ngvla
Next Generation Very Large Array

A next-generation VLA

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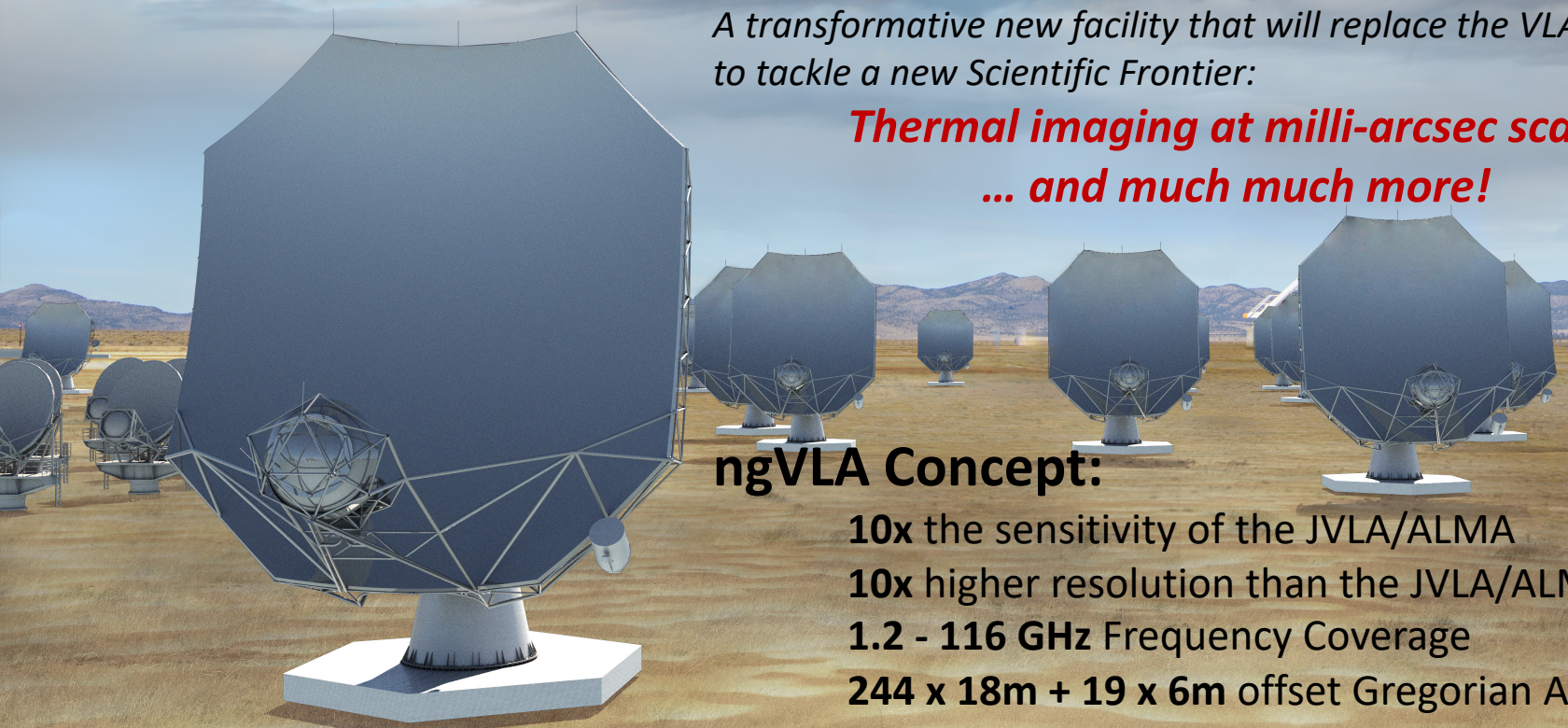
NSF AUI NRAO

The next-generation Very Large Array (ngVLA)



A transformative new facility that will replace the VLA and VLBA to tackle a new Scientific Frontier:

Thermal imaging at milli-arcsec scales.

