Investigating the Early Evolution of Planetary Systems with ALMA and the Next Generation Very Large Array

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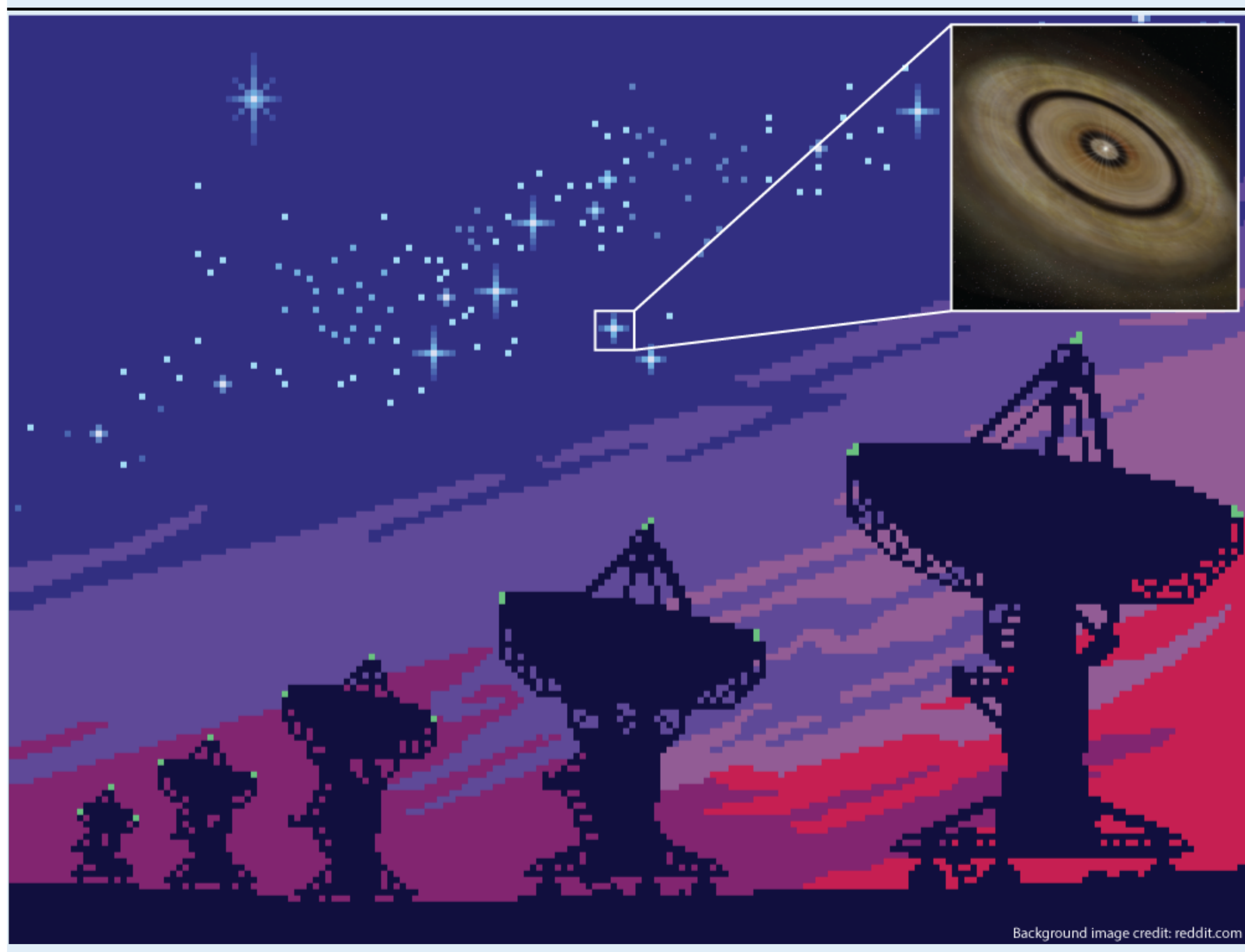
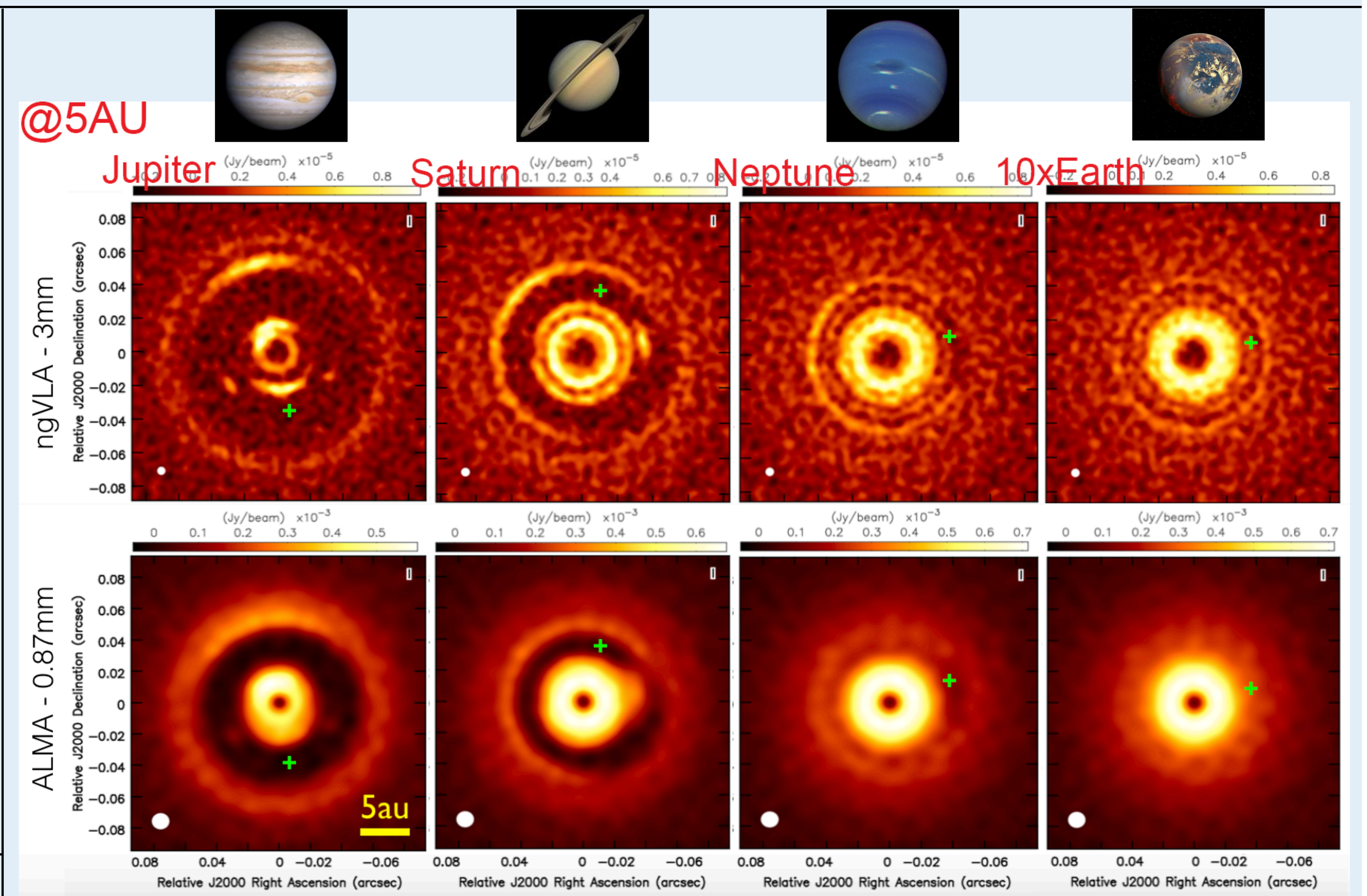
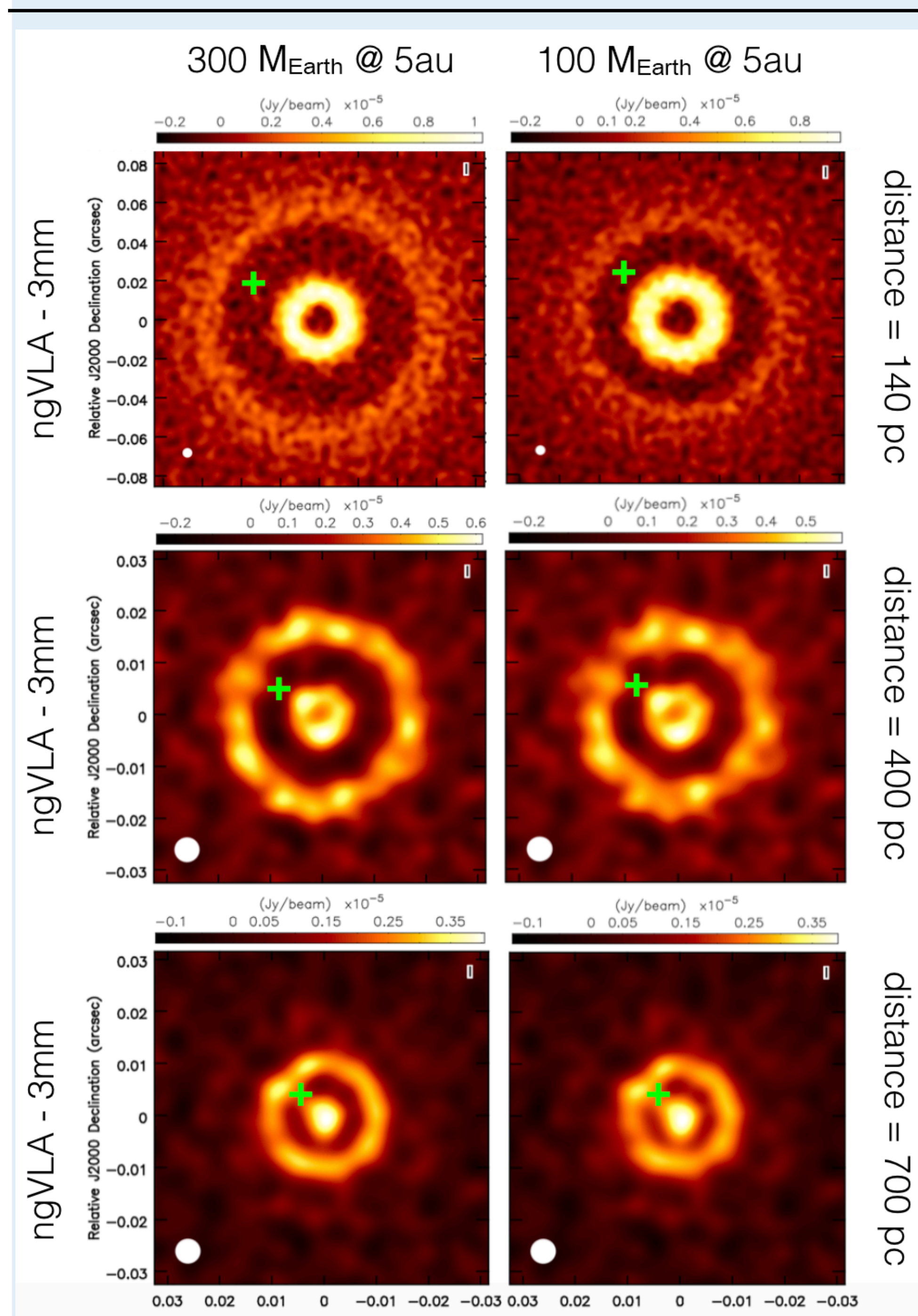
We investigate the potential of the Atacama Large Millimeter/submillimeter Array (ALMA) and the Next Generation Very Large Array (ngVLA) to observe substructures in nearby young disks which are due to the gravitational interaction between disk and planets close to the central stars. We simulate the gas and dust dynamics in the disk using the LA-COMPASS code. We generate synthetic images for the dust continuum emission at sub-millimeter to centimeter wavelengths and simulate ALMA and ngVLA observations. We find that ngVLA observations with an angular resolution of 5 milliarcsec at 3 mm can reveal and characterize gaps and azimuthal asymmetries in disks hosting planets with masses down to ~5 Earth masses at about 1 - 5 au from a Sun-like star in the closest star forming regions, whereas ALMA can detect gaps down to planetary masses of ~ 20 Earth masses at 5 au. Gaps opened by super-Earth planets with masses ~5 - 10 Earth masses are detectable by the ngVLA in the case of disks with low viscosity α ~10^-5 and low pressure scale height (h ≈ 0.025 au at 5 au).



