The Case for extending JCMT operations to 2020 (& Beyond)

Walter K. Gear
For the JCMT2020 Panel

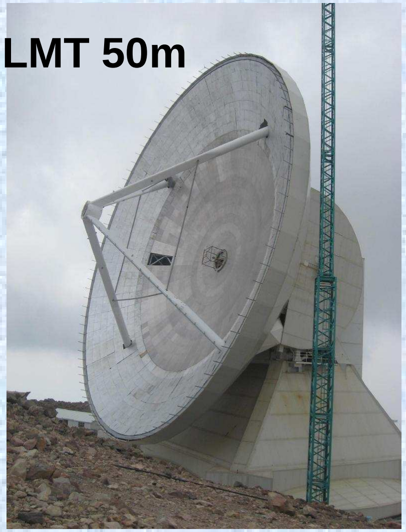
Structure

- Context
- Imaging Science => How to collect more photons
  - (a) Increase FOV
  - (b) Upgrade surface
  - (c) Large FOV camera technology
- Spectroscopic Imaging Science
  - (a) Heterodyne high spectral resolution array
  - (b) Low-resolution direct detection multi-object spectroscopy
- Way Forward from here ?

mm/submm Astronomy is entering a Golden Age, Not leaving one !! And JCMT can play a major role in it

APEX 12m

Herschel & Planck



mm/submm Astronomy is entering a Golden Age, Not leaving one !! And JCMT can play a major role in it

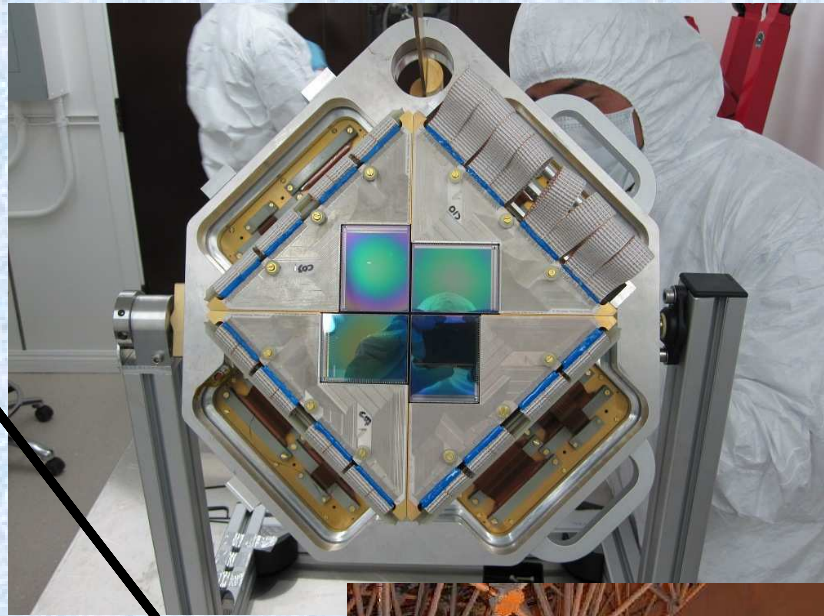
- IRAM 30m & LMT 50m are NOT on submm sites – they will focus on λ > 1mm
- APEX is not as large as JCMT and operates in "campaign mode" rather than common-user
- ALMA &NOEMA cannot cover large areas of sky & will be very oversubscribed
- CCAT 25m is not yet funded & won't operate till ~ 2020 (+?)
- +UK could probably only aspire to ~10% share in CCAT
- 15m JCMT exists now and is much better value..

SCUBA-2 & HARP are at the cutting edge for now…

- SCUBA-2 and HARP

- We can and must make the case to STFC that this investment must be exploited over the next 2-3 years

- But we also need to look beyond these to what will be possible in next few years

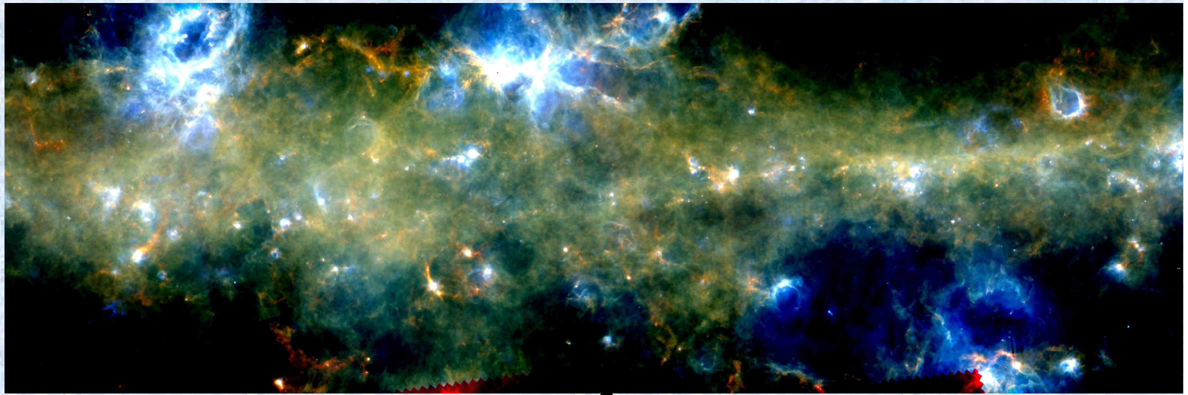


Science for 2020: (a) Imaging

- Herschel has shown what can be achieved with high sensitivity high resolution imaging in the FIR
- Longer wavelength data is essential for fully characterising luminosity, temperature & dust properties in both galactic & extragalactic images
- And (crude) photo-z for high-z objects
- However SCUBA-2 can't keep up with the same data rate
- We will need a faster mapping speed at at least 2 frequencies.….

Galactic Star formation studies: Hi-Gal

- Hi-Gal is conducting a 5 band survey of the galactic plane
- JCMT will give better angular resolution and reduce confusion
- BUT SCUBA-2 cannot match the area covered to comparable depth in a realistic time
- Needs a faster mapping instrument



7x2 deg at l=350 & l=10

(curtesy S. Molinari & HiGal team)