… and much much more!

ngVLA Concept:

10x the sensitivity of the JVLA/ALMA

10x higher resolution than the JVLA/ALMA

1.2 - 116 GHz Frequency Coverage

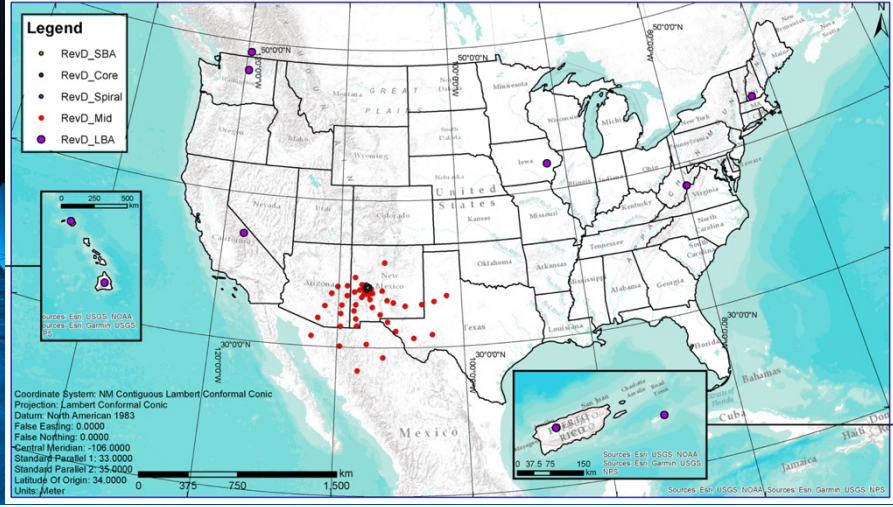
244 x 18m + 19 x 6m offset Gregorian Antennas

Centered at VLA site and concentrated in SW US.

Fixed antenna locations across North America.

ngVLA Technical Baseline

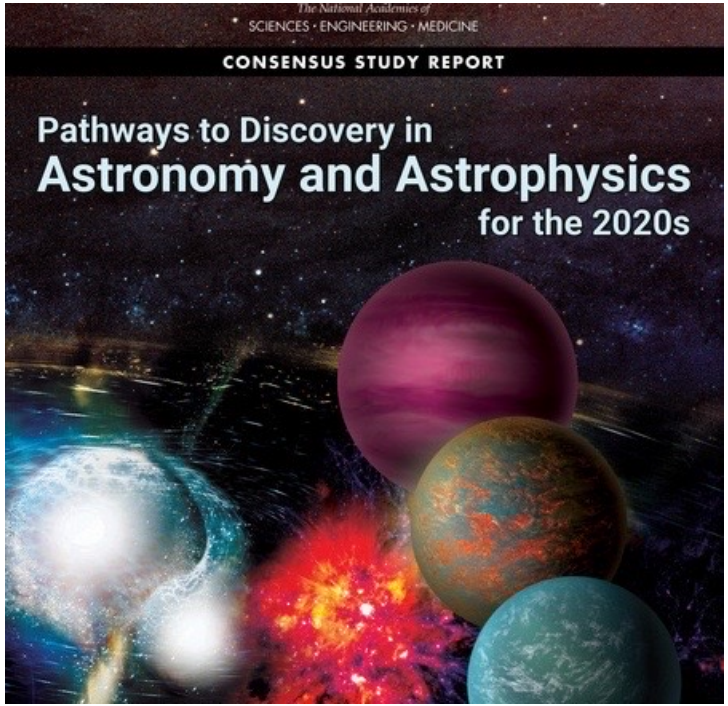
New paradigm: Will primarily operate using science sub-arrays

