Large Ground-based Projects
Astronomy & Astrophysics Advisory Committee

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Jim Whitmore (PHY)
February 25, 2019

Projects to be discussed

- US-ELT: Ralph Gaume
  - Federal participation in US-based ELT projects to provide broad community access
- ngVLA: Joe Pesce
  - Next generation radio array expanding across the American sub-continent
- IceCube-Gen2: Jim Whitmore
  - Expand the cubic kilometer neutrino detector ten-fold in volume
- CMB-S4: Nigel Sharp
  - Coordinated Stage 4 CMB experiment across Atacama high site and South Pole facility

The Aspiration

Bi-hemispheric ELT system

US-ELT

2 telescopes, 2 hemispheres, 1 system

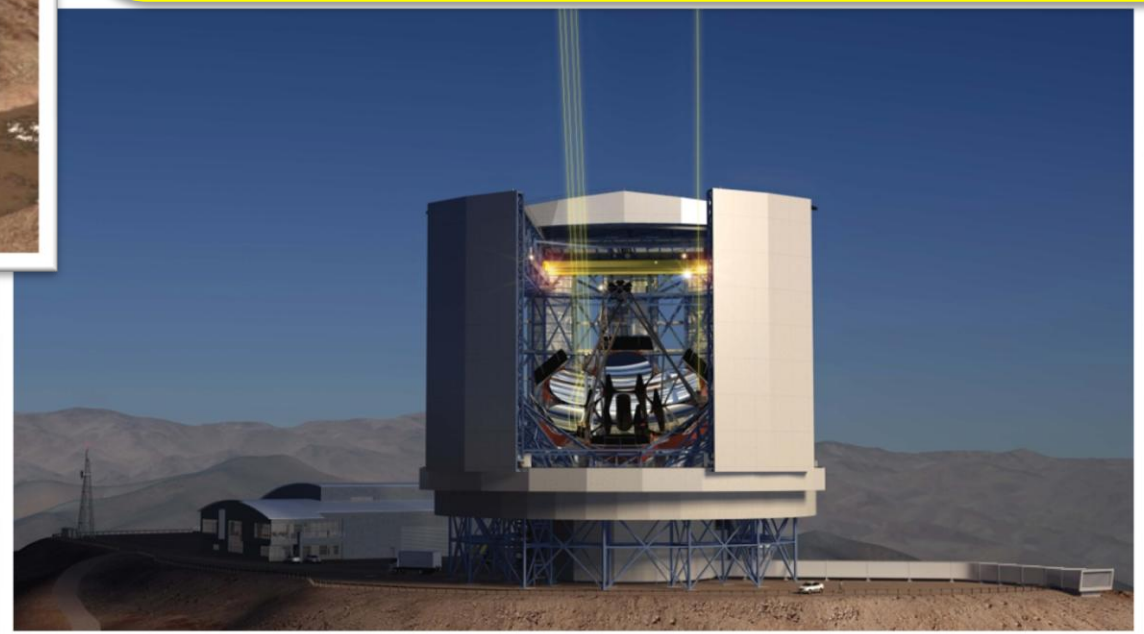
All-sky coverage

Broad instrument suite

Key Science Programs

Open Access ≥ 25% at both facilities

Strengthen U.S. scientific leadership

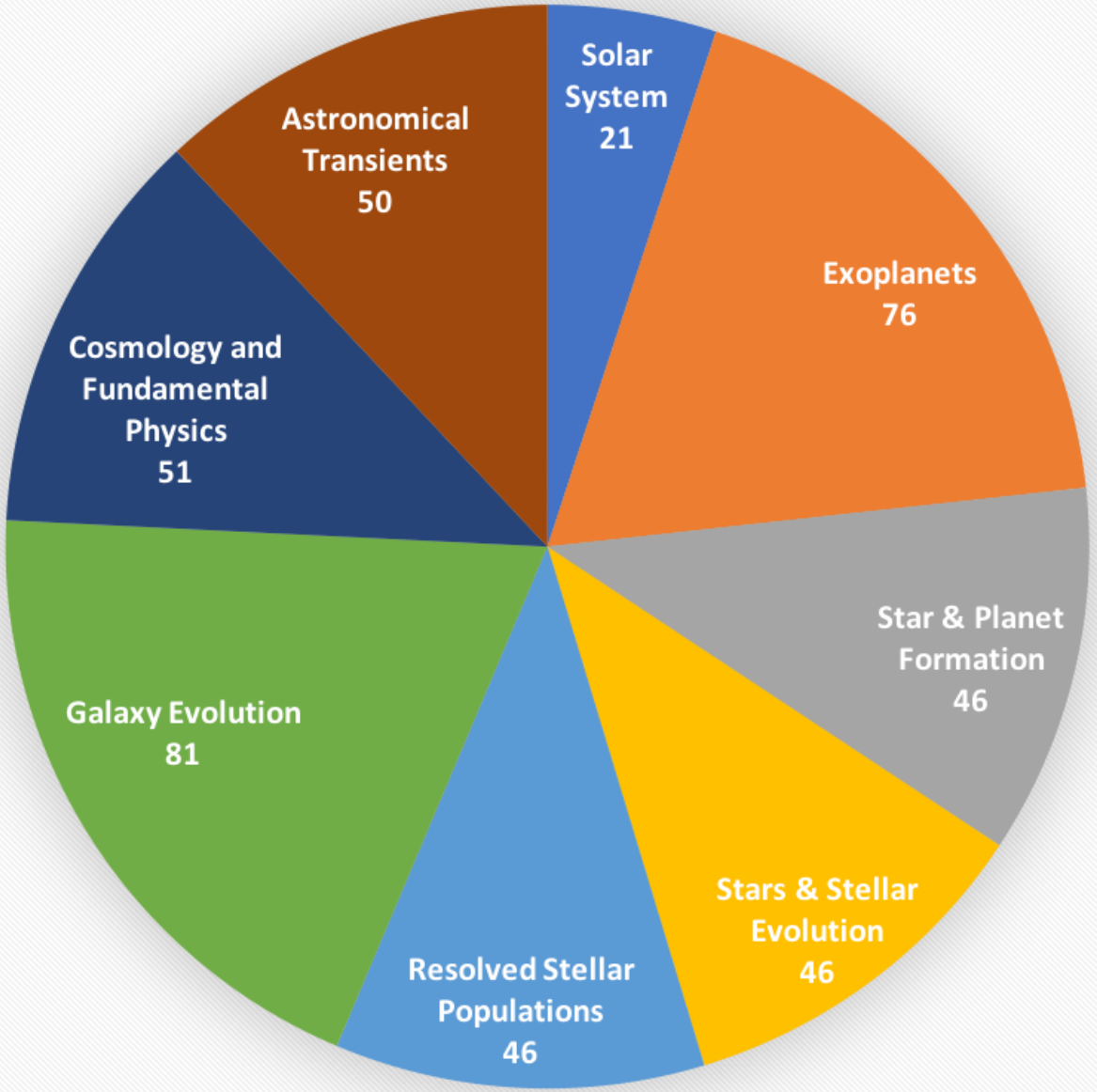


Opportunity to significantly broaden U.S. public access to the next generation of optical-infrared telescopes