Filaments permeate the ISM on all scales

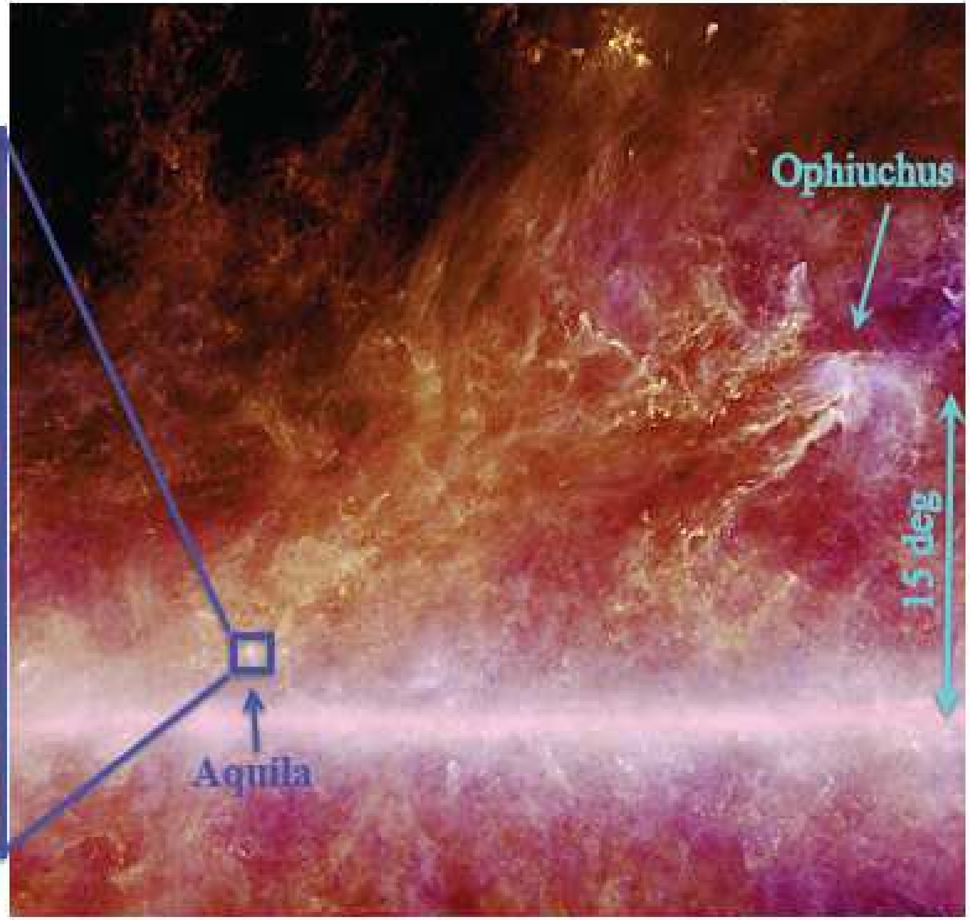
Herschel

SPIRE 500 µm
+
PACS 160/70 µm

ESA and the Gould Belt KP

Planck

HFI 540/350 µm + IRAS 100 µm

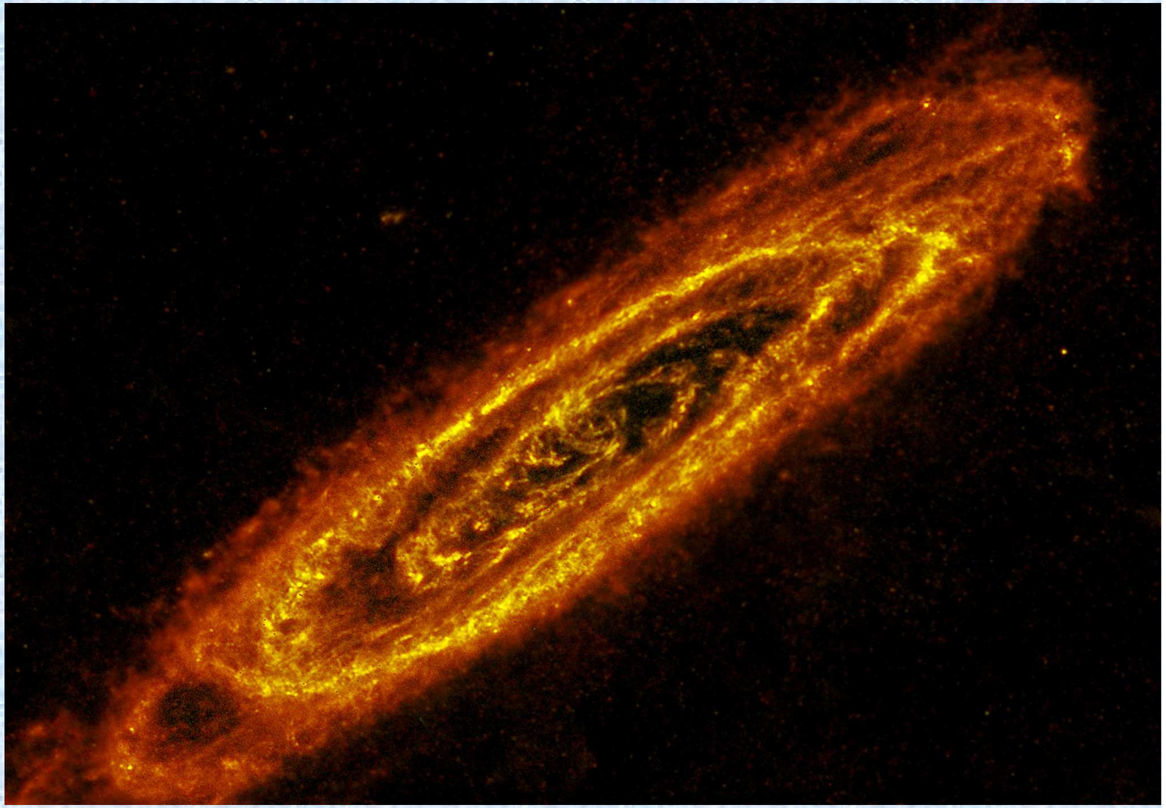


ESA and the HFI Consortium

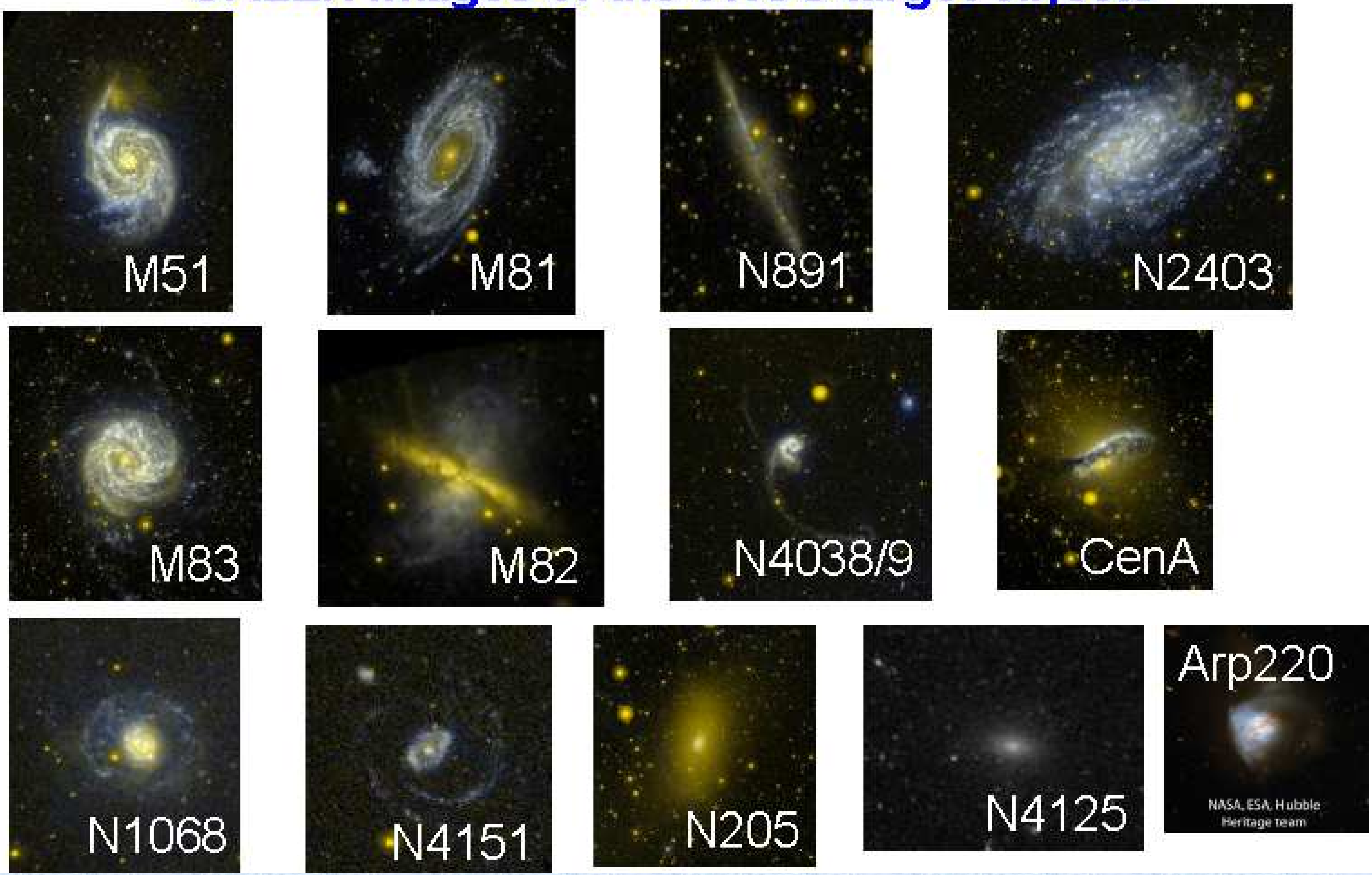
André et al., ESLAB, May 2010

Very nearby galaxies

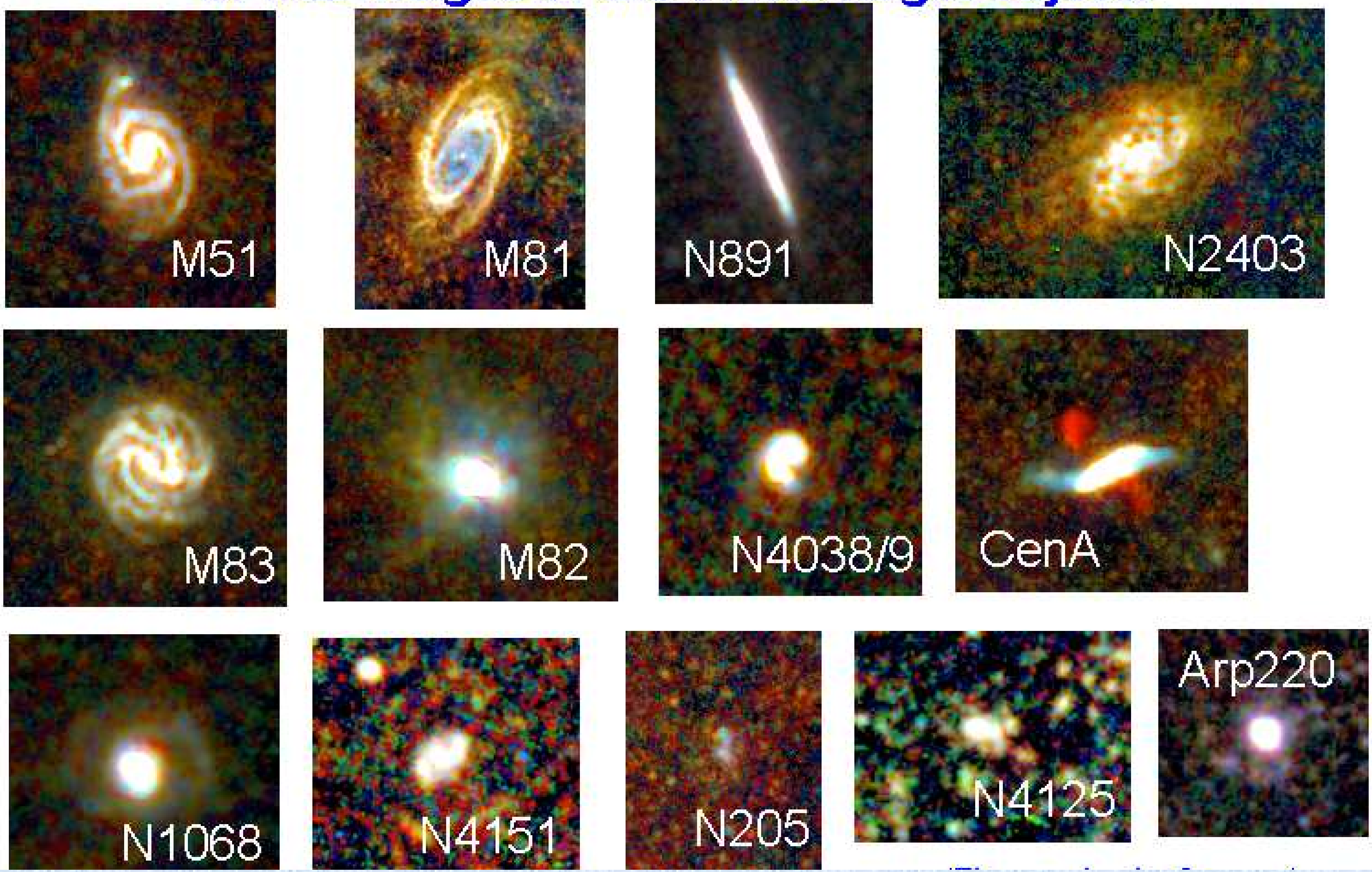
- The Herschel Andromeda 5-band image is the most detailed study of star-formation in another galaxy ever made
- It is highly complementary to Hi-Gal & we can now test the Kennicutt-Schmidt star-formation law in detail not just globally in a galaxy
- SCUBA-2 should be able to match the Herschel image at 850 microns in 100-150 hours but to do 450 would require a much faster mapping instrument
- JCMT NGLS will image ~150 galaxies but we need much larger statistical samples for comparison with high-z SMGs



