The Feasibility of Directly Imaging Cold Planets with MIRI/JWST

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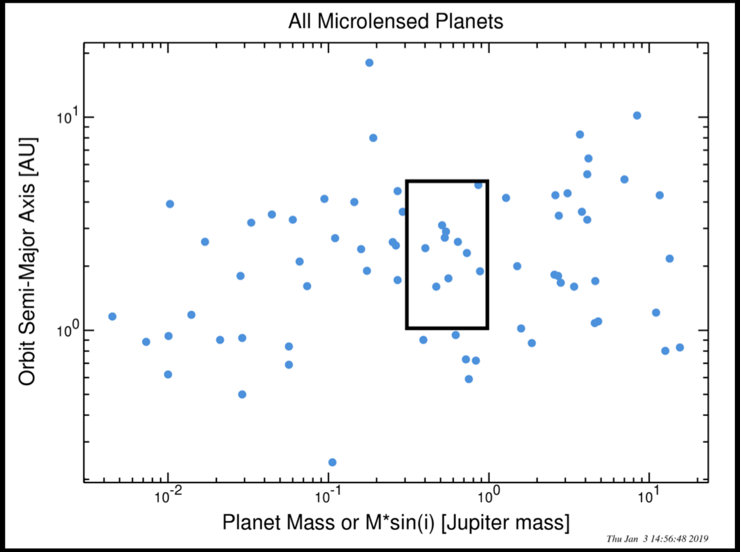
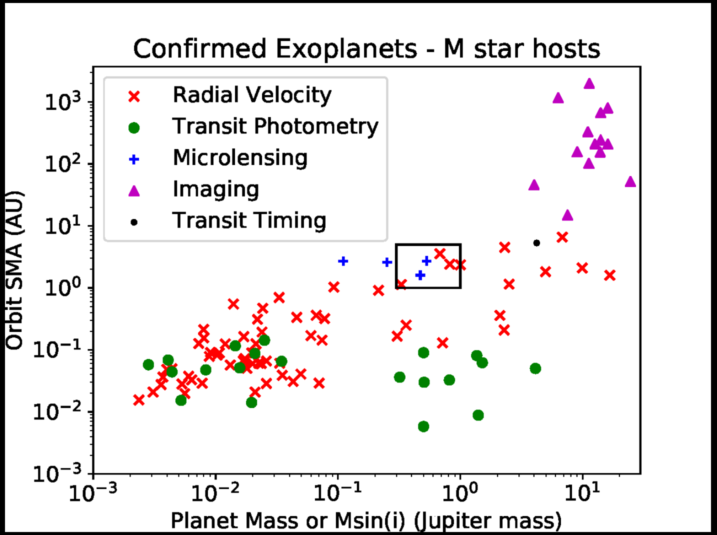
Frontier Developments

Motivation

- Microlensing surveys suggest Jovian-type planets are plentiful
- Low-mass stars have fewer giant planet companions, many Neptune-like, lower mass planets
- Some indications of ~6-10% of M-type stars have a Jupiter-mass companion < 10 AU, up to ~50% < 20 AU (Meyer et al. 2018, Bryan et al. 2016)
- At nearer separations, no direct imaging detections of ~1 MJup planets at all*



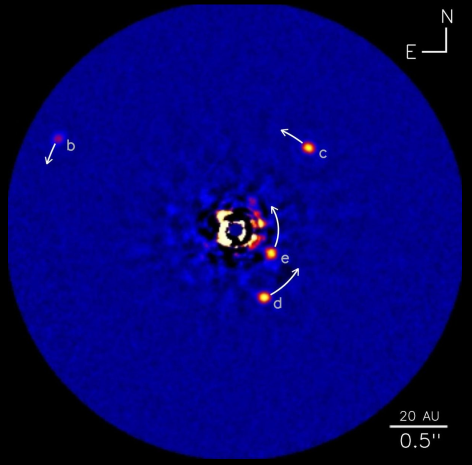
Current (2019) plot of all microlensing-discovered exoplanets, with area of interest shown

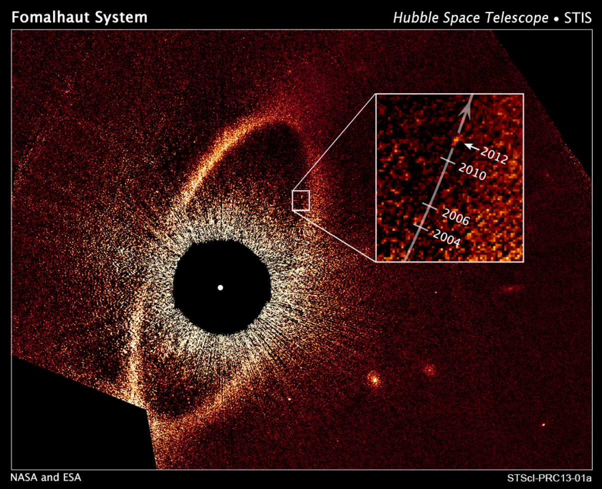


Mid-2018 plot of confirmed exoplanets around M stars, plotted by discovery method (Exoplanet Archive)

