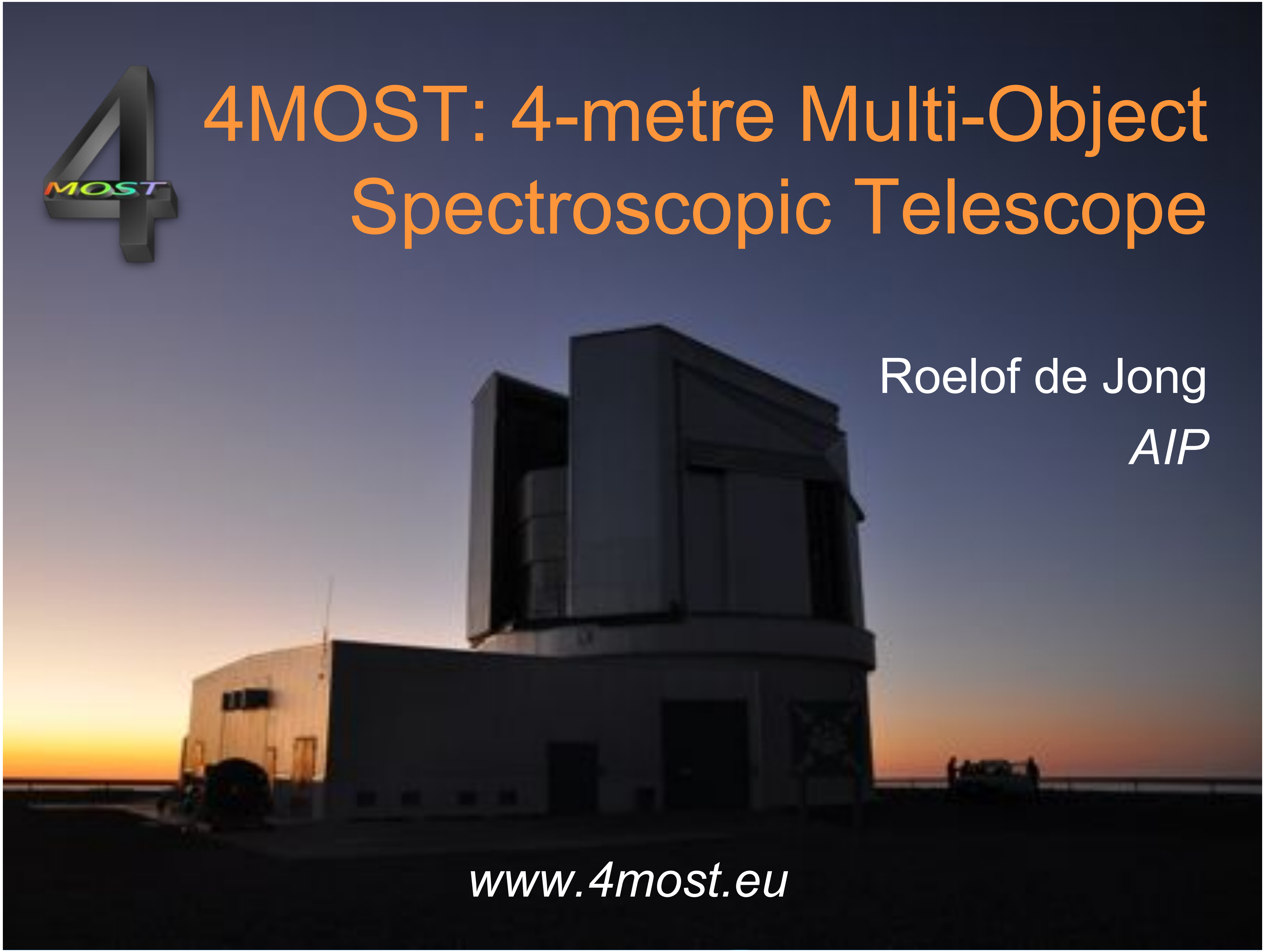

4MOST: 4-metre Multi-Object Spectroscopic Telescope

Roelof de Jong

AIP

www.4most.eu

Conceptual Design Study for ESO

- Now: Conceptual Design study, completed by Feb 2013
- Science: space mission follow-up: Gaia, eROSITA, Euclid
- Selection: 4MOST/MOONS decided ~May 2013
- Goal: start all-sky *public* surveys 2019
- Telescope: VISTA, 4m-class telescope
- Data: yearly public data releases with higher level data products

- Expected specs:
  - Very high multiplex: ~2400 fibers
  - Full optical wavelength coverage: 390-950 nm
  - Large field-of-view: ⌀=2.6°
- 4MOST provides in a 5 year, all-hemisphere survey
  - >20 $\times 10^6$ spectra @ R~5000 to m_V~20 mag at S/N=20
  - > 1 $\times 10^6$ spectra @ R~20,000 to m_V~16 mag at S/N=50

Consortium effort

4MOST – 4-metre Multi-Object Spectroscopic Telescope

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SPIE paper
http://arxiv.org/abs/1206.6885

AIP, LSW, LMU, MPE (D), IoA, RAL (UK), NOVA, RuG (NL), GEPI (F), LU, UU (S), ESO

Design philosophy:
4MOST is a **survey facility**

- ***4MOST runs all the time***:

  minimal instrument changes, no significant time sharing

- ***Coordinated system***:

  survey and target selection, strategy for operating surveys in parallel, instrument capabilities, and data product delivery are all part of facility and are tuned to work together

- ***One design fits many (4most) science cases***:

  minimize constraints on science cases, but the number of observing modes (e.g. spectrograph configurations) should be kept to a minimum

- ***Open data policy:***

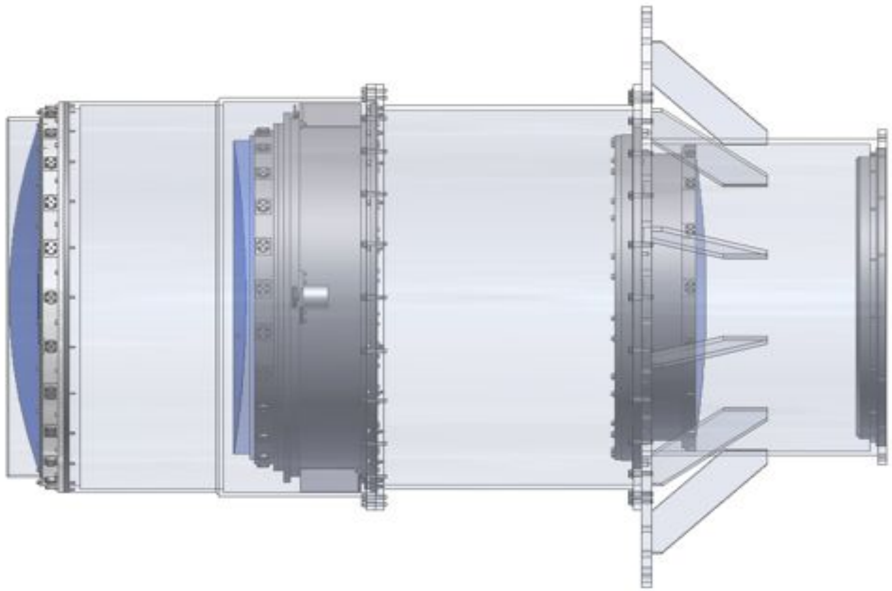
  all surveys public: raw data published immediately, higher-level data products in yearly Data Releases