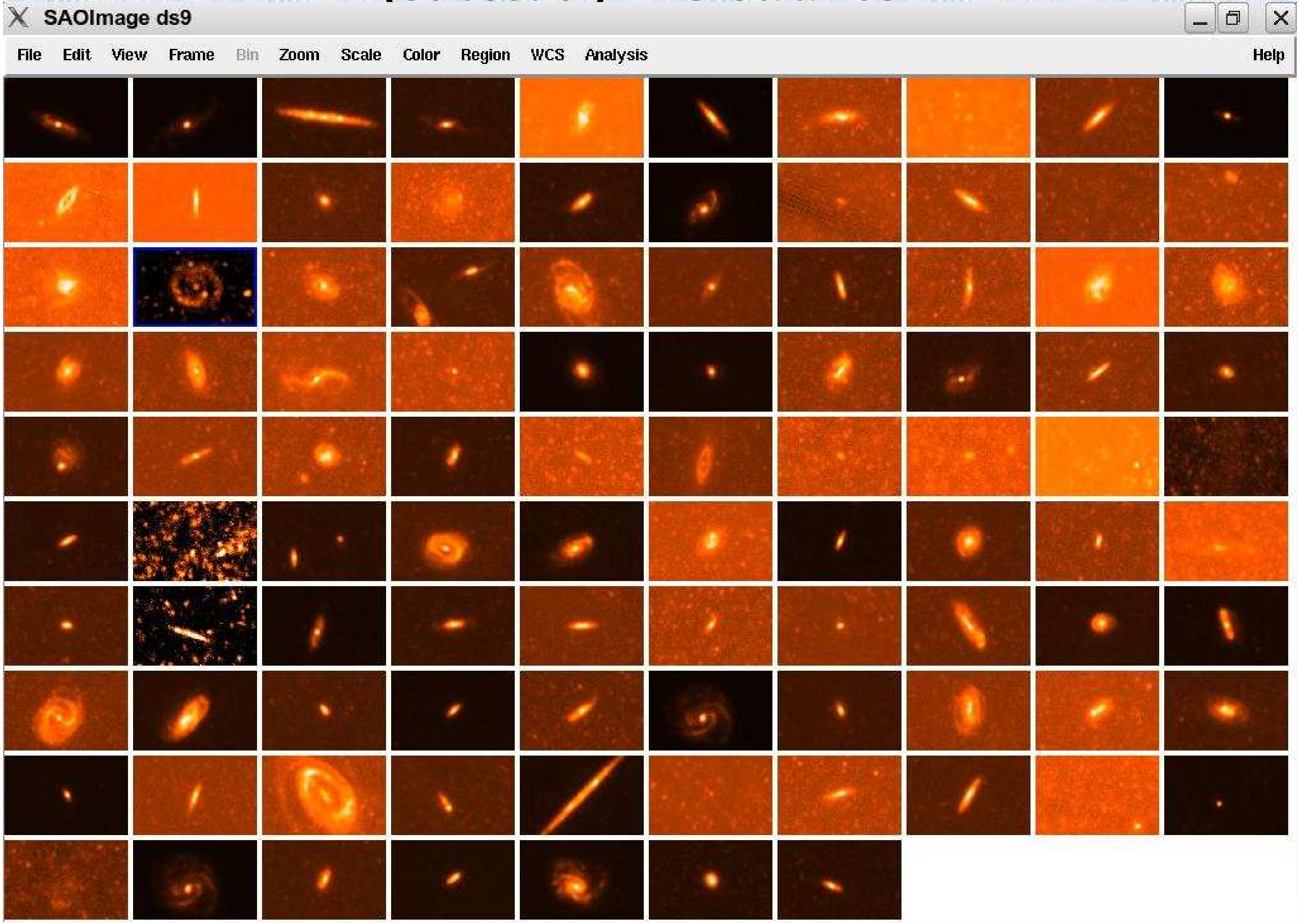
GALEX images of the VNGS target objects



SPIRE images of the VNGS target objects

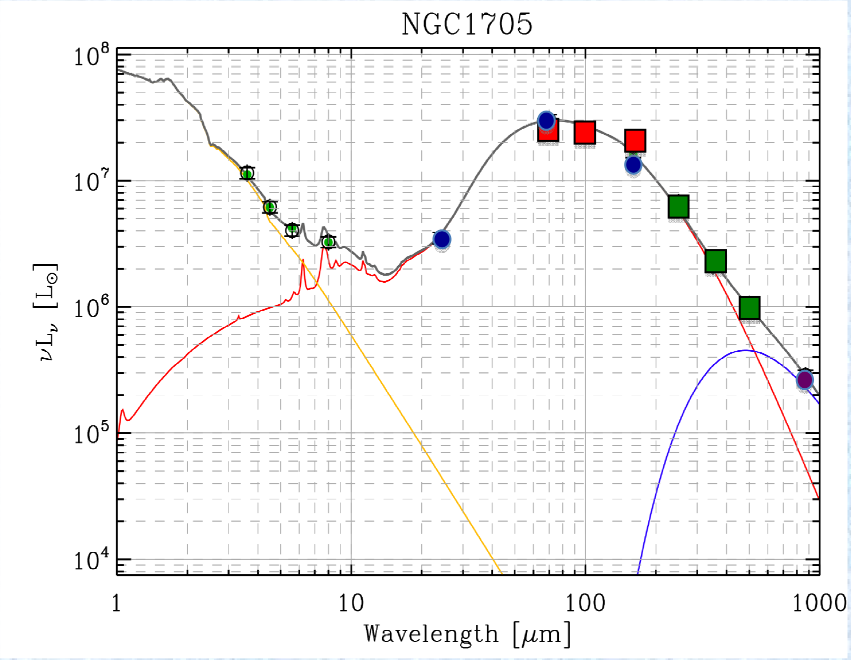


(Subset of) HRS Galaxies



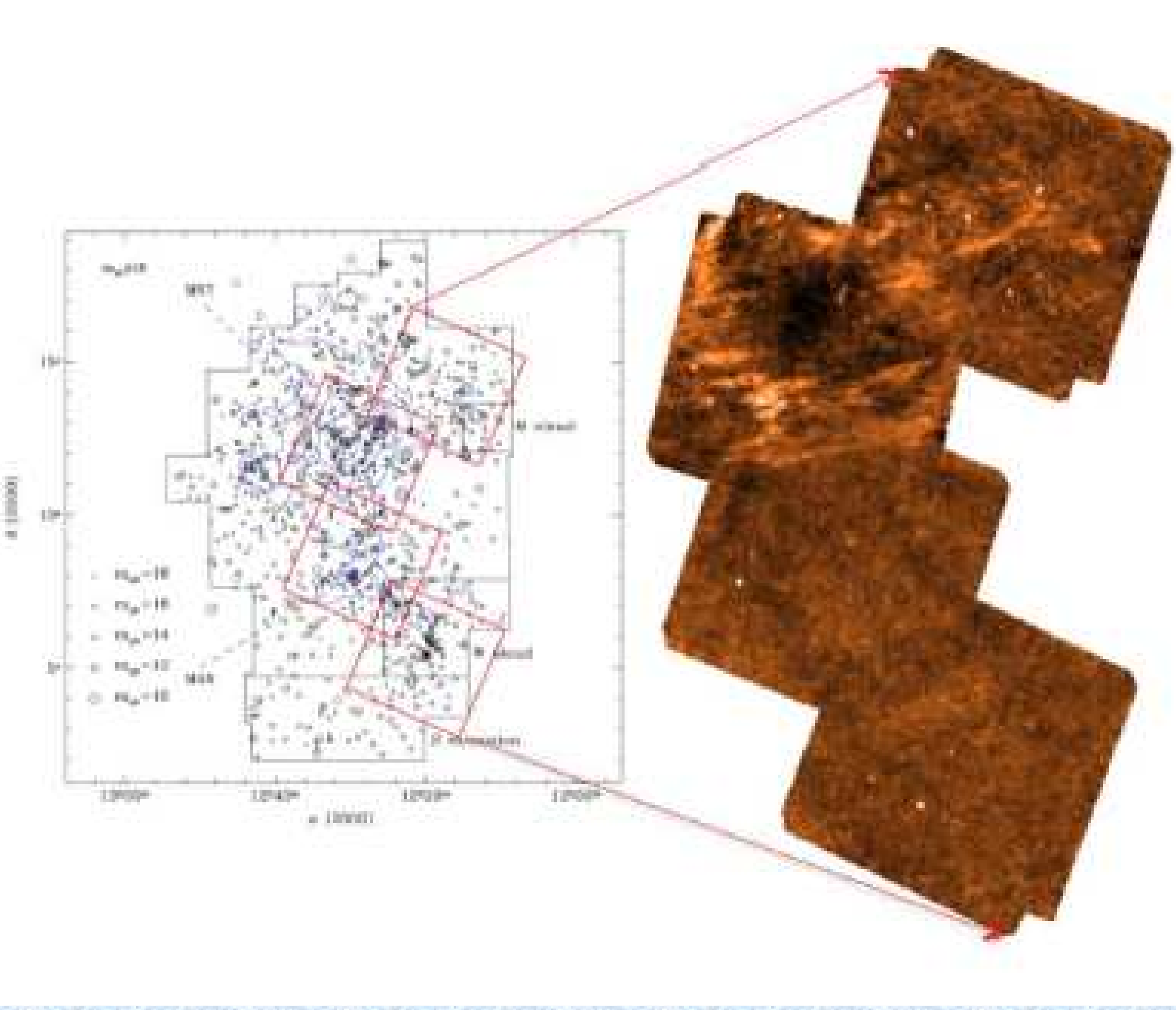
The smallest faintest (dwarf) galaxies seem to be the most interesting ….

- Evidence of long-wavelength excess in Herschel data for Dwarf galaxies which is not seen so far in "normal" spirals
- Could be a very cold dust component but would be extremely massive
- => different dust properties in low metallicity environments ?
- Longer wavelength data is required but these things are very faint and we need to measure lots of them



Clusters

- Hershel 64 sq deg image of Virgo took 400 hours
- Impossible to make matching SCUBA-2 image in any realistic timeframe
- To study Virgo and other clusters a much faster imager is needed



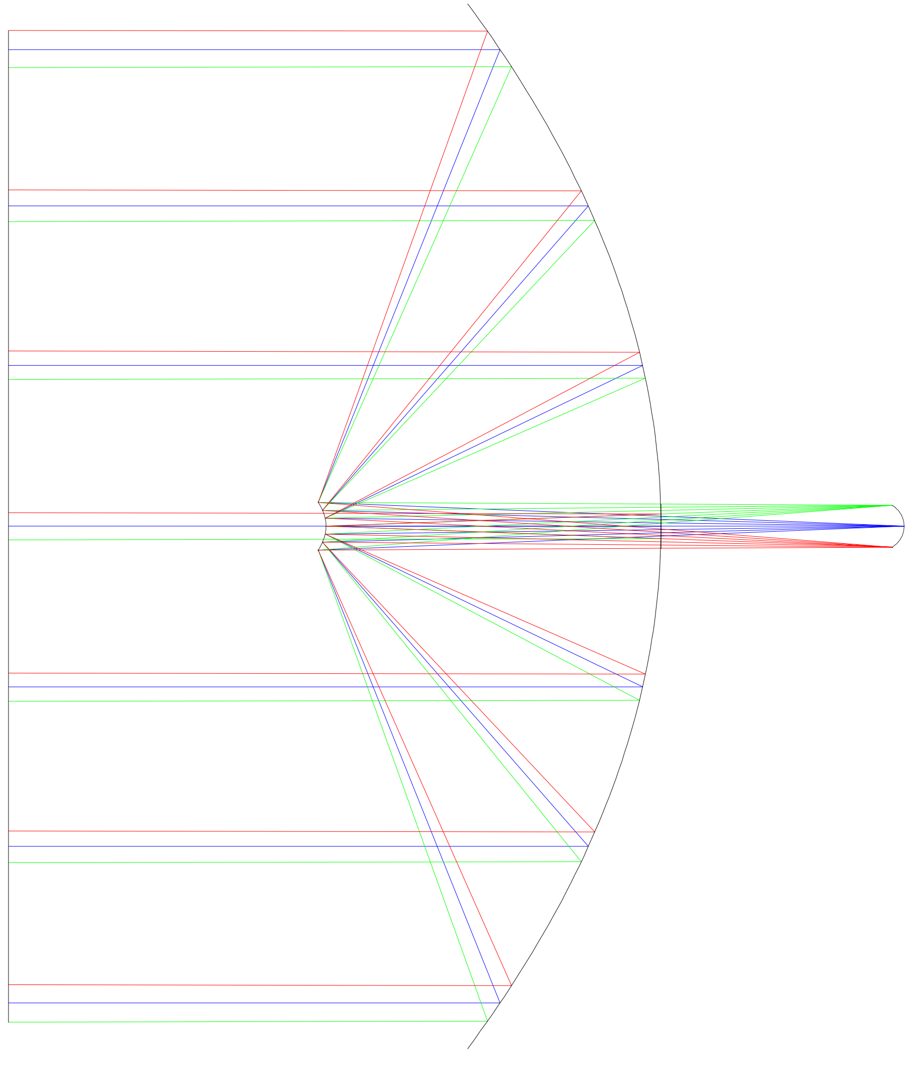