KSP development

- 6 July: NOAO issued call for **community participation in KSP development**
- **250+ participants responded**
  - 66% unaffiliated with GMT/TMT partners
- **8 Topical Groups**, each with 2 conveners
- **TMT/GMT projects** and instrument teams providing **information & support**
  - Telescope/instrumentation descriptions
  - On-line tools (e.g., some ETCs)
- 86 participants at November **KSP development workshop** (Tucson)

~80% of public time for KSPs
~20% for PI-class, allocated annually



The Power Of Two

Greater Science, More Access

All-sky access

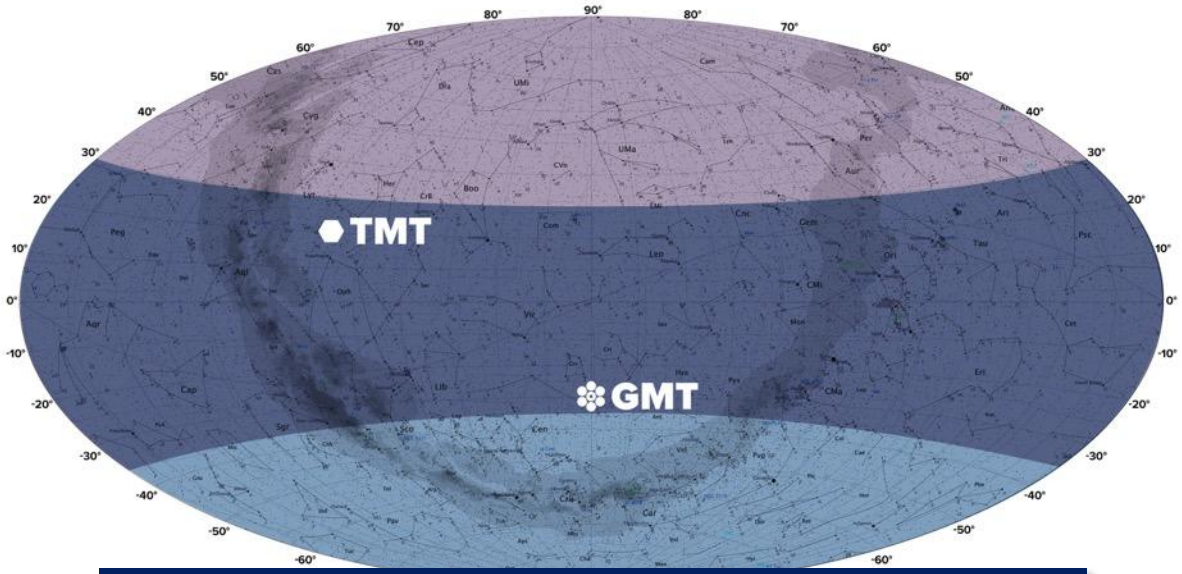
- Relatively rare objects (e.g., GW sources, nearby exoplanets)
- Unique targets in each hemisphere
- Key survey fields; e.g., GOODS, Euclid
- Synergies with other facilities (e.g., ALMA, LSST, VLA, LIGO…)
- Rare areas of low Galactic extinction

Broad instrument suite

- More capabilities at same time
- Potential to coordinate/optimize

More hours per year

- More projects
- More scientist participation



Overlap area → Airmass < 2 for 2 hours or more

Overlap zone (almost 50% of sky!)

- Joint and/or simultaneous programs on same objects

Separation in longitude (7h)

- Critical for some time-domain phenomena

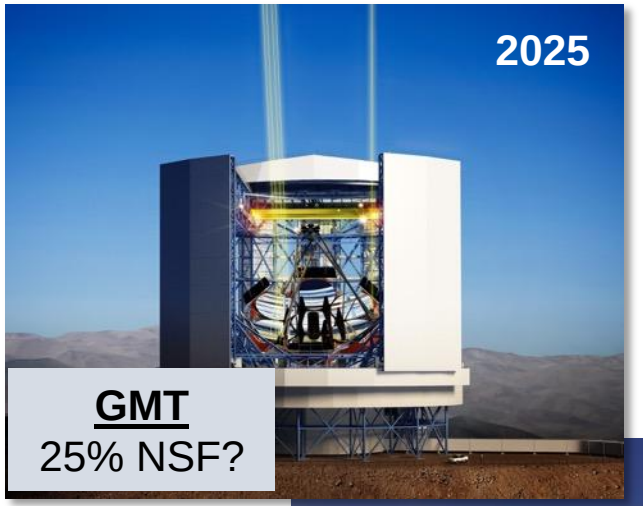
Federal Investment

ALMA-LIGO scale (~$1B) NSF investments will be needed to realize US open access to the ELTs

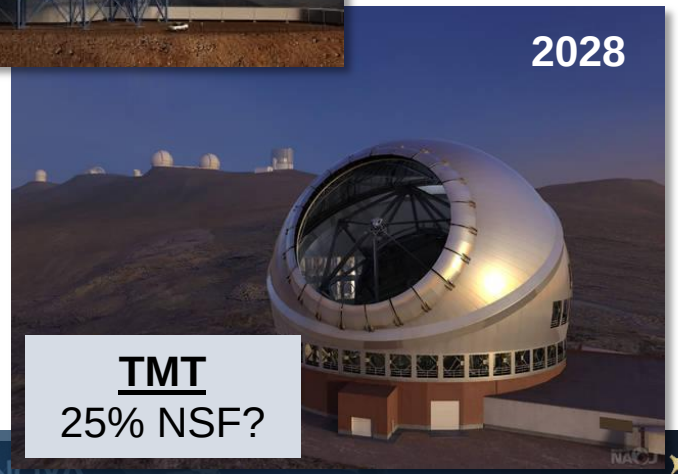
LIGO
$1.1B
100% NSF

ALMA
$1.5B
$0.5B NSF

LSST
$660M
$0.5B NSF



GMT
25% NSF?



