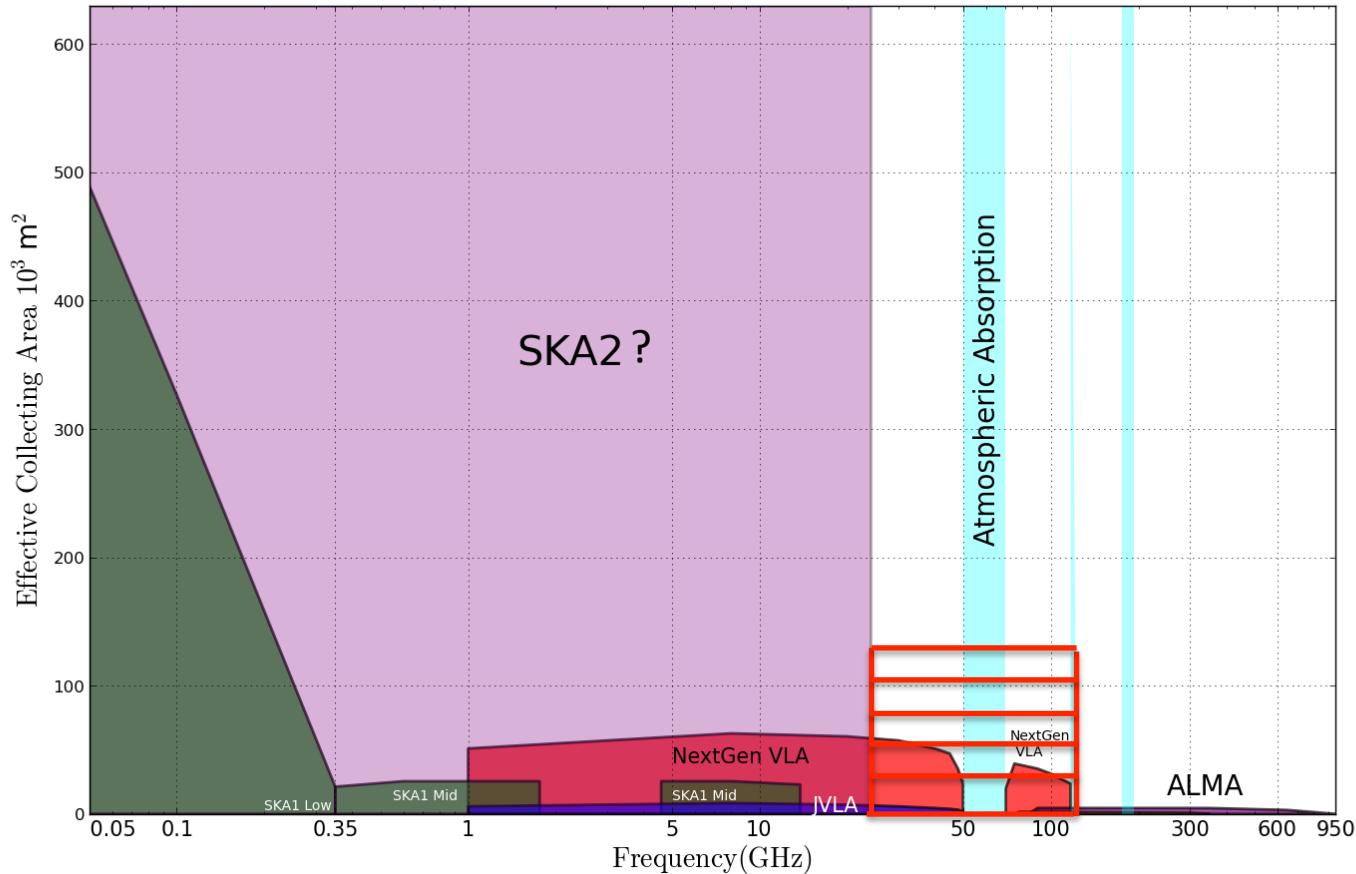
Next Steps: Science Case is not Static!

- Science Advisory Committee
- Future workshops
 - SWG focused meetings
 - Broad community meeting: Open call for papers, early 2017?
- Possible small grants program
- NRAO sci-tech support for simulations/calculations
- Goal: compelling Sci/Tech proposal to DS2020



Killer Gap

Thermal imaging on mas scales at $\lambda \sim 0.3\text{cm}$ to 3cm



- Phase 2 SKA: status unknown? 20 to 115GHz remains new window, regardless