Deep Cosmological Surveys

- This H-ATLAS SDP 4x4 degree image contains 7000 galaxies. This is 1/40th of the H-ATLAS survey
- H-ATLAS is now complete, will contain ~300,000 galaxies
- Longer wavelengths will find more high-z objects but SCUBA-2 cannot match this depth and area in a realistic time,
- SCUBA-2 legacy will cover 10 sq deg i.e. less than this one field…
- => a much larger, faster camera is required

To improve the mapping speed we need to collect more photons….

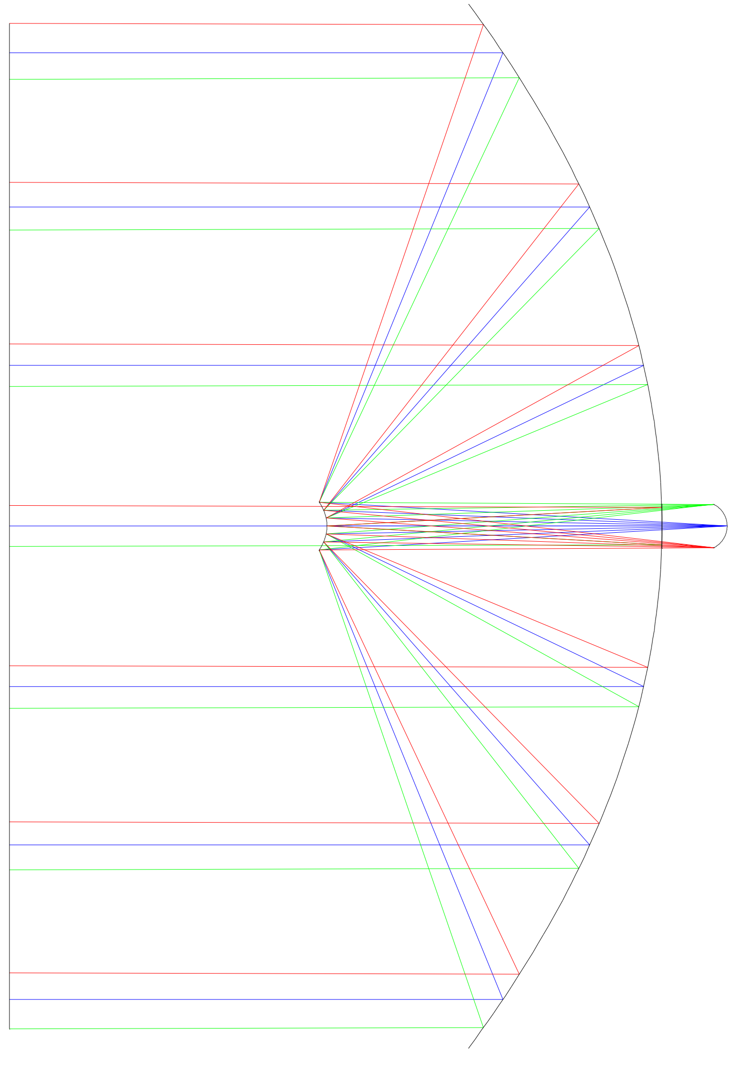
- We can make progress by improving the sensitivity per pixel. We could improve SCUBA-2 mapping speed by a factor of a few by achieving this.
- The only way to improve further is to increase the focal plane area
- But SCUBA-2 fills the maximum possible throughput at the Nasmyth focus…
- Therefore we have investigated various options to increase the FOV of the telescope from the 8 arcminutes FOV of SCUBA-2