Young pre-main sequence stars and brown dwarfs are surrounded by dusty disks that are believed to be the cradles of of planets. Embedded unseen planets can carve gaps in protoplanetary disks, which are observable in at mm and sub-mm wavelengths.

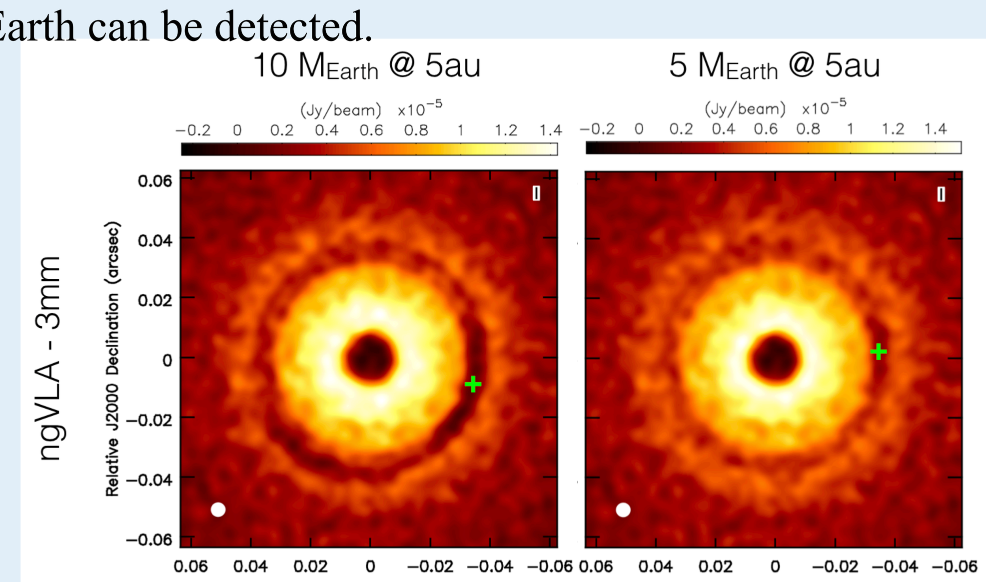


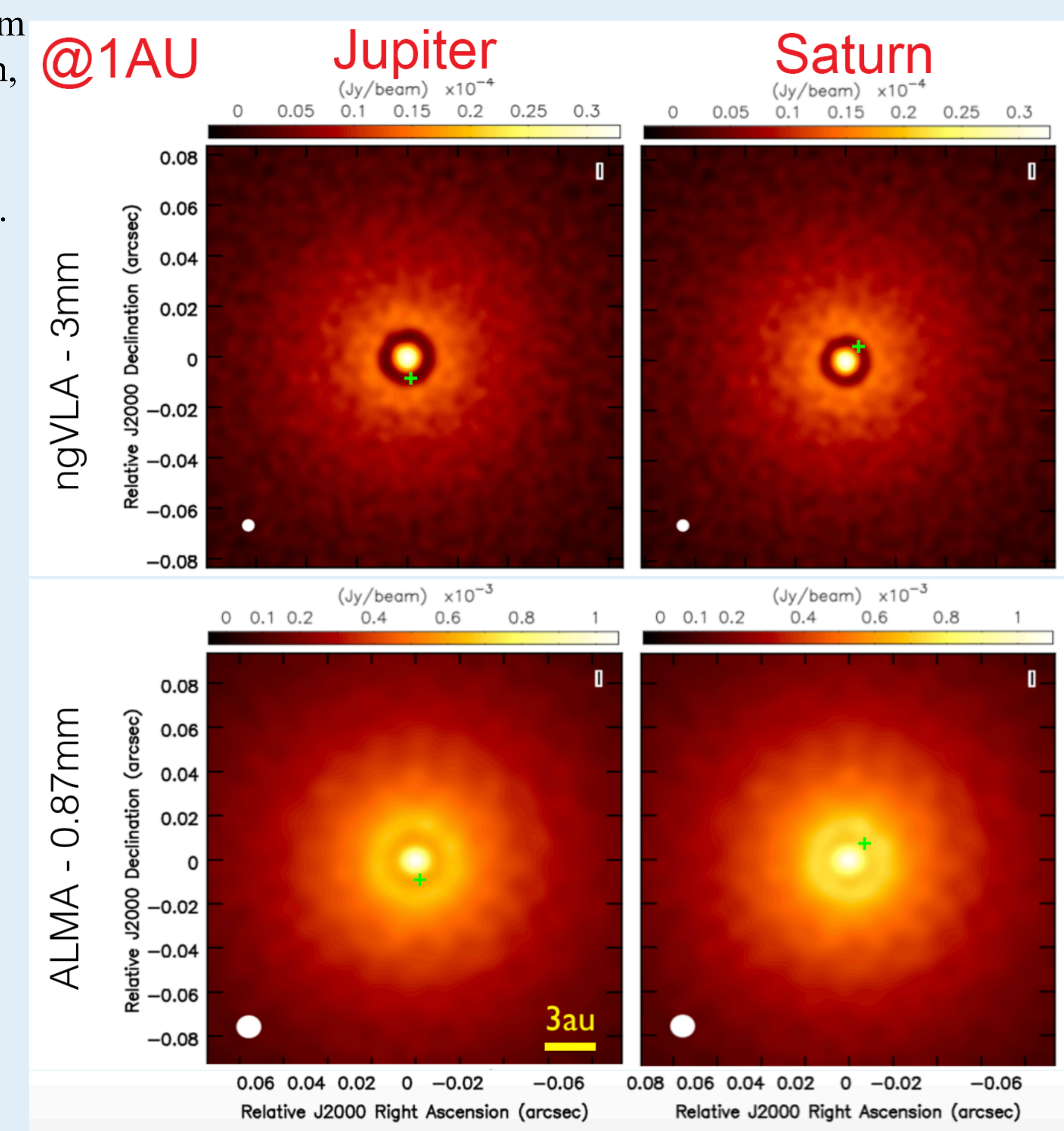
Upper fig: Simulated ngVLA and ALMA continuum maps of the disk+planet models with Jupiter, Saturn, Neptune and 10 times Earth mass planets at 5AU (indicated by the green cross). Both ngVLA and ALMA can detect gaps opened by gas giant planets. While ngVLA can even resolve gaps opened by planet that is only ten times more massive than the Earth if the alpha-viscosity of the disk is low (10^-5). And for massive embedded planets, azimuthal asymmetric dust clumps also can be well resolved by ngVLA.



Left fig: Simulated ngVLA continuum maps at 3mm wavelength of the disk+planet models at different distances from the Earth. The green cross indicates the location of the planet.

Bottom fig: Simulated ngVLA continuum maps at 3mm. The disk models have a low alpha-viscosity (10^-5), and the disk scale height h/r = 0.025 at 5AU. In this extreme case, a gap opened by a planet that is only 5 times that of the Earth can be detected.





Right fig: Simulated ngVLA and ALMA continuum maps of the disk+planet models with Jupiter and Saturn mass planets at 1 AU. ngVLA can clearly resolve those gaps, while ALMA can barely see them.

ngvla NRAO NSF Associated Universities, Inc.

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