A Concept Camera for the Next Generation mm-Wave Cosmological Galaxy Surveys

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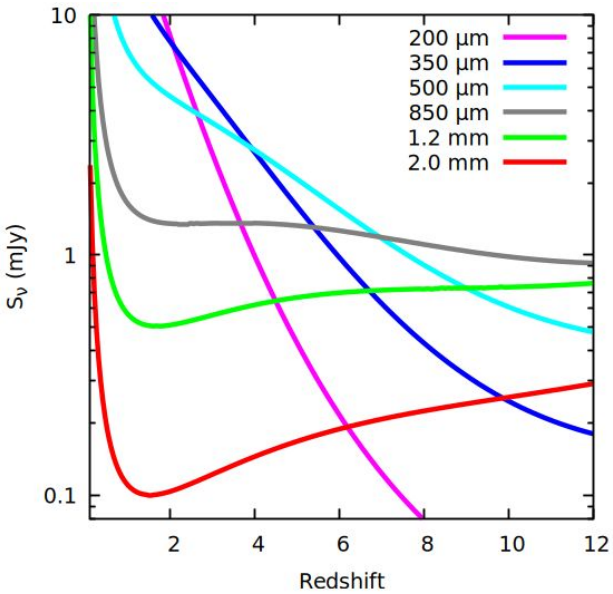
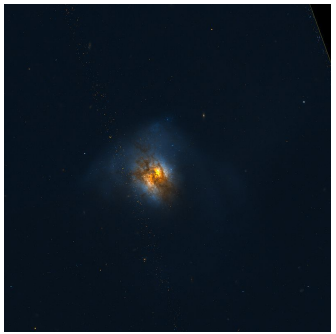
HARVARD & SMITHSONIAN

Poster 13101-170: SMA-X: Versatile information sharing in and around telescopes

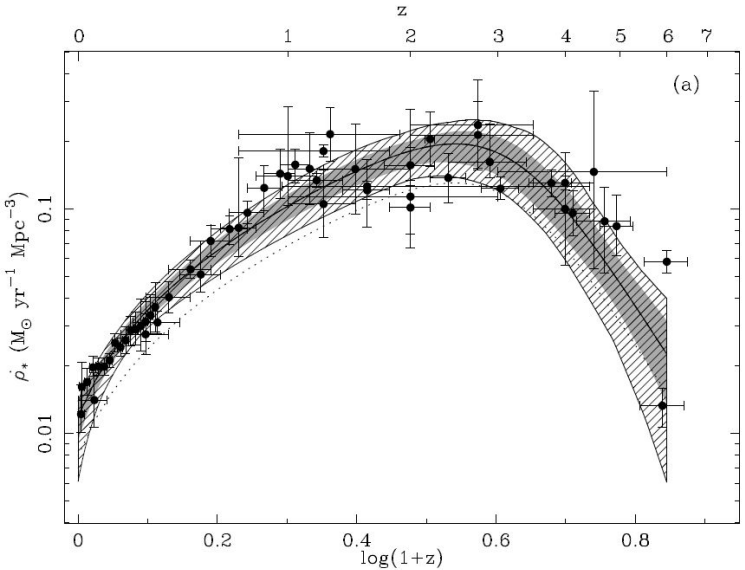
Around 1 mm-wavelength is ideal for studying global star-formation histories



At λ~1mm dusty star forming galaxies appear similarly bright regardless of redshift z ~ 1 – 12