Current Optics, enlarge central aperture in primary:
max FOV=15 arcmin   Cost minimal



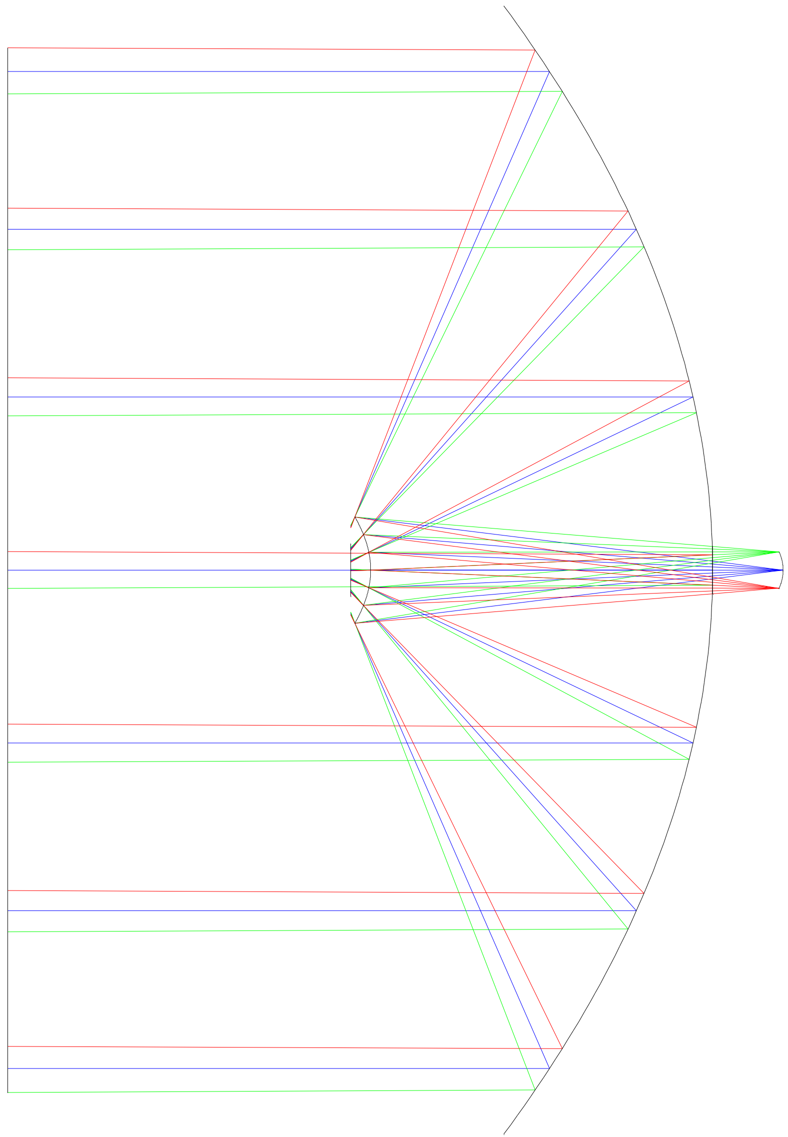
Layout

Same size secondary, different focal length, enlarged aperture
max FOV=22 arcmin Cost <£100k



Layout

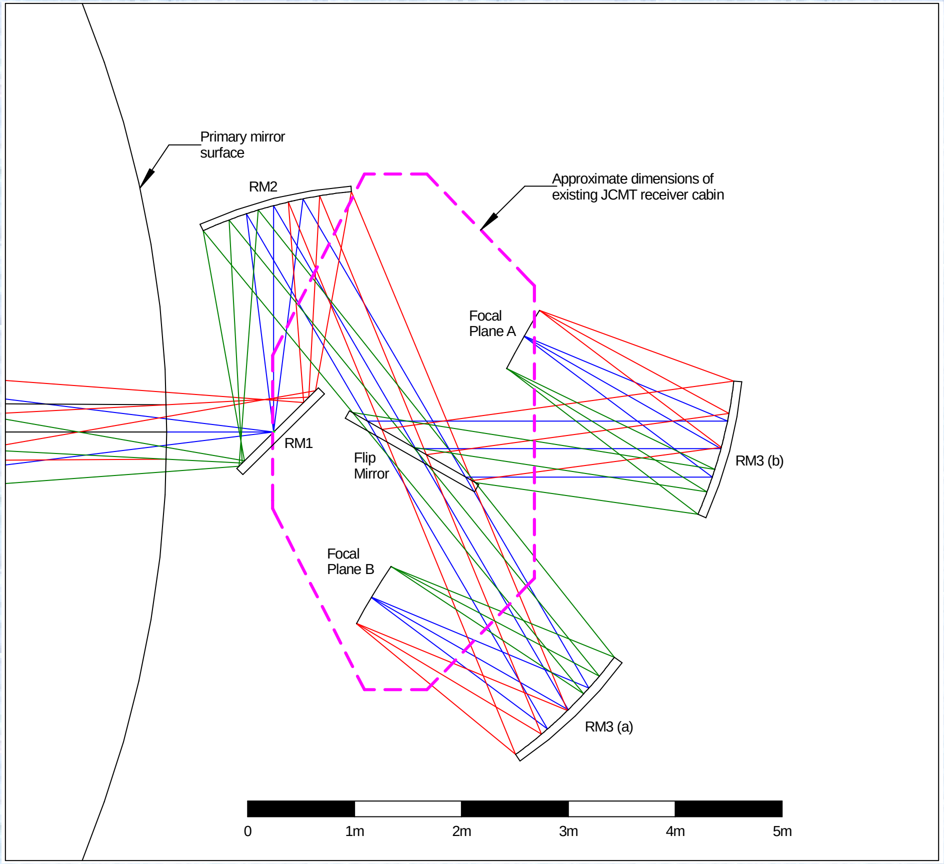
Double secondary size & move closer to primary, enlarged primary aperture, alter primary surface slightly
max FOV=37 arcmin Cost ~£100k

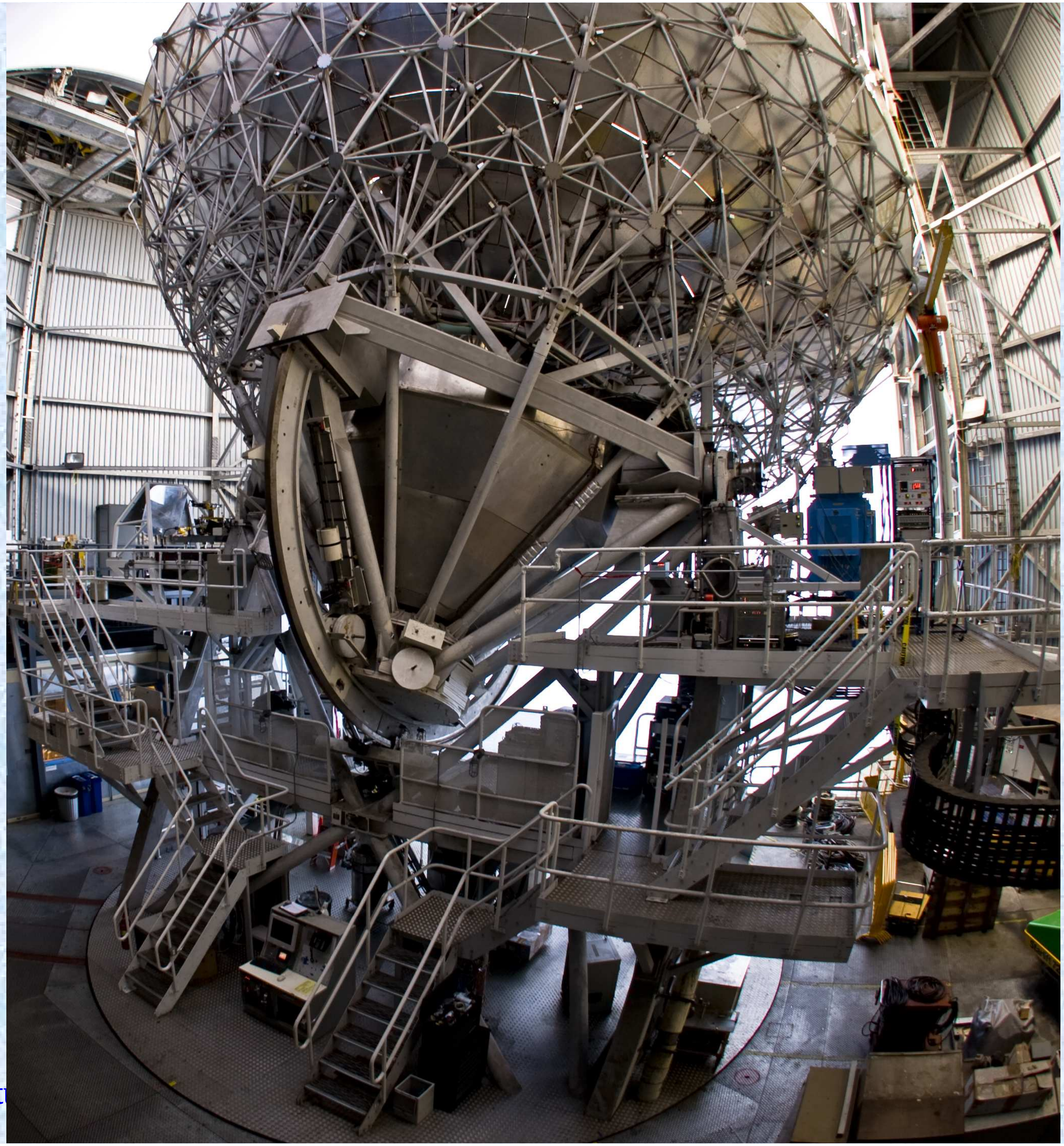


Layout

Dealing with such a large AΩ is not simple though..

