Cradle of Life Science

on the

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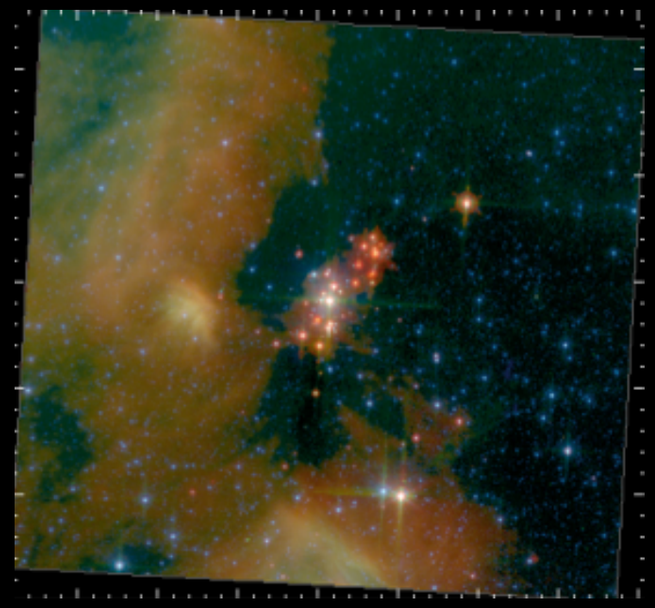
Radboud University Nijmegen

BERKELEY SETI RESEARCH CENTER

for the

Cradle of Life Science Working Group

- ★ Young Cluster Deep Field

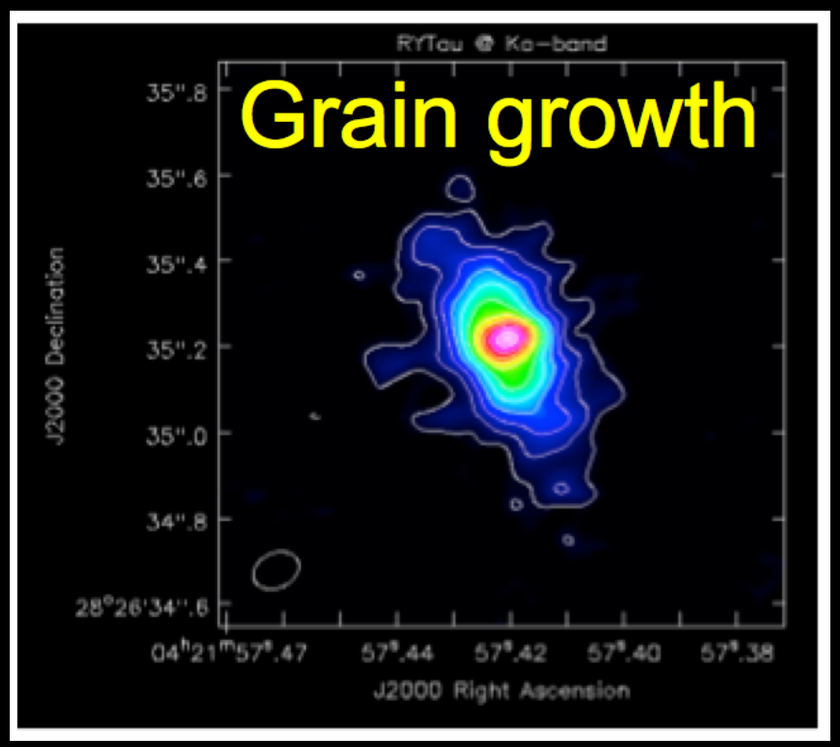


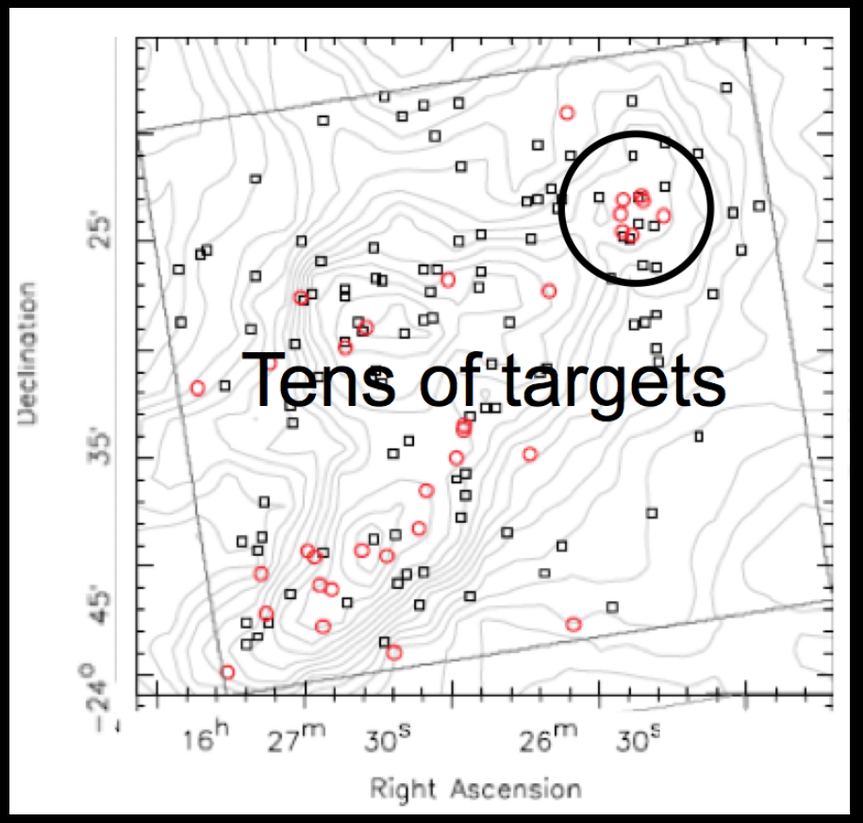
- ★ Nearby Young Stellar Clusters

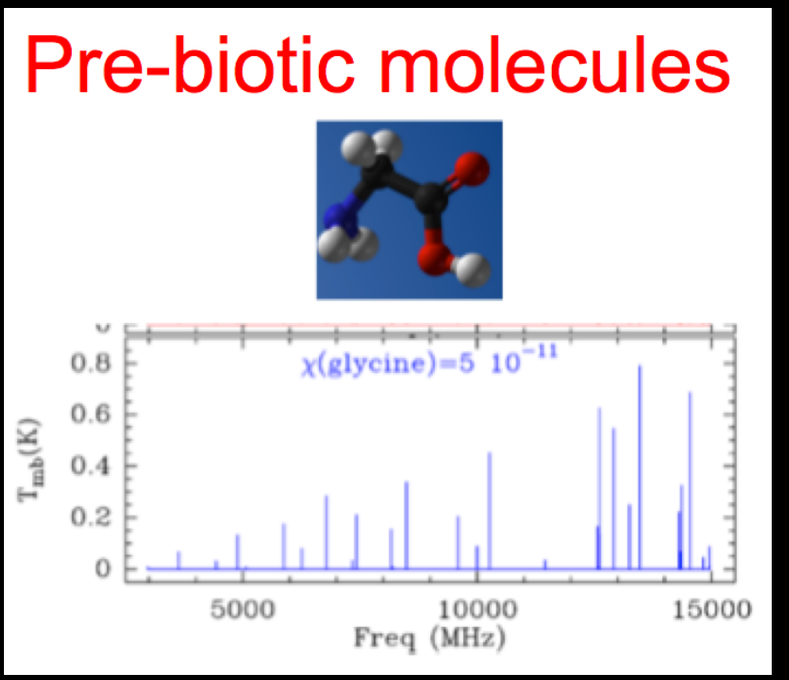
- ★ The Stellar Neighborhood:
  Stars, Planets and Civilizations