Direct Imaging

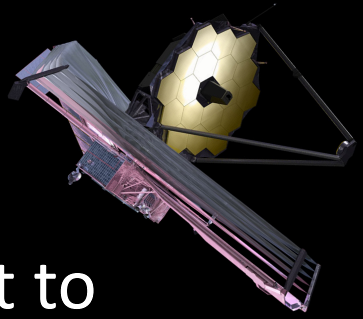
- Direct imaging of exoplanets requires high contrast, stable pointing
- Best targets: bright planets, dim stars, wide orbits, near Earth
- Most nearby systems good potential targets
- Ground-based AO/Coronagraphs most successful currently, JWST/WFIRST/LUVOIR critical to future space-based coronagraphy



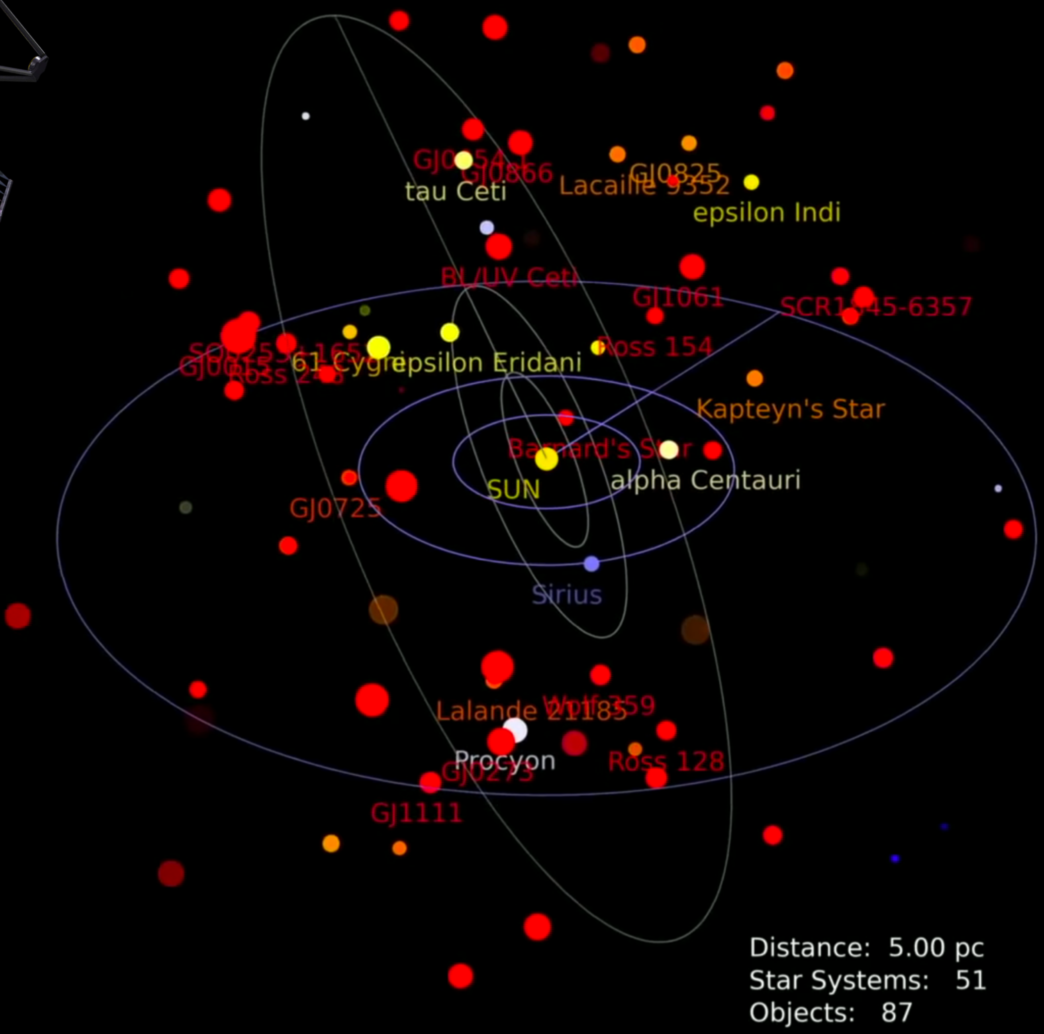


The first directly imaged exoplanets, HR 8799 b-e, and Fomalhaut b.
(Keck Observatory, NASA/ESA)

Stellar Population



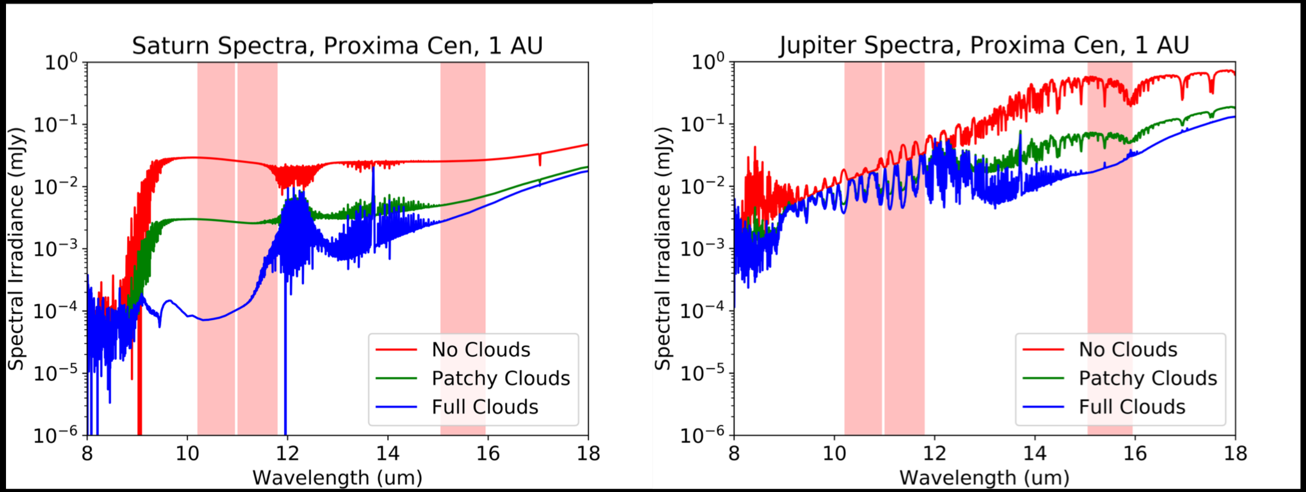
- Filtered RECONS Top 100 list to find suitable stellar targets
- Targeted M stars not in close binaries
- Found 27 stars, mostly within 5pc, among the 50 closest stars to Earth
- Found stellar parameters from RECONS/SIMBAD/Exoplanet Archive