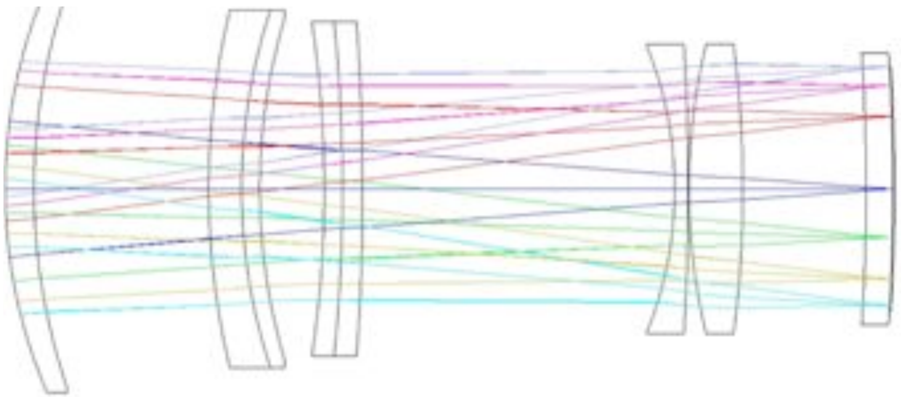
Instrument Specification

Specification	Concept Design
Field-of-View (hexagon)	4.3 degree^2 (⌀>2.6°)
Multiplex fiber positioner	~2400
Medium Resolution Spectrographs Fibres Passband	R~5000-8000 1600 fibres 390-930 nm
High Resolution Spectrograph Fibres Passband	R~20,000 800 fibres 395-456.5 & 587-673 nm
# of fibers in ⌀=2' circle	>5
Area (5 year survey)	>2h x 20,000 deg^2
Objects (5 year survey)	>15x10^6
Start operations	Mid 2019

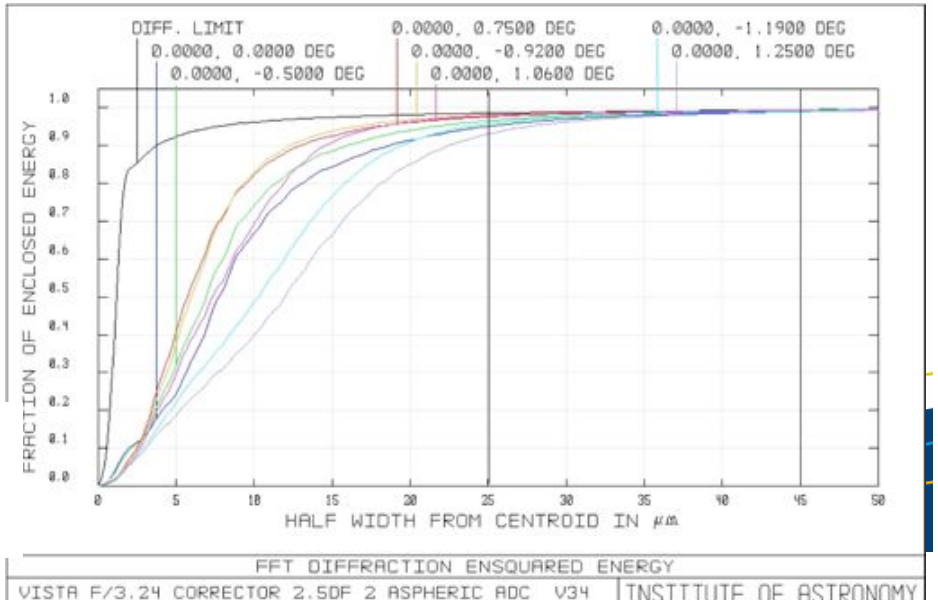
Wide-field corrector can be inserted into VISTA like IR camera

Wide-field corrector VISTA ⌀=2.6°



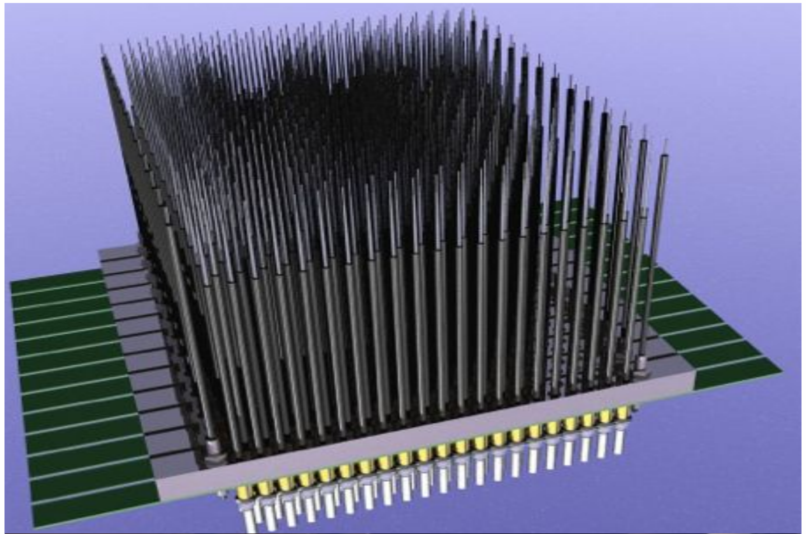


IoA Cambridge, King, Parry, Sun, et al.

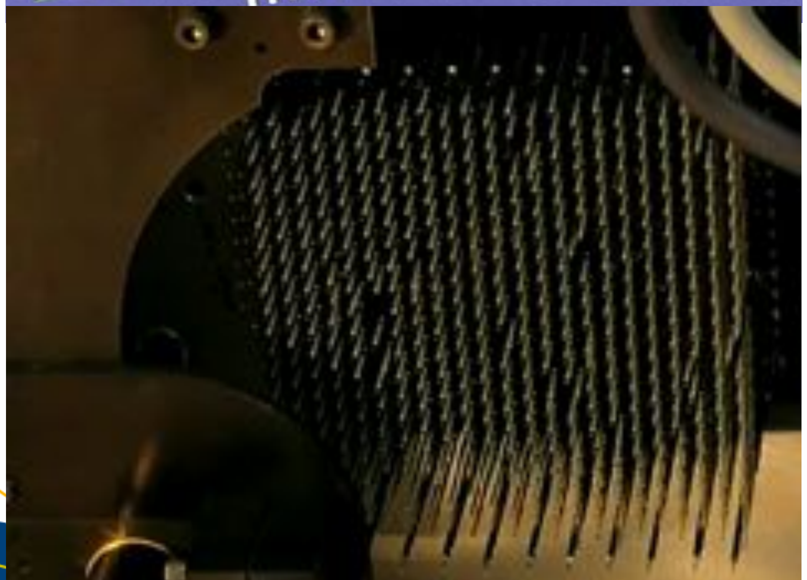


Echidna style positioner

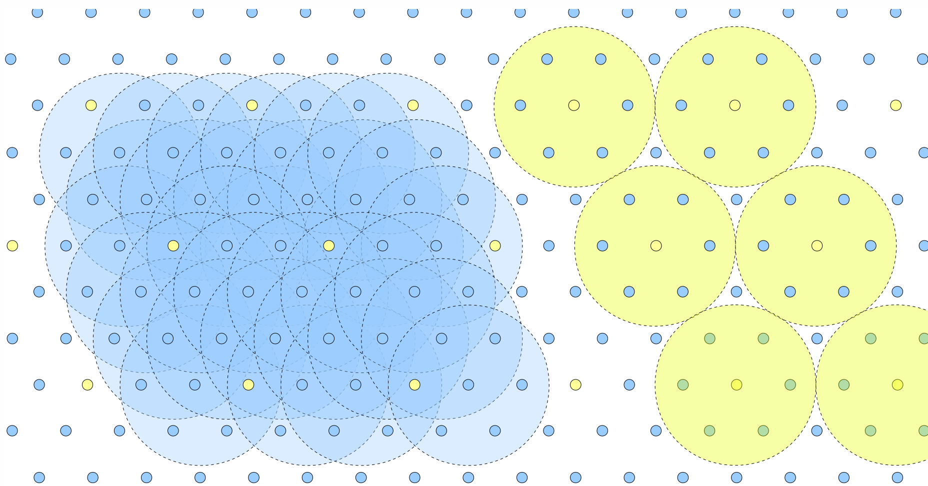
AIP



- Large, overlapping patrol areas enables
  - sparse fibres for high resolution spectrograph
  - clustered fibres (e.g. galaxy clusters)
- Pitch ~10 mm, Patrol R: ~1.2x pitch
- Reconfiguration time <1 min
- Proven technology



