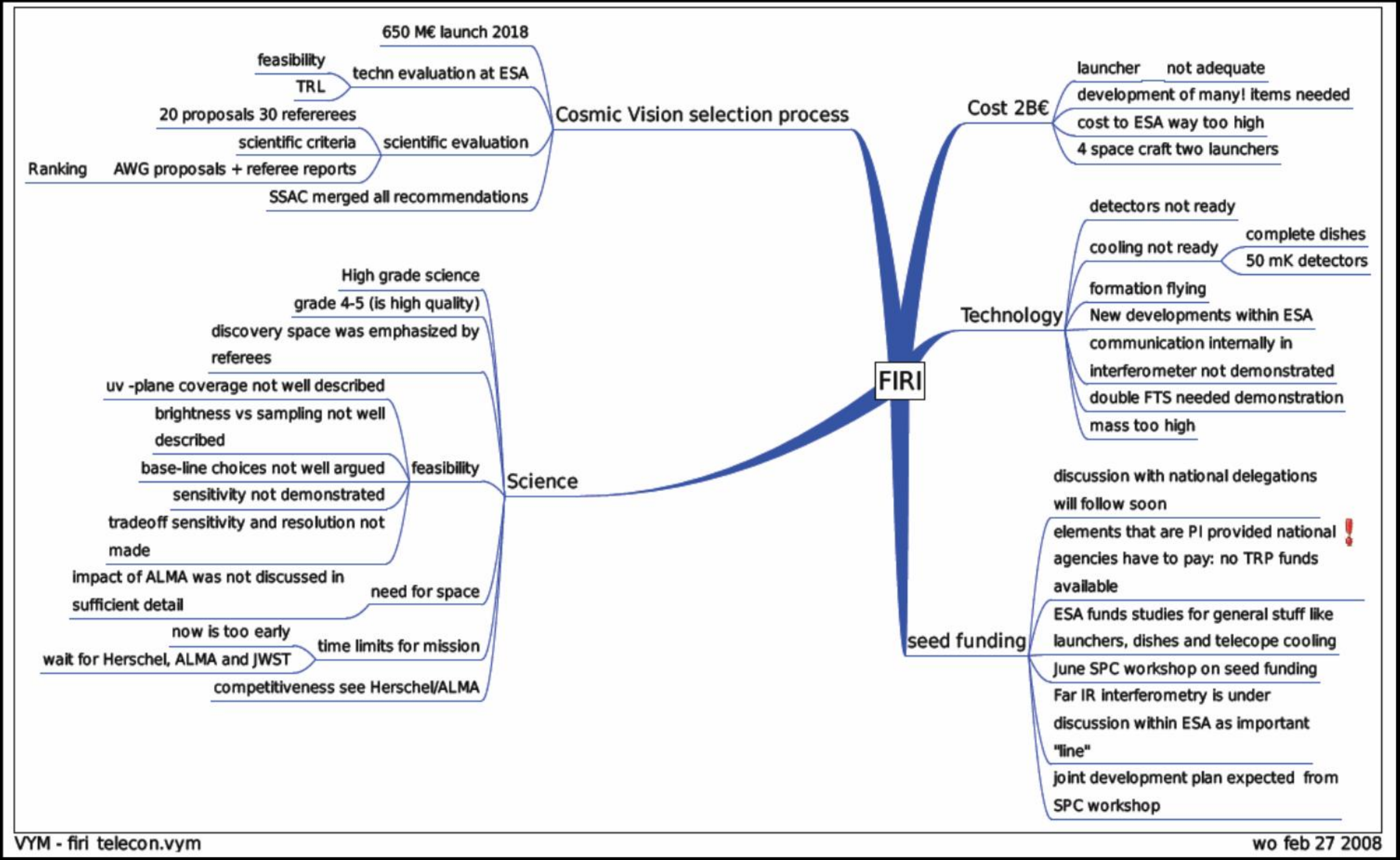
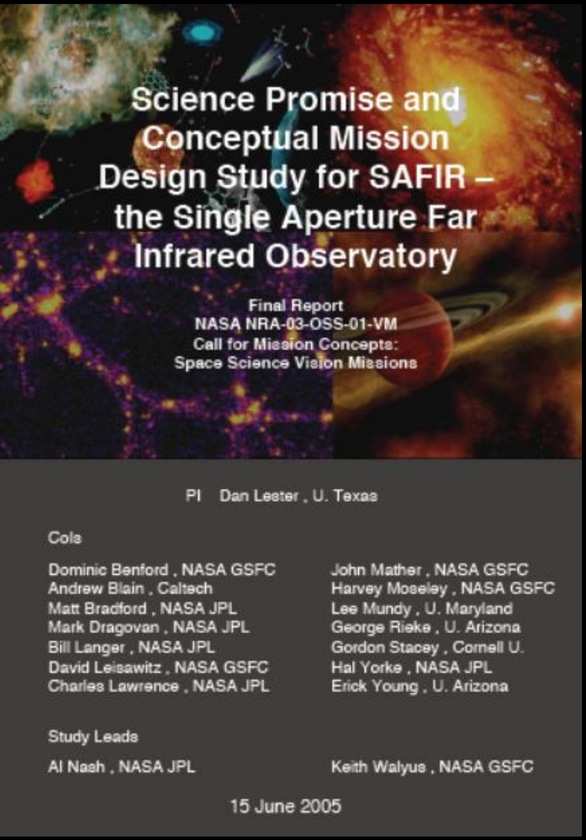
Some Key Scientific Goals for FIRI