TMT
25% NSF?

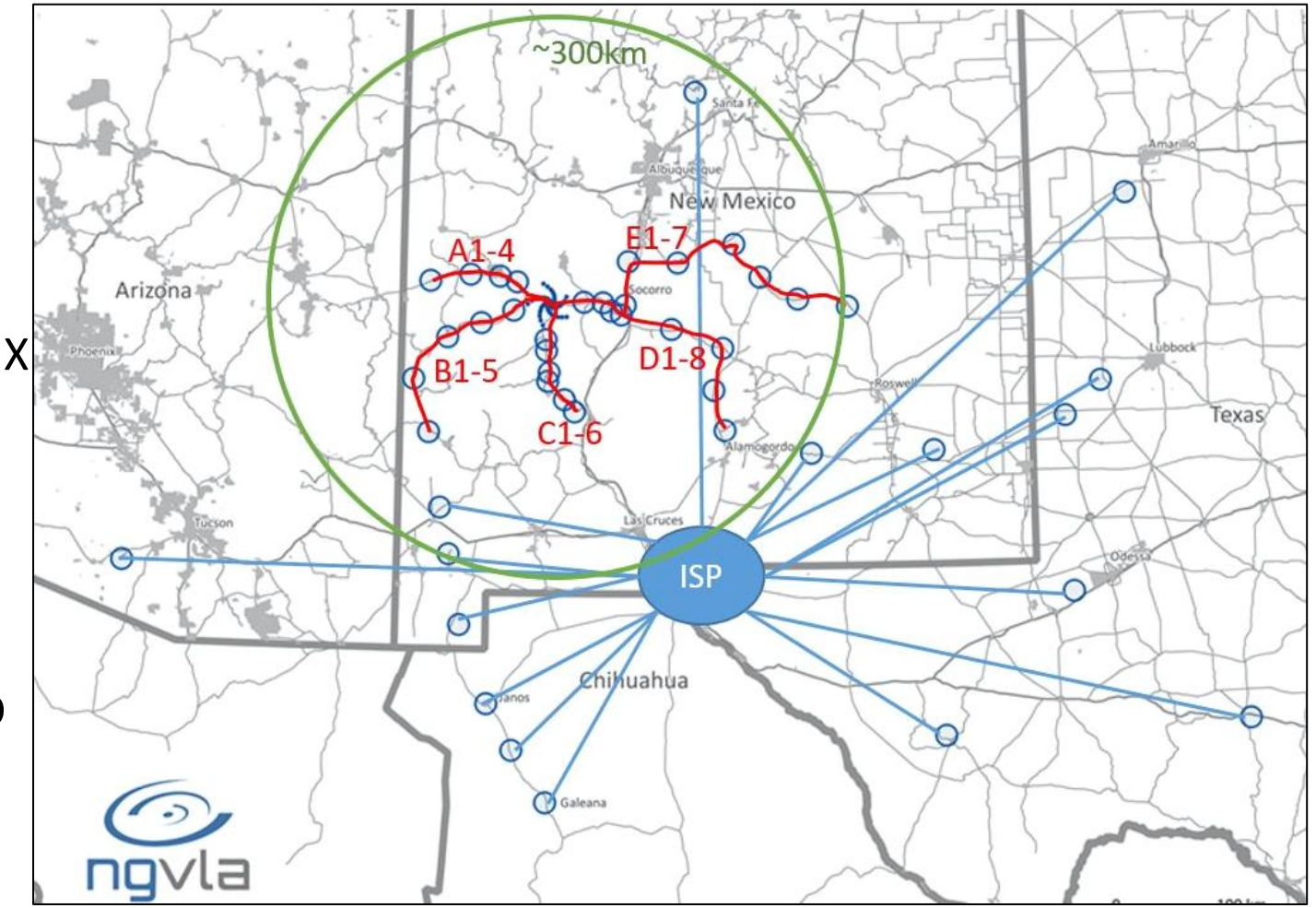
Next Generation Very Large Array (ngVLA) Key Science Goals

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*

ngVLA Technical Description

Thermal Imaging on milli-arcsecond scales at λ ~ 0.3cm to 3cm

- **1.2 - 116 GHz** Frequency Coverage
- **Main Array**: 214 x 18m offset Gregorian antennas
  - Fixed antenna locations across NM, TX, AZ, MX
- **Short Baseline Array**: 19 x 6m offset Gregorian antennas
  - Use 4 x 18m in TP mode to fill in (*u, v*) hole.
- **Long Baseline Array**: 30 x 18m antennas located across continent for baselines up to 8000km.