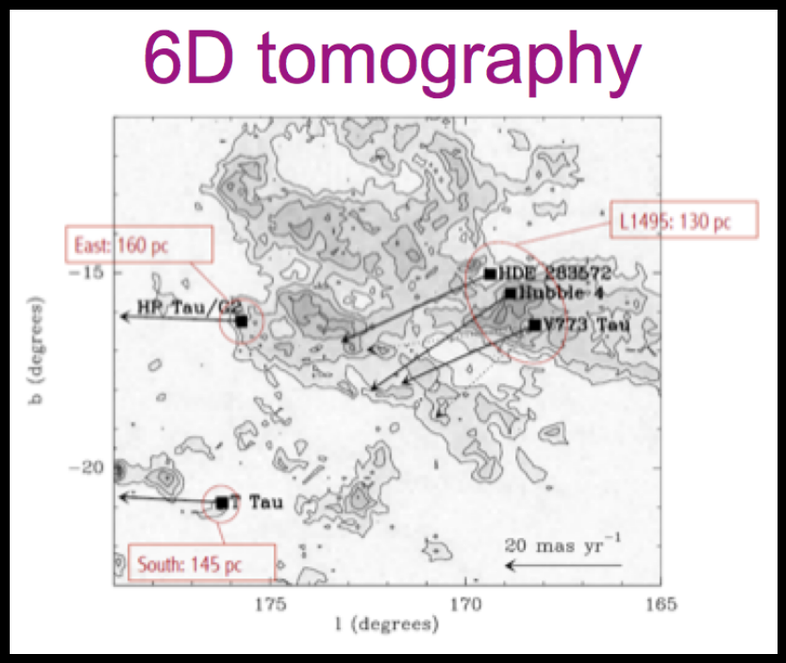
- ★ The SKA-1 SETI Survey

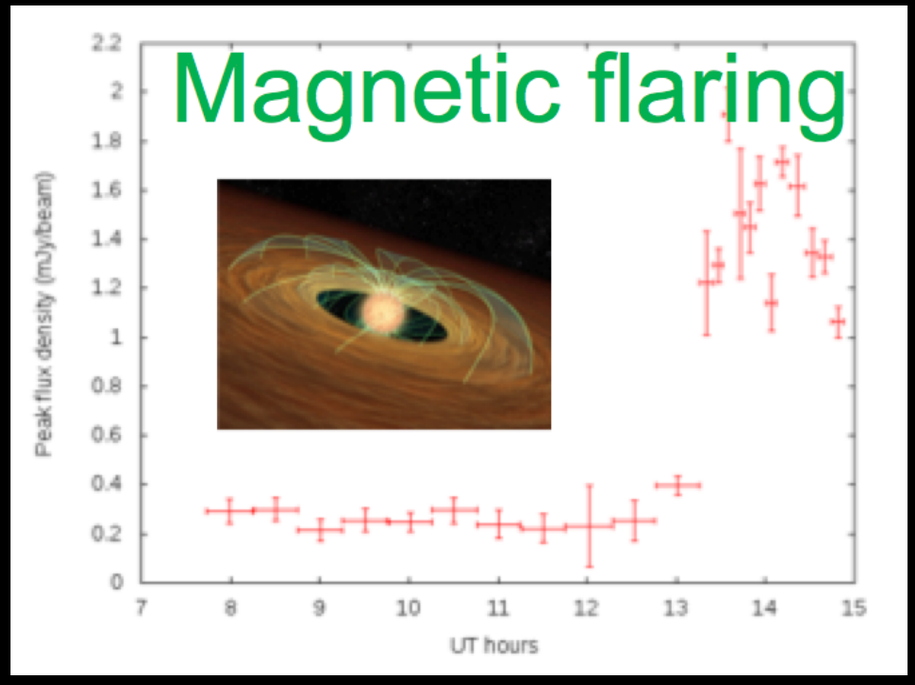
KSP 1: Young Cluster Deep Field

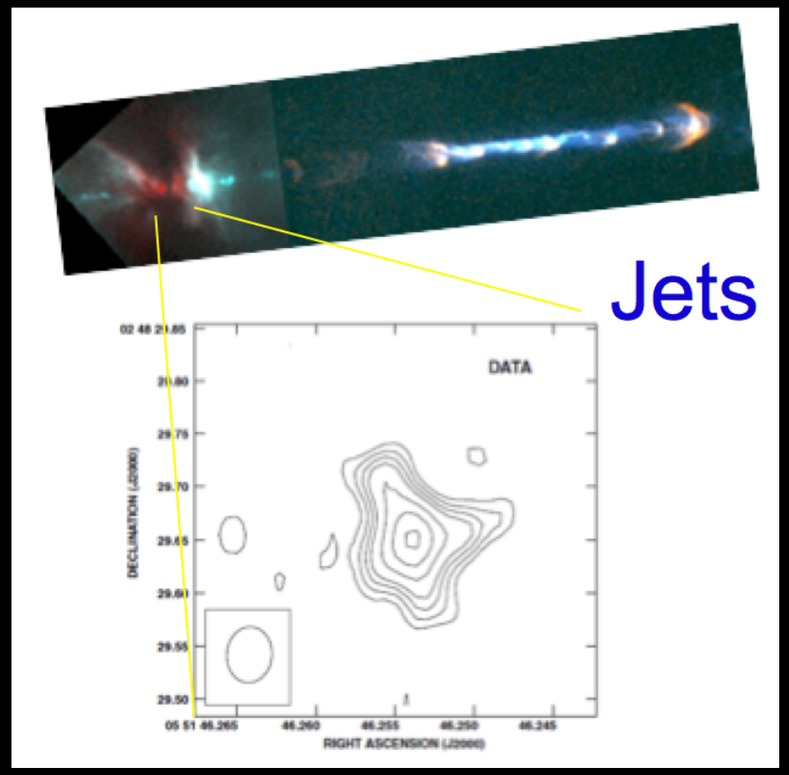






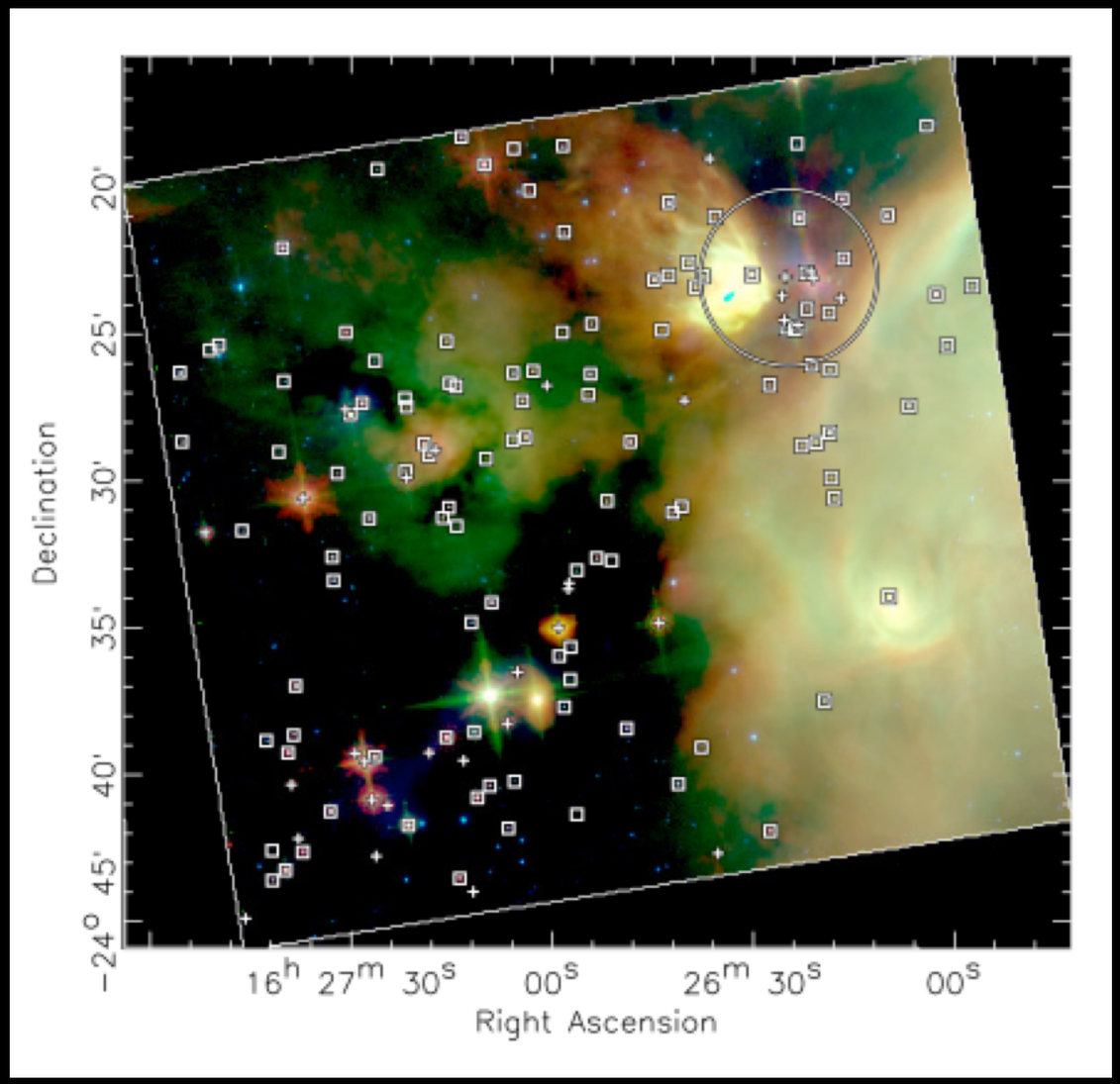






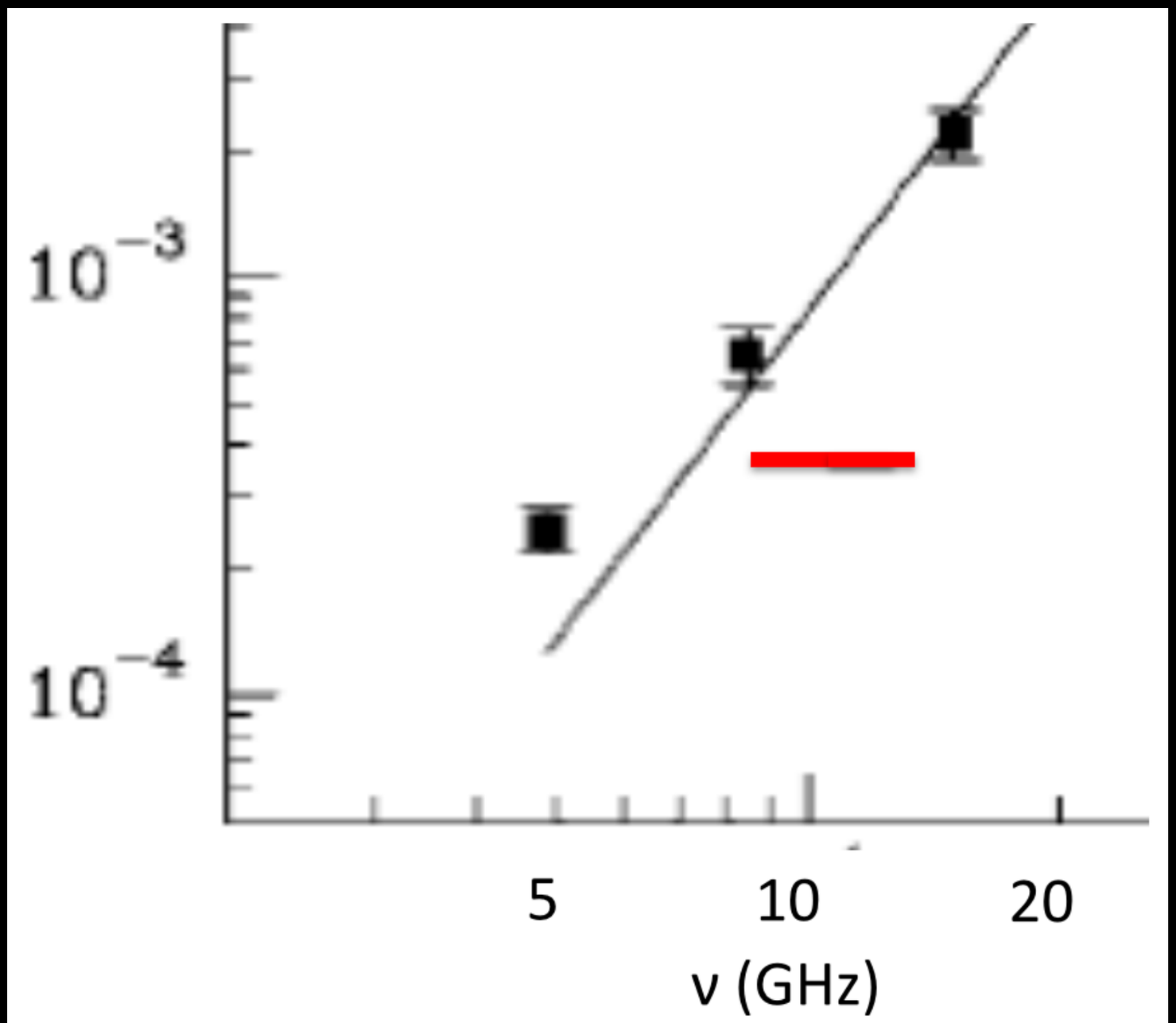
Basic Outline

- **~ 1000 hr single pointing with SKA1-Mid**
- **Top end of band 5**
- **40 mas resolution equivalent to 5 au at 125 pc**
- **JVLA pilot study of ~ 10 clusters to choose final target**