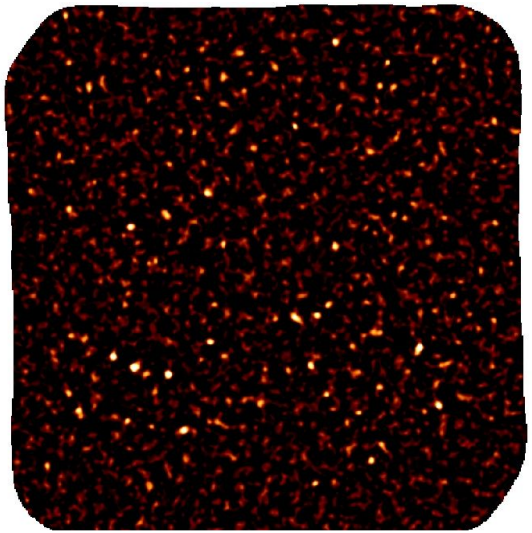
Arp 220



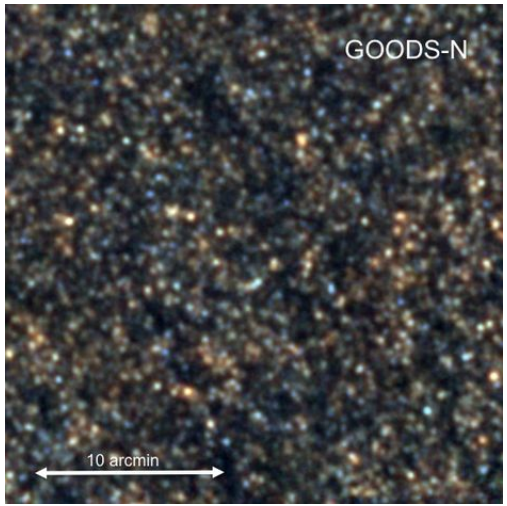
Ferreras et al. 2021

Most stars formed between z ~ 2 – 3

Past mm-wave surveys



ALESS
(Weiss et al. 2008)



HerMES
(Oliver et al. 2012)

No distances

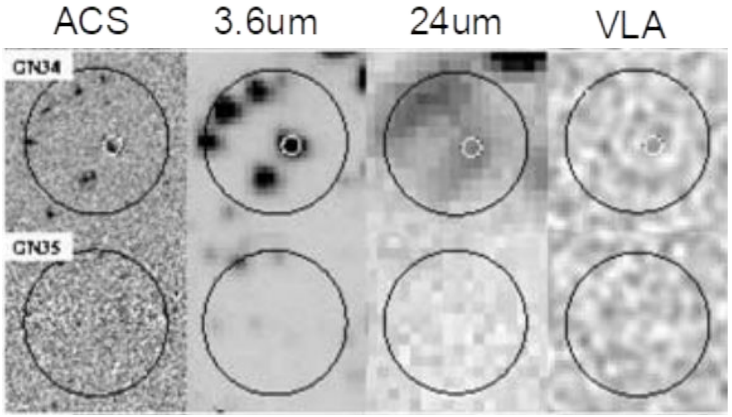
Sources can be at almost any distance, thanks to the flat selection.

Confusion

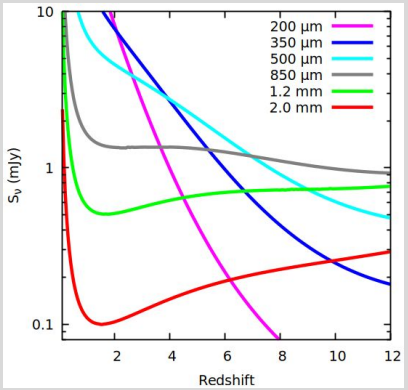
Nearly every beam has a source, some beams have several.