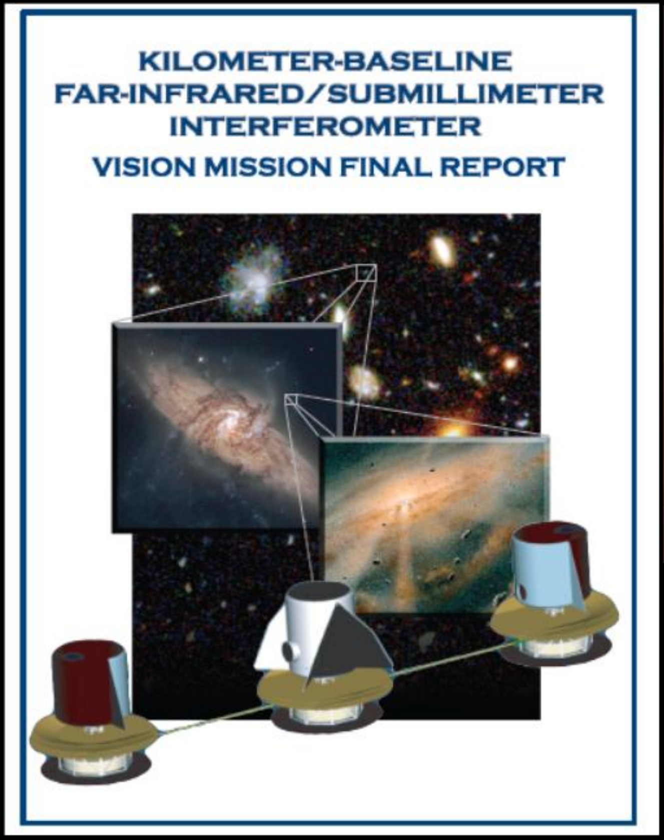
- Study the gas, ice and dust in **forming planetetary systems** at high angular resolution
- **Resolve the FIR background** into individual sources and study their **internal structure**
- Study the **assembly of Milky Way type galaxies**
- Understand the formation and evolution of **AGN with their host galaxies**
- Observe the **formation of the first stars** from primordial material and the first production of heavy elements