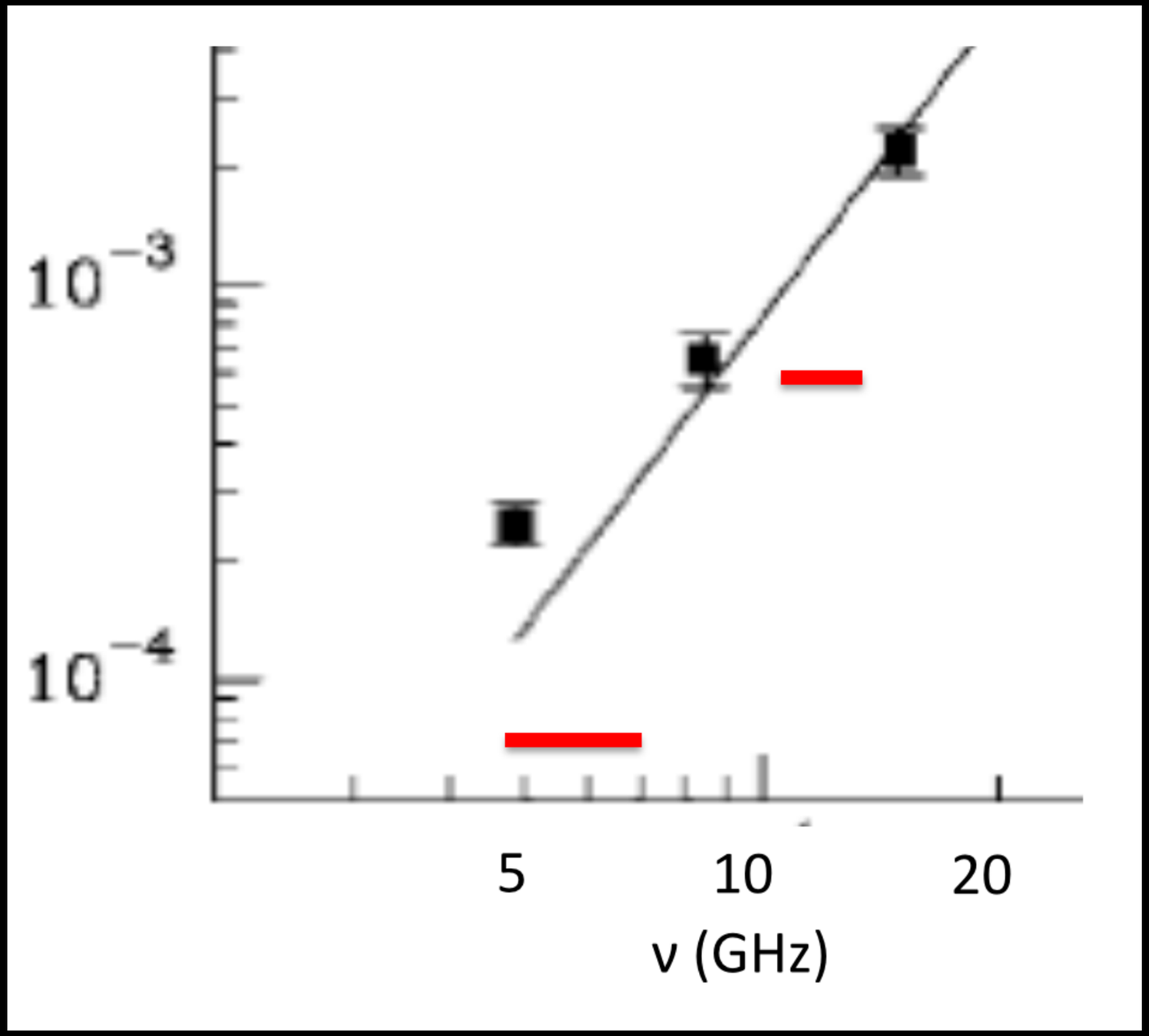
KSP 1: Young Cluster Deep Field

Frequency Set-up



- **Where to place the 2 x 2.5 GHz bands?**
- **One at the top end of band 5 for resolution and sensitivity**

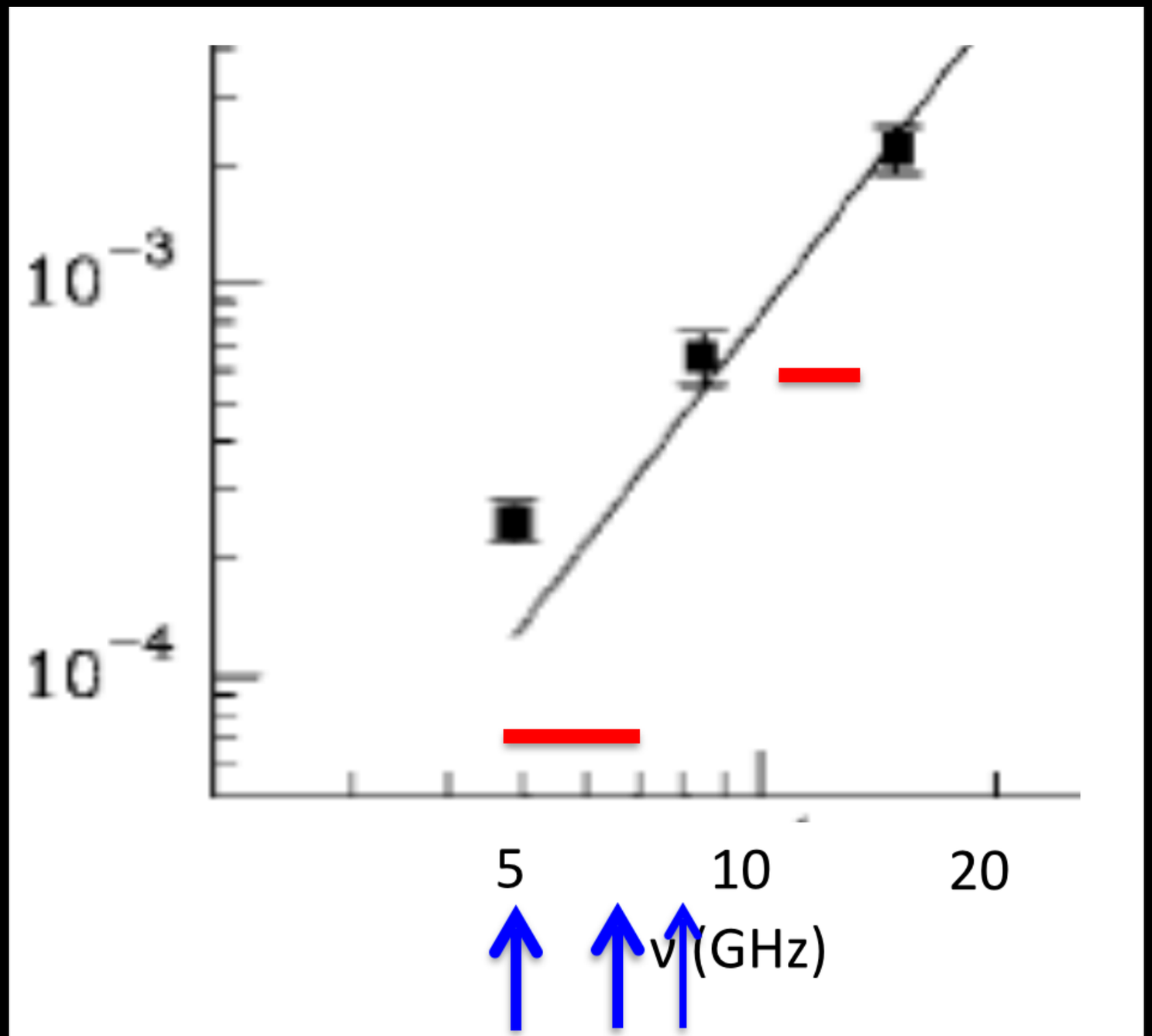
Frequency Set-up



- Place the other at bottom end?
- Less signal and resolution at lower frequency, but probe larger grains and better spectral index measurement