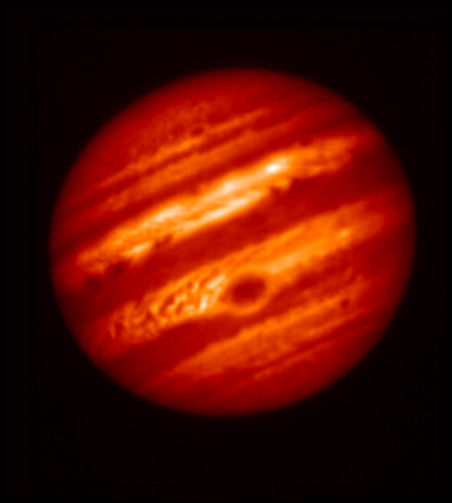
A. Riedel, RECONS

Planetary Models

- We use solar system Saturn and Jupiter as planetary analogues
- Planets placed at 1, 2, 5 AU
- Atmospheric scattering/cloud cover is most important for brightness
- Vary from no clouds/scattering to 90% to full cloud cover
- Planetary spectra show which MIRI coronagraphic filters would be optimal



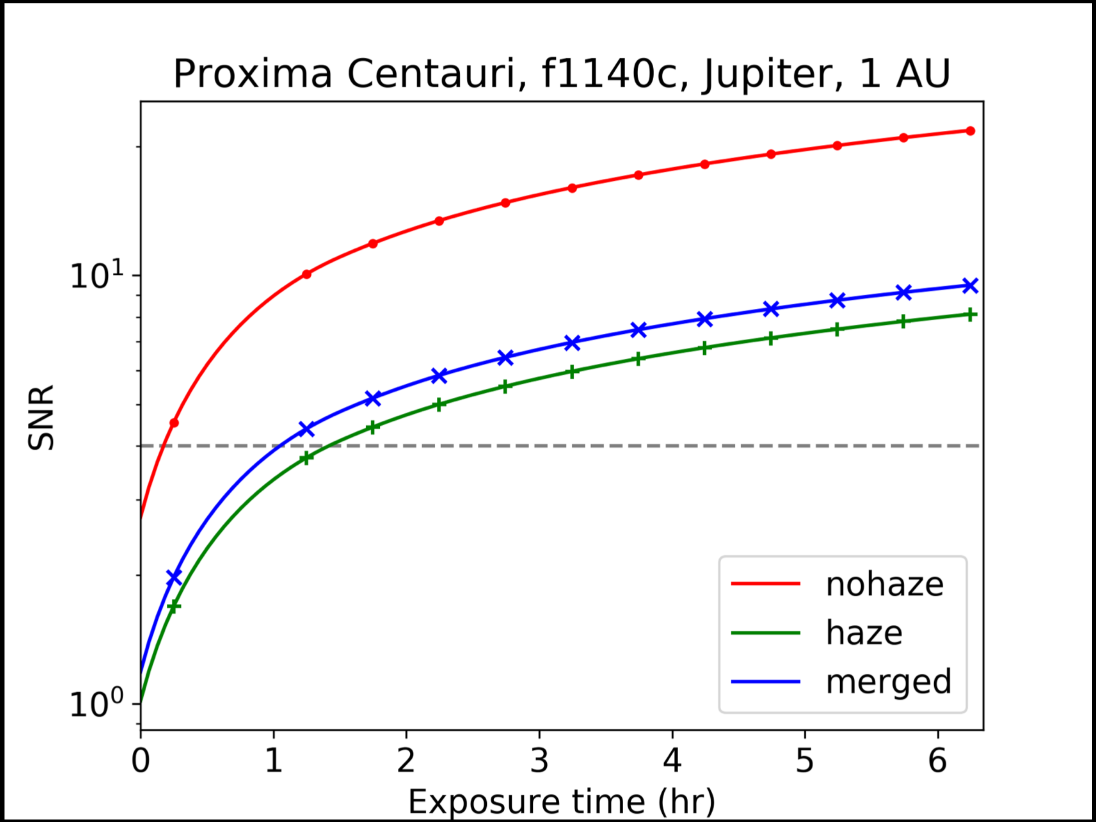
Sample spectra of Saturn and Jupiter, placed around Prox Cen.