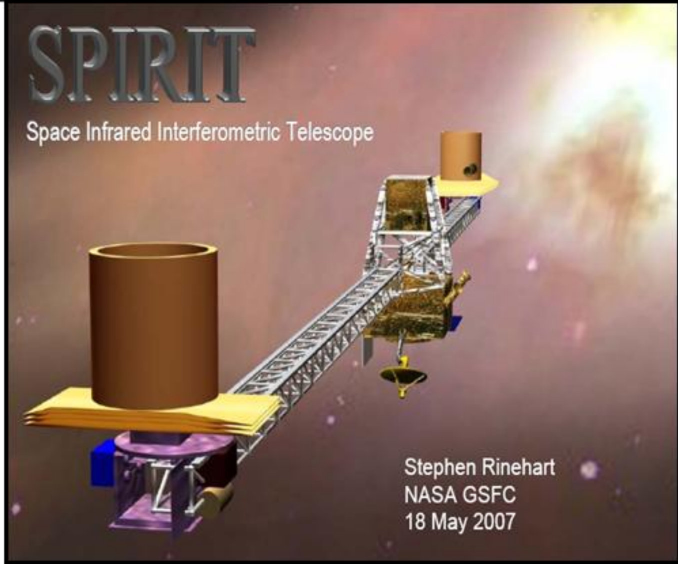
FIRI in Cosmic Vision



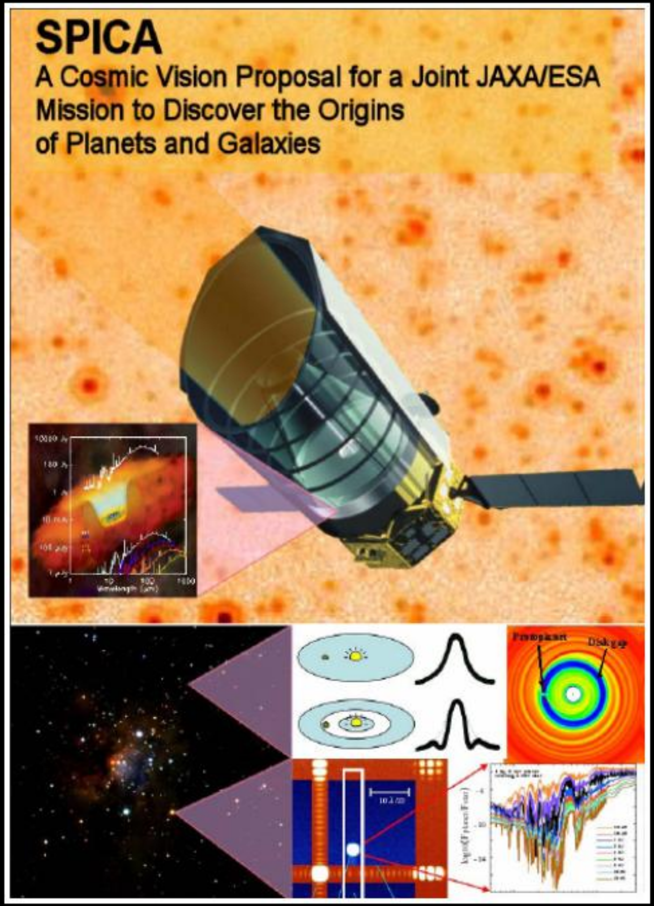
- USA: SAFIR, SPIRIT, SPECS





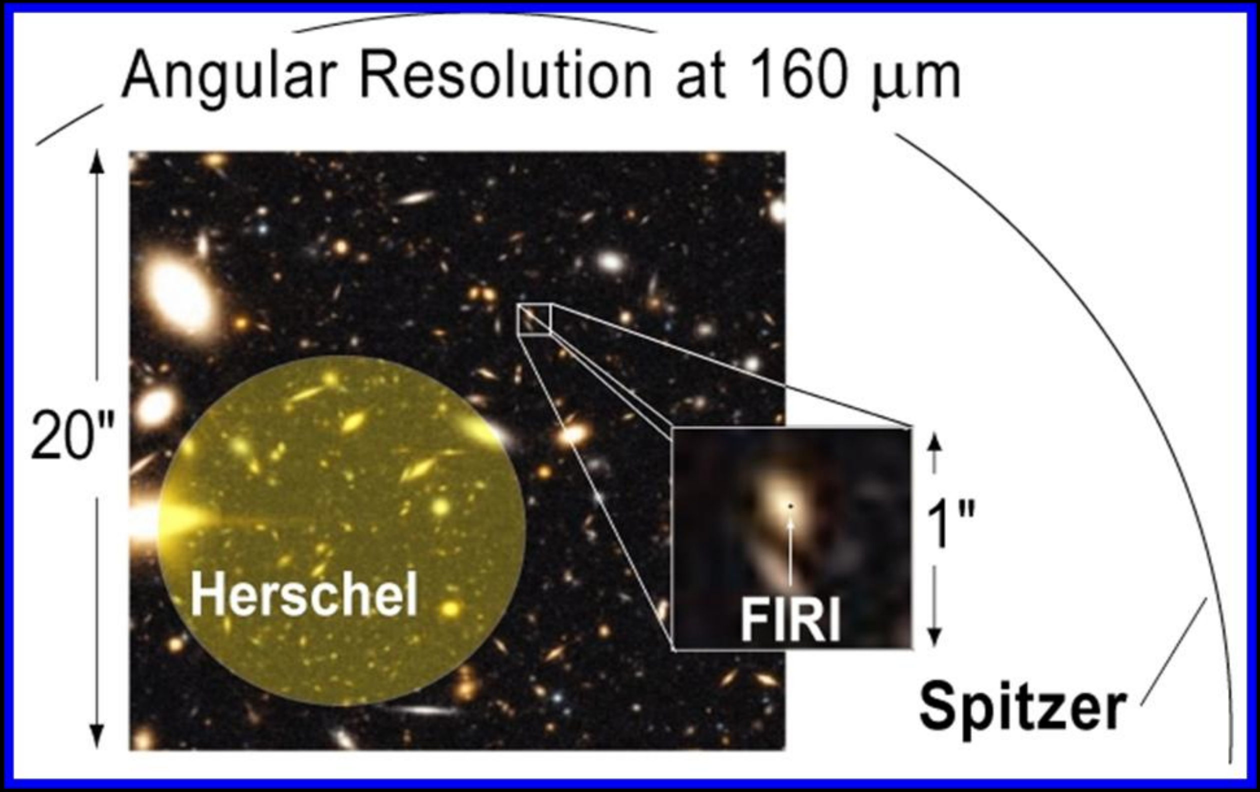


- Europe/Japan
  - SPICA/SAFARI
  - ESA Far Infrared Interferometer study (“FIRI” – but not necessarily the same as our FIRI)