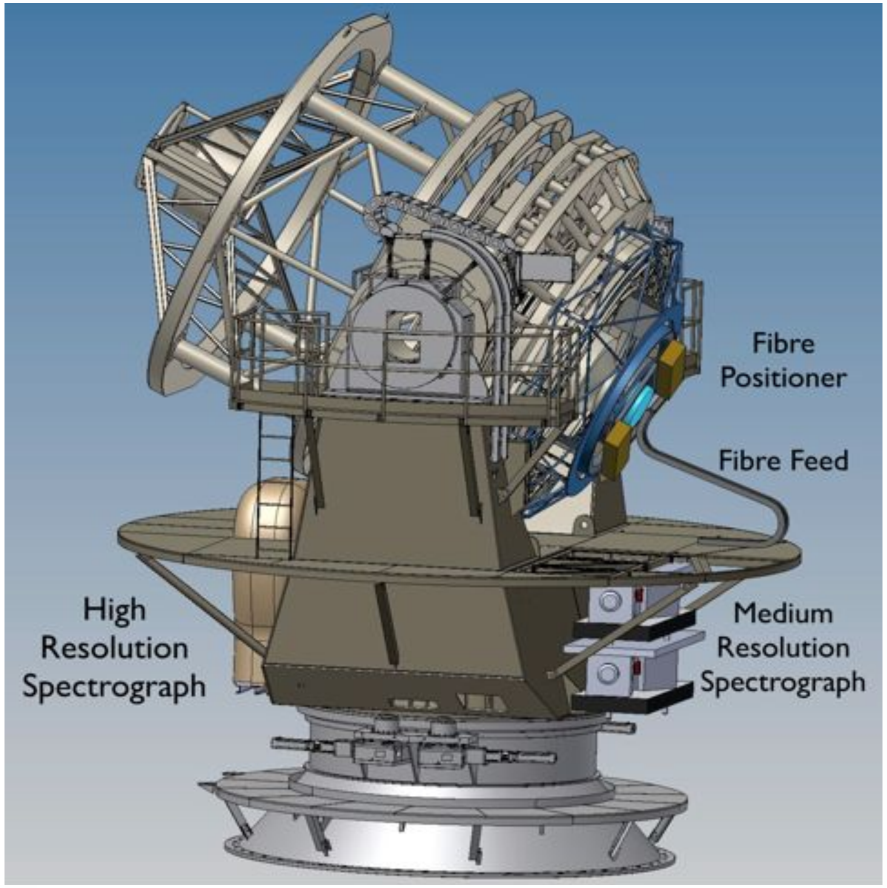
FMOS Echidna on Subaru



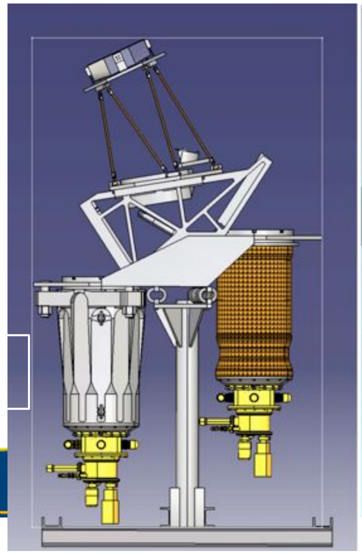
Positioner: AAO, Metrology & Control: AIP

Fibre routing and spectrographs

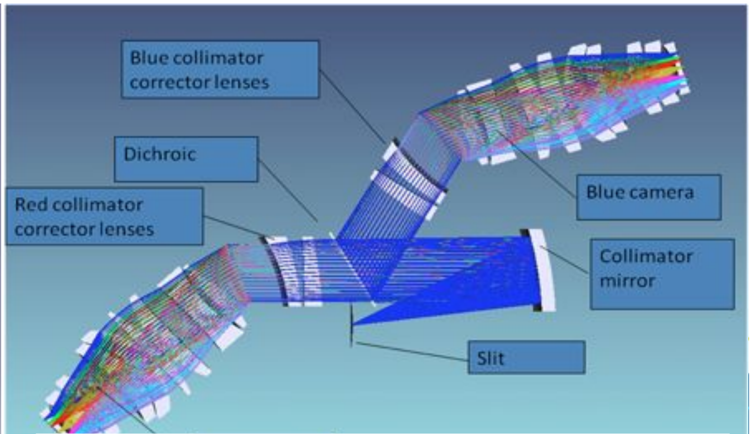
- Spectrographs gravitation invariant and outside dome environment
- Short fibre run (~10–15 m)
- Location High and Medium Resolution Spectrographs may be swapped (TBD)
- Fixed configuration spectrographs, high throughput with VPH gratings
- Two arm spectrographs, two 3k x 8k CCDs per arm



Fibres: AIP



High-Res Spectrograph: GEPI



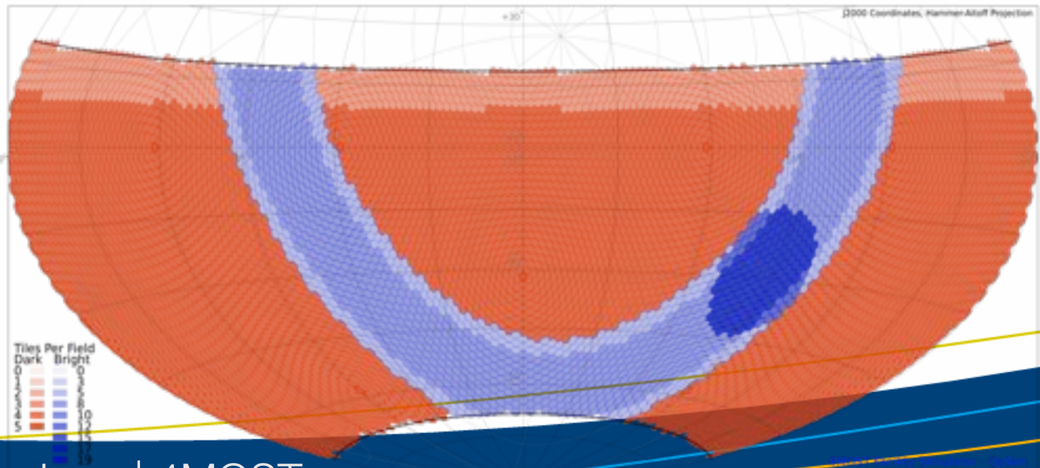
NOVA/ASTRON & RAL/Oxford, LSW

What shall 4MOST deliver?

