How Did the Earth Form?

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Proto-planetary Disks

• What we know (or think we know)
  – All of the planets in the solar system nearly in a plane.
  – Disks of dust and gas detected around nearby forming stars.
  – Simulations of proto-planetary disks show planets growing.

• Ergo, planets form in disks of material around stars.
Simulation of Planet Formation
Proto-planetary Disks
From Dust to Planets
(what we think happens ...)

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Collisional agglomeration

??? collective effects?

Gravity-assisted growth

Gas capture

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(dust) (pebbles) (boulders) (planetesimals) (planets)

$1 \mu m$ $1 mm$ $1 m$ $1 km$ $1000 km$

(From D. Wilner)
Proto-planetary Disks

- All of the planets in the solar system nearly in a plane.
- Disks of dust and gas detected around nearby forming stars.
- Ergo, planets form in disks of material around stars.
- Want to understand how planets grow in proto-planetary disks

- Disks are opaque to visible light.
- Want observations at 5 GHz to 1 THz → mm- and cm-wavelength radiation, comparable to size of particles.
Radio Astronomy Service and Planet Formation

Expanded Very Large Array
(1 GHz to 50 GHz; US-Canada-Mexican partnership)

Atacama Large Millimeter/submillimeter Array
(100 GHz to 1 THz; US-European-Japanese partnership)

EVLA observations: ongoing—60+ nearby stars with disks
(example shows C-band observations of disk around star DG Taurus, illustrating decimeter-sized particles in the disk)

ALMA status: in commissioning
Formation of Planets and the Radio Spectrum

Understanding the formation of planets, and how we came to be, requires

- Infrared telescopes in space;
  ... and X-ray telescopes in space?
  - **E-S**: 2110–2120 MHz, 7145–7190 MHz, 34.2–34.7 GHz
  - **S-E**: 2290–2300 MHz, 8400–8450 MHz, 31.8–32.3 GHz

- Telescopes on the ground operating from 5 GHz to 1 THz.