KSP 1: Young Cluster Deep Field

Simultaneous VLBI

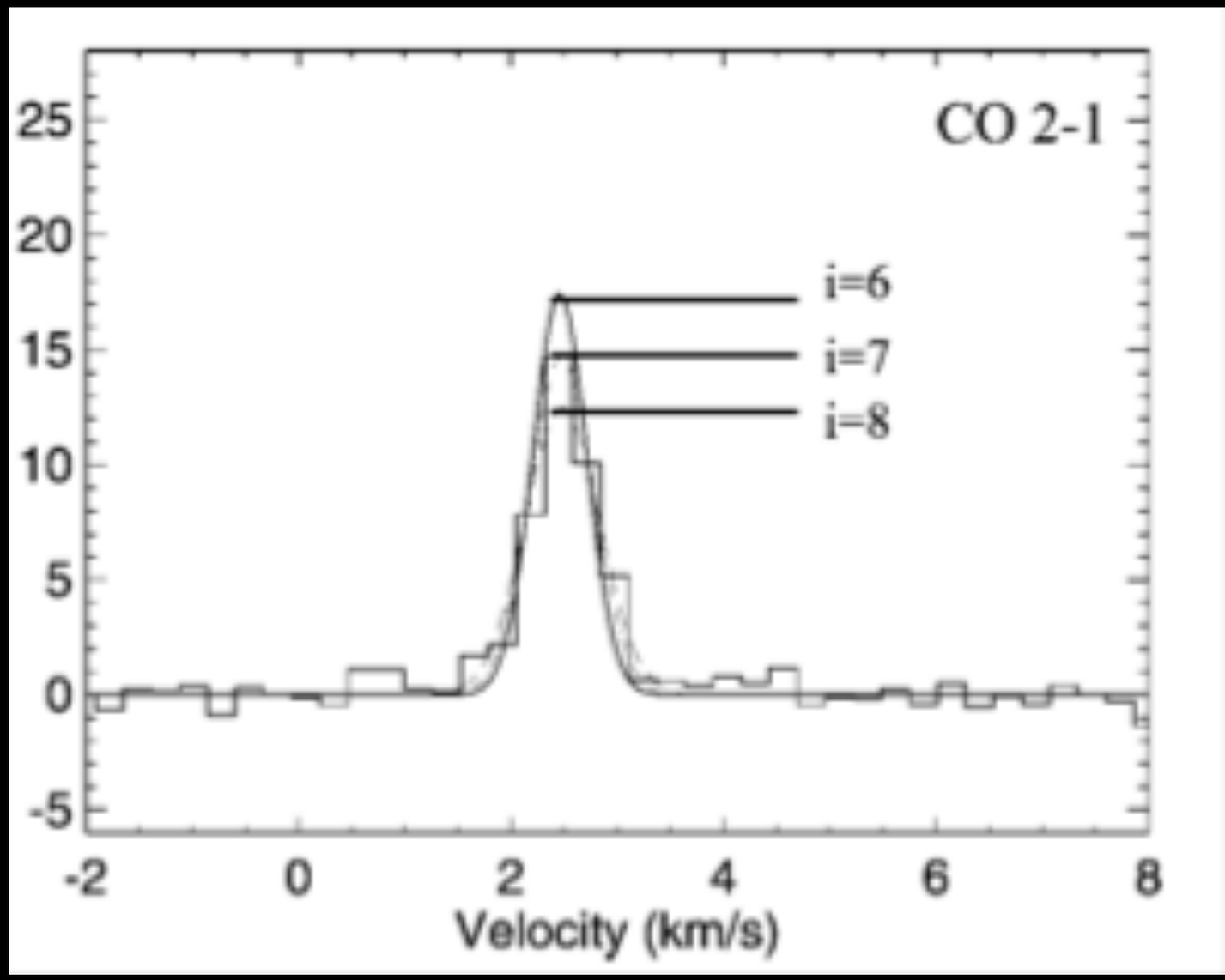


- VLBI dishes only overlap at 5, 6.7, or in some cases 8 GHz
- This could dictate the placement of the lower 2.5 GHz band

KSP 1: Young Cluster Deep Field

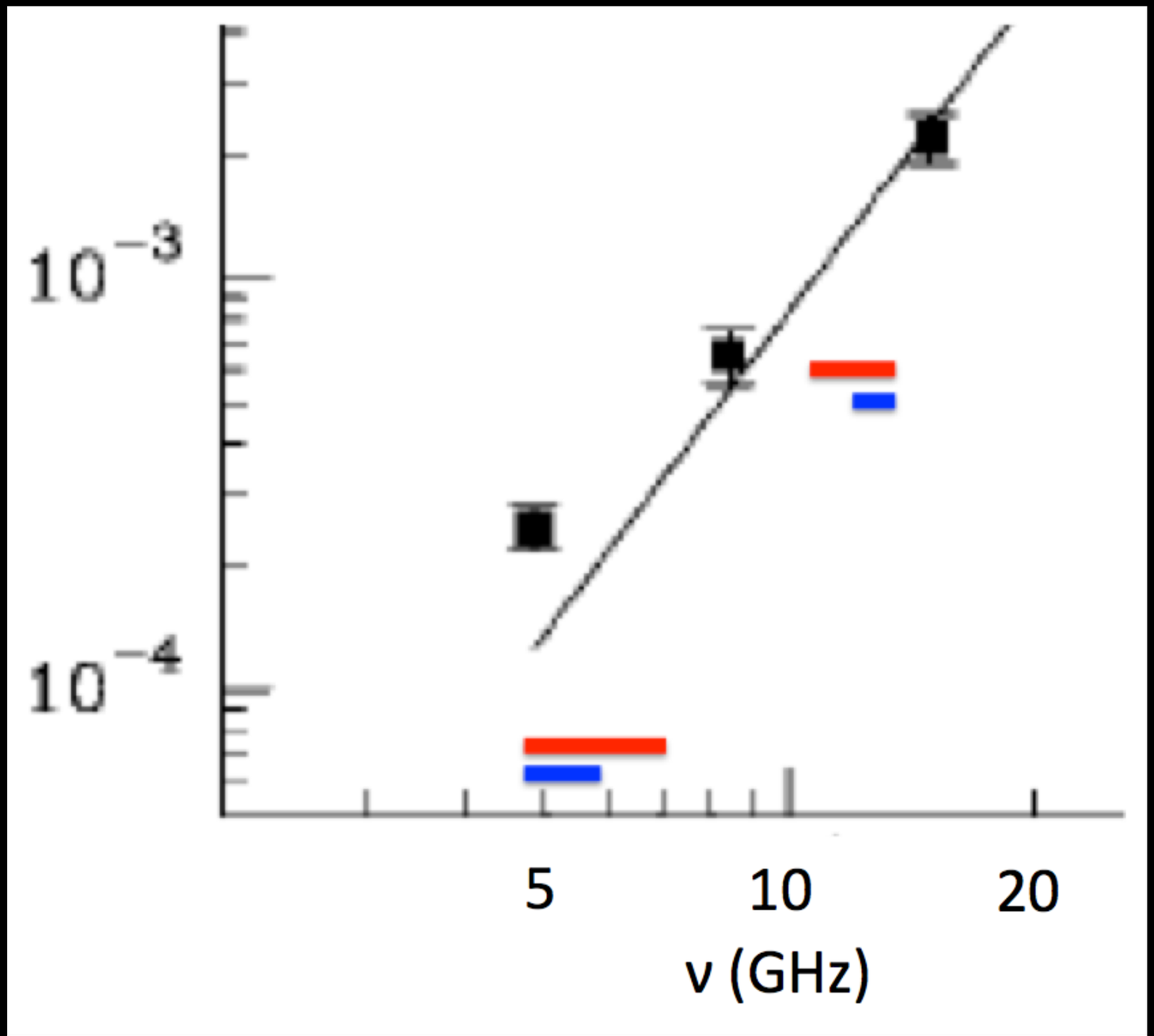
Spectral Resolution

- **Proto-planetary disc line widths are about 0.8 kms^{-1}**
- **Minimum resolution for molecular line search**



TW Hya (Qi et al. 2004)

Spectral Line Set-up



- Use 4x256 MHz zooms to give 0.8 kms^{-1} at 12 GHz
- Resolution only 1.6 kms^{-1} at 6 GHz
- Can only search 1 GHz of spectrum for lines

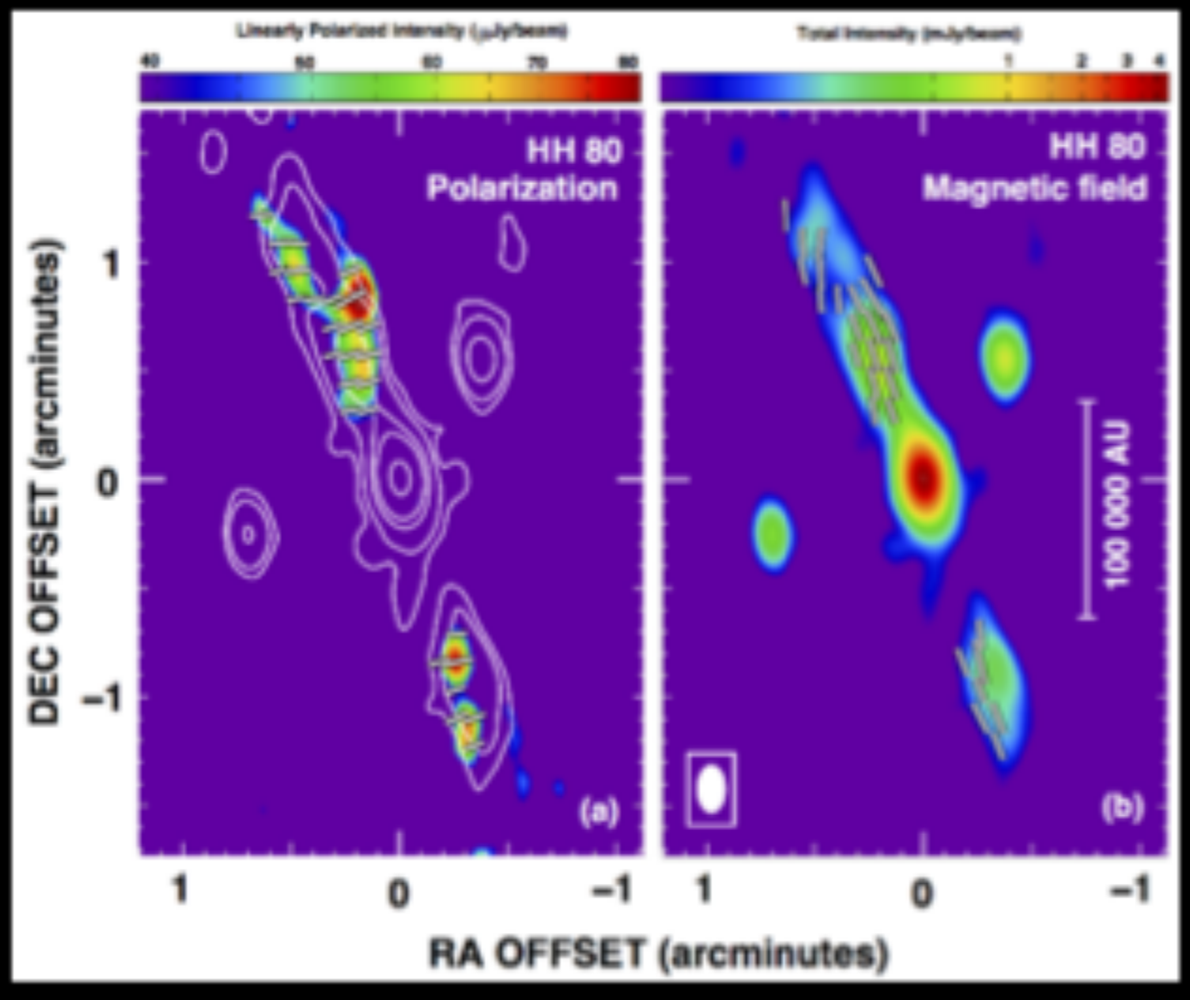
Spectral Line Set-up

- **Rest of continuum band now only has 1 MHz channels or 25 kms^{-1} at 12 GHz**