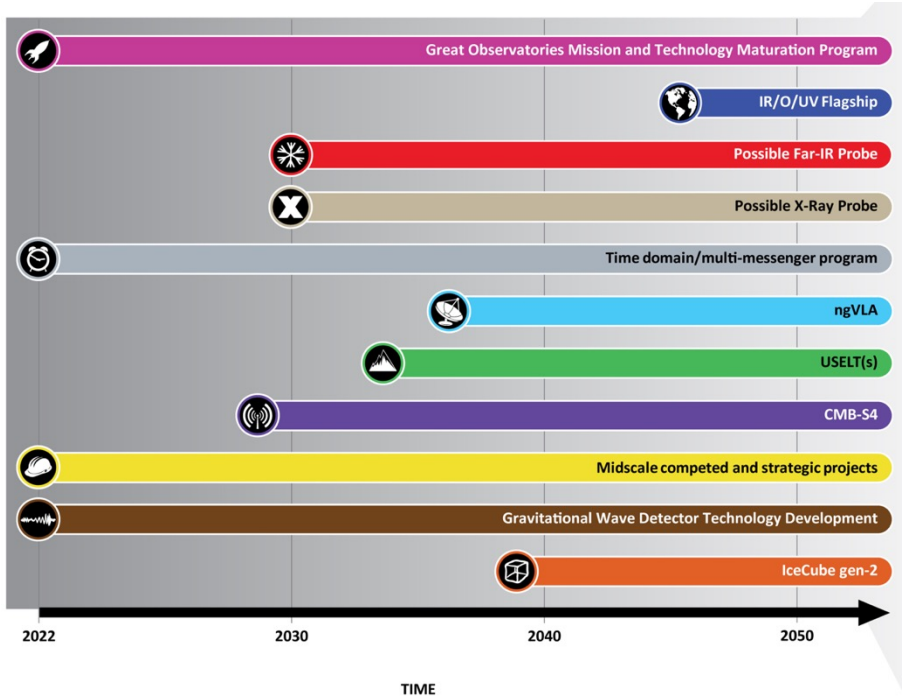


- **1.2 - 116 GHz** Frequency Coverage
- **Array Design**: 244 x 18m offset Gregorian Antennas
  - **Core**: 114 fixed antennas; B_{max} = 4.3 km
  - **Spiral**: 54 fixed antennas; B_{max} = 39 km
  - **Mid**: 46 fixed antennas spread into NM, AZ, TX, MX; B_{max} = 1070 km
  - **Long**: 30 x 18m antennas located across continent; B_{max} = 8860 km
- **Short Baseline Array**: 19 x 6m offset Greg. Antennas
  - Use 4 x 18m in **TP mode** to fill in (*u, v*) hole.

Band #	Dewar	f_L GHz	f_M GHz	f_H GHz	f_H: f_L	BW GHz
1	A	1.2	2.35	3.5	2.91	2.3
2	B	3.5	7.90	12.3	3.51	8.8
3	B	12.3	16.4	20.5	1.67	8.2
4	B	20.5	27.3	34.0	1.66	13.5
5	B	30.5	40.5	50.5	1.66	20.0
6	B	70.0	93.0	116	1.66	46.0

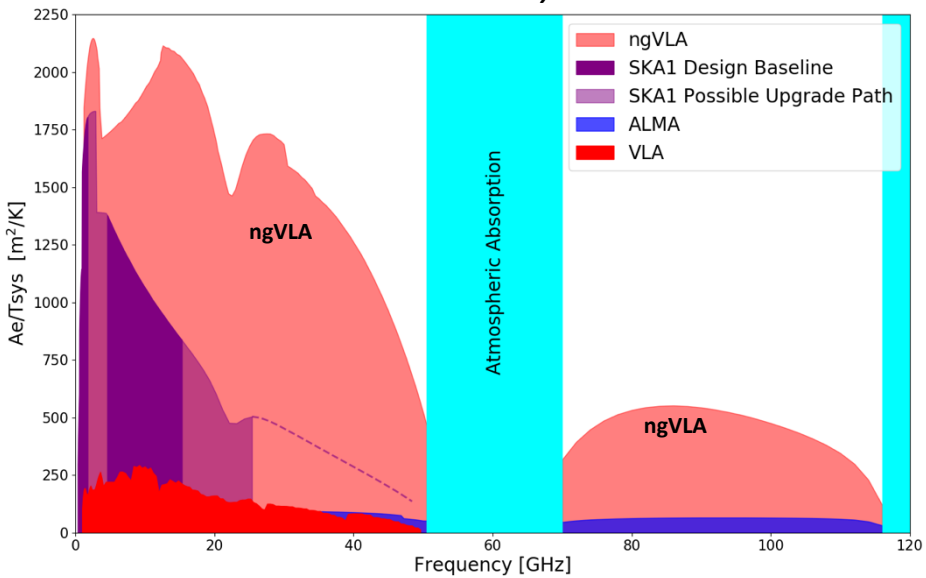
Astro2020 identified the ngVLA as a high-priority large, ground-based facility whose construction should start this decade.