Larger telescopes with smaller beam sizes can help a bit (but not a lot)…

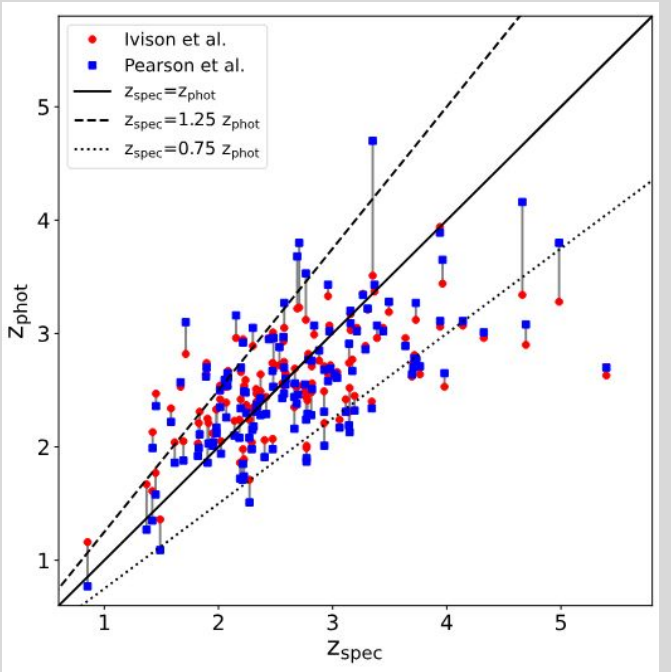
The redshift headache



Pope et al. 2006



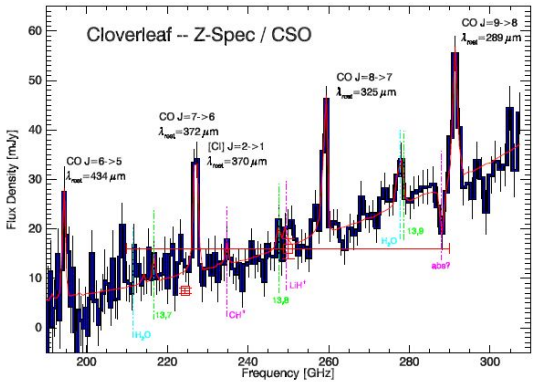
Photometric redshifts are unreliable
(no evolution)



Cox et al. 2023

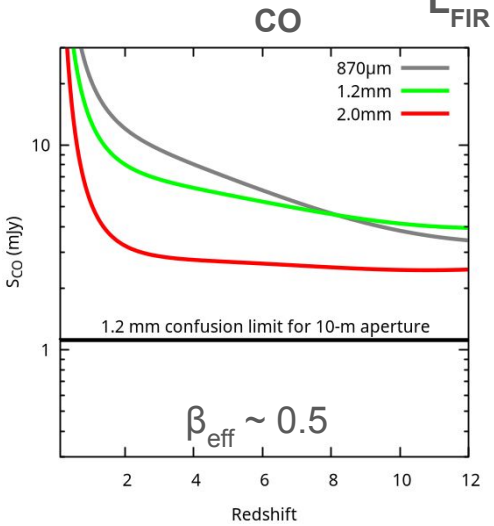
Cross-IDs miss nearly half of population