- 4MOST shall be able to obtain:
  - *Radial velocities* of ≤2 km/s accuracy and
    Stellar parameters of <0.15 dex accuracy of any Gaia star
    - R~5000 spectra of 19.5 r-mag stars with S/N=10 per Ångström
  - *Abundances* of up to 15 chemical elements
    - R~20000 spectra of 15.5 r-mag stars with S/N=140 per Ångström
  - *Redshifts* of AGN and galaxies (also in clusters)
    - R~500 spectra of 22 r-mag targets with S/N=5 with >3 targets in ⌀=2'
- In a 5 year survey 4MOST shall obtain:
  - *20 (goal 30) million targets* at R~5000
  - *2.0 (goal 3.0) million targets* at R~20,000
  - *16,000 (goal 23,000) degree^2* area on the sky at least two times

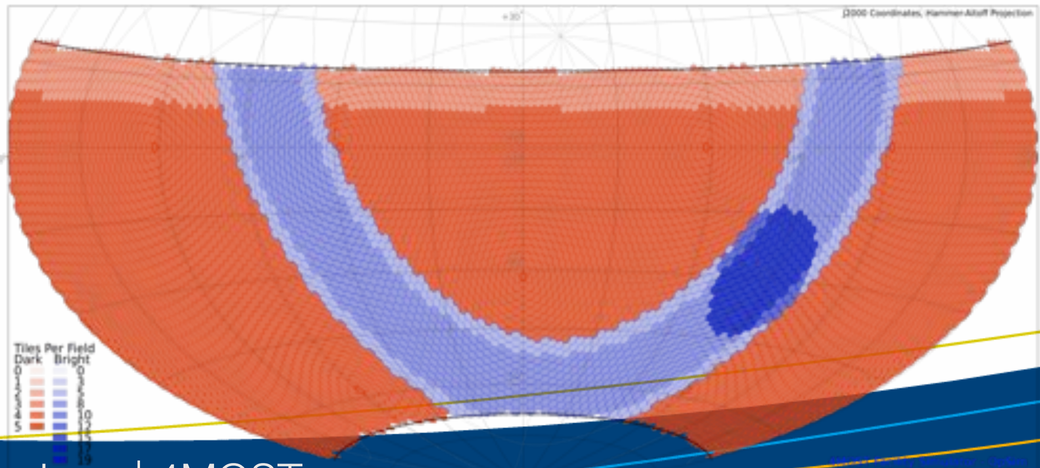
How are we going to run 4MOST?

- 4MOST program defined by *Public Surveys* of 5 years
- Surveys will be defined by ***Consortium*** and ***Community***
- All Surveys will run in parallel
  - Surveys share fibres per exposure for increased efficiency
- ***Key Surveys*** will define observing strategy
  - Millions of targests all sky
- ***Add-on Surveys*** for smaller surveys
  - Small fraction fibers all sky
  - Dedicated small area

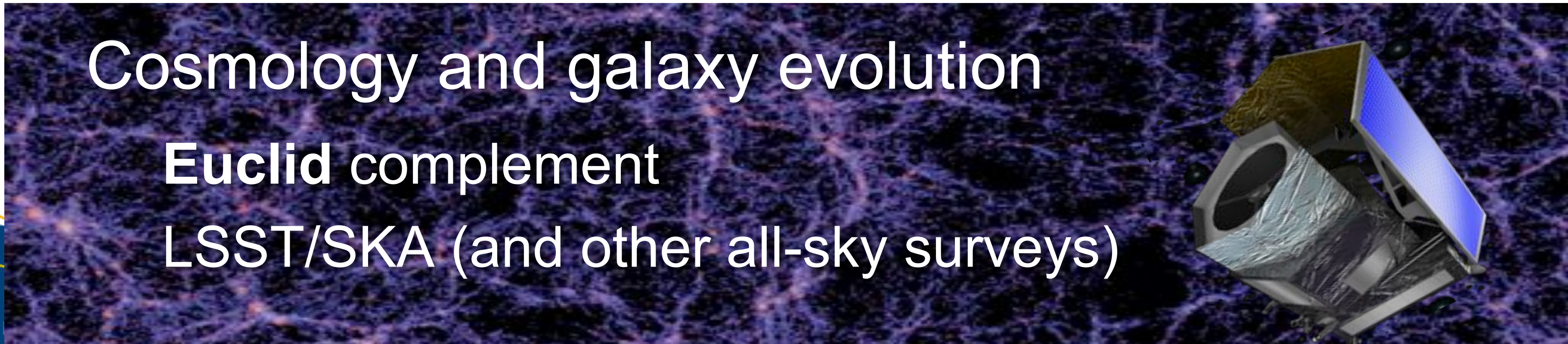


How are we going to run 4MOST?

- Consortium Surveys will ensure whole hemisphere covered with at least ~120 minutes total exposure time
- Each exposure 20 minutes, repeats possible
- Total exposures times per target between 20 and 120 min (and more) possible
- Areas with more targets visited more than 120 min

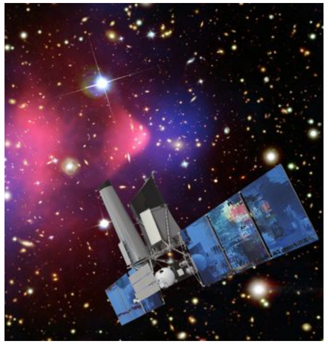


Main science drivers

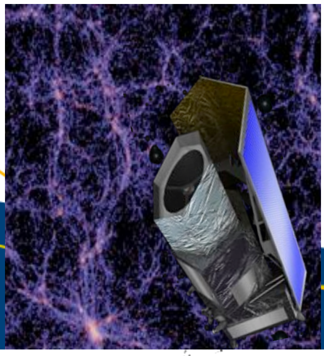


Design Reference Surveys

- Milky Way halo R>5000 (~2M objects
  - Chemo-dynamics streams
- Milky Way halo R>20,000 (~ 0.2M objects)
  - Chemical evolution of accreted components
- Milky Way disks/bulge R>5000 (~10M objects)
  - Chemo-dynamics of bulge/disks
- Milky Way disks/bulge R>20,000 (~1.5M objects)
  - Chemical evolution in situ components

