Report from the
Cradle of Life Science Working Group

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Dusty Environments

Optically thin

Optically thick

Low Mass Star Formation

Protoplanetary Disks

Debris Disks
Compact Objects

Protostellar disks ………………….. < 10^3 AU
(Hyper/Ultra) Compact HII regions .. < 10^3 AU
Protoplanetary disks …………………< 10^2 AU
Planet forming region ……………… < 10  AU

Require angular resolution between 1-1000 mas
Angular Resolution is Critical

Ground based telescopes

JWST

HST

Spitzer

Herschel

CCAT

GBT

ALMA

CARMA/PBI

SMA

SKA

NGVLA

Angular Resolution (arcsec)

Diffraction lim. (optical & IR interferometry)

300 THz

30 THz

3 THz

300 GHz

30 GHz

3 GHz

300 MHz

100 km

100 m

1 km

10 km

10 m

1 m

0.1 AU

1 AU

10 AU

D=140 pc

0.1 mas

1 mas

10 mas

100 mas

1000 mas

1 cm

10 cm

100 cm

1 m

10 m

100 m

1 km

10 km
Planet Formation Imager

Image credit: Kraus et al. (2014)
Continuum Image rms in Kelvin (10 hours, natural weighting)

<table>
<thead>
<tr>
<th>Area</th>
<th>Max B (5-15GHz)</th>
<th>Max B (20-40GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area</td>
<td>36.4km</td>
</tr>
<tr>
<td>1 x VLA</td>
<td>0.070</td>
<td>1.75</td>
</tr>
<tr>
<td>5 x VLA</td>
<td>0.014</td>
<td>0.35</td>
</tr>
<tr>
<td>10 x VLA</td>
<td>0.007</td>
<td>0.17</td>
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Ground-based telescopes

JWST

HST

CCAT

JWST

SKA

ALMA

NGVLA

CARMA/PB

Herschel

Spitzer

HST

JWST

Next Generation Vary Large Array Workshop :: 225th AAS meeting :: Seattle :: 04 Jan 2015
The low frequencies of the NGVLA (compared to ALMA) gives access to:

1. Ammonia (NH3) one of the most (perhaps the most) important N-bearing volatile,

2. volatile molecules in very dense regions, e.g. the innermost parts of protoplanetary disks, that are otherwise veiled by optically thick dust at shorter wavelengths,

3. low-lying excitation modes of moderately complex organic molecules, enabling the observations of molecules such as CH3CN in the cold regions where they are proposed to form through ice chemistry, and

4. lines of very complex organic molecules such as glycine because of a lower line density at cm wavelengths compared to mm wavelengths.
From Dust to Planets

Low Mass Star Formation

Protoplanetary Disks

Debris Disks

From Dust to Planets

Isella et al. (2010)
Pérez et al. (2012)
Testi et al. (2014)
Fu et al. (2014)
Not only dust!

Spectrum of an HII region on the Galactic plane

Dust emission

Free-free emission
High Mass Star Formation

1. Resolving the inner ionized regions of accreting massive stars ($M_{\text{star}} > 10 \, \text{Msun}$)

Right: G11.11, S1.3cm $\approx 100 \, \mu\text{Jy}$, $\theta < 300$ mas (Rosero+2014)
High Mass Star Formation

2. Star formation in the inner 2-4 pc in the Galactic Center

- Is star formation in the extreme environment of the Galactic center possible, and if yes, different from SF in the Galactic disk?
- 10 mas (80 AU) resolution can resolve circumstellar disks/jets around Sgr A*
- Coverage from few GHz to 50-100 GHz is needed to disentangle dust from free-free

Simulation of SF around a supermassive black hole of $\text{MBH} = 3 \times 10^6 \text{M}_\odot$
(Bonnel & Rice, 2008)
Mapping deep atmospheres of giant planets

Maps at 5-100 GHz: 3-D distribution of temperature and absorbers in deep atmospheres (troposphere, < 1 bar):
-> tracing deep atmospheric dynamics

NGVLA resolution: storms and small scale features on Jupiter / Saturn, mapping of Neptune / Uranus

NGVLA sensitivity: longitudinal resolution on fast-rotating planets

IR and radio (VLA-2cm) thermal maps of Jupiter, from Sault et al., 2004

System III Longitude
• Detection and mapping of water in comets and planetary atmospheres (H$_2$O line at 22 GHz)
  → Mars water distribution monitoring, water plumes detection on moons, asteroids

• Detection of faint ammonia line in comets (24 GHz)
  → ammonia/water ratio near nuclei links to primordial disk ratio

• Radar observations of Near Earth Asteroids
  → best precision for orbit and shape determination

Water line mapping on Mars' limb with VLA, from Clancy et al., 1992
Search for narrow-band coherent (artificial) radio signal

New SETI targeted searches based on GAIA / TESS / Kepler-2 using SKA, ATA

NGVLA: complements SKA spectrum, sensitivity (5 x EVLA) to detect aircraft radars from dozens nearby stars in 10 min

**Optimal observation mode:** Multi-beam phased array, wide bandwidth. Possibility of commensal observations ('piggy-back')

<table>
<thead>
<tr>
<th>Transmitter Type</th>
<th>Luminosity (EIRP) (ergs/sec)</th>
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</thead>
<tbody>
<tr>
<td>Interplanetary Radar</td>
<td>$\sim 2 \times 10^{20}$</td>
</tr>
<tr>
<td>Long Range Aircraft Radar</td>
<td>$\sim 1 \times 10^{17}$</td>
</tr>
<tr>
<td>High Power TV and Radio</td>
<td>$\sim 5 \times 10^{12}$</td>
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</tbody>
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*Artificial terrestrial radio sources, from Siemion et al., 2014*
https://safe.nrao.edu/wiki/bin/view/NGVLA/CradleOfLifeSWG