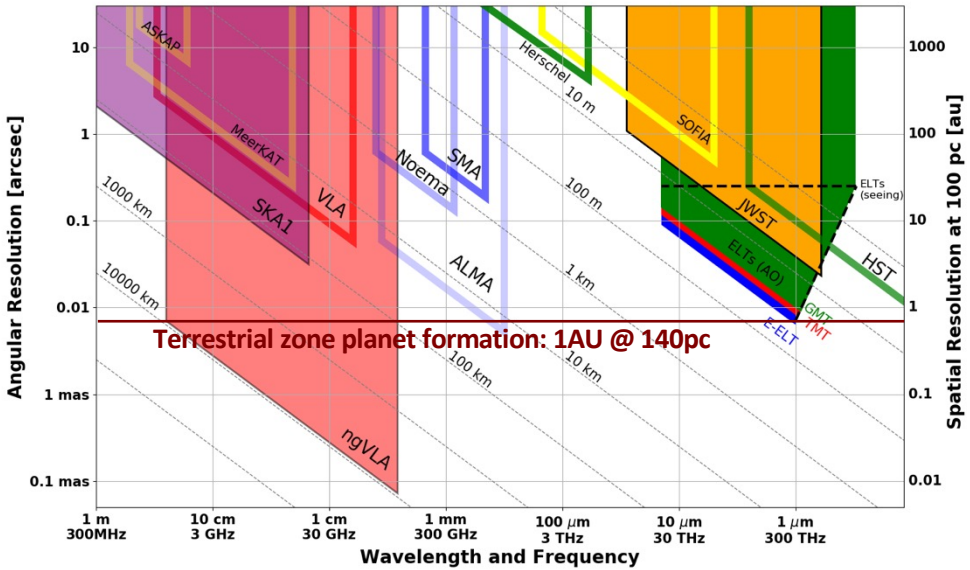


Linking SKA & ALMA Scientifically

Sensitivity



Resolution

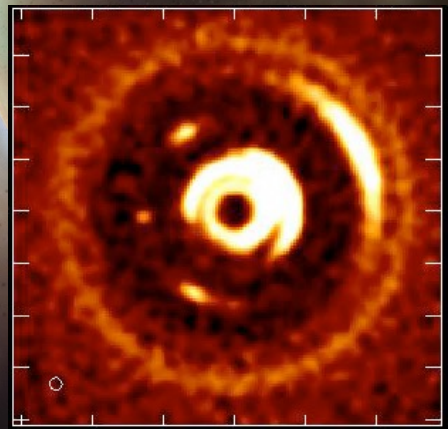


Complementary suite from cm to submm arrays for the mid-21st century

- **< 0.3cm:** ALMA 2030 superb for chemistry, dust, fine structure lines
- **0.3 to 3cm: ngVLA superb for terrestrial planet formation, dense gas history, baryon cycling**
- **> 3cm:** SKA superb for pulsars, reionization, HI + continuum surveys

ngVLA Key Science Goals (ngVLA memo #19)

1. *Unveiling the Formation of Solar System Analogues on Terrestrial Scales*
2. *Probing the Initial Conditions for Planetary Systems and Life with Astrochemistry*
3. *Charting the Assembly, Structure, and Evolution of Galaxies Over Cosmic Time*
4. *Using Pulsars in the Galactic Center as Fundamental Tests of Gravity*
5. *Understanding the Formation and Evolution of Stellar and Supermassive BH's in the Era of Multi-Messenger Astronomy*