- One option would be a single instrument at Cass focus
- Limits telescope options however
- A 2nd focus either inside the cabin or at Nasmyth should be possible, esp if it is not using the full FOV
- Cost probably a few x£100k (needs more detailed work)

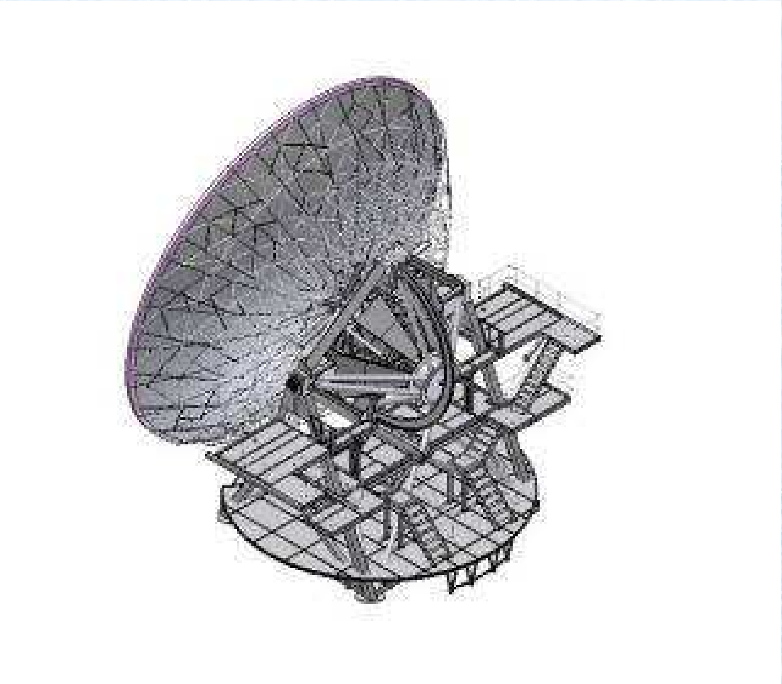


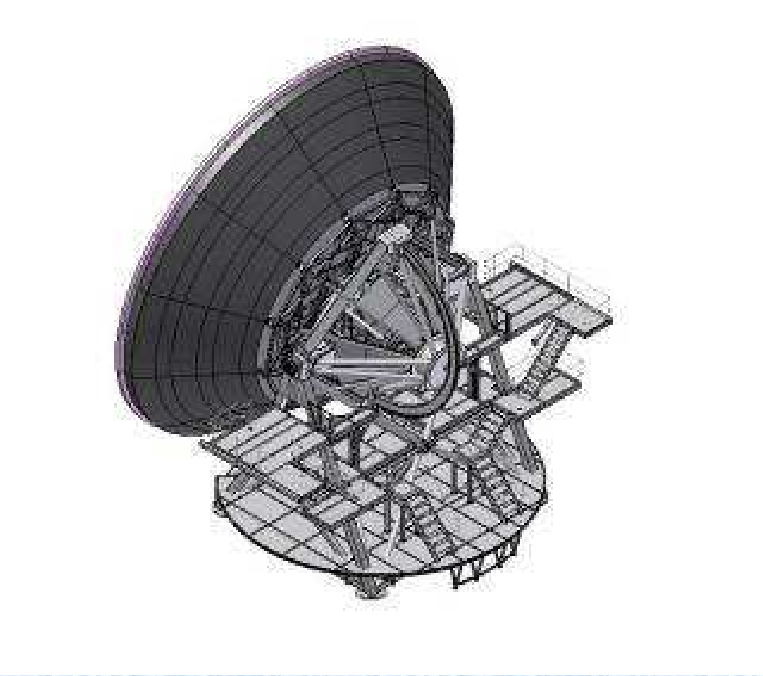


Another way to increase efficiency of collecting photons is to improve the primary surface

- A study done in the 1990s concluded that the current panels could be refurbished to improve the overall rms from ~25 microns to ~18 at a cost of ~£2M
- This gives an improvement in efficiency of 27% at 450 and 47 % at 350 microns & make possible diffraction limited observations at 350 i.e. beam of 5.5 arcseconds
- A new study by EIE based on ALMA technology suggests replacing the current panels and backing structure could improve the rms to ~13 microns, an improvement of 43% at 450 and 80% at 350
- This could also remove the need for a wind-blind increasing transmission at 450 microns by a further ~15% & improving polarization performance
- Cost ~£5M