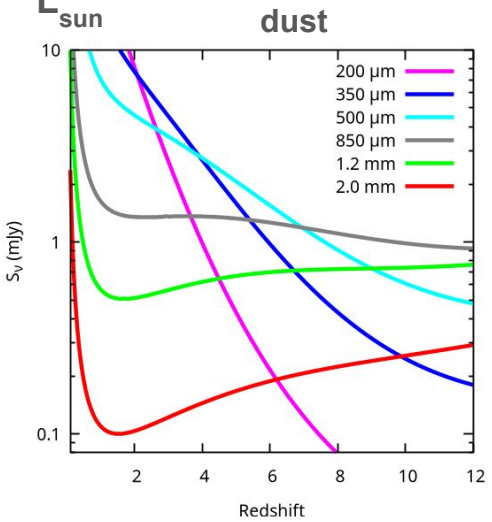
CO vs dust as a star-formation tracer



Bradford et al. 2009

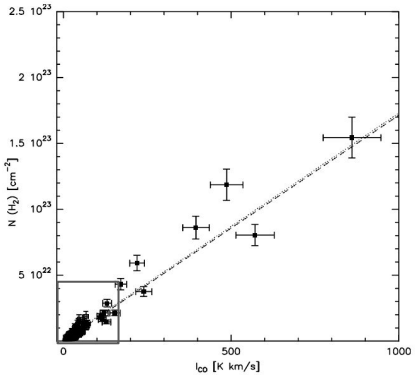
$L_{FIR} \sim 10^{12} L_{sun}$

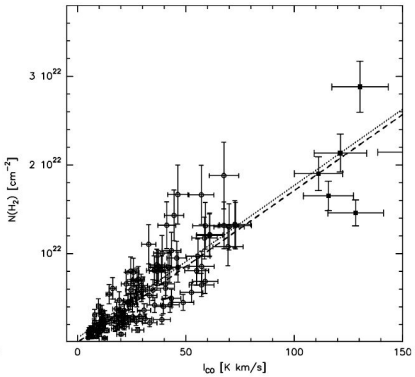


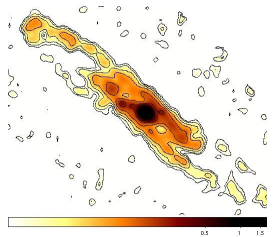


CO spacing $\Delta f = 115$ GHz / (1+z)