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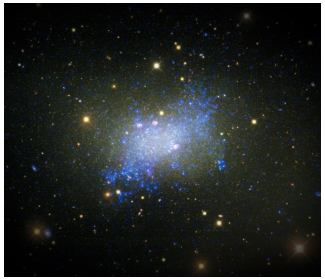
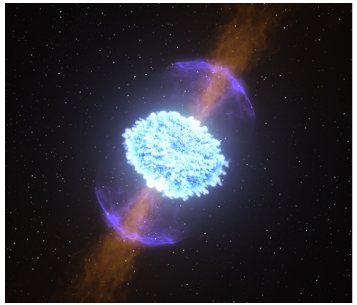
UVEX Baseline Science Program



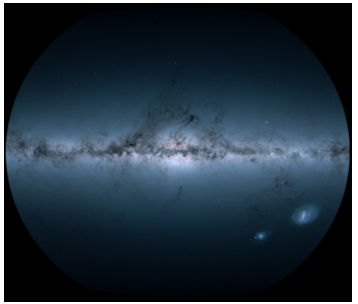


I. Low-Mass, Low-Metallicity Galaxy Frontier

- ngVLA KSG3: Gas and extinction-free SF properties

II. New Views on the Dynamic Universe

- ngVLA KSG5: Pre-selection/characterizing of GW sources

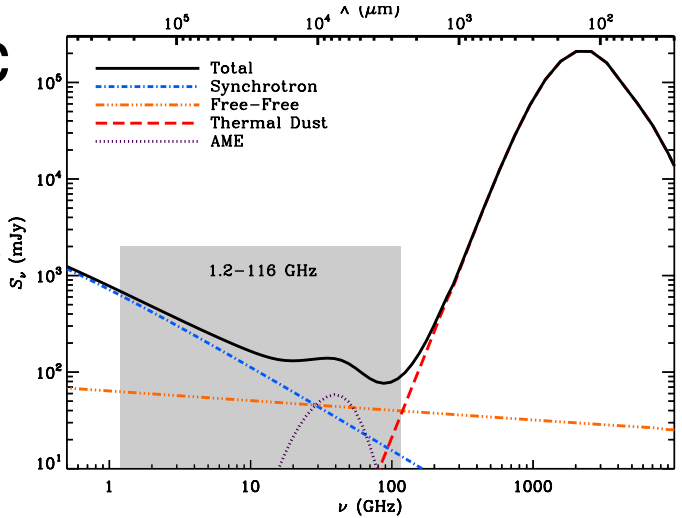


III. A Legacy of Deep Synoptic All-Sky Surveys

- All KSGs: Precision radio follow-up of all astrophysical sources

An Accounting of Energetic Processes in Galaxies

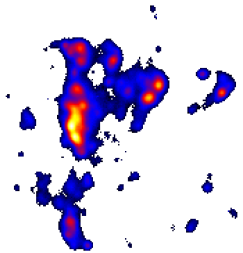
- The ngVLA will map and decompose the radio continuum emission from heterogeneous samples of nearby galaxies on 10 – 100 pc scales to account for the energetic processes powering the various emission components.
  - **Free-free**: HII regions, ionized gas, dust-unbiased SFRs
  - **Synchrotron**: SNe, CR's, B-fields
  - **AME**: dust physics, grain distribution, CMB foregrounds
  - **Thermal Dust**: cold dust/ISM mass
  - ***… and map gas (HI + CO)***



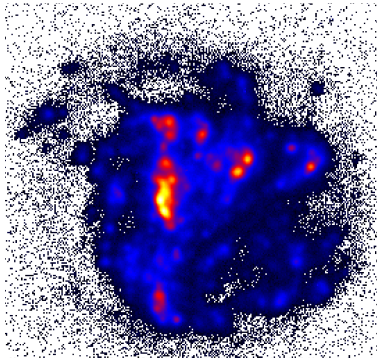
- The ngVLA will create Hα –like images (i.e., sensitivity & resolution) w/out extinction, FG stars, or [NII] contamination for large samples of nearby galaxies.
  - And do THINGS-like (HI) survey (~400 hr w/ VLA) in less than 2 days