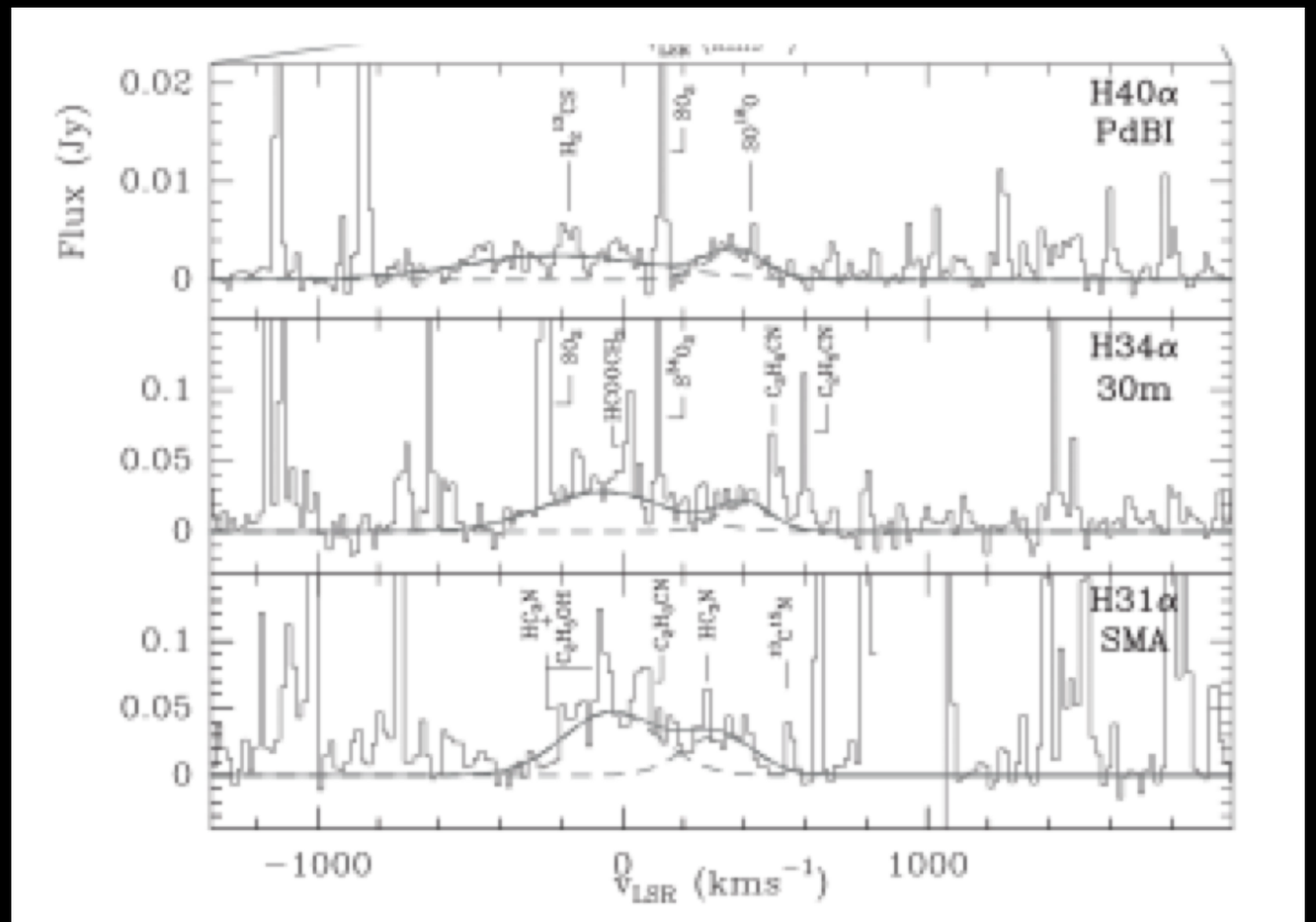
- **Not good enough to remove line contamination from the continuum**

- **The zooms will allow us to check this so place these at either end of the frequency range to give good spectral index measurement in 2 x 0.5 GHz blocks**

Additional Jet Physics



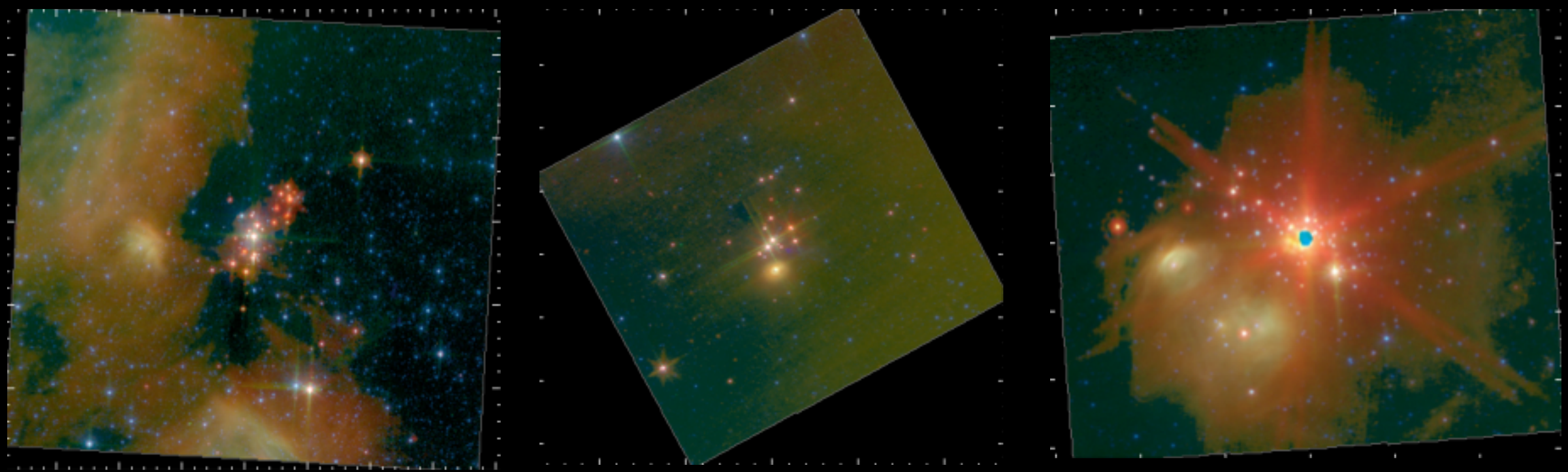
- Jet polarization should be possible to study magnetic field



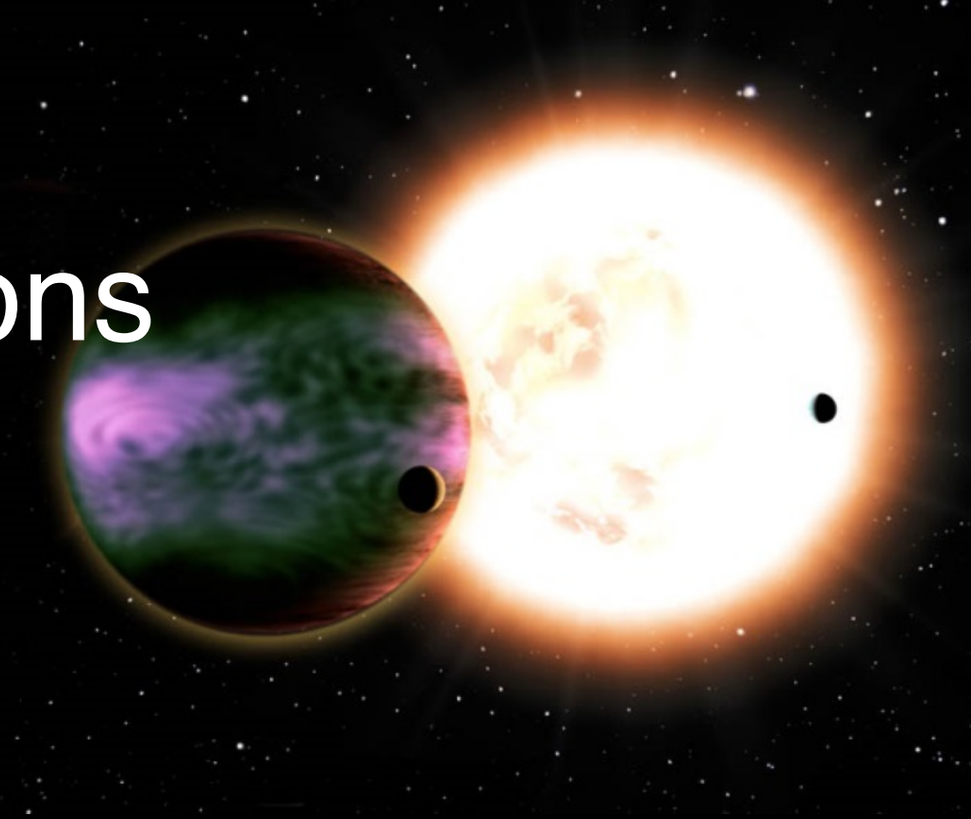
- Broad recombination lines in jets
- 22 RRLs across 2x2.5 GHz
- 5 RRLs in 4x256 MHz zooms