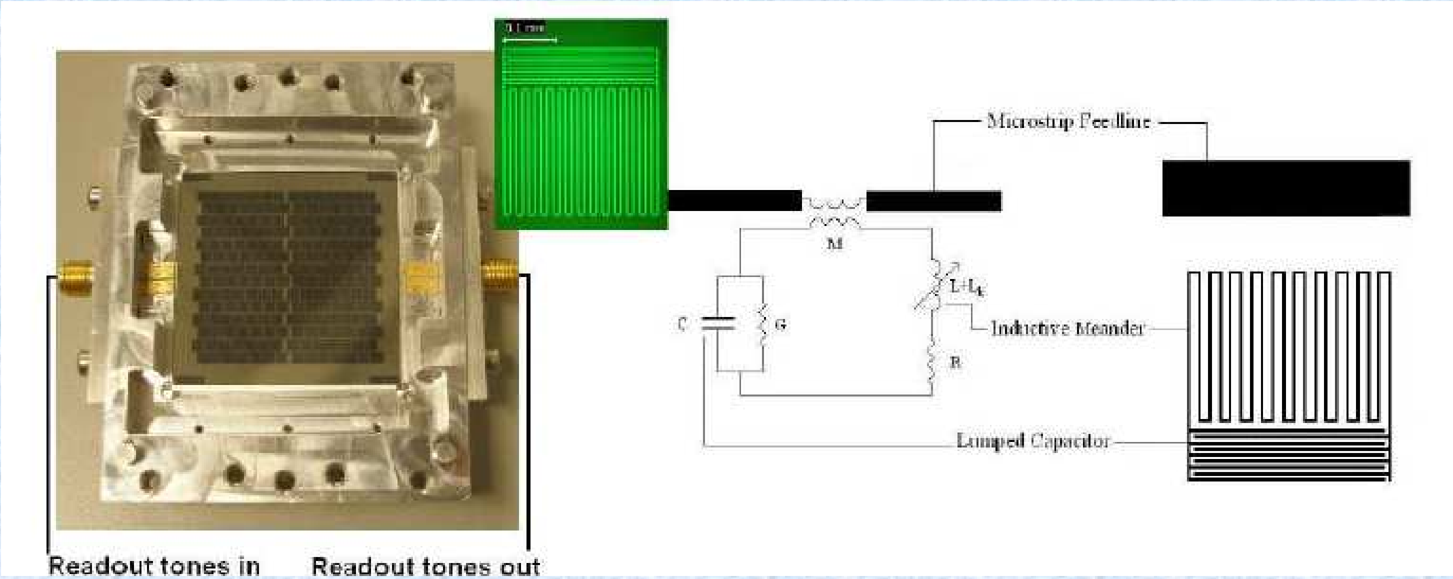
EIE Proposal





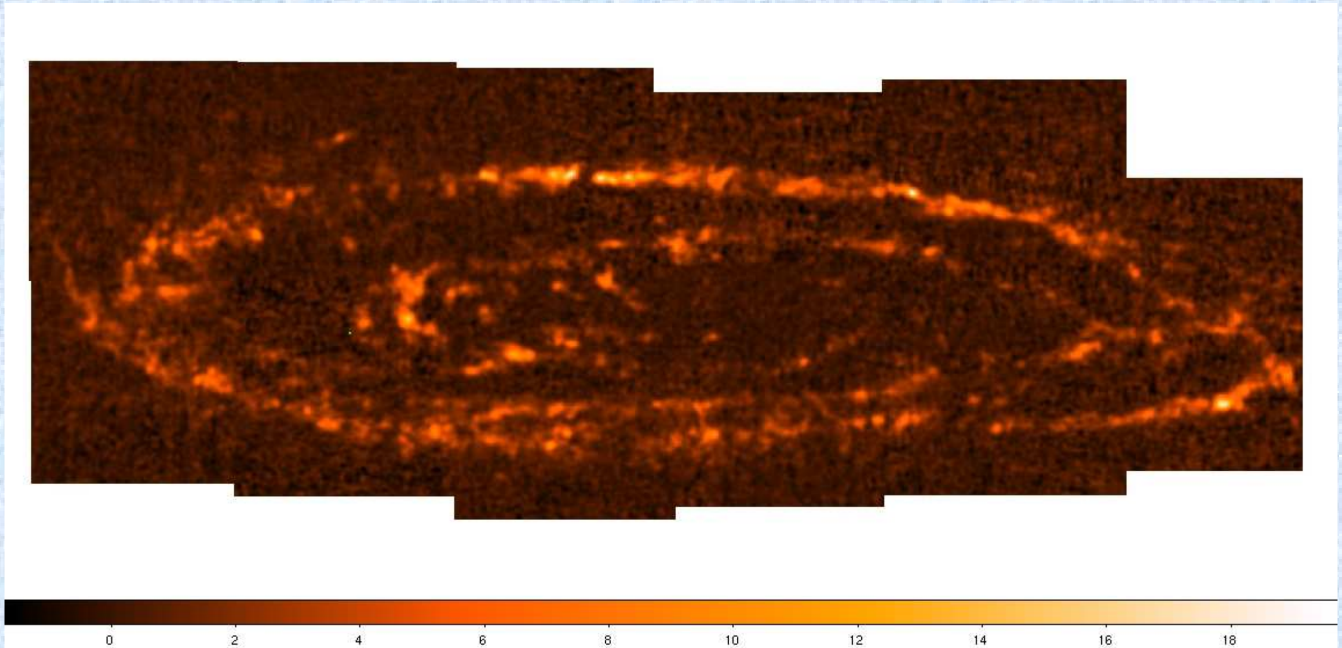
Current dish **EIE Proposal**

The solution to achieve large format cameras: A large multi-frequency KID camera

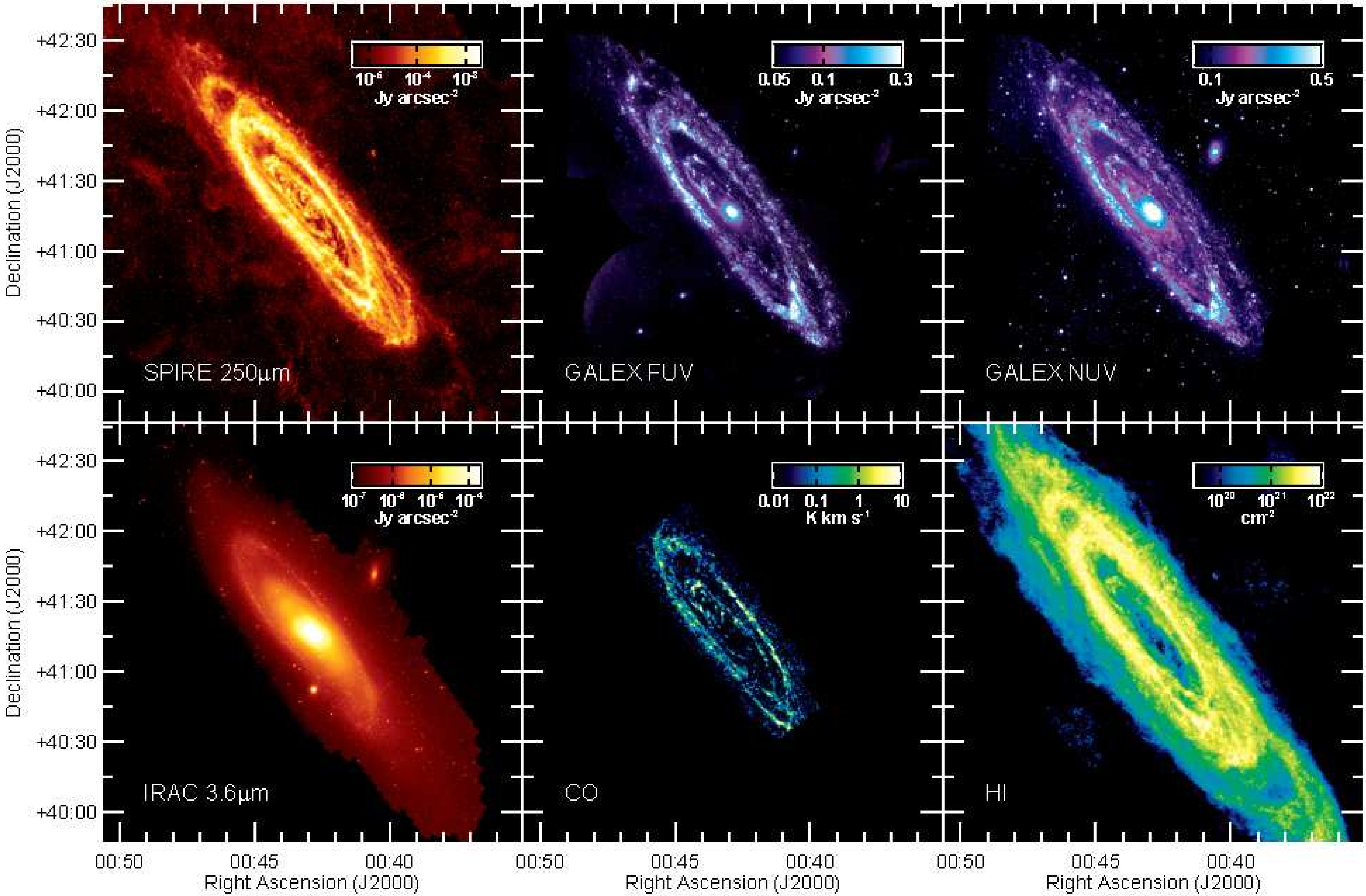


- To fill the larger FOV discussed previously would need a 100,000 pixel focal plane, at at least 2 frequencies….
- Kinetic Inductance Detectors (KIDs) offer the best way forward to this target.
- They are much simpler to fabricate and to readout than the TES detectors used in SCUBA-2
- **~10^5 pixel camera could be built by ~2016, cost ~£4-5M**

Science for 2020: (b) Spectroscopic Imaging



- Image above of CO(1-0) in Andromeda took 500 hours on the IRAM 30m with the 32 pixel heterodyne array but is still much smaller than Herschel and other wavelength images
- It is not possible to make a comparable 3-2 image with Harp in any reasonable time
- With a ~100 element array it should be achievable in a few x100 hours
- A large-format medium resolution imaging camera could also achieve this in much less time but at risk of contamination from different lines

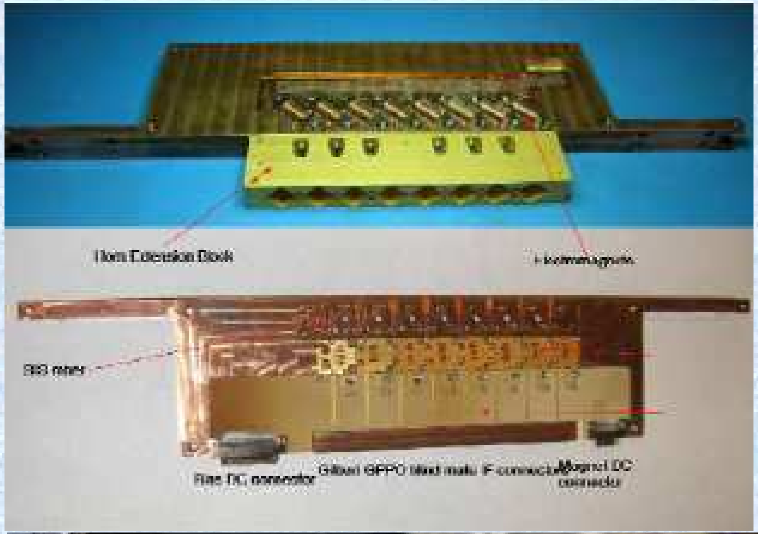

+42:30
+42:00
+41:30
+41:00
+40:30
+40:00
Declination (J2000)
SPIRE 250μm
GALEX FUV
GALEX NUV
IRAC 3.6μm
CO
HI
Jy arcsec⁻²
K km s⁻¹
cm⁻²
00:50
00:45
00:40
Right Ascension (J2000)

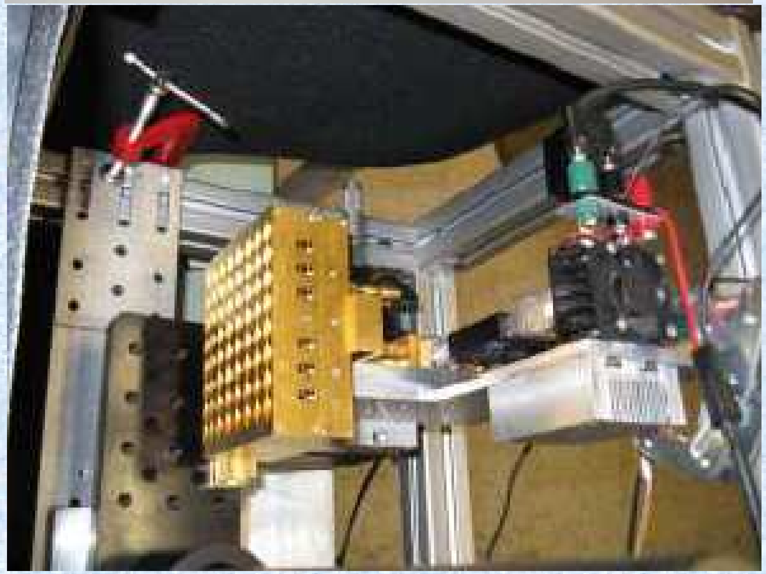
Line surveys of the Milky way

- HARP has (impressively) managed to map 24 sq deg of the galactic plane in CO (3-2)
- This is only ~5% of Hi-GAL however….
- Complementary continuum & velocity surveys are essential to overcome line-of-sight confusion in the galaxy to properly statistically sample the mass/luminosity & spatial distribution of GMCs and star-forming clouds