Number of CO lines $N_{CO} \sim (1+z)$



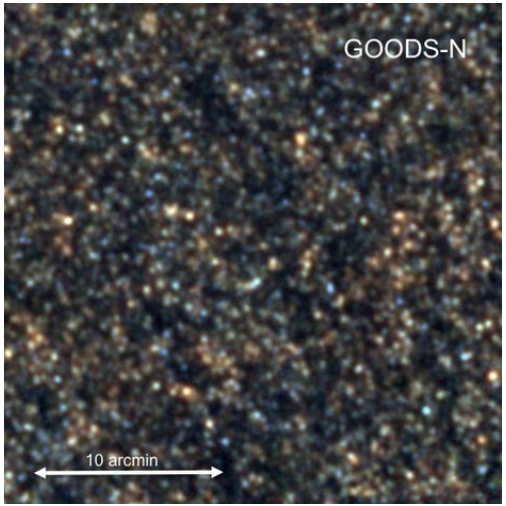


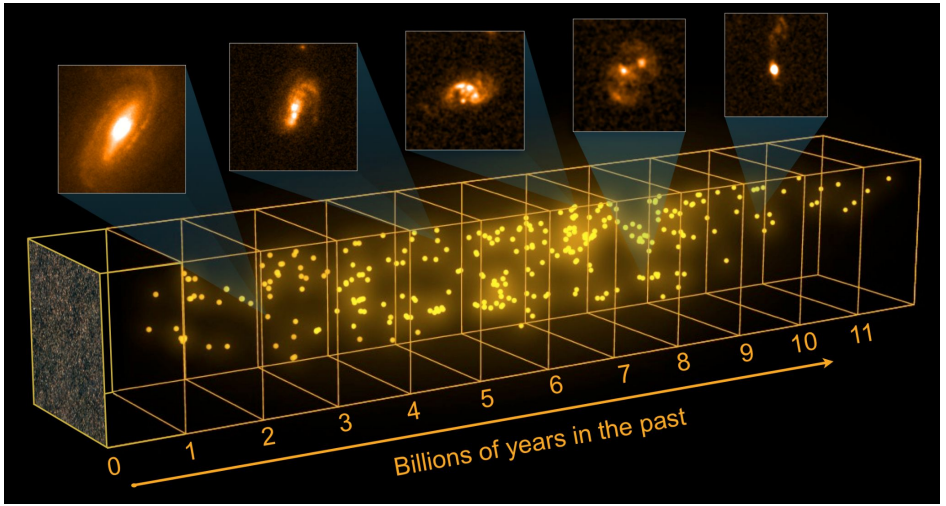


Weiss et al. 2008

Survey in redshift slices

$\Delta z = (1 + z) / R$



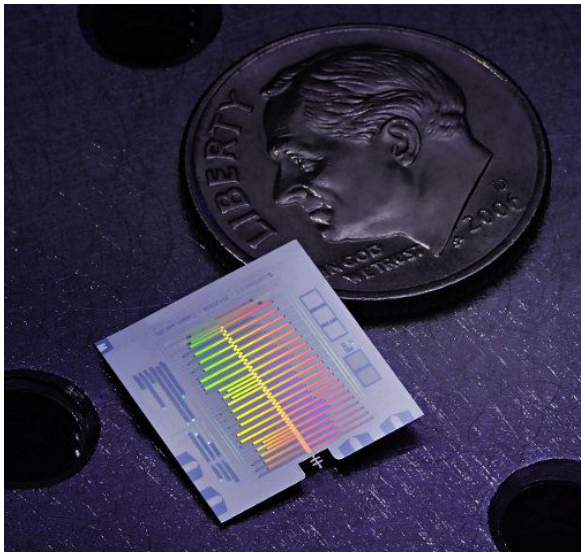


From broadband continuum
With no redshifts…

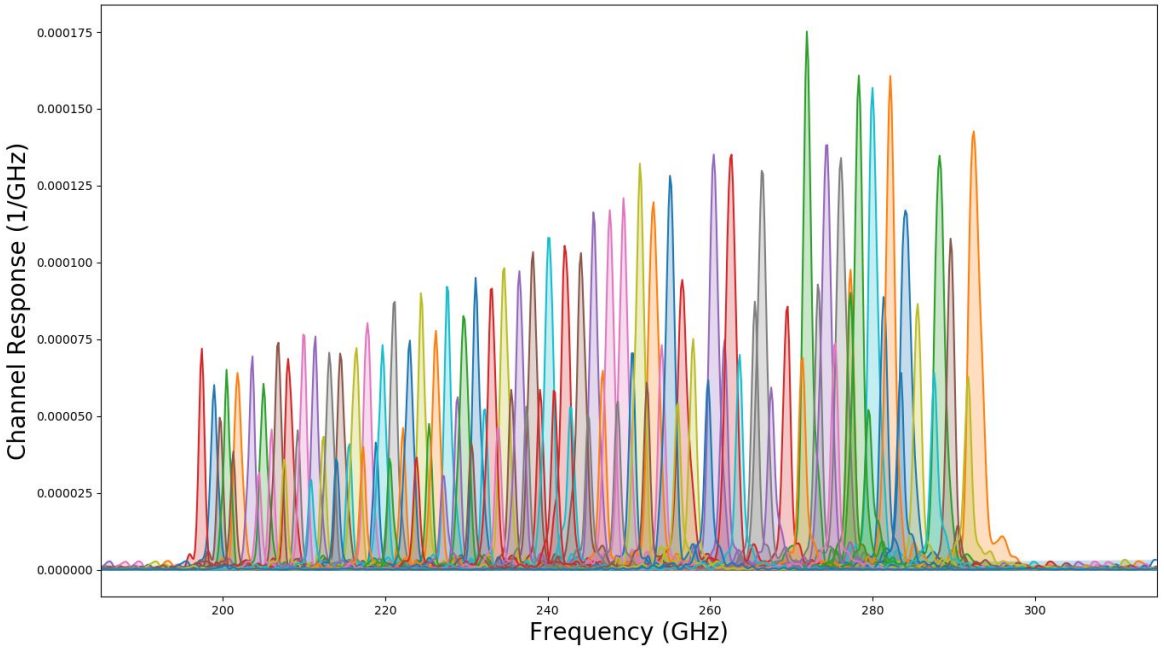
To wideband (R ~ 200 – 1000) spectroscopy

- Secure CO redshifts
- Can probe an order of magnitude deeper w/o confusion

The game changer: on-chip spectrometers at mm wavelengths



50 channel test device



Size driven by readout frequency at 100 – 200 MHz

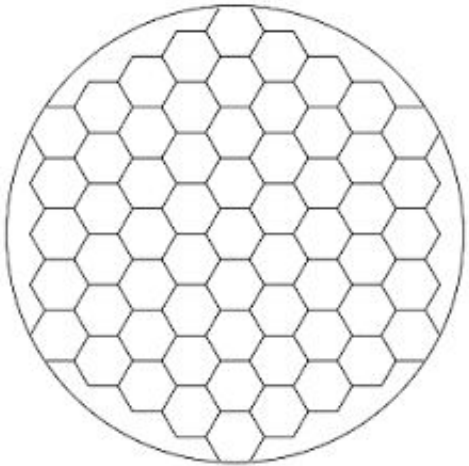
Can shrink detectors by ~40 fold if reading out at ~6 GHz instead…