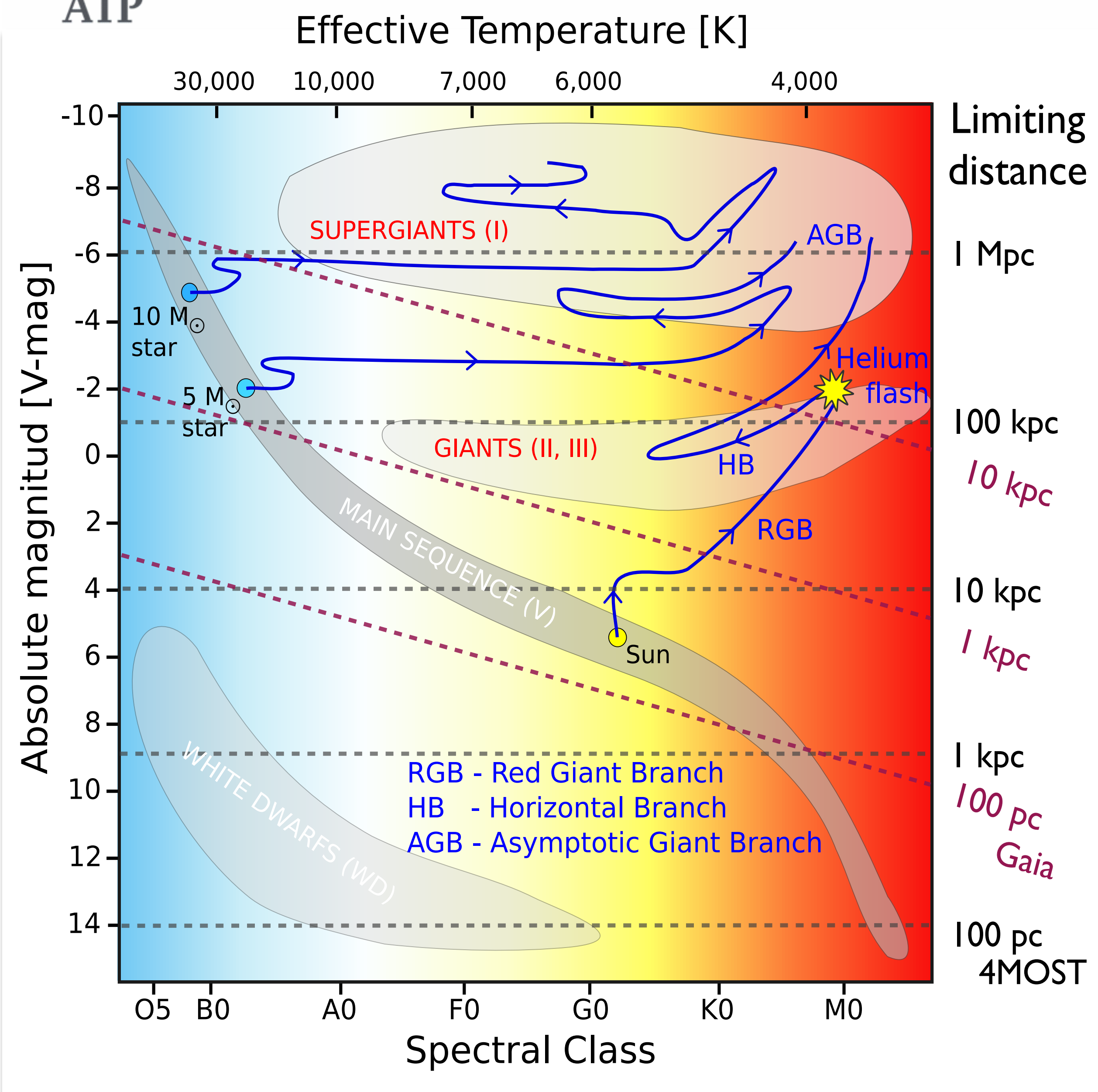


- eROSITA galaxy clusters (~50,000 clusters, ~2.5M objects)
  - Dark Energy and galaxy evolution
- eROSITA AGN (~1M objects)
  - Evolution of AGN and the connection to their host galaxies



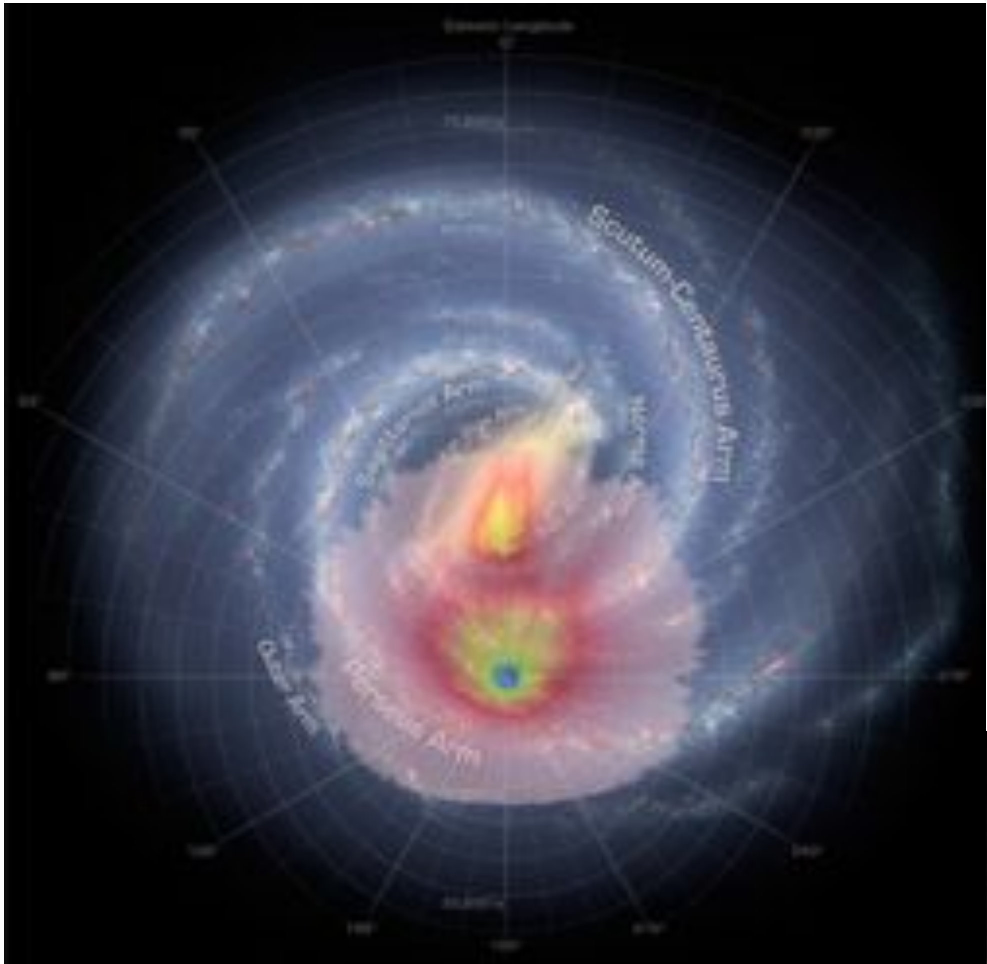
- Extra-galactic/BAO survey (~10M objects)
  - Luminous red and blue galaxies survey

Gaia needs spectroscopic follow-up to achieve its full potential



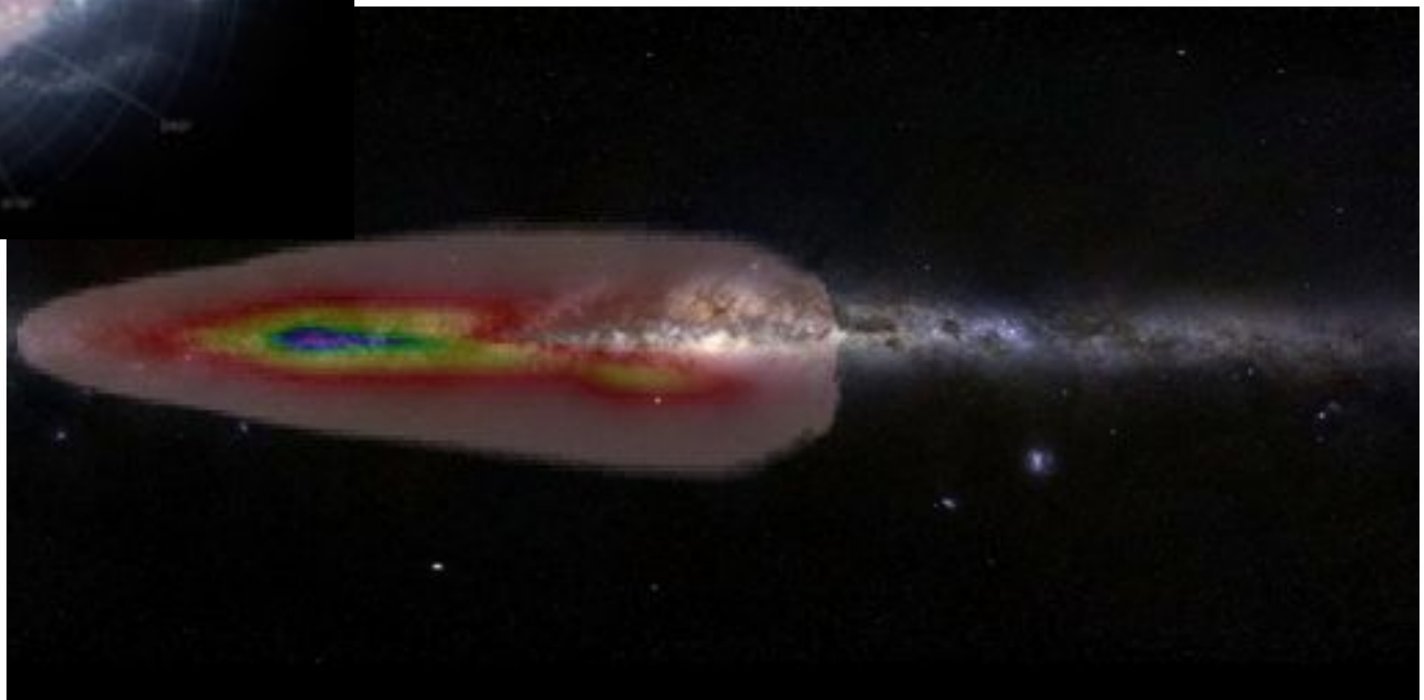
4MOST extents the Gaia volume by 1000x in the red and 1 million in the blue!