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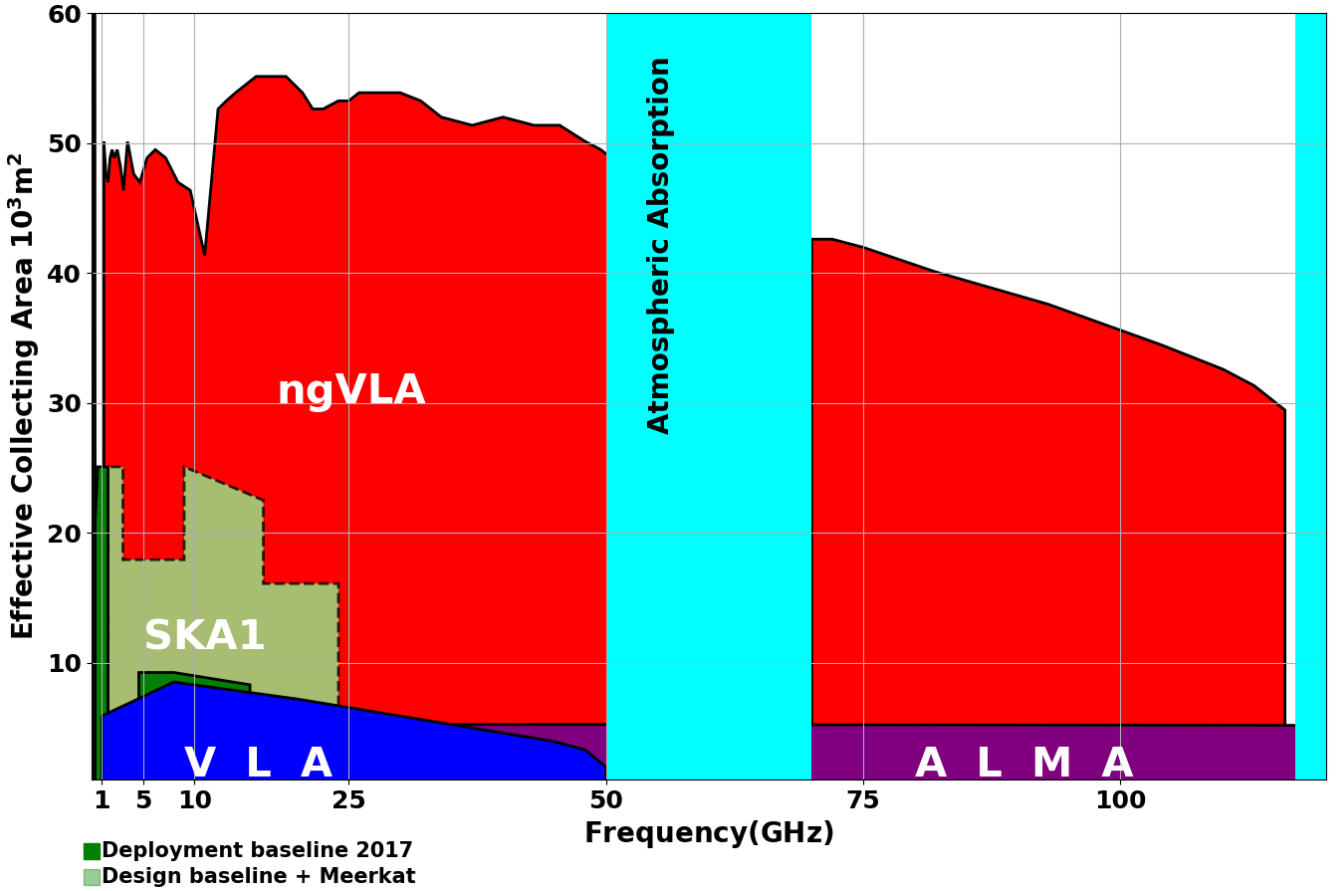

