# Sciences summary, discussion items and homeworks

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# Sciences

- Great science ideas. And lots of ideas.
- ALMA had 3 key science goals. JWST? WFIRST?
- We need to do a better job connecting to a post-WFIRST and post-JWST era.
- We need a mechanism to sub-select the large number of "sciences goals" down to a few key questions.
- Common science themes are probably easy to convert to high-level science requirements. (?)
- Several clear common themes emerged from talks yesterday *(without any coordination between the groups).*
- *We need an elevator pitch. Not there yet.*

- Can we use a set of clear well-defined questions ("musts") to help guide the architecture selections?

# *Possible* killer apps
### ("musts"?; can we convert these to killer questions?)

- Origin of Earth's water: A census of D/H in 100s of comets and TNOs (plus C,N,Os+).  *[- follow-up of LSST comets?]*
- *Spatial distribution? 100 necessary?*
- Census of total water content for 1000s of proto-planetary disks.  *- can separate warm, ice and snow-line with FIR only.*
- *Focus on water – contain other volatiles, NH3 (Klaus)*
- *Do a wide range of stars, M-dwarfs to solar mass*
- *Across all evolutionary stages, across stellar mass range, ~500 pc.*
- *1000 not defined!*
- *Building blocks habitable planets – (Margaret)*
- *Tracing the ingredients of habitable worlds (Ted)*
- *Learning what they are made of. -  ALMA is doing.*
- *Minimum mass solar nebula.*

# Possible killer apps

## ("musts"?; can we convert these to killer questions?)

- How common are Jupiter and Saturns in other exoplanet systems?
- *CO2 – cool planets*
- *NH3 Jupiter types*
- *FIR is not about how common. Characterization of cool planets – 300K area. Other methods get hot things.*
- *Using disk structure to count planets. WFIRST will do a microlensing survey and get statistics. Additional room?*
- *Debris disk looking at younger ones?*
- *Spectroscopy/direct imaging….*
- *mid-IR characterizing greenhouse effect in extrasolar planets*

# *Possible* killer apps
## ("musts"?; can we convert these to killer questions?)

- Time variation of mass accretion across the Galactic plane.
- - not clear if this is helpful scientifically for SF
- Star-formation?
- Total energy budget of the galaxy.
- Energy of the ISM.
- Magnetic fields and polarization.
- [to other groups: polarization sciences?]
- SF as a function of environment.

# *Possible* killer apps
### ("musts"?; can we convert these to killer questions?)

- From gas to stars and blackholes: growth and evolution of galaxies over the full cosmic history. *[FIR can do BHs and SFRs at the same time! - aim more on Milky Way-like at z=1,2,3,4,5]*

- *Connect galaxies from local universe to formation epoch.*
- *Not a JWST – JWST will get stellar mass.*
- *WFIRST – Halpha/Hbeta –*
- *Spectroscopy, PAH, OIV, Ne, S,…. -*

# *Possible* killer apps
## ("musts"?; can we convert these to killer questions?)

- Beginnings of Chemistry: the formation of heavy elements,dust and molecules. *[not sure what the exact observable here is?]* The epoch of dust formation in the Universe...

- *JWST followup? This is not a JWST topic. JWST will provide targets.*
- *What are z=10 JWST-detected galaxies?*
- *Density, metallicity. SFR, ....*
- *Dust molecule – ALMA; PAHs. Unique for FIR.?*
- *Angular resolution needed to separate JWST-detected galaxies*

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# *Possible* killer apps

### ("musts"?; can we convert these to killer questions?)

- Detecting the first galaxy formation sites via H2 cooling during the cosmic dark ages. - *[pushes beyond JWST]*
- *Homework – to perfect the calculations related to H2 and HD.*