Cover the bulge/halo interaction and the Magellanic Clouds



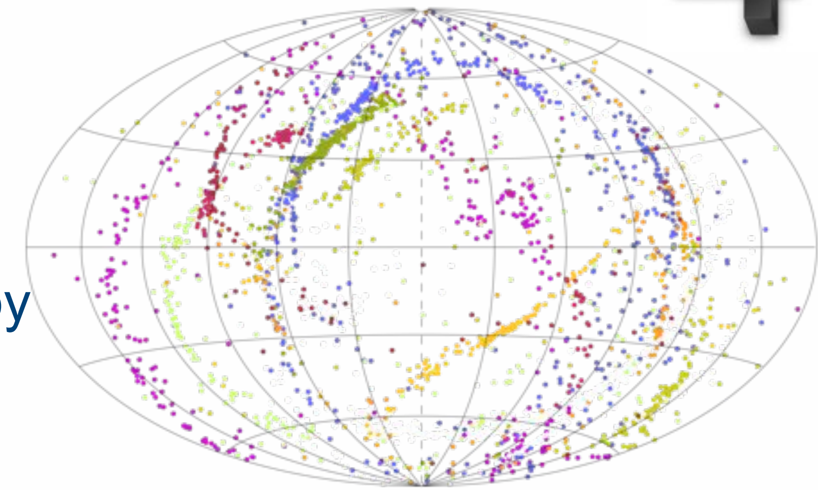
Gaia astrometric detections

- Accurate radial velocities of Gaia will cover only Solar vicinity

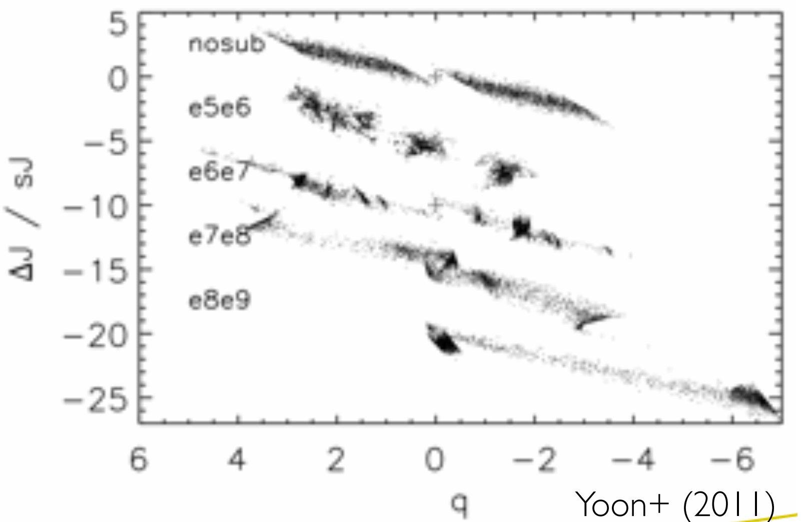


Near-field cosmology with Milky Way chemo-dynamics

- Determine the Milky Way 3D potential to ~100kpc
- Mass spectrum of Dark Matter subhalos by the kinematic imprint on cold streams
- Measure the effect of baryons:
  - has there been adiabatic contraction?
  - is there a disk-like DM component?
- Chemical abundance substructure Milky Way halo
- Chemical abundances of very first stars
- Requirements for |b|>25°:
  - ~2M objects at R~5000 to m_V=20
  - ~0.2M objects at R~20,000 to m_V=16



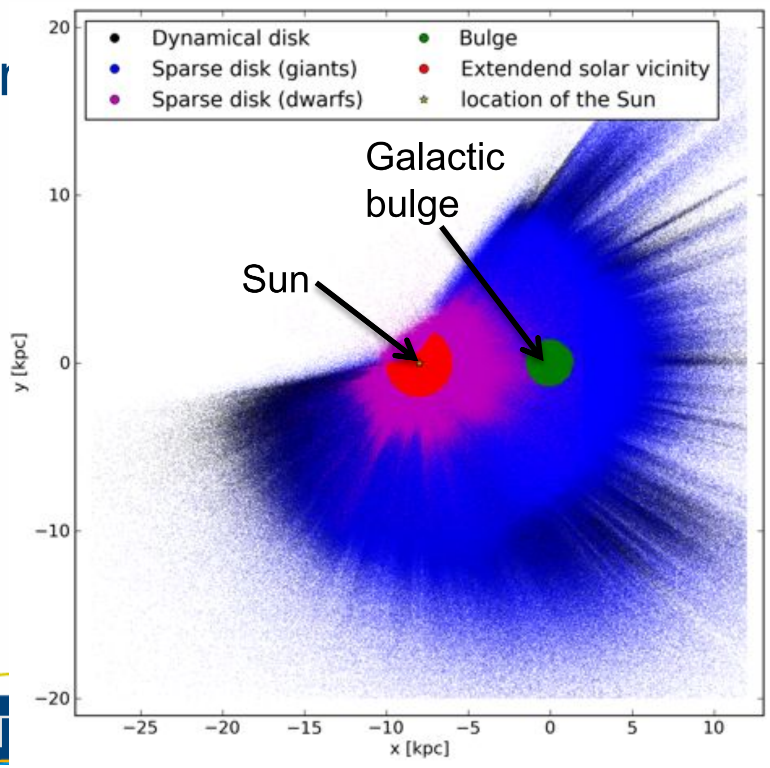
Cooper+ (2010)



Yoon+ (2011)

Dissect the Assembly history of the Milky Way bulge and disks

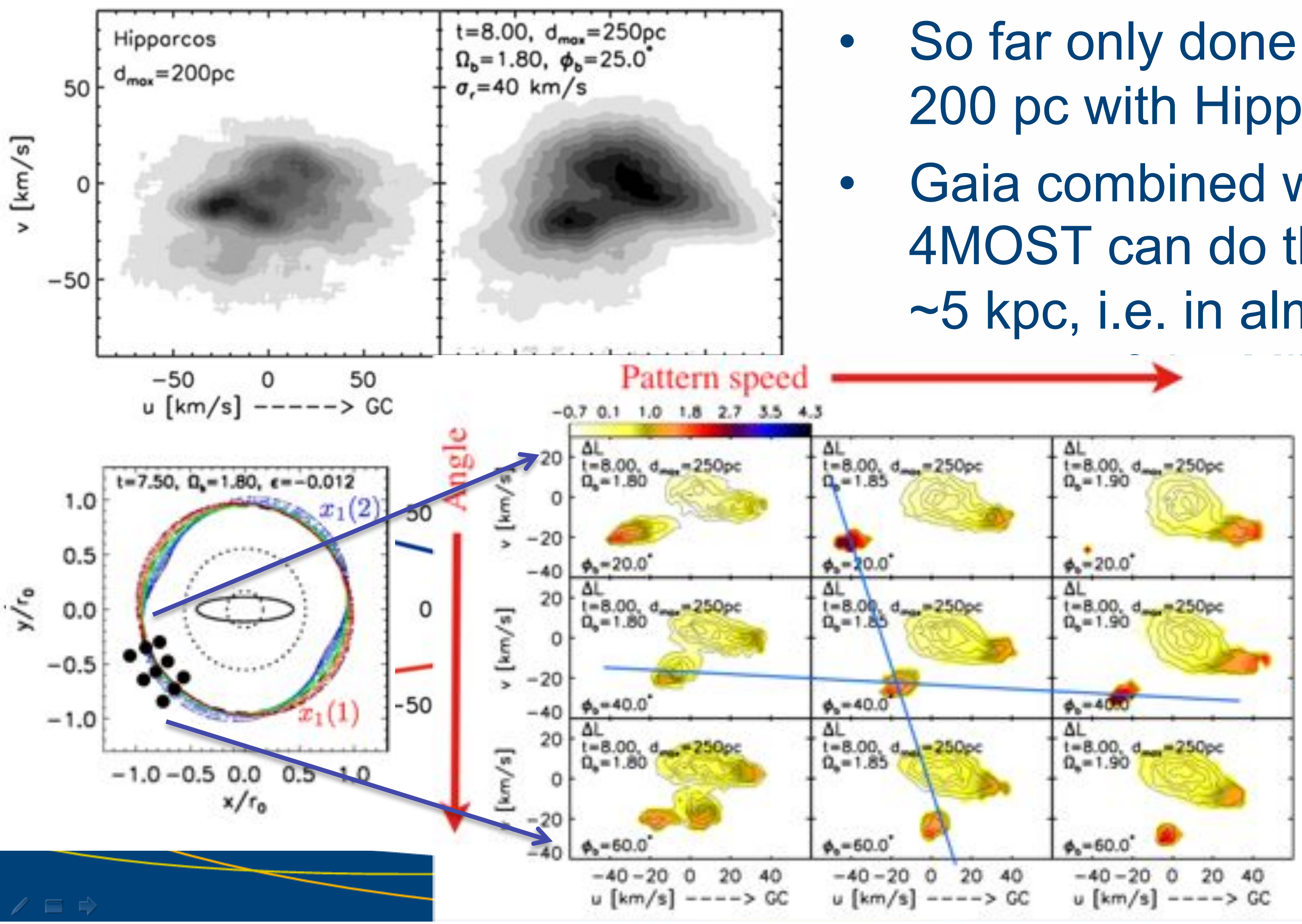
- Detailed 6D chemo-dynamics of bar/spiral structure in disks
- Chemo-dynamical formation history of the bulge
  - how much is a classical merger remnant versus disk migration
- Formation mechanisms of the thickened disk (in situ formation, heating, accretion, migration, etc.)
- Quantify the importance secular evolutio[n], resonances, radial migration in the disks
- Early chemical evolution in bulge/disk (rare stars!)
- Requirements (all sky):
  - ~10M objects at R~5000 to m_V=20
  - ~2M objects at R~20,000 to m_V=16