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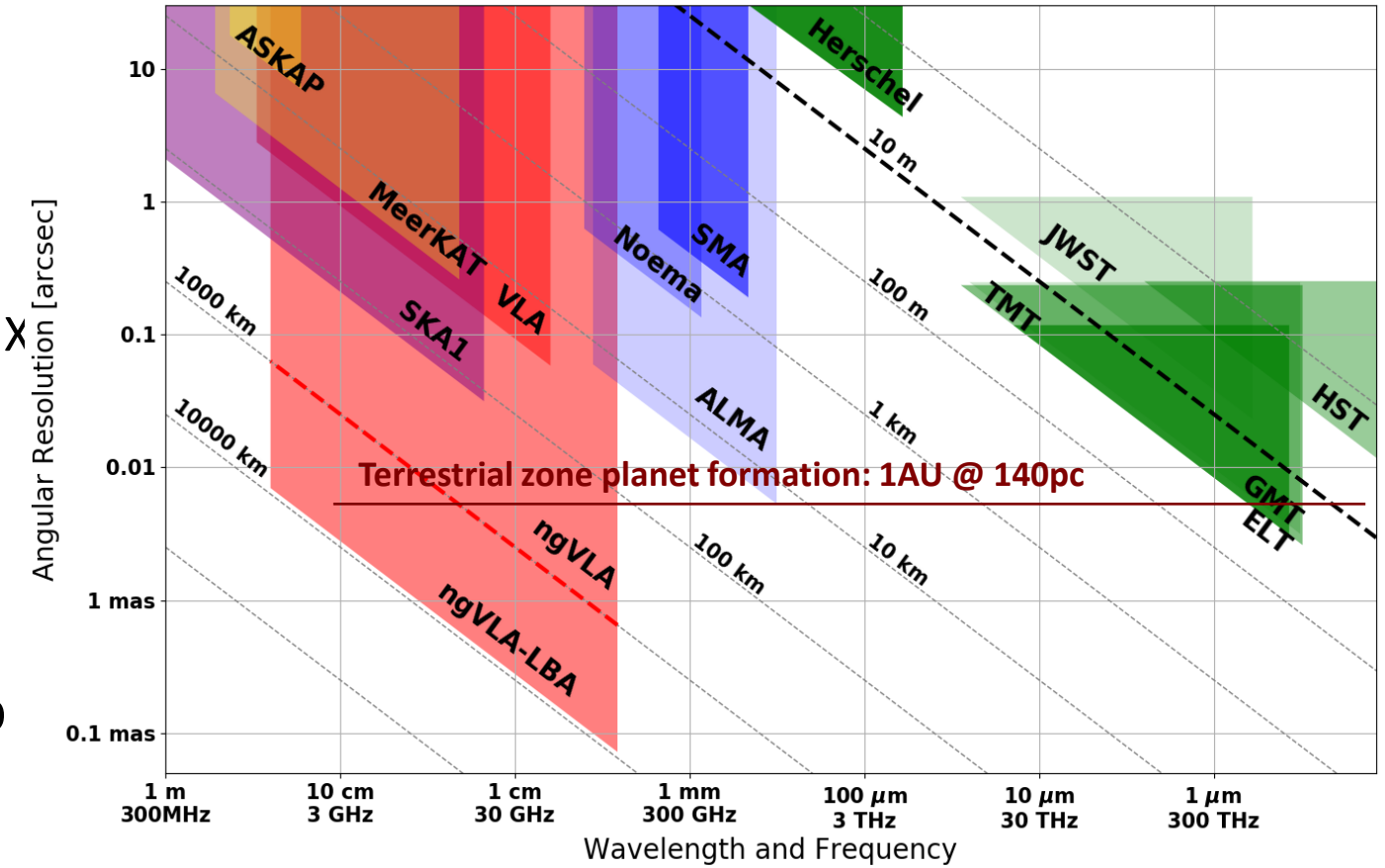
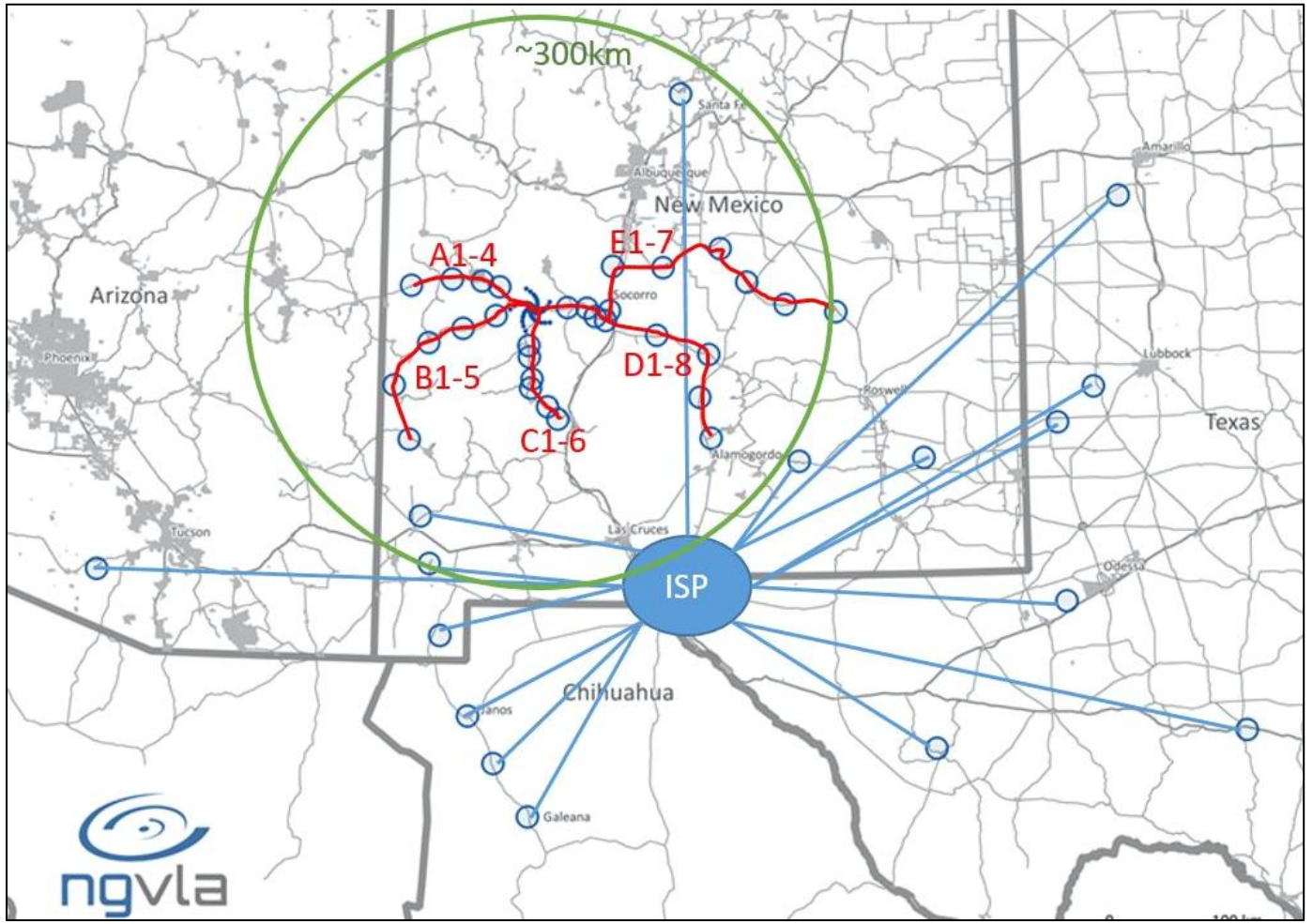