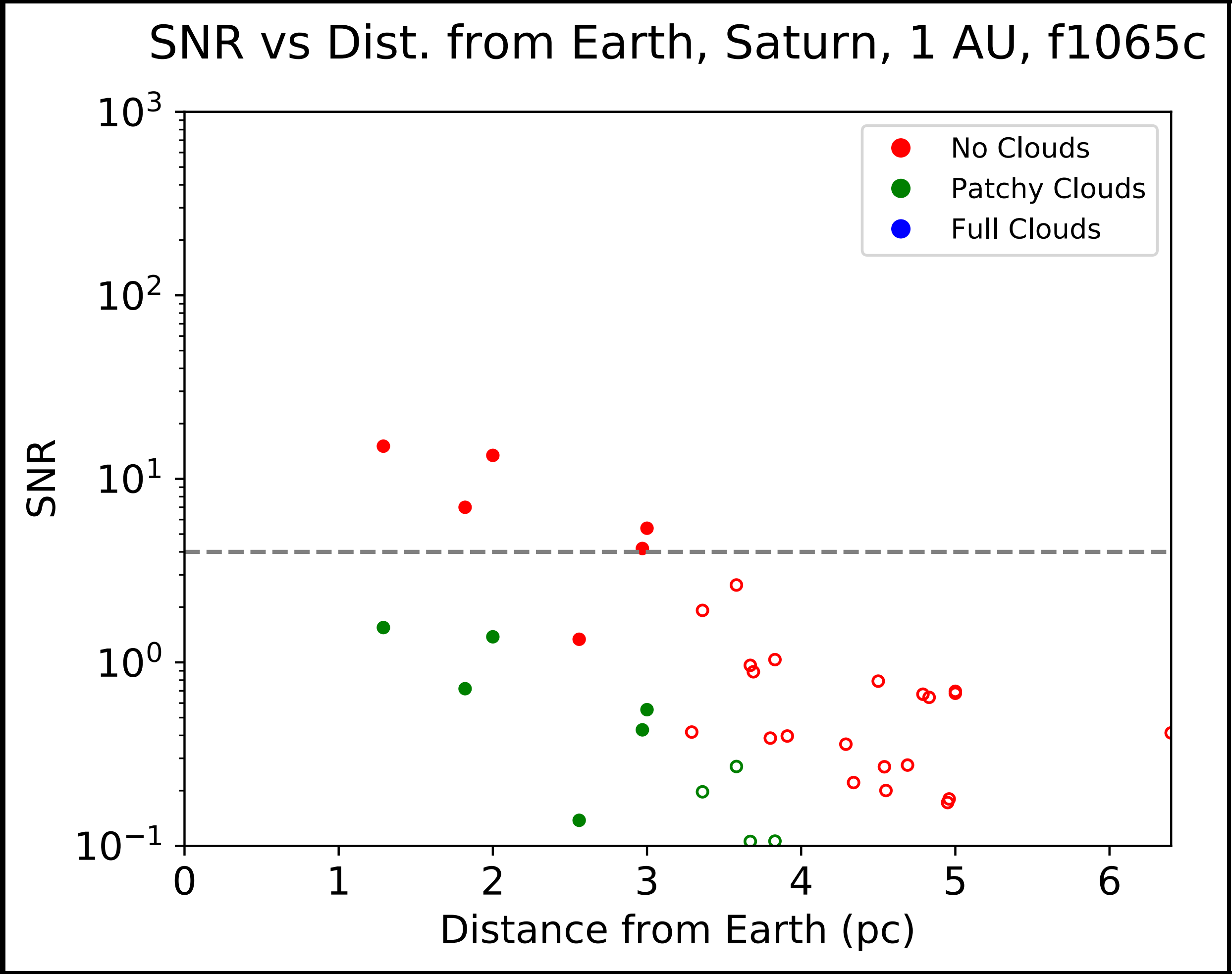
Jupiter at 8.8 micron, showing variation in brightness across the disk, which we tried to emulate.