KSP 2: Grain Growth Evolution

- **Shallower survey of ~10 clusters with a range of ages – joint with Our Galaxy**
- **Change in average dust disc spectral index as a function of time and stellar mass**



The Stellar Neighborhood: Stars, Planets and Civilizations

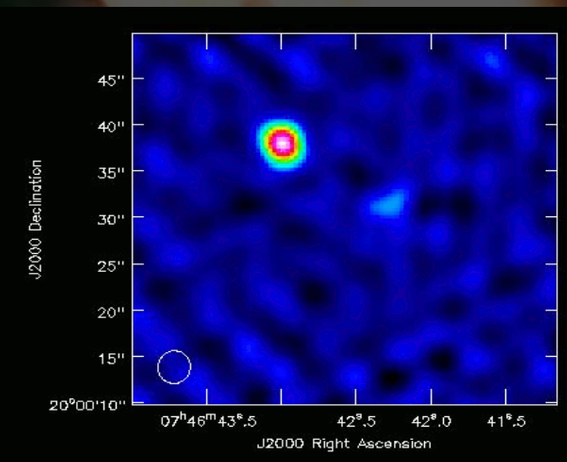


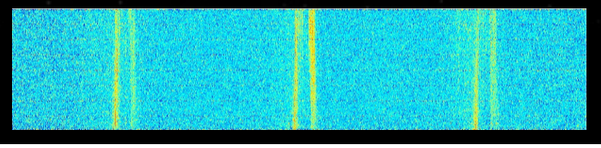
KSP 3: The Stellar Neighborhood: Stars, Planets and Civilizations

Magnetic fields, Cyclotron Maser Instability (CMI):
comparative exo-magnetospheric physics, extrasolar space weather
- CMI from exoplanets, star-planet interactions
- Auroral emission from brown dwarfs
- Stellar Coronal Mass Ejections (~ Solar type II)
- Controlled (SW V,n,B) or triggered (CME) planetary emissions
- Thermal emission from FGKM stars.

Astrobiology Implications: SETI
- Probe ~leakage radiation from Kardashev 0-1 civilizations
on nearby planets.

All stars within 10 pc, ~250 stars including 35 known exoplanets (statistically hundreds of exoplanets)

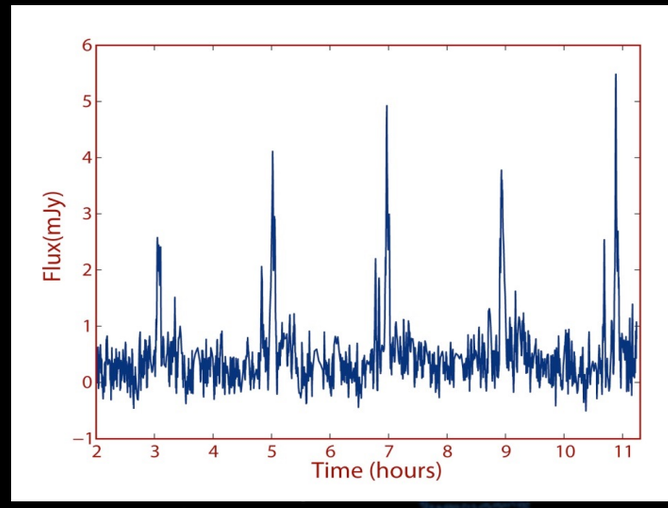




With SKA-Low, imaging, V & I or 4 Stokes

- **~ 1 to 10 sec & 0.1 to 1 MHz**
- **1 beam 50-87.5 MHz + 1 beam 300-337.5 MHz per targe**
- **4 targets observable in (total of 8 beams x 37.5 MHz = 300 MHz)**
- **12 hours per target, multi-epoch TBD**

Total 750 hours, max sensitivity 50 & 10 microJy
*** Jupiter emission or Solar type II detectable)**



[Hallinan et al., 2007, 2008]

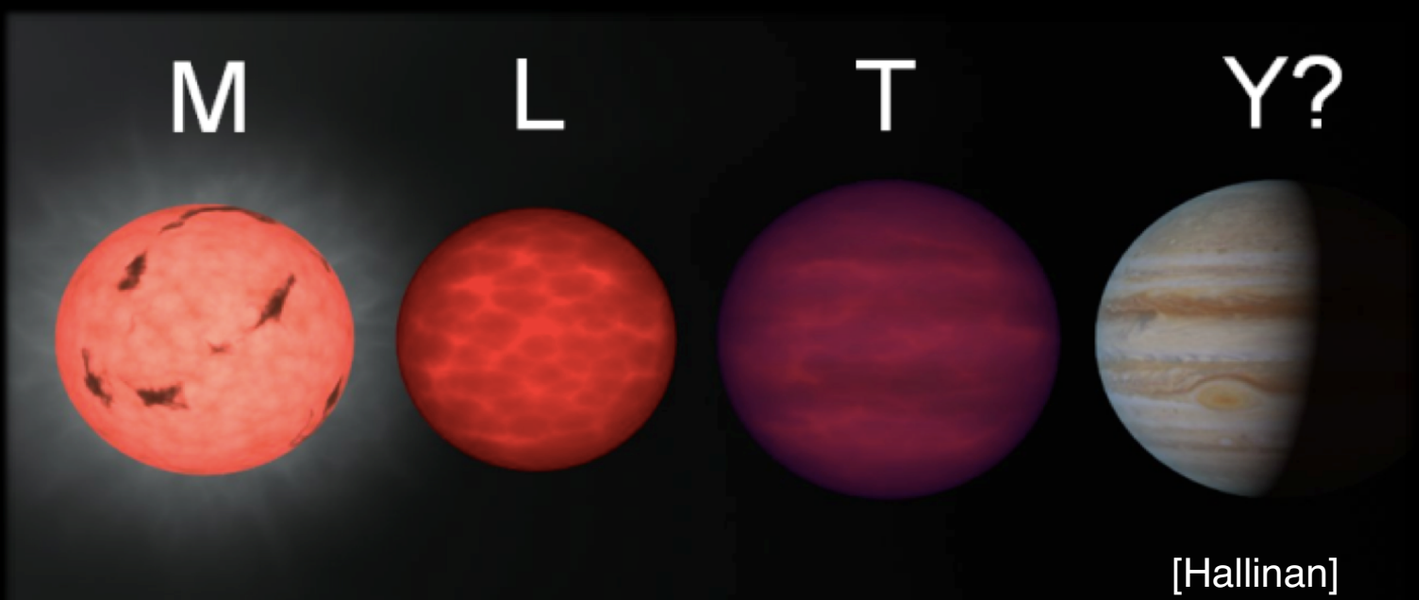
With SKA-Mid imaging observations on the same targets (all bands)
3 hours / target with full array

***Possible extension to a large fraction of the stars within 20 pc => ~7x more targets added; if 4 to 6 hours / target, then total 1700 to 2600 hours.**

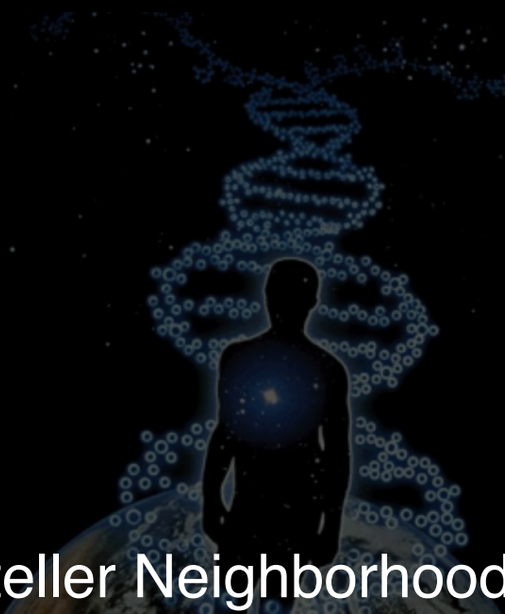
Selected Sample of Known Exoplanets, Brown Dwarfs and Low Mass Stars

Target list selected from existing observations (including radio) and theoretical considerations (hot Jupiters, etc.) at the time of the proposal.

10 to 20 hours per target (possibly with sub-arrays), distributed according to the known periodicities of the system (orbital period, stellar rotation …)



[Hallinan]



KSP 3: The Steller Neighborhood

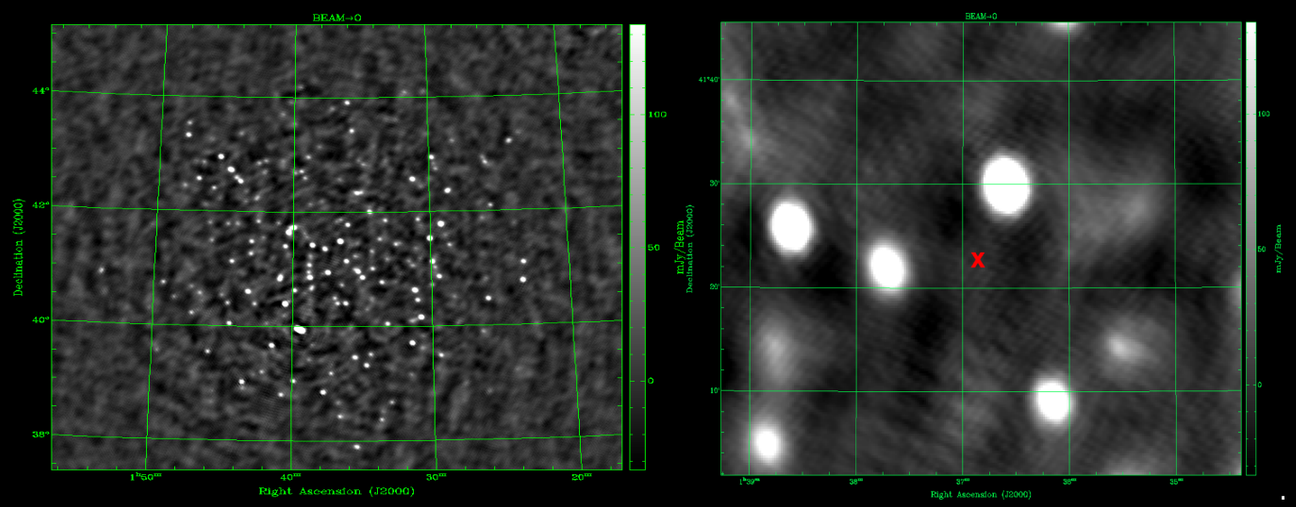
Low-frequency Search of low Galactic latitudes for Exoplanets, Brown Dwarfs and Low-mass stars

EoR will survey the high Galactic latitudes (~10000 sq.deg typically ≥ 30° Gal. lat.), 10 hours / field, in the band 50-250 MHz. We ask for commensal use of their data (see below).