ngVLA Technical Description

Thermal Imaging on milli-arcsecond scales at λ ~ 0.3cm to 3cm

STATUS:

- Partnership development
- 2018 Science Conference (Portland, OR)
- Science Book: Major community effort; 88 peer-reviewed contributions and 286 unique authors
- Design and Development work (internal plus proposals to NSF)
- Preparing for Decadal



ngVLA: Cost Estimates as of October 2018

- Construction
  - **$2.3B** in 2018 risk-adjusted, base-year dollars
    - Seeking ~25% International Partner Contributions (discussions underway)

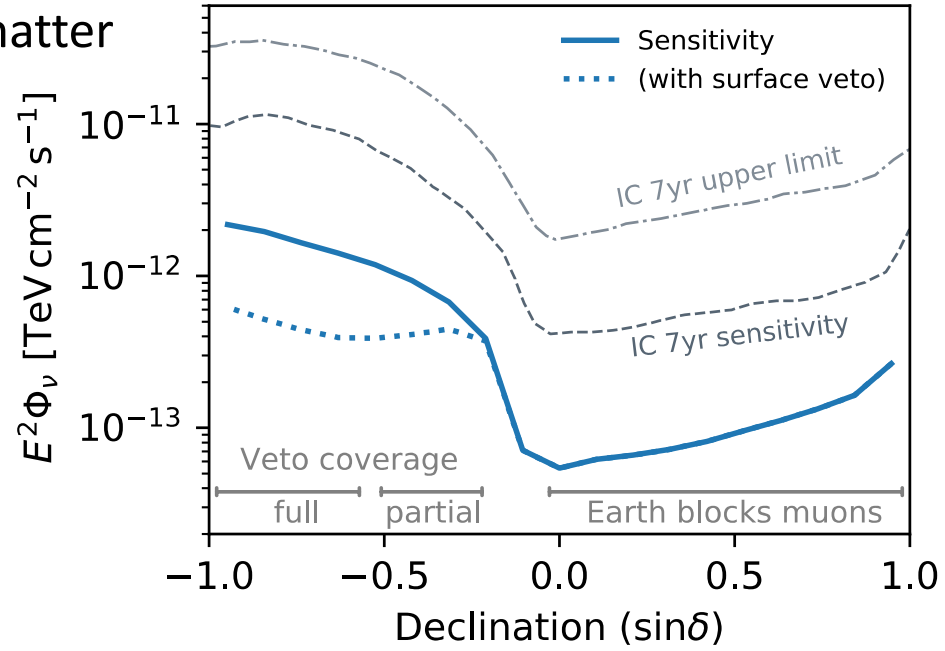
2018$1.75B U.S. Contribution to ngVLA

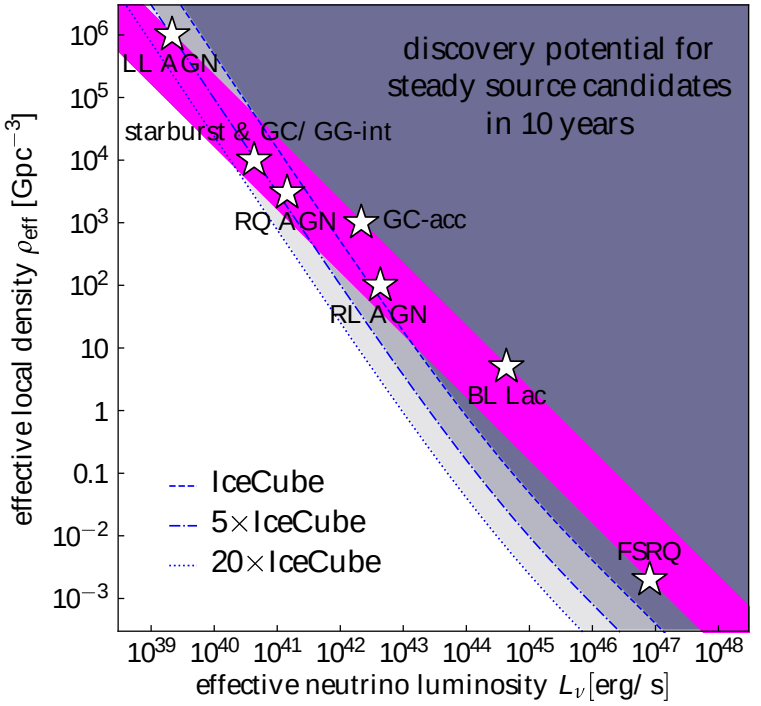
- Operations Goal: **(3x current VLA + VLBA)** (approx. **2018$80M/yr**)

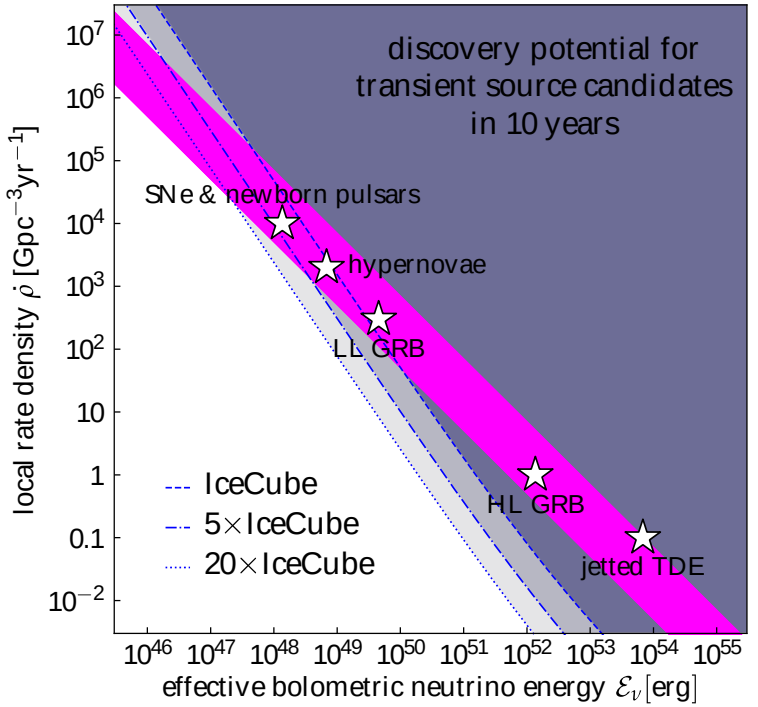
IceCube-Gen2 Scientific Objectives

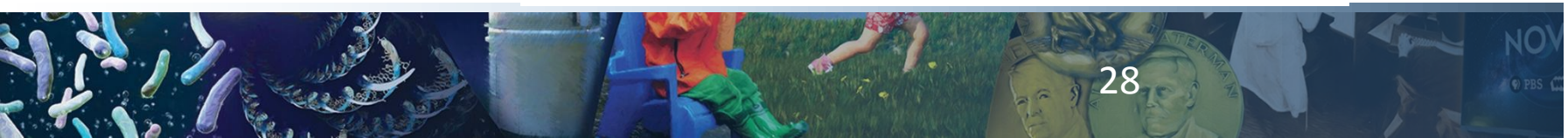
- Multi-messenger astrophysics with high-energy neutrinos/Neutrino Astronomy
  - Neutrino sensitivity to all candidate source populations
  - ~4x significance to a September 22, 2017/TXS 0506+056 type event!
- Studies of fundamental physics (at some of the most extreme energies measured)
  - Studies of neutrino properties and tests of beyond the SM physics
  - Tests of symmetries in nature
  - Searches for dark matter