- UVEX: Σ_{SFR} ~ 1x10^{-3} $M_\odot$/yr/kpc^2 (FUV; 5σ survey depth – 50Mpc)
- ngVLA(ff): Σ_{SFR} ~ 2x10^{-2} $M_\odot$/yr/kpc^2 (27 GHz; 5σ in 1hr – 50Mpc)
- ngVLA(NT): Σ_{SFR} ~ 4x10^{-3} $M_\odot$/yr/kpc^2 (2.4 GHz; 5σ in 1hr – 50Mpc)
  - ***Ideal tools to map faint star formation in low mass/low-Z galaxies – e.g. IMF variations***

NGC 5713



VLA 10hr @ 27GHz



ngVLA 10hr @ 27GHz

How does the IMF affect FUV and Radio Emission?

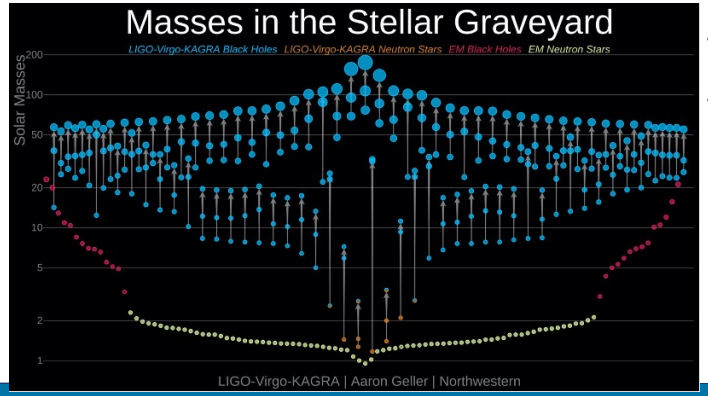
IMF	L_{FUV} (ergs/s/Hz)	$Q(H^0)$ (s^{-1}) ~ L_{ff} (ergs/s)	q_{SNR} (century^{-1})
Kroupa (1.3,2.3)	1.14×10^{28}	1.37×10^{53}	1.16
Top Heavy (1.3,1.5)	3.57×10^{28}	7.78×10^{53}	2.69
Ratio (THK/K)	3.13	5.58	2.32

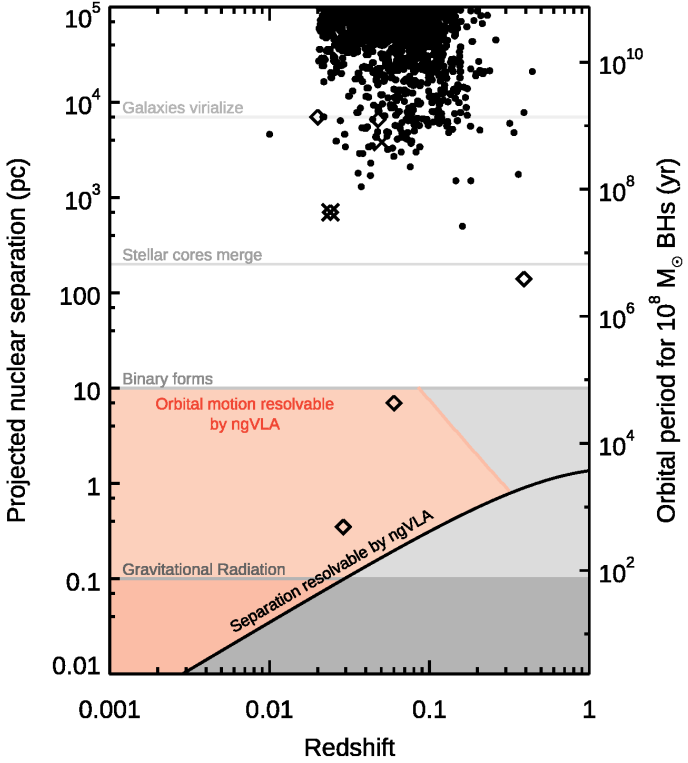
Starburst99: Continuous SF; 1 M/yr; 100Myr; EJM11