Suitable for packing 1cm^2 focal plane pixels with ~300 detectors

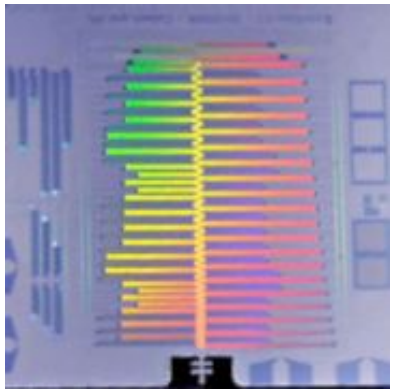
Superspec (Kovacs+2012)

A spectroscopic imager camera

Focal-plane camera

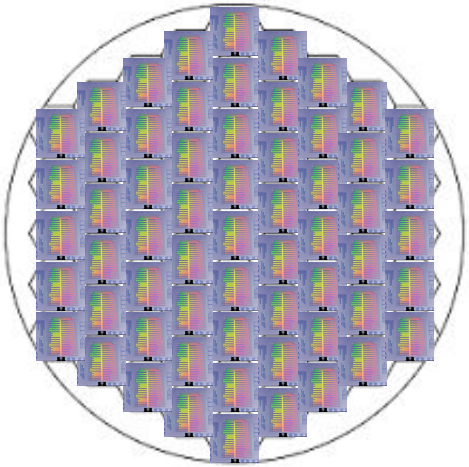


R ~ 300 spectrometer



Fill FoV with pixels

200 – 300 spectral channels on every pixel



20k+ detectors…

Survey capability on 10-m telescope

Table 1. R=200 spectrometer pixel properties.

λ (mm)	Band (GHz)	Bandwidth (GHz)	z_{min}	octaves	channels (count)
2	125 – 175	50	0.31	0.5	200
1.2	190 – 310	120	0.15	0.7	280
0.87	330 – 360	30	2.9	0.13	52

Table 3. R=200 $f/5$ camera and survey overview.

λ (mm)	FWHM (arcsec)	pixels (count)	detectors (count)	A_{det} (mm^2)	Mapping Speed (deg^2/year)	N_{gals} (count/year)
2	42	37	7,400	1.73	0.82	10,800
1.2	25	91	25,480	0.45	0.45	23,300
0.87	18	169	8,788	1.26	0.30	5,500

Dreaming bigger…

Go faster…
Go deeper...
Better astrometry (for follow-ups)...
Not using all observing time (300h / year)