Integrated sensitivity to a single source (15 years Gen2) ~ 10x ICNO





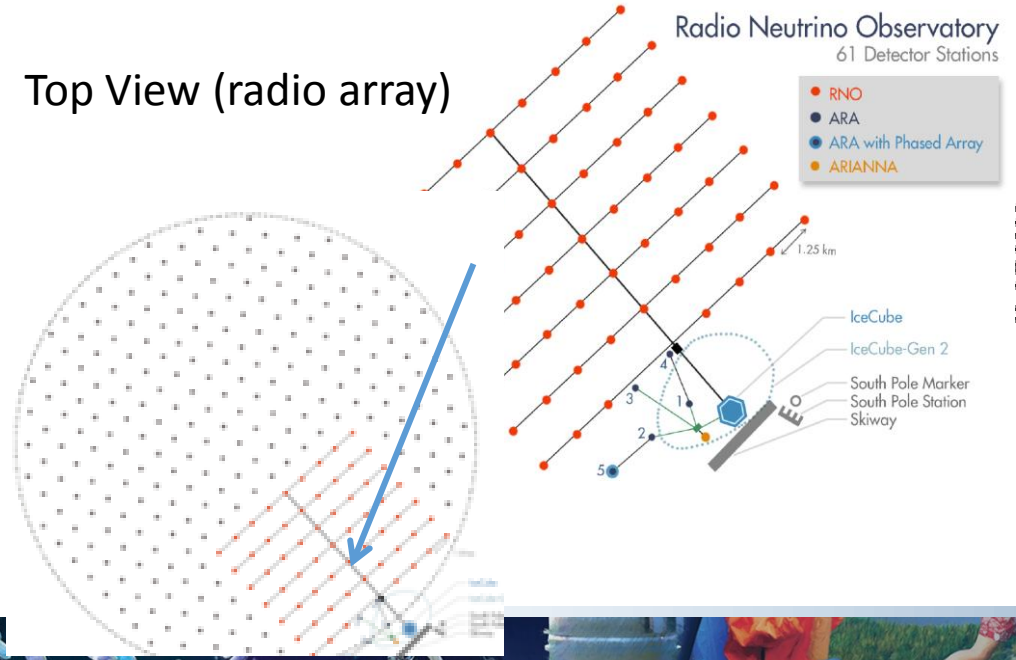




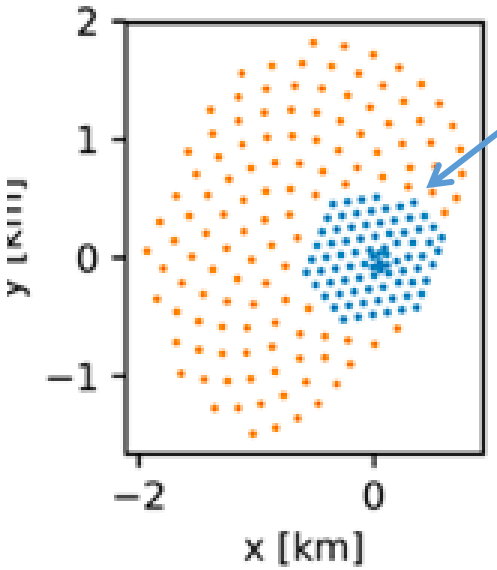
IceCube-Gen2 Neutrino Observatory Status

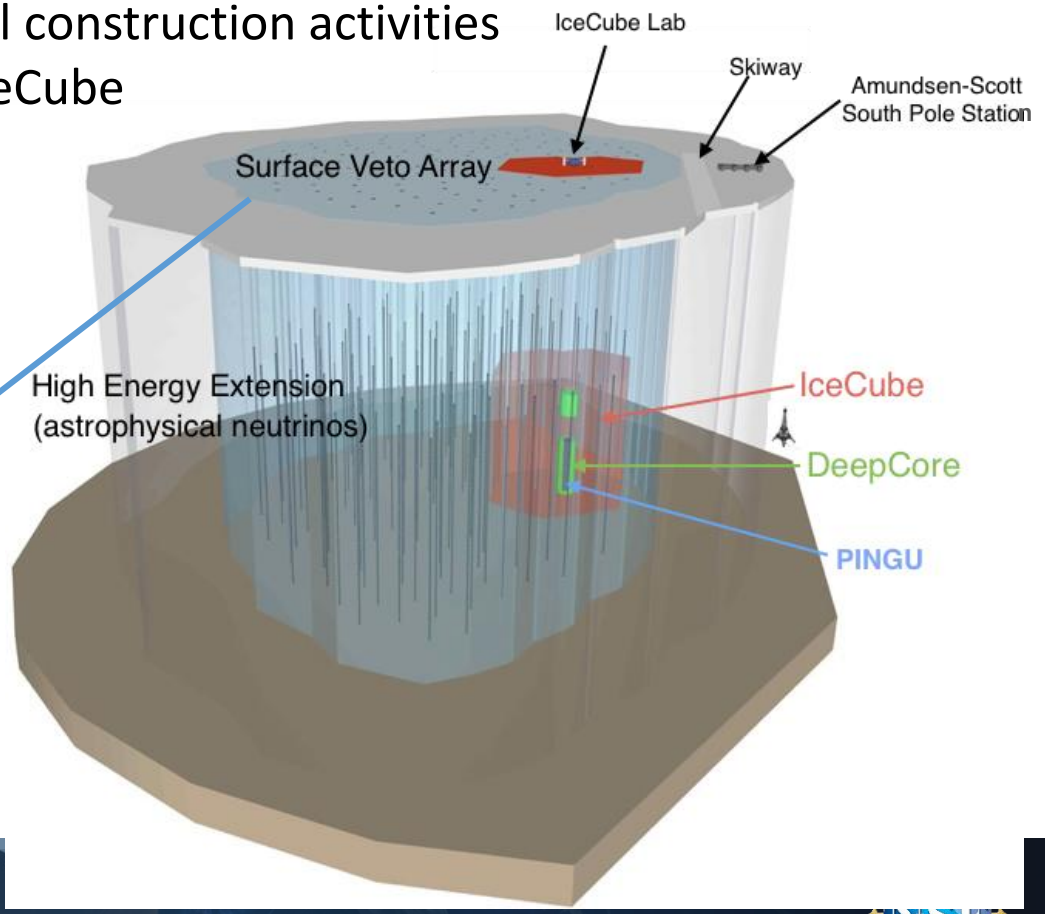
- Primary deep-ice optical detector array of 120 strings of sensors **(240m apart, depths to 2600 m, volume ~ 10x IceCube)** sensitive to neutrinos up to **~100 PeV**
- Radio Neutrino Observatory (RNO) sensitive to neutrinos beyond **~100 PeV**
- GEN2 and RNO concepts are mature; developed from knowledge/expertise gained from IceCube design/construction/operations and the Upgrade design/initial construction activities
- Preliminary Gen2 design work is currently underway by the IceCube collaboration (project execution plan, budget, schedule…)

Top View (radio array)



Top View (optical array)





IceCube-Gen2 Neutrino Observatory – Project Scope and Costs

- Primary deep-ice optical detector array fiscal scope is anticipated to be similar to the IceCube MREFC – O($300M);
- The radio array is not included in this estimate and we don’t have guidance on this at the moment;
- Preliminary design activities include improvements in logistical efficiencies; e.g. transportation via traverse, and at the South Pole (drilling construction footprint and operations continue to aim for lowering power requirements for the sensors, mitigating needs for annual on-going snow maintenance for deployed surface elements, bandwidth for data transmission etc.)
- Expect operations costs to be somewhat higher than for the current ICNO ($7M/year from NSF + similar amount from non-US)

Cosmic Microwave Background Stage 4 (CMB-S4)