- FUV comparison with free-free
  - $L_{ff}/L_{FUV} \sim 2$
- Free-free comparison with non-thermal radio (SN rate)
  - $L_{ff}/L_{NT} \sim 2.5$
- FUV comparison with total (re-radiated Balmer continuum)
  - $L_{IR}/L_{FUV} \sim 1$
- *FUV and radio comparisons could identify potential IMF variations in low-Z dwarf galaxies.*
  - *Caveat… stochasticity, but non-thermal radio should not be as strongly affected – same population of stars powering FUV*

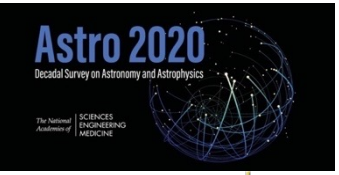
KSG5: Understanding the Formation and Evolution of Black Holes in the Era of *Multi-Messenger Astronomy*

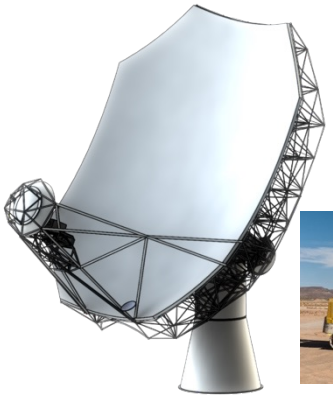
- The ngVLA's sensitivity & angular resolution will be able to:
  - Localize & Resolve dual AGN and BH binaries directly in the Radio.
    - Detect GW170817 source at Adv LIGO horizon dist. of 200 Mpc.
  - Measure proper motion expansion over 5 year periods (orange shaded region), including GW sources
- Search for BHs across all masses
  - e.g., weakly accreting MW BHs & SMBHs in nearby dwarfs via *proper motions*
  - Increase sample by ~x10

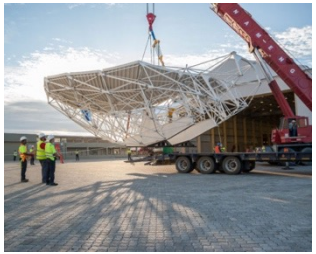


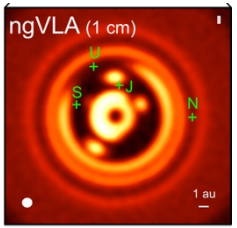


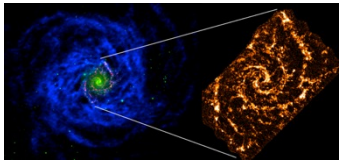
Project Timeline

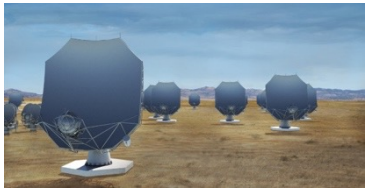


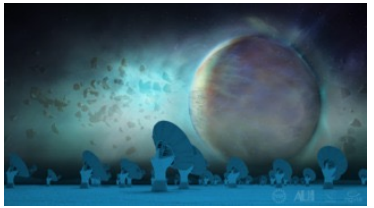












2019 — ngVLA Submission to Astro2020

2021 — Astro2020 Recommendation Published

2023 — Prototype Delivered to VLA Site; Submit ngVLA Proposal to NSF/MREFC

2027 — Complete NSF/MREFC FDR; ngVLA Construction →

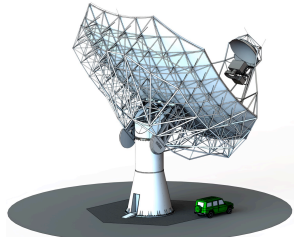
~2030 — Initiate ngVLA Early Science (> VLA capabilities)

~2037 — Achieve Full Science Operations

Next Major Steps – Design Phase

- Expect Project to be Declared MREFC Design Candidate by NSF Imminently
- Hold proposal review for full design-phase funding (FY24 - FY26.5)
  - FY24 funding level and ramp up are critical.
- Working with NSF to finalize Design Review Schedule.
  - Project already technically baselined, will baseline cost later this year.
  - Working towards NSF-run Preliminary and Final Design reviews 2024 and 2026
- Secure international partnership contributions for final design and construction. Baseline plan and work package distribution by PDR.
- ***Prototype Antenna will be validated at the VLA site Next Year***

Summary



- The ngVLA Science Case and Design have been driven by the international astronomy community and will be transformative in many areas of astrophysics
  - By being called out as a high priority by Astro2020, the project is currently well positioned to complete its design and start construction later this decade.