Heterodyne arrays

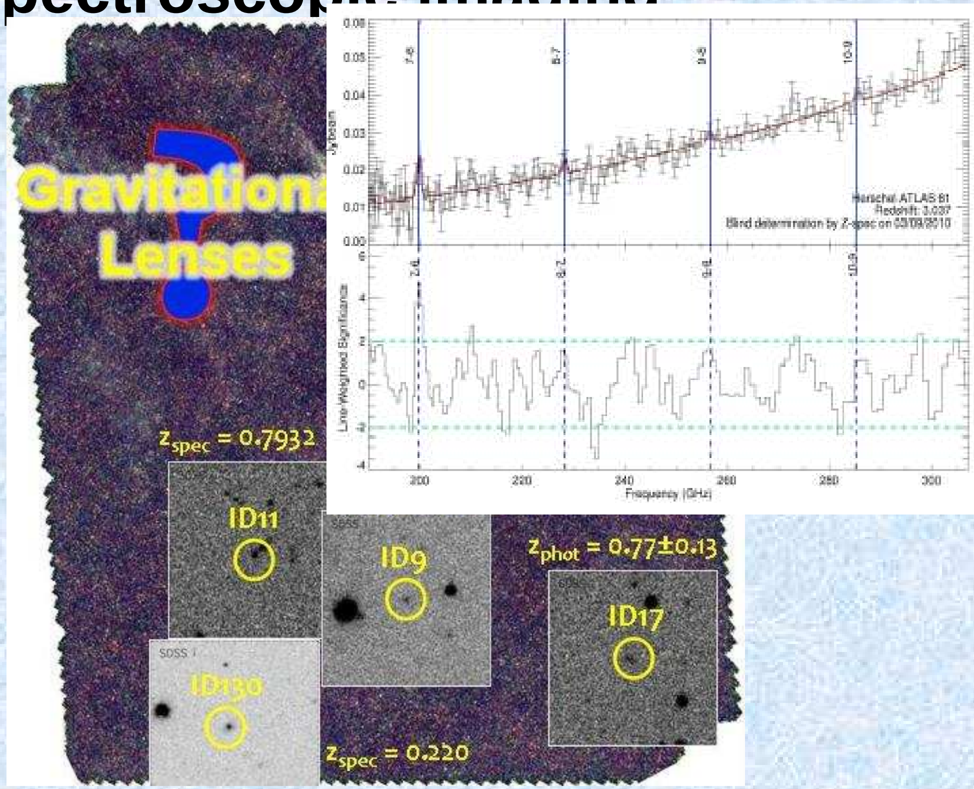
- Integrated, modular detector & LO injection systems have been developed for HHT in Arizona
- Backend is also a challenge but digital electronics continues to develop rapidly
- e.g. IRAM PdB 6x8GHz=> NOEMA 12x32 GHz is x4 baselines x4 b/w
- A >~100 pixel heterodyne should be achievable by 2018
- Cost ~£10M ?





Low-resolution spectroscopic imaging

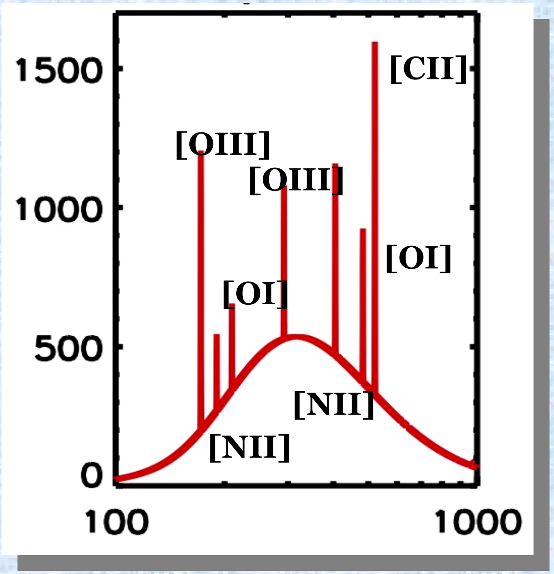
- For follow up of cosmological surveys low-resolution spectra are OK to find redshifts
- 5 unusual-looking SEDs in the SDP field all lenses, confirmed by CO redshifts
- There are another 150 candidates in this field alone
- These would all be found immediately in a spectroscopic survey….

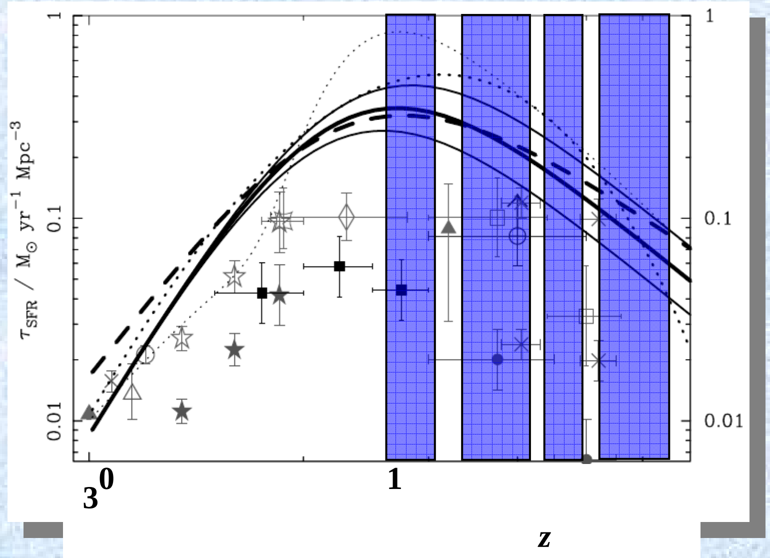


Source	Optical redshift	CO redshift
9	0.679	1.577
11	0.72	1.786
17	0.77 (photo-z)	0.942+2.308
81	0.334	3.037
130	0.239	2.625

CII & other atomic lines

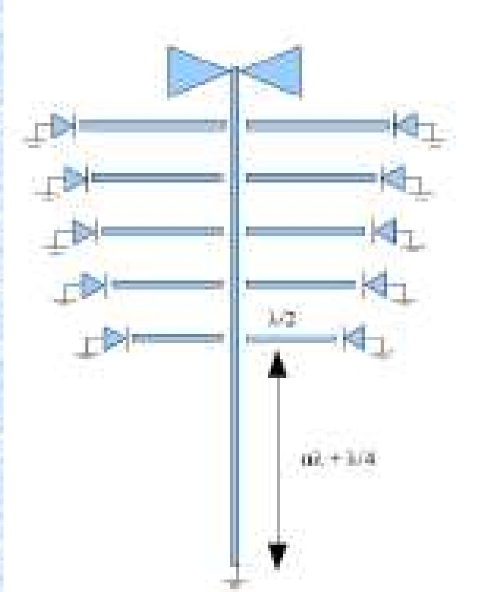
- As pointed out yesterday CII line much brighter than CO
- Also more suited to submm window for z of interest (Do CO at LMT or GBT)
- z~1.7 to 5 in submm with CII
- Other atomc lines also give wider range of z & probing physics of ISM

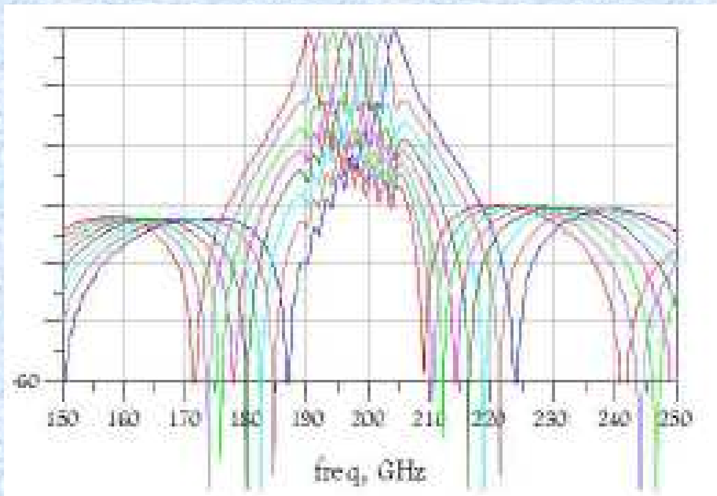




The Ultimate Instrument ?

- If we could fill the maximum FOV with pixels each of which produced a full spectrum in each band we would be absolutely maximising the science from the telescope
- Such an instrument is probably a decade away form reality, cost ~£10M
- But technology development with promising potential is already taking place…
- Single or few pixel prototypes could be tested on JCMT by 2014/5





The way forward : A personal view…

- The community should make a strong representation to STFC for extension of operations of JCMT by ~3 years to exploit the (original) science case with SCUBA-2 (&FTS & Pol)
- Meanwhile conduct further detailed study of science cases and technical options for possible upgrades to JCMT beyond 2014, including staged milestones.
- Bear in mind possible UK collaboration with LMT & also APEX and make a clear statement on maintaining JCMT vs involvement in CCAT
- Once the science priorities and subsequent technical priorities agreed ensure that STFC are made aware of this so it can be taken into account in an STFC technology roadmap as well as a scientific one (E.g. investment in large-format imaging vs multi-object spectroscopy)

Where we don’t want to be ….