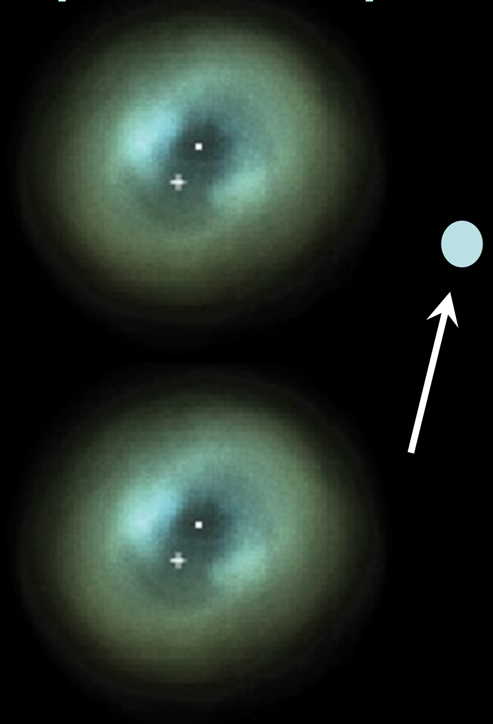


"Our" FIRI

- **Improved sensitivity from larger (4-m class) apertures**
- **Improved angular resolution (0.01") from longer (~ 1 km) baseline**



Debris disk with planet at 30 pc



Beam at 40 μm (36-m baseline)