JCMT

15m

IRAM Pico Veleta

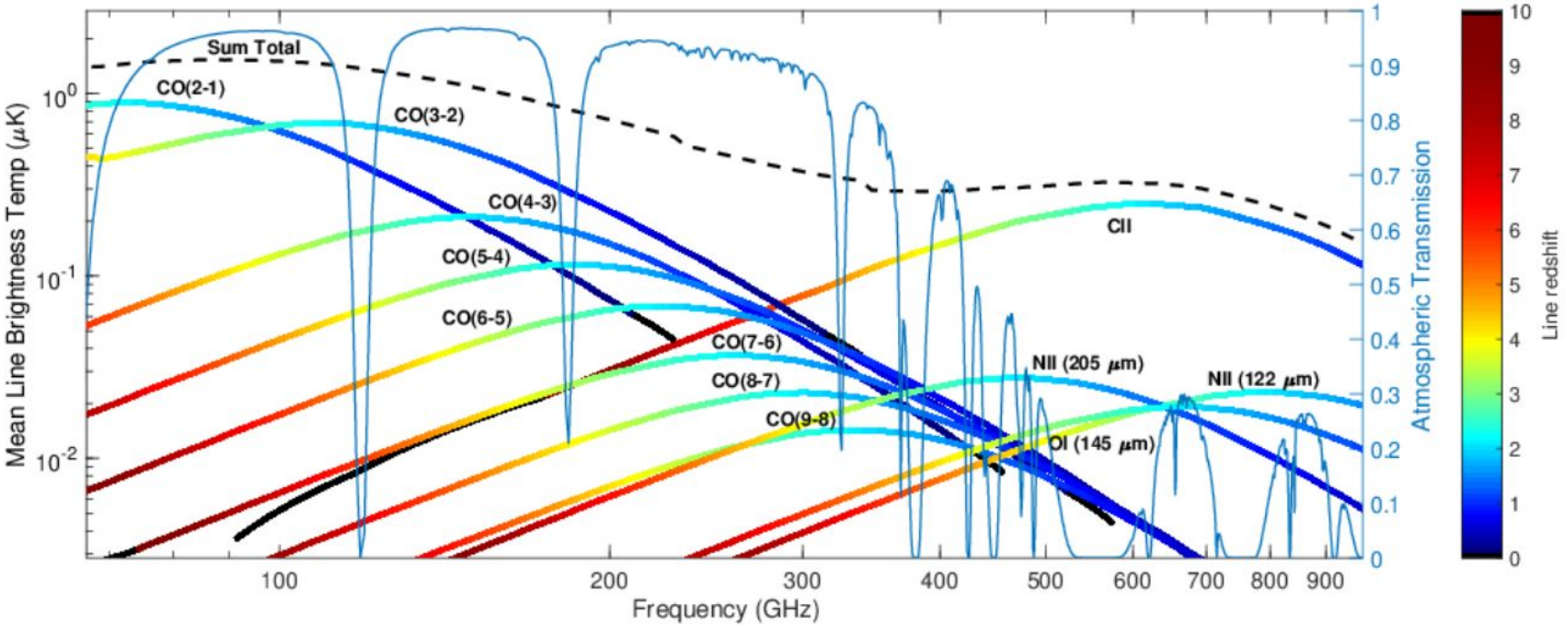
30m

LMT

50m

AtLAST (50m?)

Line Intensity Mapping (LIM)



Moradinezhad et al. 2022

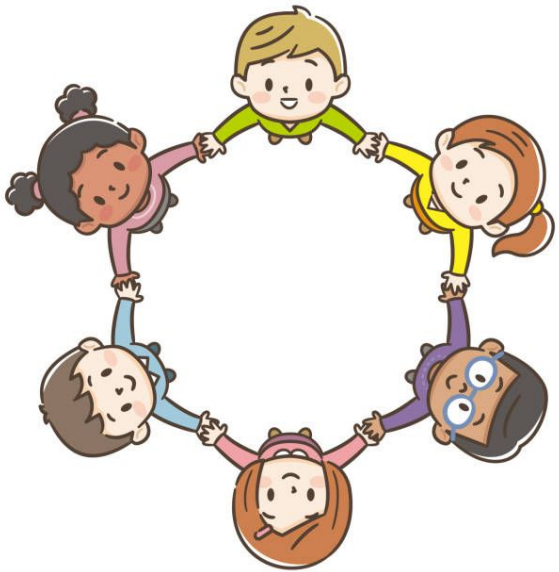
Challenges

- **Stray-light and out-of-band light rejection**
  (200x better than for continuum camera)
- **Standing waves**
- **Phononic isolation**
  (200x better than for continuum camera)
- **Magnetic shielding**
- **Cryogenic performance**
  (operating temperature, stability, tilting)
- **Multiband capability**
  (for LIM)