- *Naturally, it is highly aligned with the key science that UVEX is being designed around.*

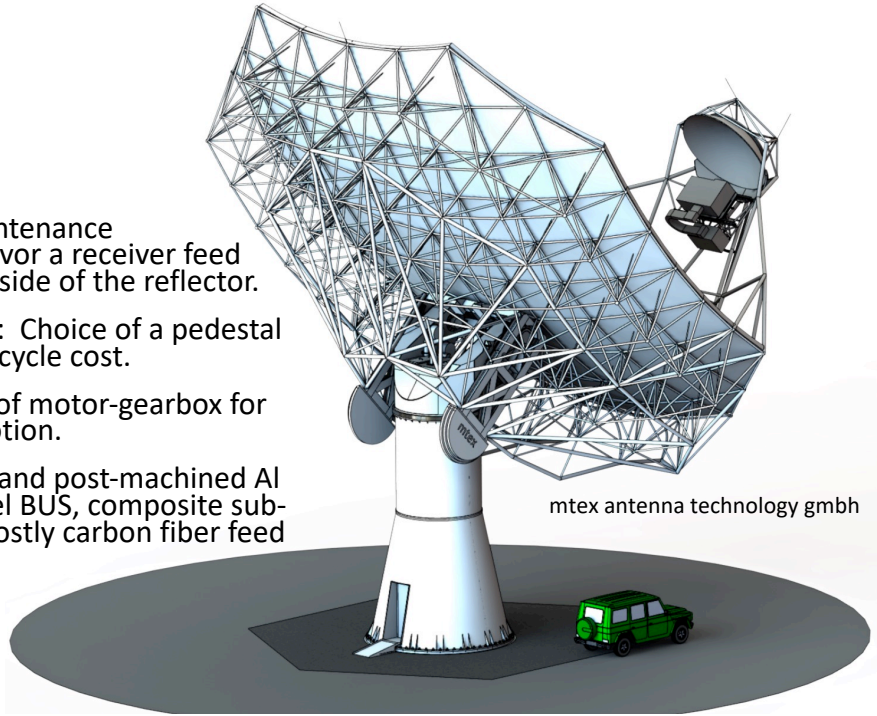
- ***Get Involved!*** *Join an ngVLA SWG to help identify science & operation requirements.*
  - https://ngvla.nrao.edu/page/workinggroups
  - Currently working with community to analyze possible VLA/VLBA to ngVLA transition options

- *All this has been made possible by **strong** NSF support!*


ngvla
Next Generation Very Large Array

Antenna Development

- **Feed Low**: Maintenance requirements favor a receiver feed arm on the low side of the reflector.
- **Mount concept**: Choice of a pedestal concept for life-cycle cost.
- **Drives:** Choice of motor-gearbox for both axes of motion.
- **Materials:** Cast and post-machined Al panels with steel BUS, composite sub-reflector and mostly carbon fiber feed arm.



Final Design and Prototype RFP Schedule (tentative):

Milestone	Description	Date
KO	Kick-Off Meeting Complete	7/6/21
PDR - Ph. 1	Preliminary Design Review – Phase 1 Complete	3/4/22
PDR - Ph. 2	Preliminary Design Review – Phase 2 Complete	12/11/22
AARn	**Antenna Acceptance Review** at ngVLA Site Complete	8/21/24
CDR	**Critical Design Review** Complete	2/20/25
PDP	Final **Production Data Package** Delivered	8/25/25

Key Specifications	
18m Aperture	Offset Gregorian
Shaped Optics	4° Slew & Settle in 10 sec
Surface: 160 µm rms	Referenced Pointing: 3” rms