Type	λ,ν (micron, GHz)	Δλ,Δν, Δv (micron, GHz, km/s)	R	Area,Ω	ΔΩ (arcsec)	N_{fields}	S_{min}, ΔT_{min}(Jy, W/m2, K)	UV-constraints	Dynamic range
Water protoplanetary disks	**557, 1667, 1113.3 GHz**	**100 km/s**	**0.25 km/s**	**10x10**	**0.02-0.1**	**40**	**0.2 K**	**Natural weighting short/zero spacings**	**100**
Dust protoplanetary disks	**30-150 micron**	**40 micron**	**1500**	**200x200**	**<0.01**	**10**	**5 μJy**		**1000**
Dust debris disks	**30-150 micron**	**40 micron**	**1500**	**10x10**	**<0.01**	**10**	**5 μJy**		**1000**
HD – total gas	112 micron	100 km/s	0.5 km/s	10x10	0.01-0.1	40	0.1K		100
Temp. structure trans. Disks	158, 63 145 micron	100 km/s	0.5 km/s	10x10	0.1	40	0.1 K	Incl. Compact	100
The origin of outflows (ambitious)	50-300 micron 63,205	40 micron	30,000	0.015x 0.015	50 micro-arcsec	100	2 μJy	Short/zero spacings	>1000
The origin of outflows (conservative)	50-300 micron 53, 63, 205	40 micron	30,000	1x1	0.05	20	50 mJy	Short/zero spacings	>1000
Lum. Funct. In clusters	**50-300 micron**	**20-40 micron**	**3-10**	**900x900**	**0.01**	**50**	**1 mJy**		**100,000**
Cloud core stellar content	50-300 micron	70	1-5	60x60-900x900	<0.1	10	5 μJy	Short/zero spacings	100,000
Water tracing infall	Water lines in 50-600 micron	100 km/s	0.1 km/s	20x20	<0.1	40	0.5 K		>100
Giant planets in pp-disks	30-150 micron		1500	10x10	0.001	40	5μJy		>1000
Solar system	Several lines between 0.5-6 THz	0.1-10 GHz	0.1-100 km/s	30x30 max	0.1	10	0.1 Jy		>100
PDRs	63,158 micron	100 km/s	0.25 km/s	10x30	0.1	10	1 K		>20
Turbulent ISM	Hydrides 0.5 4 THz	500 km/s	0.1 km/s	30x30	0.1	10	0.1 K		>100
AGB shells/ young PNe	Several lines between 63-300 micron	200 km/s	0.3-1 km/s	5x5	0.01-0.1	>15	<3K <0.2 Jy/beam	standard	>30

SRON

Line

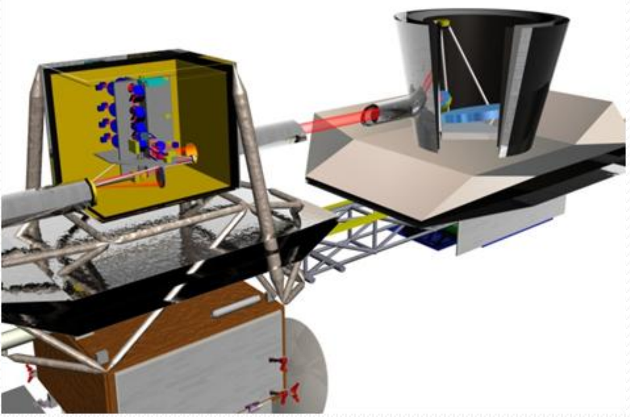
Type	λ,ν (micron)	$\Delta\lambda,\Delta\nu$, Δv (micron, km/s)	R	Area,Ω (arcsec^2)	$\Delta\Omega$ (arcsec)	N_{fields}	Sensitivity, rms (W/m^2)	UV constraints	Dynamic range
OVERALL	25-300	1500 km/s	R~1000	10x10	0.01-1	1	10^{-22}	Short baselines when needed	>100
Gas in ULIRGS	Fine structure lines	1500 km/s	R~10^3	10x10	<0.05	<10	10^{-18}	Strong driver for good uv coverage	>100
Gas evolution at z=1-7	25-200	1500 km/s	R~10^3	1x1	0.3-1	1	2 x 10^{-22}	Short baselines	>100
Probing Compton-thick AGN	25-300	~40 micron	R~300	5x5	0.5-1	1	2 x 10^{-23}		>100
Line diagnostics for AGN/galaxies	25-660		R=500 to 5000	20x20	<0.05	1	5 x 10^{-21}		~1000
Probing H_2 in blank fields	Large		R~10^3	60x60	~0.1	1	<10^{-23}		~1000
Probing H_2 in objects with known z	50-250		R~10^3	3x3	~0.1	1	<10^{-20}		>10