Open-source collaboration model

Open to everyone, as long as…

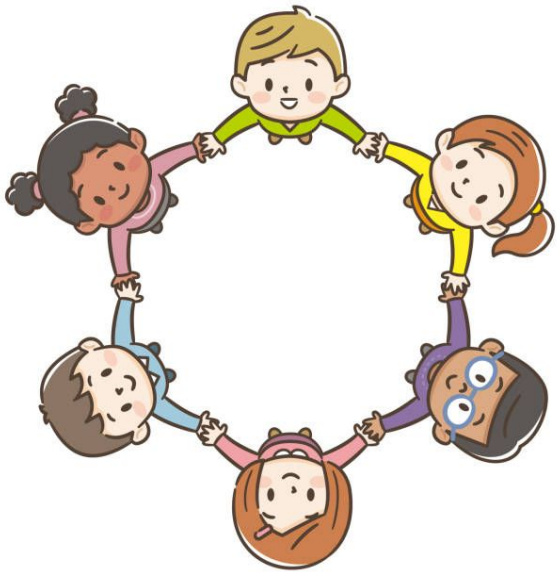
- You intend to contribute something
- You respect and acknowledge the contributions of others
- You take what you need, but contribute back what you did with it (or how you modified it)



Open-source collaboration model

Not a consortium!

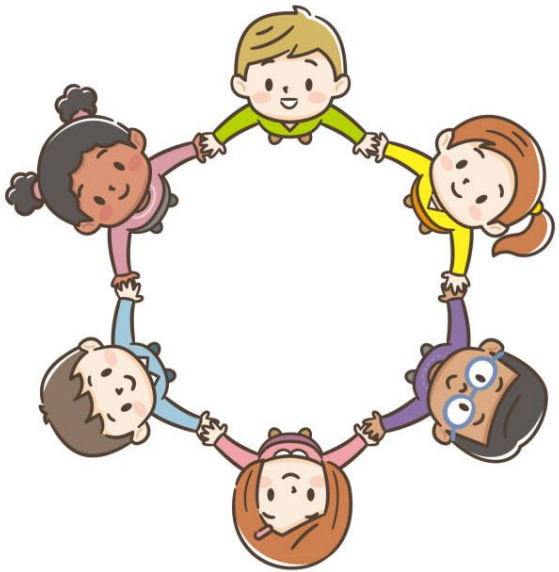
- You are free to work alone or whoever you like within the collaboration (as long as you acknowledge the work of others also)
- You are free to pursue your own goals, your own funding, the way you want it.
- Your shared knowledge is not public, shared only within the collaboration with rules on hot it can be used (we want to protect your intellectual property)
- You are free to publish your own work, as long as you acknowledge the collaboration.



Open-source collaboration model

A library of knowledge

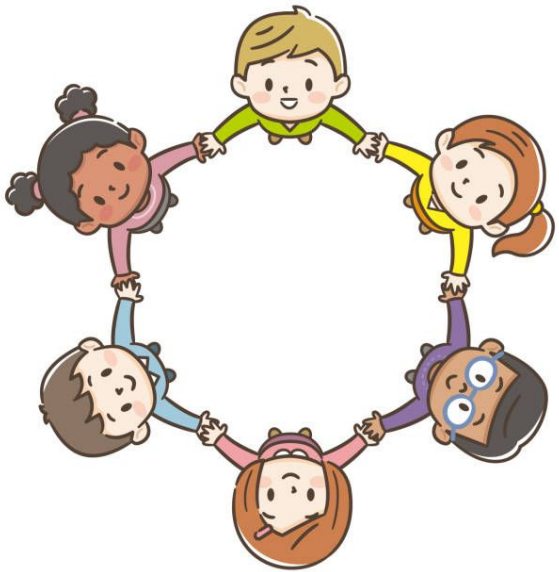
- No a single camera, or singular design
- Modularity and standardization will make components more reusable
- Every component may have design variants, e.g. optimized differently.
- Share designs, measurements, and/or hardware



Join us (we need you!)

People, institutions, telescope organizations…

- To contribute your expertise
- To source ideas / designs / components for your instrument
- To claim a piece of the transformational science, e.g. by operating a camera at your telescope institution



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