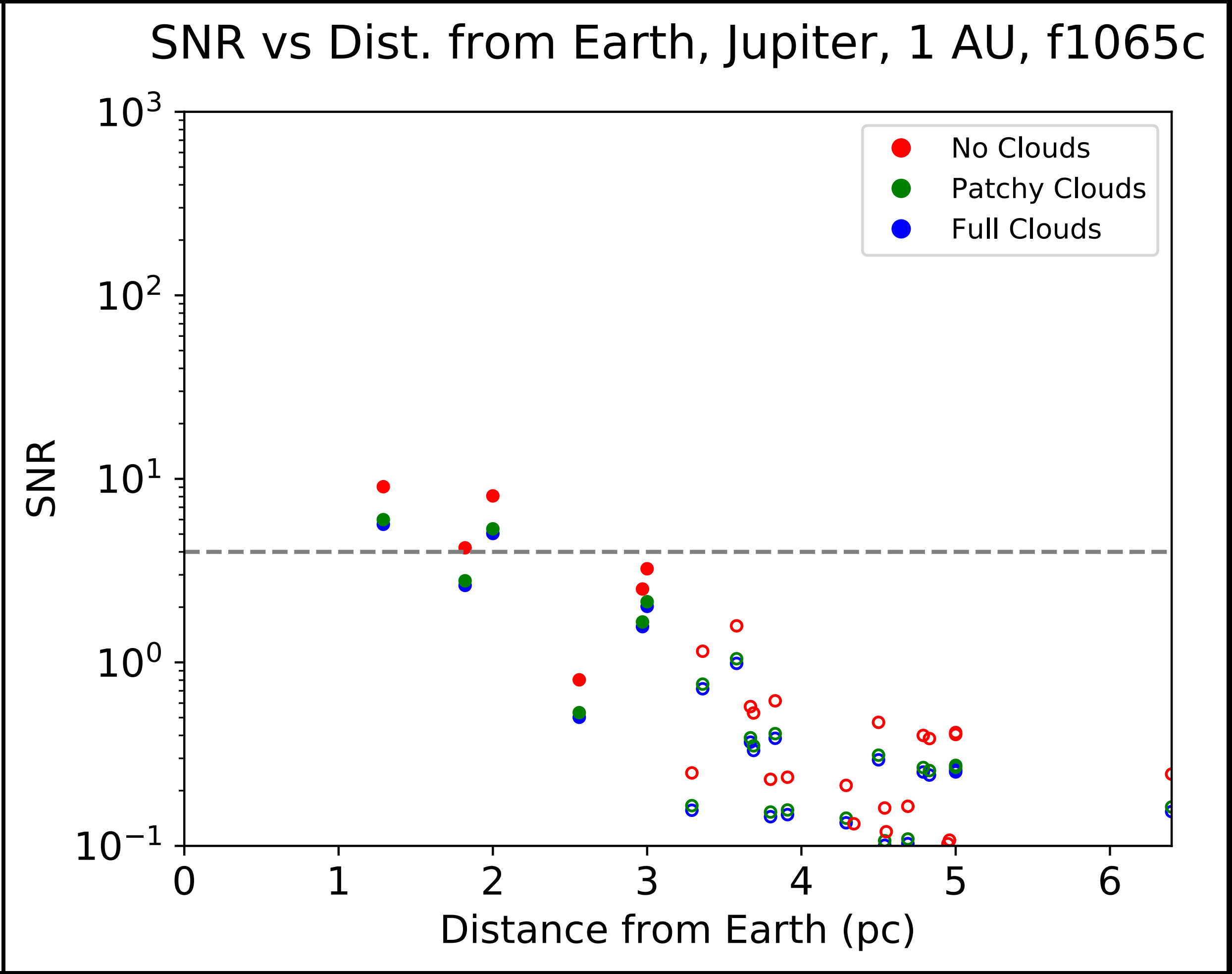
Simulating Observations

- GSFC's Planetary Spectrum Generator
- STSCI's Pandeia Python module
- Goddard Private Cloud
- Simulations running for 27 M-stars, three MIRI coronagraphic filters, two planet analogues, 3 atmospheric configurations, 3 orbital distances, 12 exposure times. ~17,500 total sims



Selected Results





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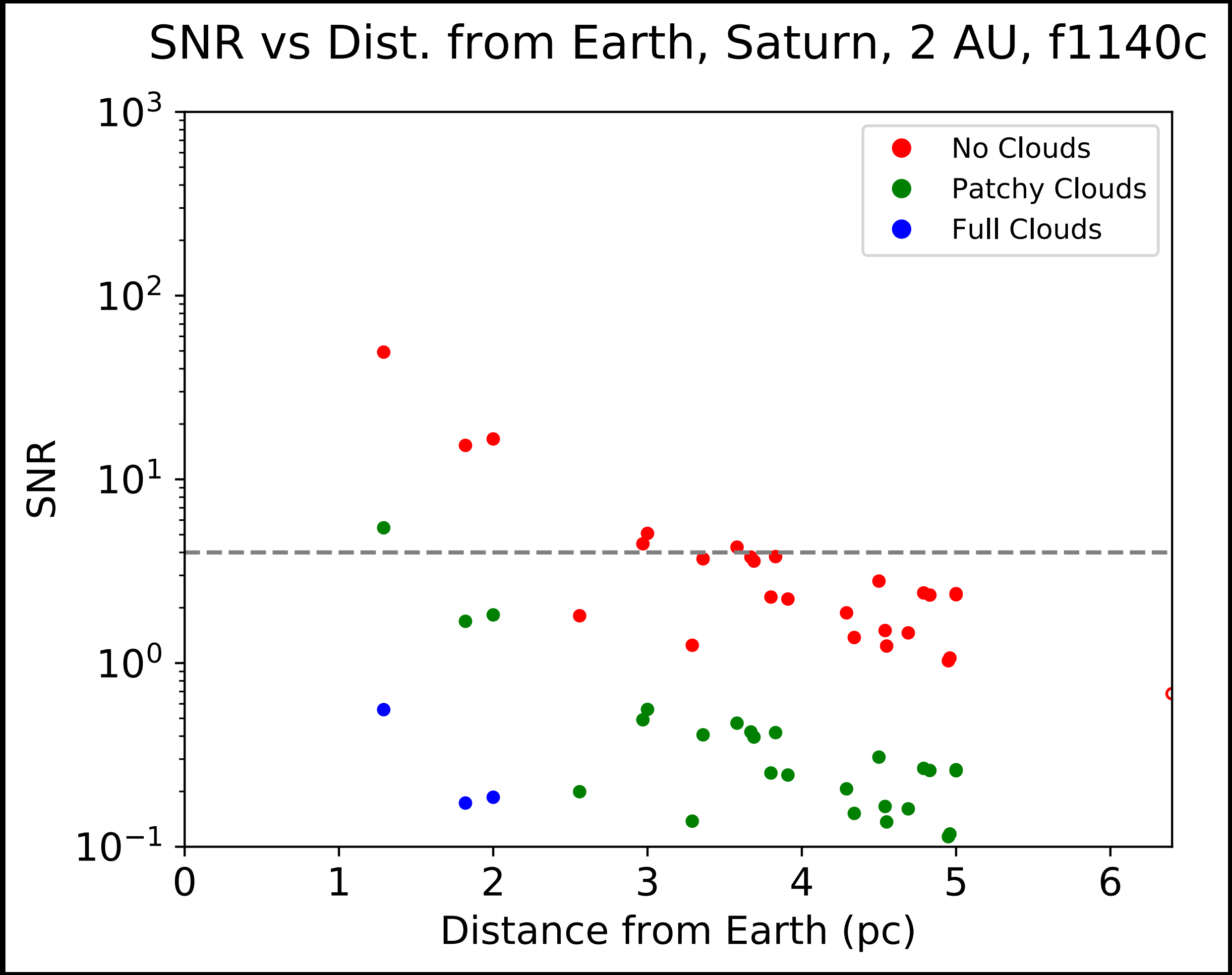