Science

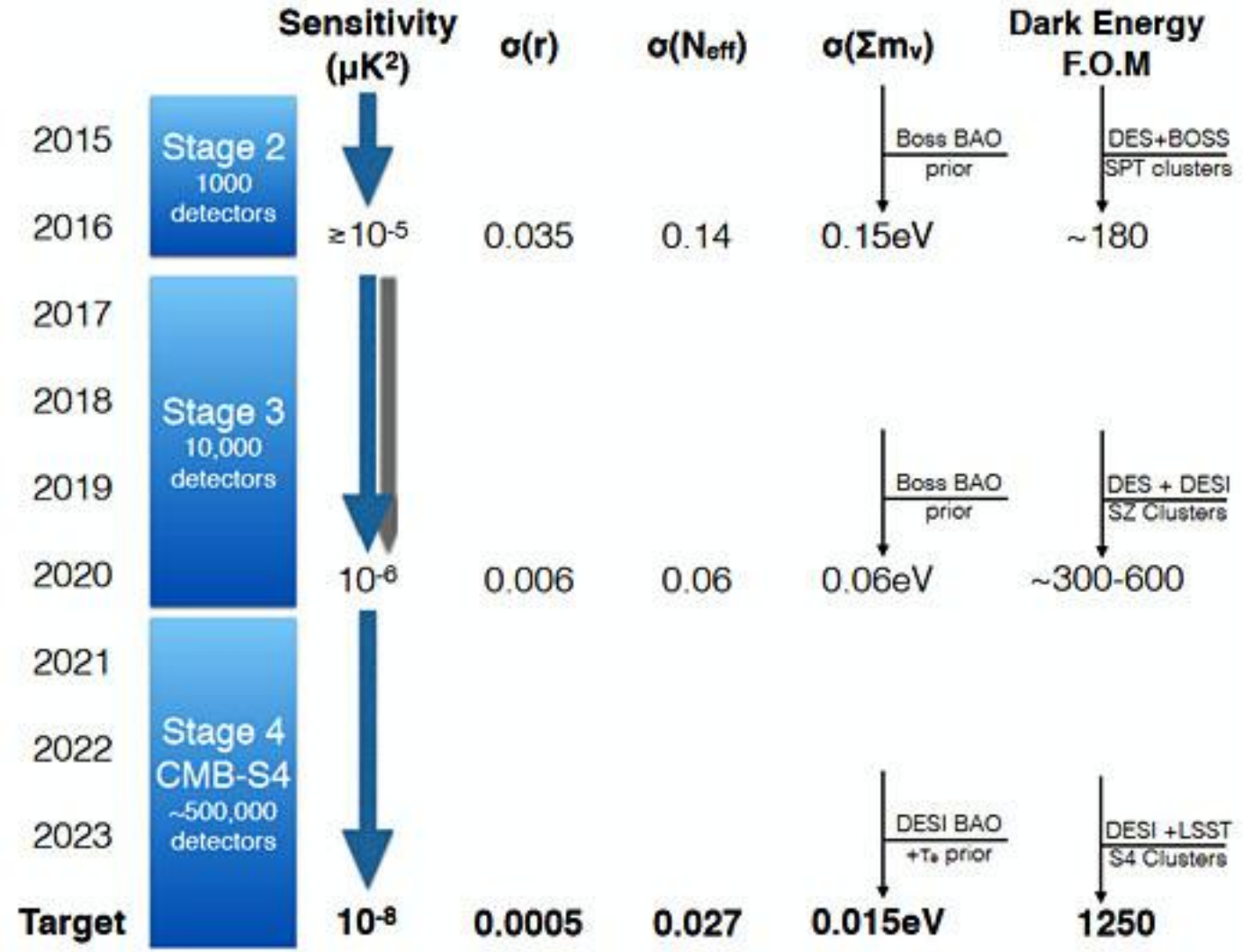
The 'Stage-4' ground-based experiment, CMB-S4, will provide a dramatic – not just incremental – leap forward in understanding space, time, and the evolution of the Universe. CMB-S4 will cross critical thresholds in testing inflation, determining the number and masses of the neutrinos, constraining possible new light relic particles, providing precise constraints on the nature of dark energy, and testing general relativity on large scales.

https://cmb-s4.org

CMB-S4 Science Book, arXiv: 1610.02743v1 [astro-ph.CO]

(Figure to right taken from Science Book)

CMB-S4 Technology Book, arXiv: 1706.02464v2 [astro-ph.IM]



Cosmic Microwave Background Stage 4 (CMB-S4)

Status

CMB-S4 collaboration formed, pre-Project Development Group set up, white paper submissions for Decadal Survey in progress, continued development funding requests in preparation (mostly risk reduction as current technology is sufficient).

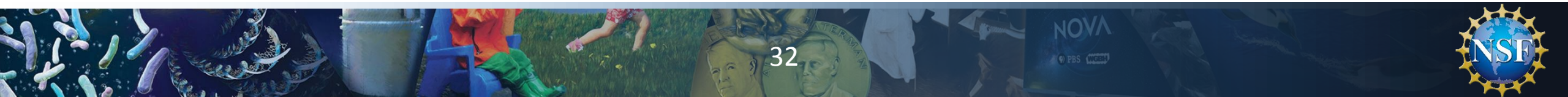
Builds on existing investments: CMB-S4 is the convergence of ACT, BICEP, POLARBEAR, SPT and others. Convergence beginning: ACT+POLARBEAR-> Simons Observatory; BICEP+SPT-> South Pole Observatory.

Groups agree to share technical and cost data, and lessons learned. Work towards S4 while continuing their own valuable science programs.

Technical plan includes three 6m-class telescopes, fourteen 1-m class, 512k detectors; discussion continues about the extent to which existing systems can be reused, and the optimum siting.

Collaborative project requiring both NSF and DOE: Joint Coordination Group (JCG) set up with DOE and NSF program staff. Meets bi-weekly amongst agencies, intermittently with CMB projects staff.

Support to realize CMB-S4 expected/anticipated/hoped from NSF (OPP, AST, PHY) and from DOE (both hardware and operations), plus private fund-raising.



Cosmic Microwave Background Stage 4 (CMB-S4)

Estimated costs

Cosmic Microwave Background Stage 4 Concept Definition Task Force (CDT) reported to AAAC October 2017

CDT strawperson estimate:

$9M D&D, **$412M** construction (options range $354M to $470M)
annual O&M **$18M+$14M** science

Estimates being refined for white paper submissions and decadal planning; decadal survey expects to make its own cost estimates for major projects.

Significant private investment has already happened (Simons Foundation primary). International partners engaged, more expressing interest. Significant DOE investment already in SPT. Significant NSF investment in SPT and Atacama high site. Have yet to include costs of on-ice logistical support (separately funded but needed for true total cost estimate).