This KSP would complement EoR by an additional survey of Gal. lat. ≤30° (~10000 sq.deg) in the band 50-100 MHz.

~500 observations, 20 sq.deg each x 10 hours / 6 simultaneous beams = 833 hours

Likely extensive commensality with other surveys.



[Daiboo, Zarka, et al]

KSP 3: The Steller Neighborhood

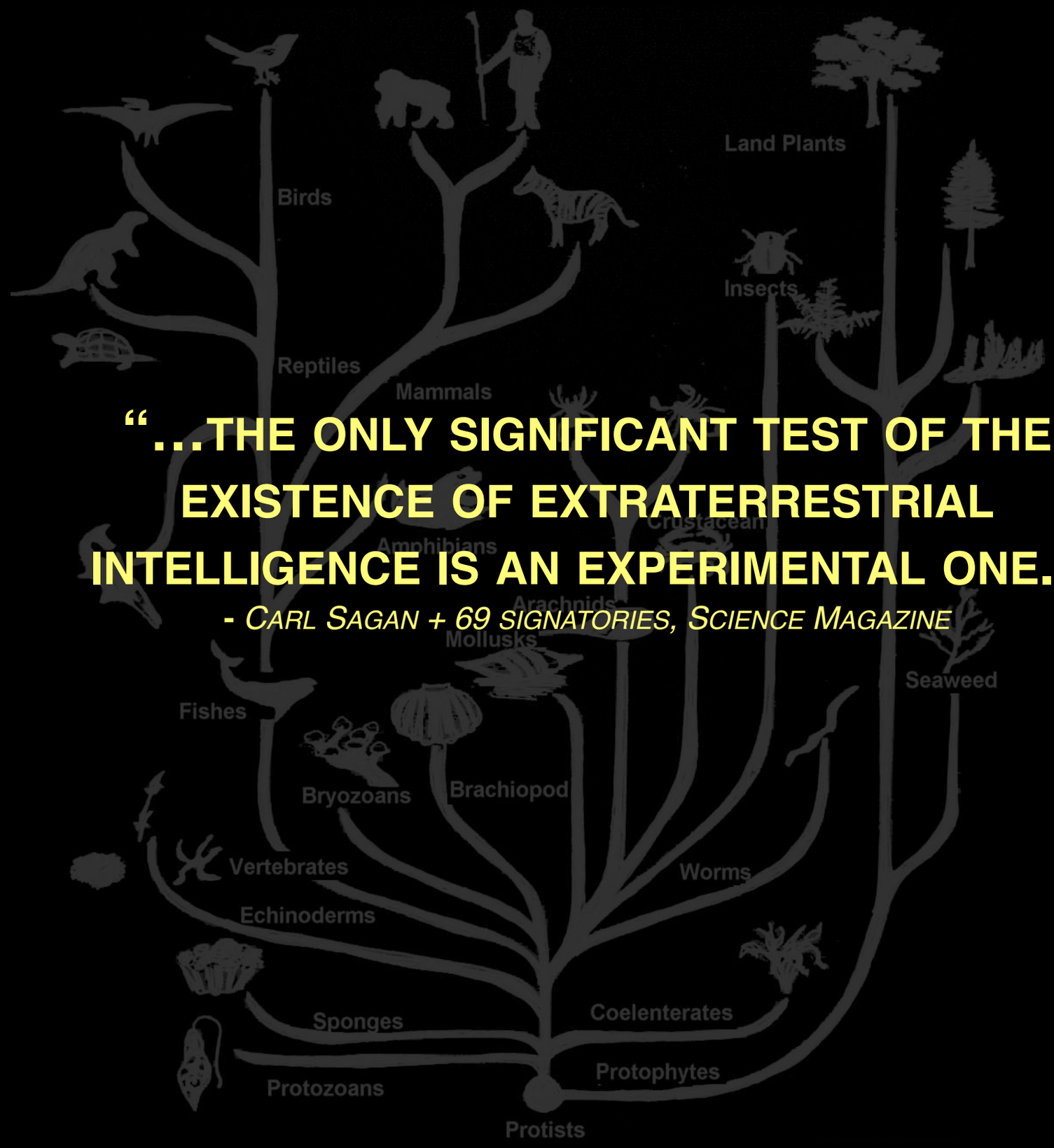
Commensal search for advanced life

Tied-array beam observations of all targets (nearby stars, brown dwarfs, known exoplanets) with both LOW and MID.

Additional tied array beam for interference excision.

Deep searches allow sensitivities ~ 10^{17} ergs/sec (EIRP), nearing the highest power leakage transmitters from Earth.

KSP 4: THE SKA-1 SETI SURVEY

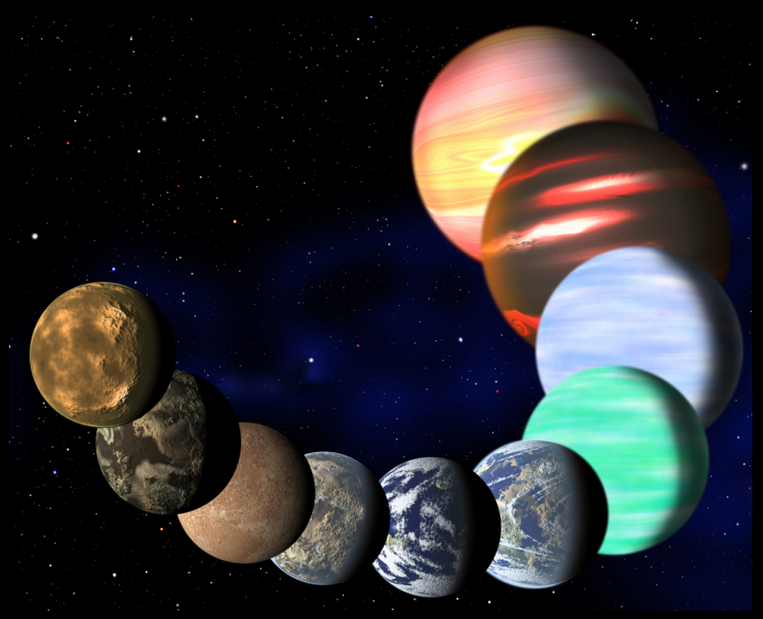


"…THE ONLY SIGNIFICANT TEST OF THE EXISTENCE OF EXTRATERRESTRIAL INTELLIGENCE IS AN EXPERIMENTAL ONE."

- CARL SAGAN + 69 SIGNATORIES, SCIENCE MAGAZINE

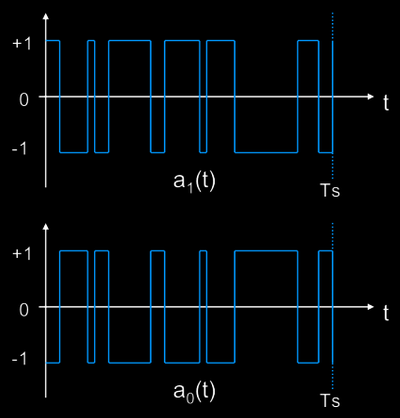
Observations

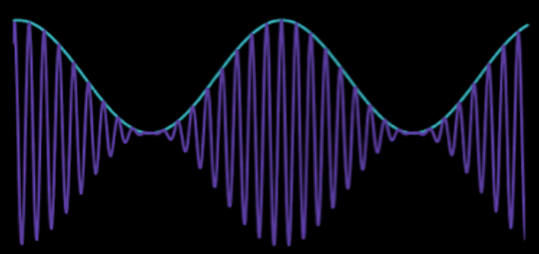
- **Five year fully commensal campaign on both -low and -mid.**
- **Will use 4-8 tied array beams (voltage).**
- **Survey *1 M objects* to a luminosity limit (EIRP) ~ 2 x 10^{18} ergs/sec.**
- **Raster scan survey of regions of high stellar density (inner galaxy, nearby galaxies)**

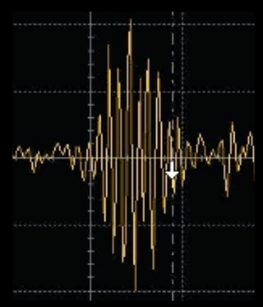


Search Parameters

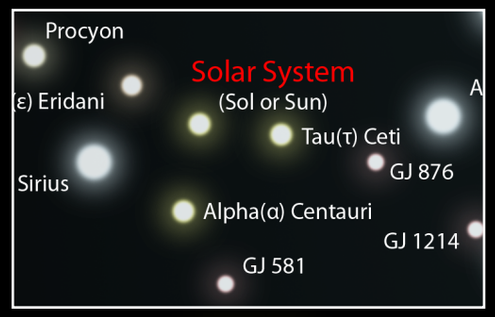
- **1000 times more objects, 10 times more sensitive than the most thorough previous SETI search (Project Phoenix, *Backus et al. 2002*)**
- **Target catalog constructed by a KSP consortium.**
- **Conventional narrow-band (0.1 Hz) search over +/- 10 Hz/sec Doppler drifts + wideband algorithms (autocorrelation).**
- **Will produce an exquisite, dynamic and public RFI catalog**