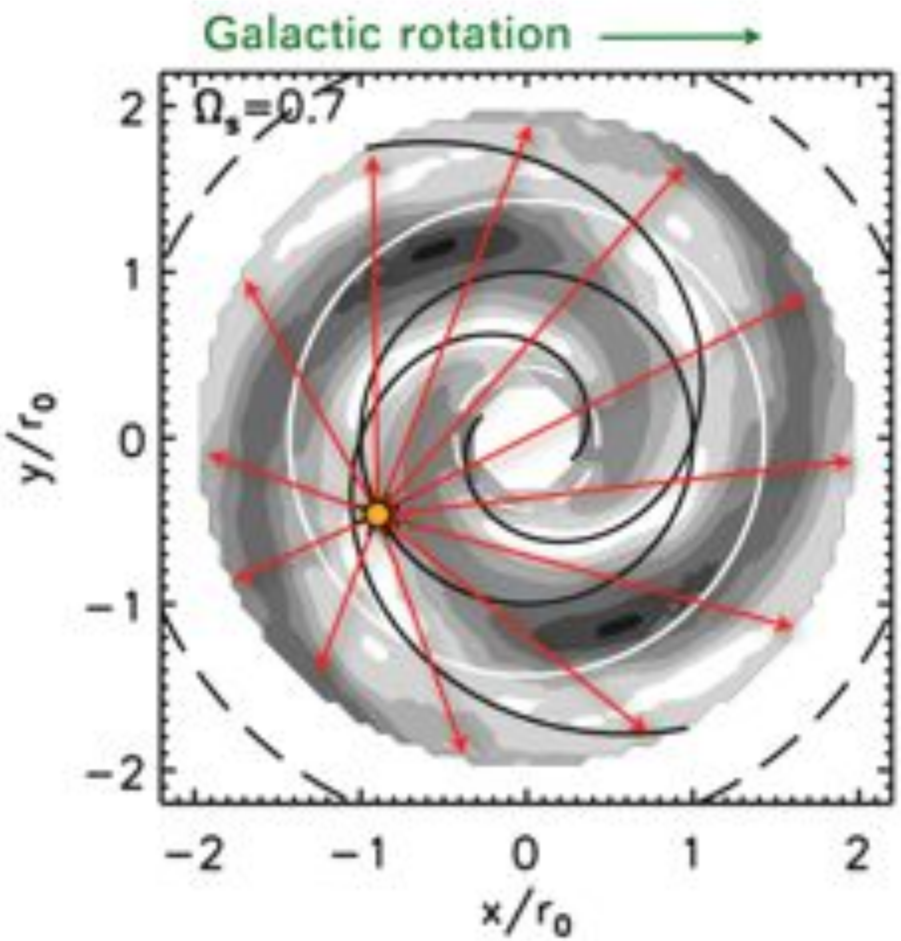
Milky way bar creates moving groups in velocity distribution

- So far only done out to 200 pc with Hipparcos
- Gaia combined with 4MOST can do this to ~5 kpc, i.e. in almost a

ky Way



Study global structure and abundance gradients with faint Giants sample



- Due to the complexity of asymmetries expected, such as multiple spiral patterns, we need to survey the entire disk
- Strong variation in the migration efficiency expected with galactic radius
- Mergers create thick disks flares and thus we need to know the thick disk scale-height as a function of Galactic radius

eROSITA follow-up

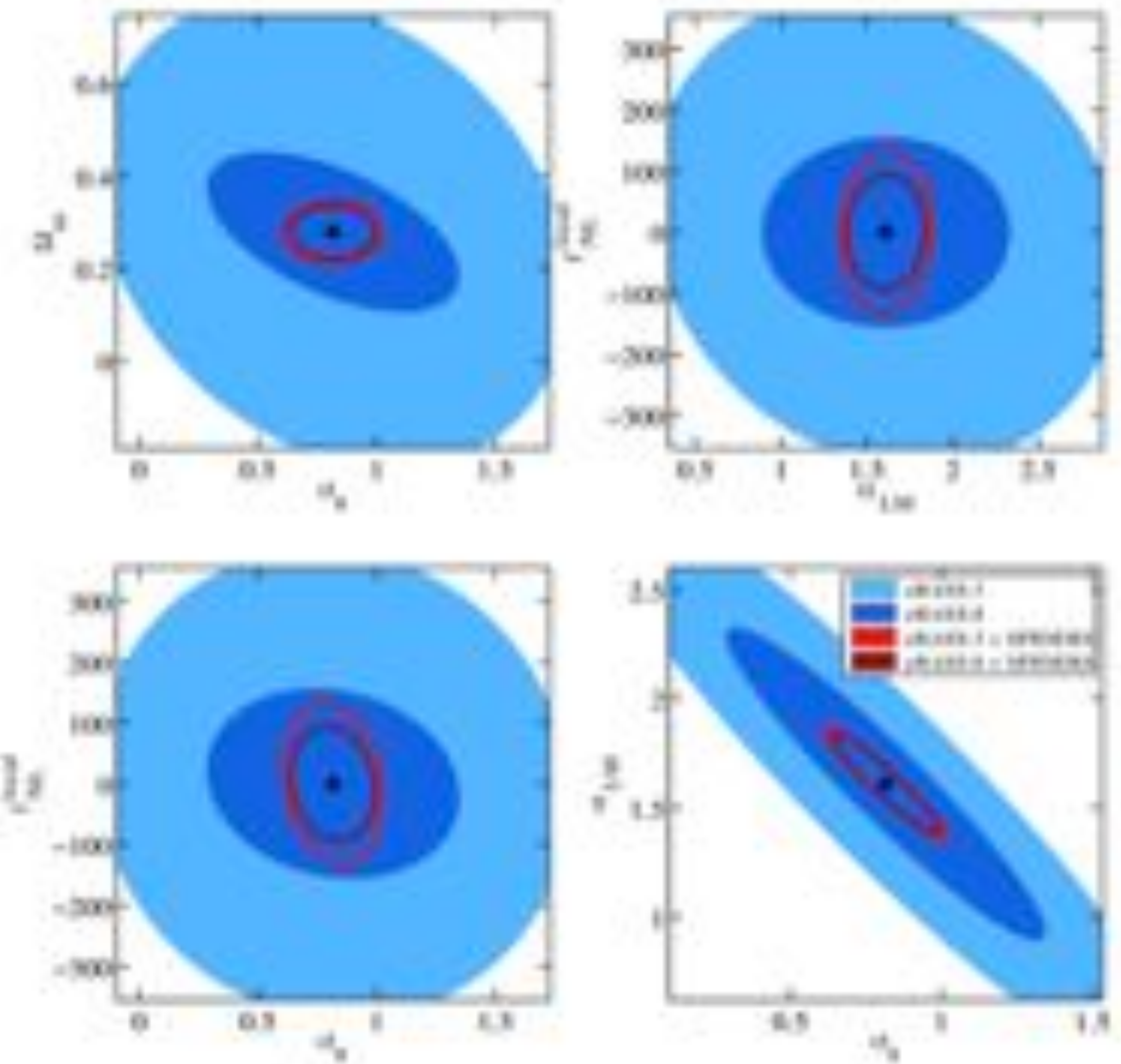
- German - Russian mission
- 0.3-4.5 keV, beam ~25”
- 8x all sky survey (4 year) + 3 years pointed observations
- Sky divided in two, German and Russian half
- Launch 2014
- Mission goals:
  - Dark Matter and Energy, growth of structure
  - X-ray detection of 100000 galaxy clusters
  - X-ray detection of 3 million point sources (AGN and Galactic)