FIRI: xgal science requirements

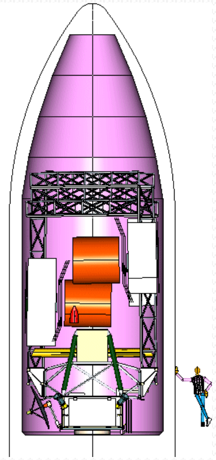
Continuum

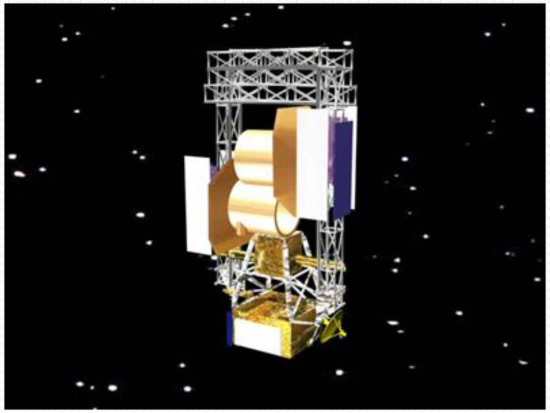
Type	λ,ν (micron)	$\Delta\lambda,\Delta\nu, \Delta v$ (micron, km/s)	R	Area,Ω (arcsec^2)	$\Delta\Omega$ (arcsec)	N_{fields}	Sensitivity rms (Jy)	UV constraints	Dynamic range
OVERALL	24-300		R~5-10	5x5	0.01-1	1	1μJy	Short baselines when necessary	>100
Dust in ULIRGS	24-240		R<5	10x10	<0.05	<10	<10μJy	Strong driver for good uv coverage	>100
Merging AGN	40-220		R<5	2.5x2.5	<0.02	1	1μJy	Point sources only	>100
Dust evolution at z=2-10	25-200	~50 micron	R~100	2x2	0.3-1	1	1μJy	Short baselines	>100
Timing of starburst and AGN phenomena	40-660		R<5	5x5	<0.02	1	2μJy		>1000
Cosmic history of SF and SFE	30-300		R~10	5x5	0.1-2	1	1μJy		>100

SPIRIT after iterating trades



- 1 m afocal, off-axis telescopes (no deployments)
- Interferometric baselines from ~7 to 36 m
- Dense *u-v* plane coverage (very good image quality)
- Michelson (pupil plane) beam combination
- Scanning optical delay line for $\lambda/\Delta\lambda = 3000$ spectroscopy
- All optics at 4 K
- Transition Edge Sensor bolometers in small arrays (up to 14 x 14 pixels) cooled to 50 mK





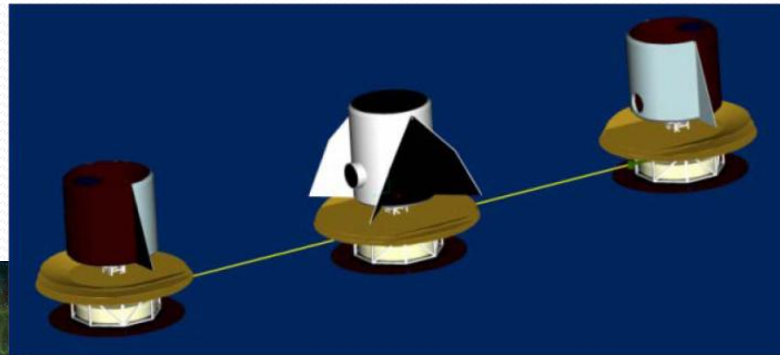
Astrophysical background-limited sensitivity across a four-octave spectral range from **25 to 400 μm**

Avg time per observation ~29 hrs

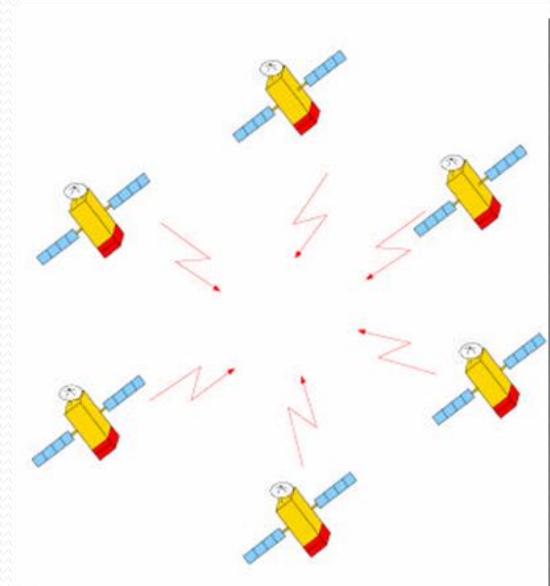
- Sun shades sized for 40 deg wide viewing zone around the ecliptic plane
- Operates in Lissajous orbit at Sun-Earth L2

Each observation yields a spatial-spectral data cube with sub-arcsecond angular resolution over a 1 arcmin square field and a spectrum for every resolution element

Direct or coherent detection?