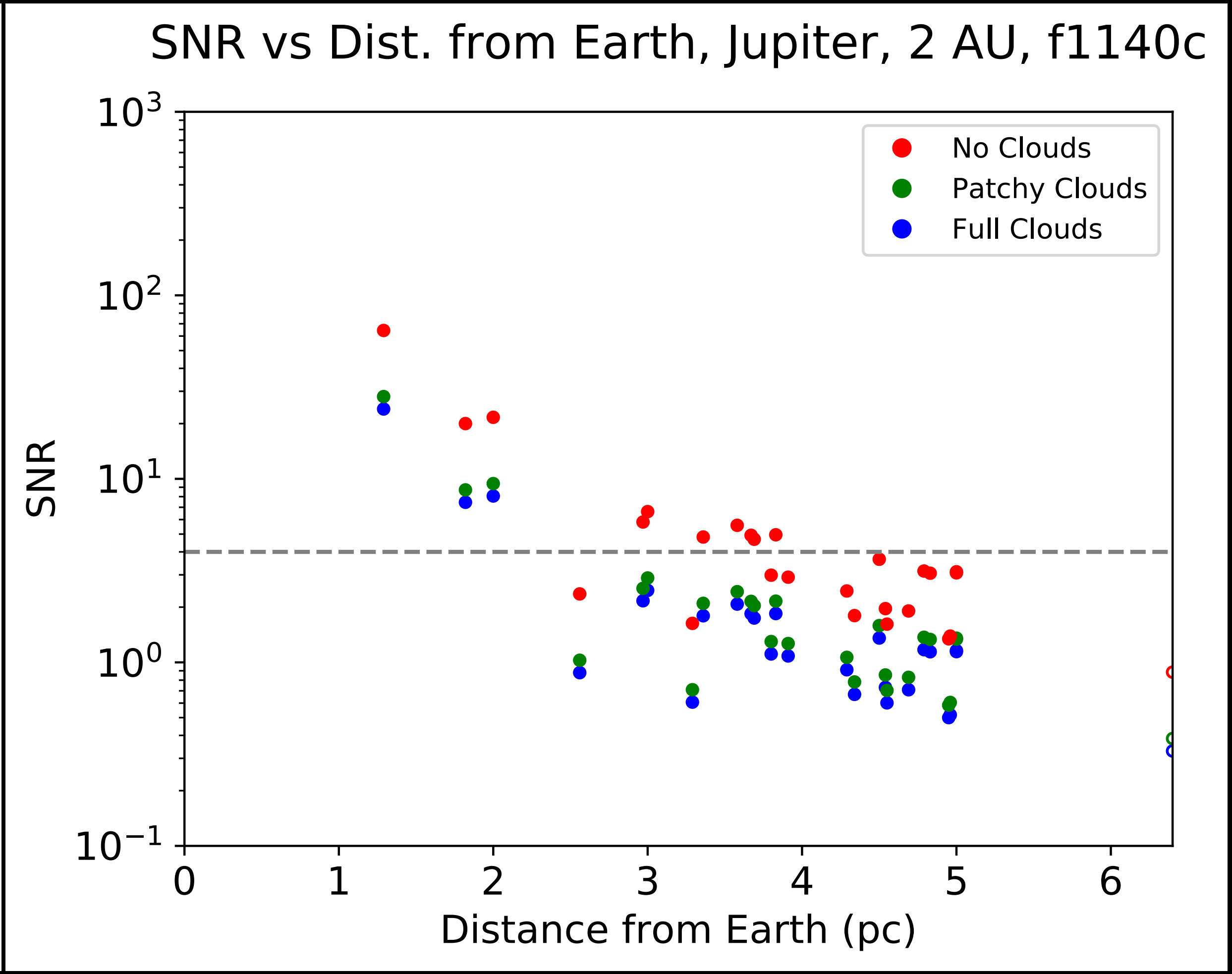

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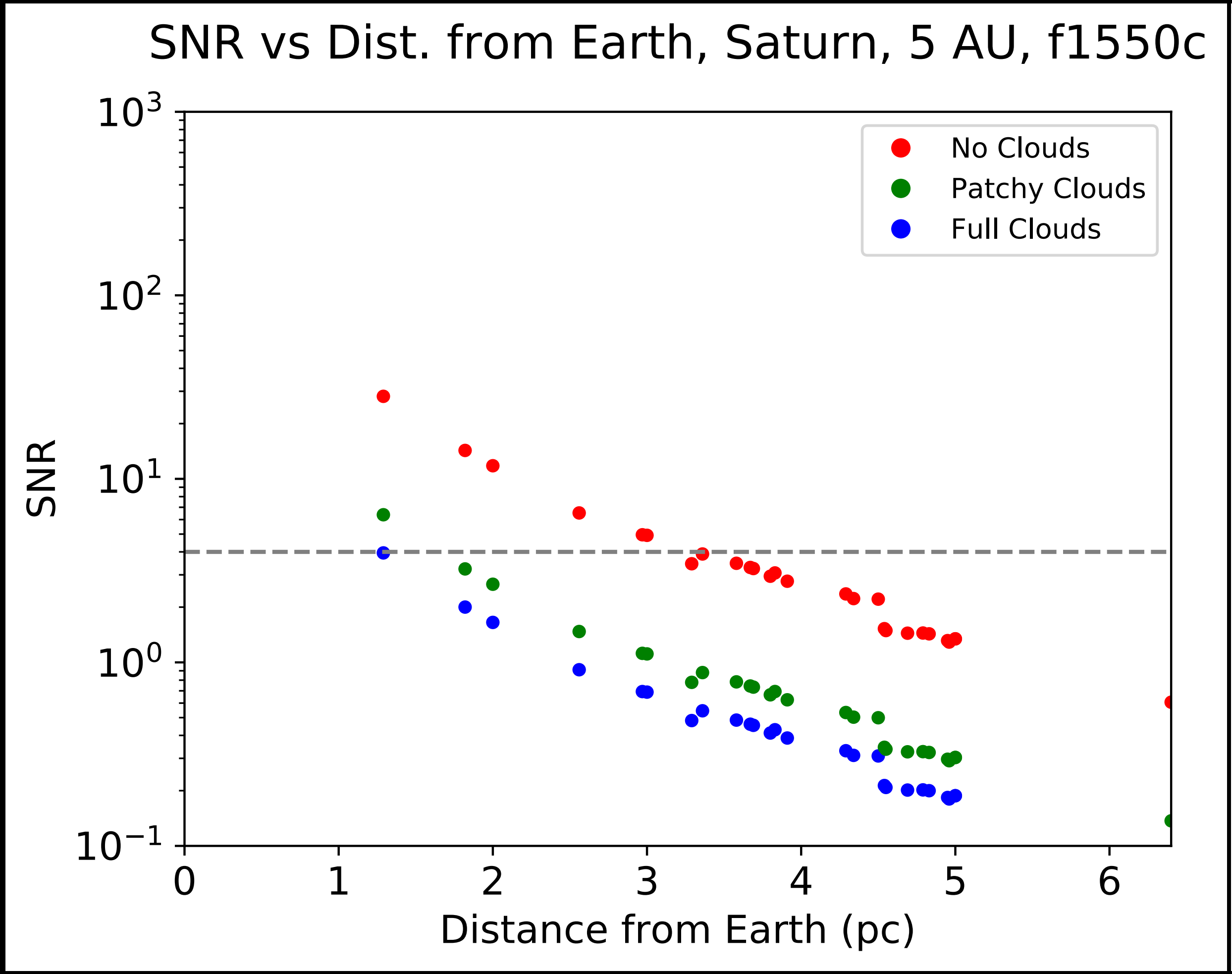
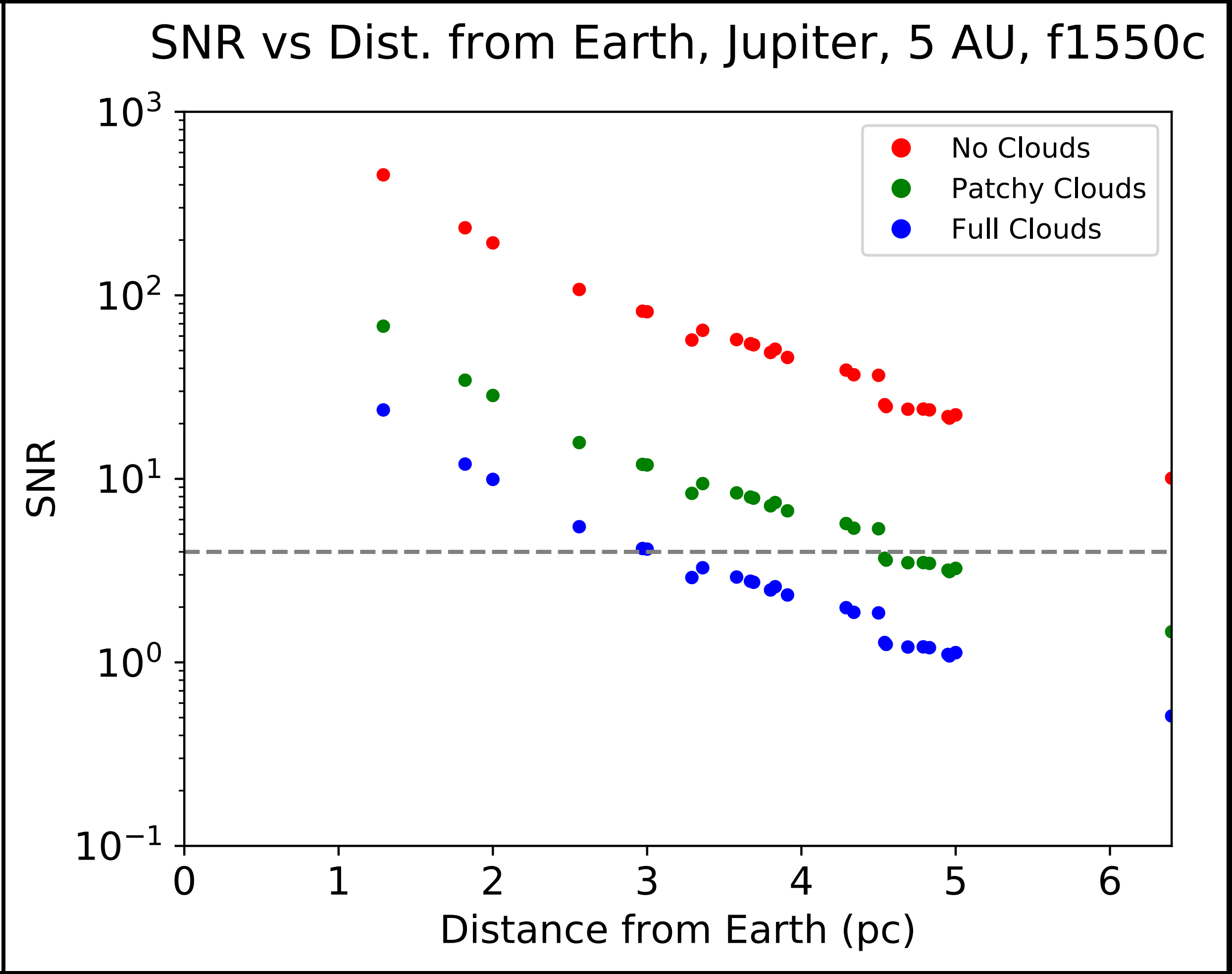
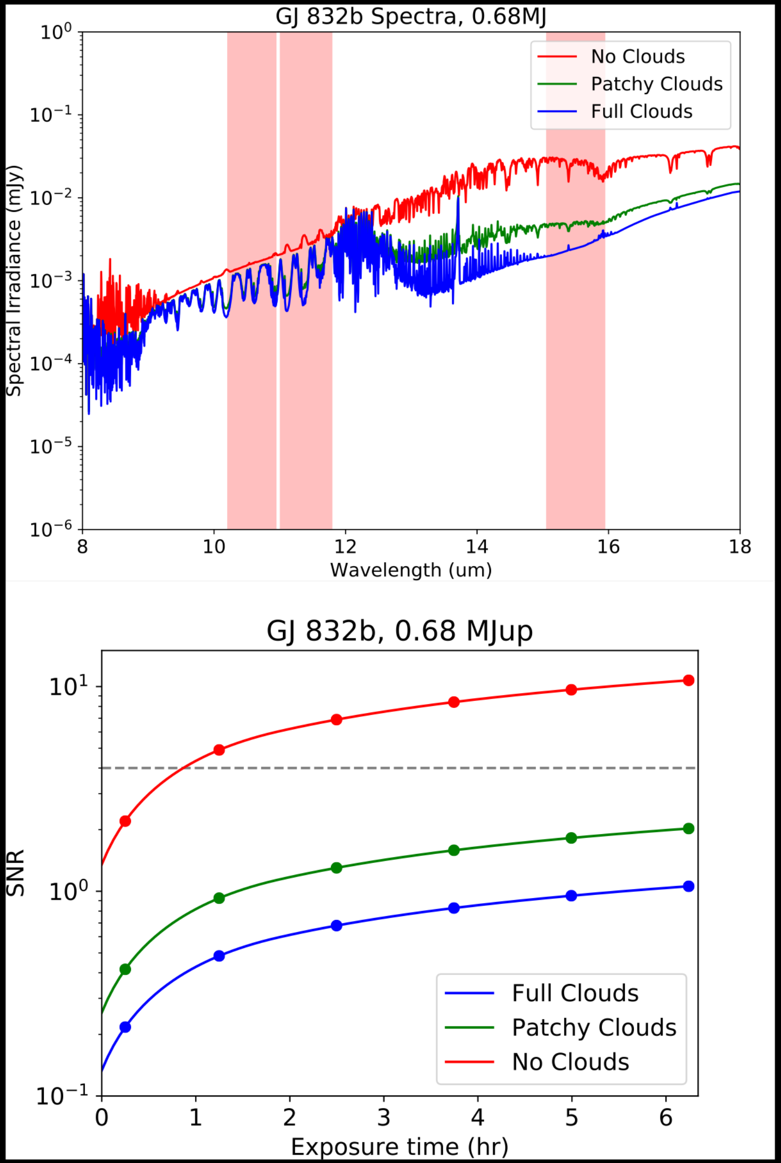




Proof of Concept – GJ 832b

- M2V, ~3400K, ~0.45Msun, ~4.95 pc
- 1 known Jovian exoplanet, ~0.68 MJup, 3.56 AU
- Modeled with Jupiter-like atmosphere and varying clouds/scattering
- Brightest configuration detectable
- Many unknowns about system, potentially detectable in future



Can we directly image?

- In the best cases, yes!
- The brightest Saturns are detectable, and are best in 11.4µm. Effective detection limit around 2-3pc.
- All Jupiters have at least one detection, but are most detectable at 15.5µm. Most successful search within 3pc, but bright Jupiters are detectable out past 5pc.
- GJ 832 is our best (and only!) test system, with a potentially detectable giant planet.
- From current occurrence estimates, perhaps 1-2 more planets btw 1-5 AU, could be many more at further separations