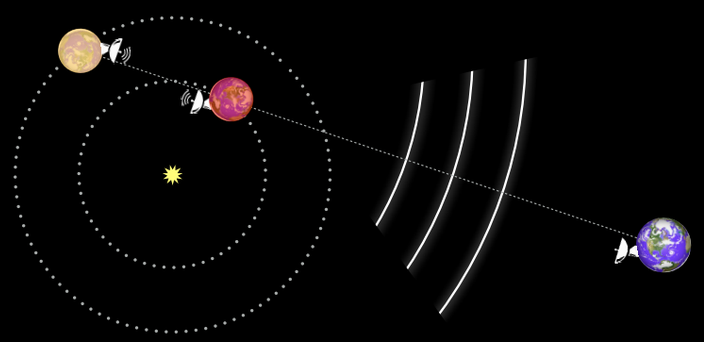
A Million Object SETI Survey



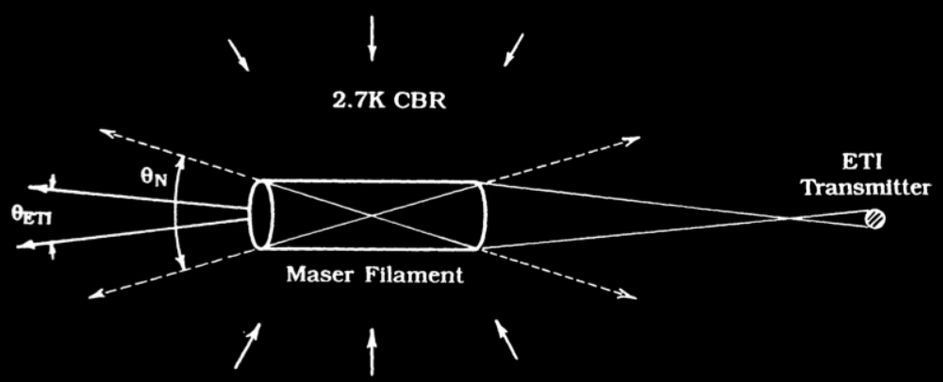
Nearby Stars

Sun-like Stars

Known Earth-like Exoplanets or Solar System-like Exoplanet Systems

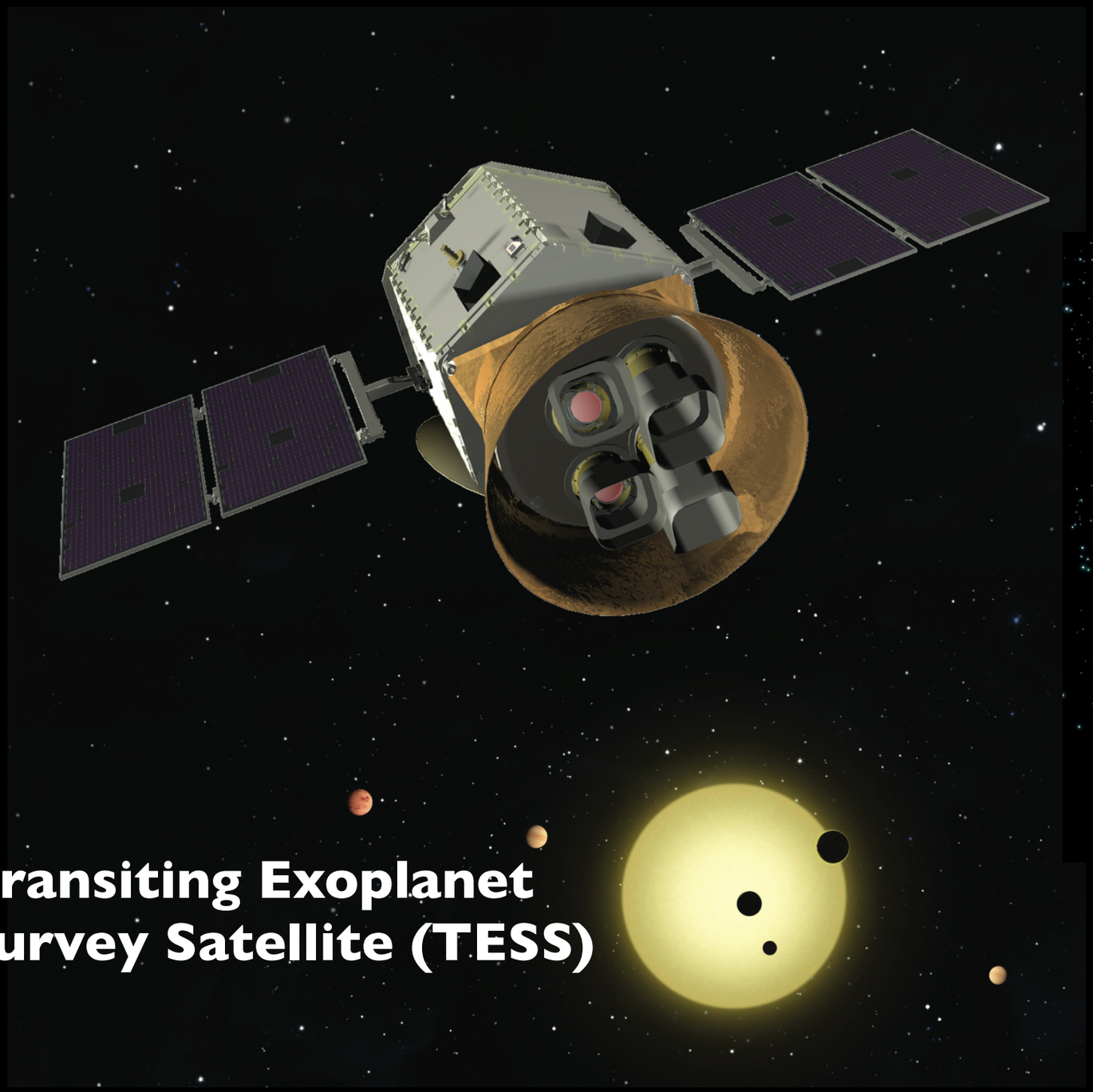


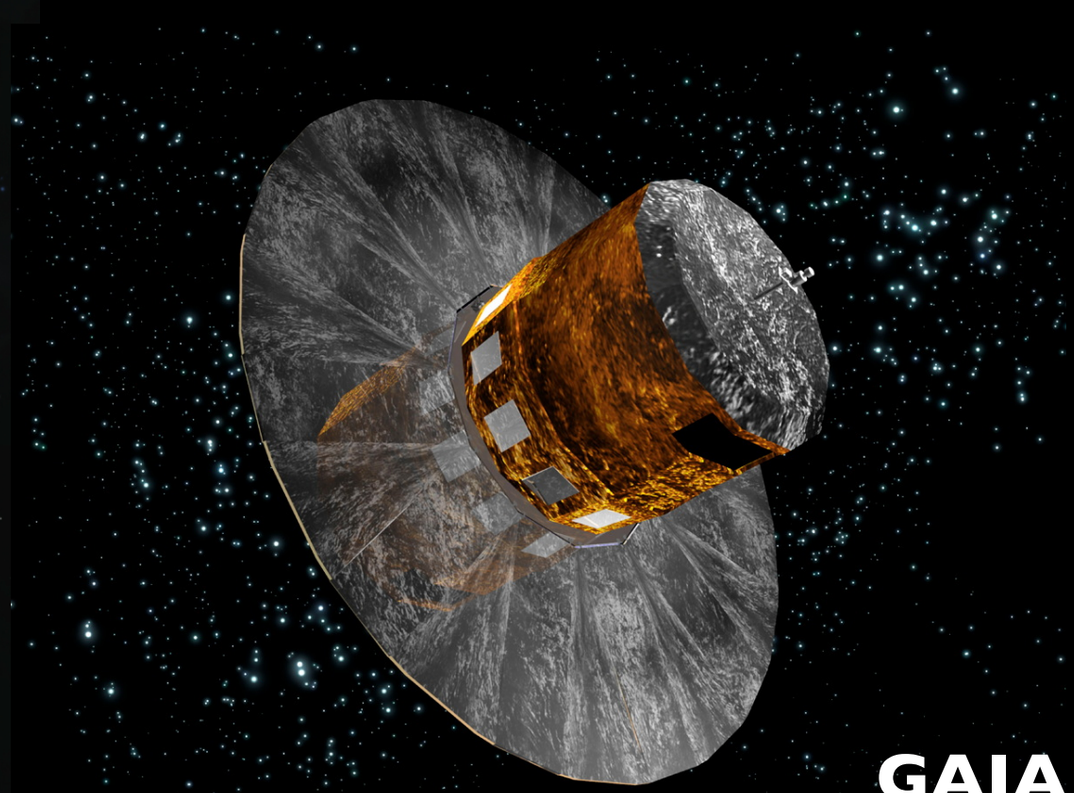
Serendipitous Alignments, e.g. multiple exoplanets in a single system along a line of sight to the Earth, *"eavesdropping SETI"*



Exotica, e.g. natural amplifiers, astrophysical masers, a la Cordes, 1993

SKA SETI Synergies





Commensality…

Commensality…

ICARUS 53, 147–155 (1983)

The Berkeley Parasitic SETI Program

STUART BOWYER,[1] GERRY ZEITLIN, JILL TARTER, MICHAEL LAMPTON, AND WILLIAM J. WELCH[1]

Space Sciences Laboratory, University of California, Berkeley, California 94720

Received January 14, 1982; revised May 21, 1982

Parasitic programs for the Search for Extraterrestrial Intelligence (SETI), carried out concurrently with conventional radio astronomical observing programs, can be an attractive and cost-effective means of exploring the large multidimensional search space intrinsic to this effort. We describe a microprocessor-based automated SETI acquisition system which searches for and records spectra of narrowband signals in the IF band of an observatory receiver. Data taken with this system over 35 days at the Hat Creek Radio Observatory at 1612 MHz are discussed. Out of approximately 10^5 spectra processed during this period, 4000 were identified by the system as containing narrowband signals and were recorded. Subsequent analysis indicates that over 3900 of these are due to local RF contamination. The remainder are undergoing further investigation.

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Must be more specific about types of commensalism and capabilities o the observatory:

- commensal data (same data product, or same raw data product)

- commensal observation (same telescope pointing, different data product and/or backend, e.g. imaging + non-imaging)

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For non-KSP time: critical for provisions to be made for disseminating accurate information about not just the current state of the telescope, but the future state of the telescope.

Cradle of Life Science

on the