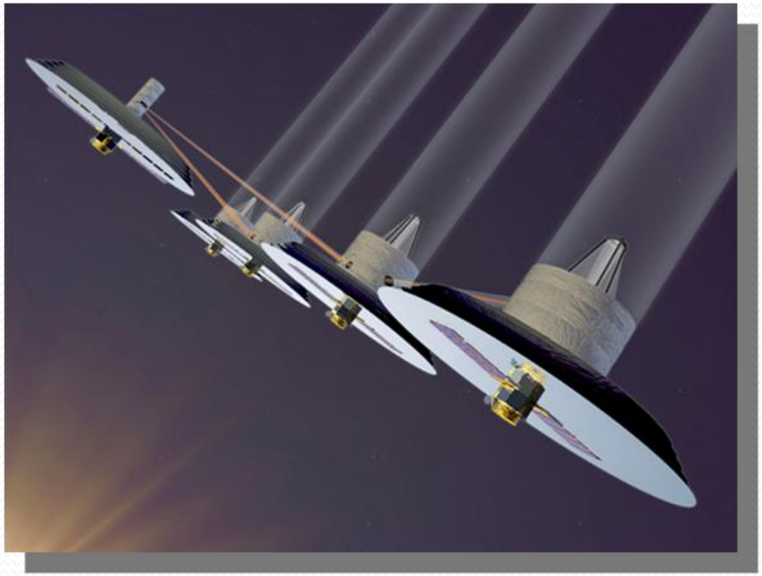
Direct detection offers better sensitivity. With cold telescopes and advanced detectors, sky photon noise dominates instrument noise.

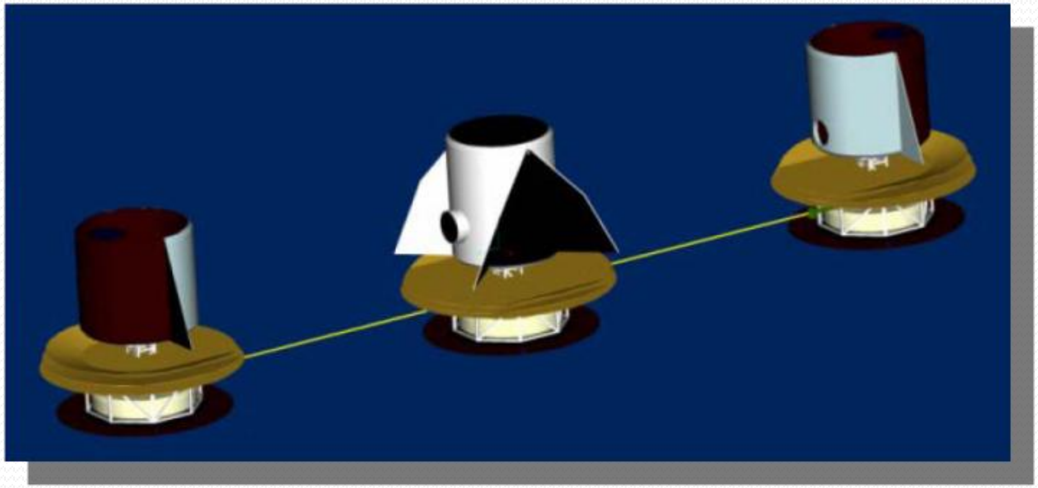


Coherent detection allows greater spectral resolution.

Evaluation of FIRI Design Reference Mission suggests a stronger case exists for direct detection interferometry. The coherent approach is needed for science requiring spectral resolution $>>10^3$.

"Strings" attached?





Free formation flight

- All baseline changes consume fuel
- Must sacrifice either image quality (sparse u-v coverage) or number of target fields per mission lifetime

… even with the most efficient thrusters

Tethered formation flight

- Very fuel efficient
- Thrust only to change targets and for orbit maintenance

Ref. Lorenzini et al., Ap. Sp. Sci., 302, 225 (2006)

“My” job in FISICA

- **FIRI proposal makes case**
- **Science needs updating**
  - **in context of ALMA, Herschel, SPICA, CCAT, JWST, E-ELT, SKA**
  - **Identify killer apps**
  - **polarimetry case?**
  - **Can we live with ~30m baselines?**
- **Update Sci Req document**
- **20% of me “gratis” from STFC**