Merloni talk Thursday

eROSITA needs spectroscopic follow-up to reach its full potential

- X-ray selected galaxy clusters:
  - Competitive cosmological constraints using both growth rate of most massive over-densities and topology of large scale structure
  - Calibrate the L_X – M relation to z~0.8 using cluster velocity dispersions
  - Evolution of galaxies in dense environments
  - Requirements:
    - R~500, redshifts to z~1 @ r~22 mag
- X-ray selected AGN:
  - Cosmology from large scale structure formation
  - Evolution of active galaxies up to z=5
  - Galaxy–Black Hole co-evolution relations to z=3
  - Properties of gas around AGN
  - Requirements:
    - R~3000, emission line redshifts to z=5

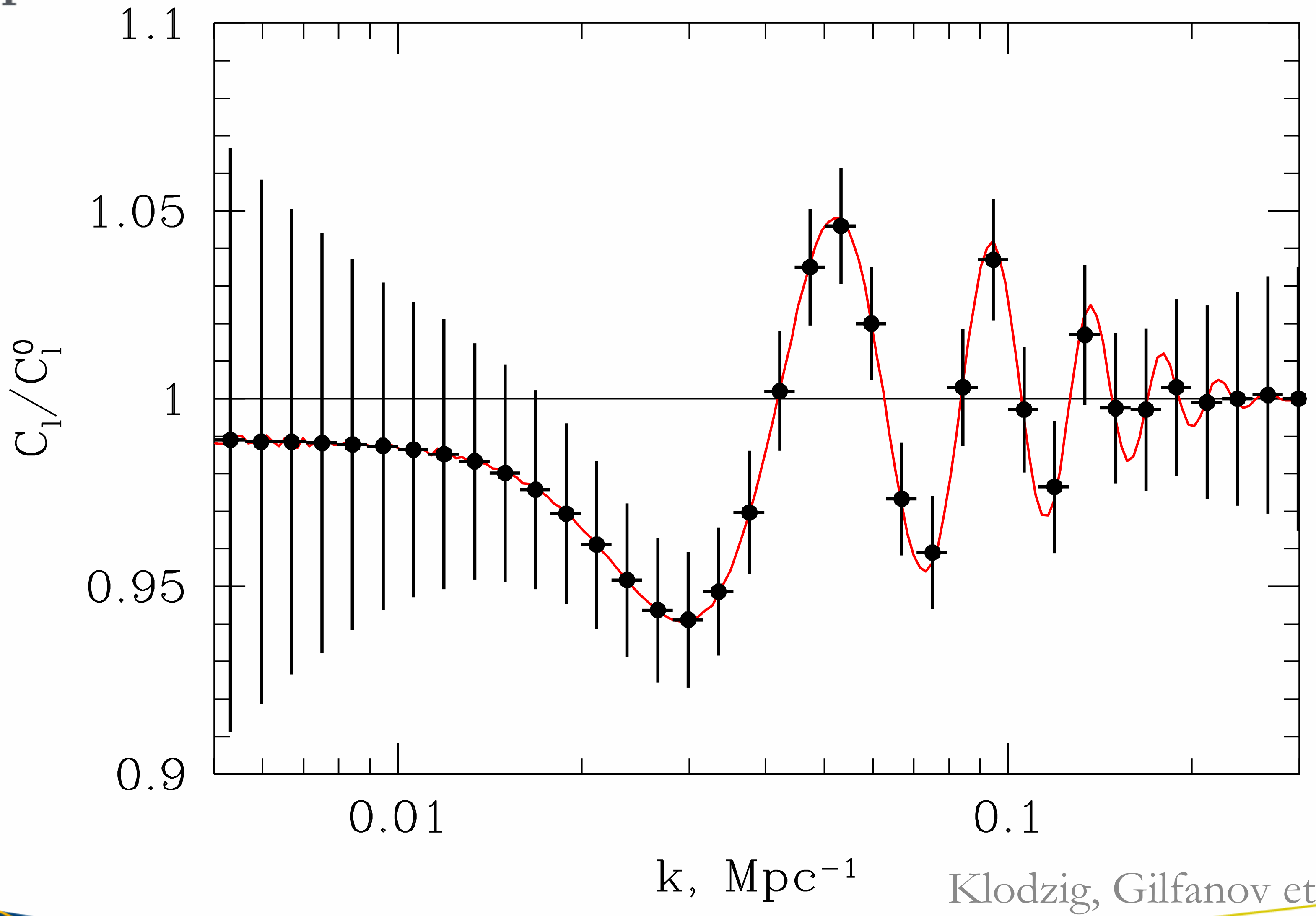
Cosmological constraints by obtaining redshifts and velocity dispersions of galaxy clusters



- Using both cluster abundance and clustering, but no additional constraints
- Blue: no redshifts
- Red: with redshifts

- This is for 8000 clusters, goal for 4MOST is 50,000 clusters

BAO with X-ray selected AGN



Strengths of 4MOST

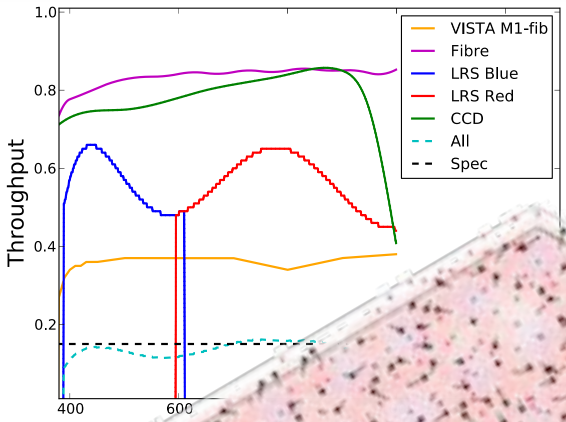
- Dedicated spectroscopic survey facility
- Full, continues optical wavelength coverage
- All-sky coverage
- High multi-plex
- Power of 4m-class telescope exposing several hours

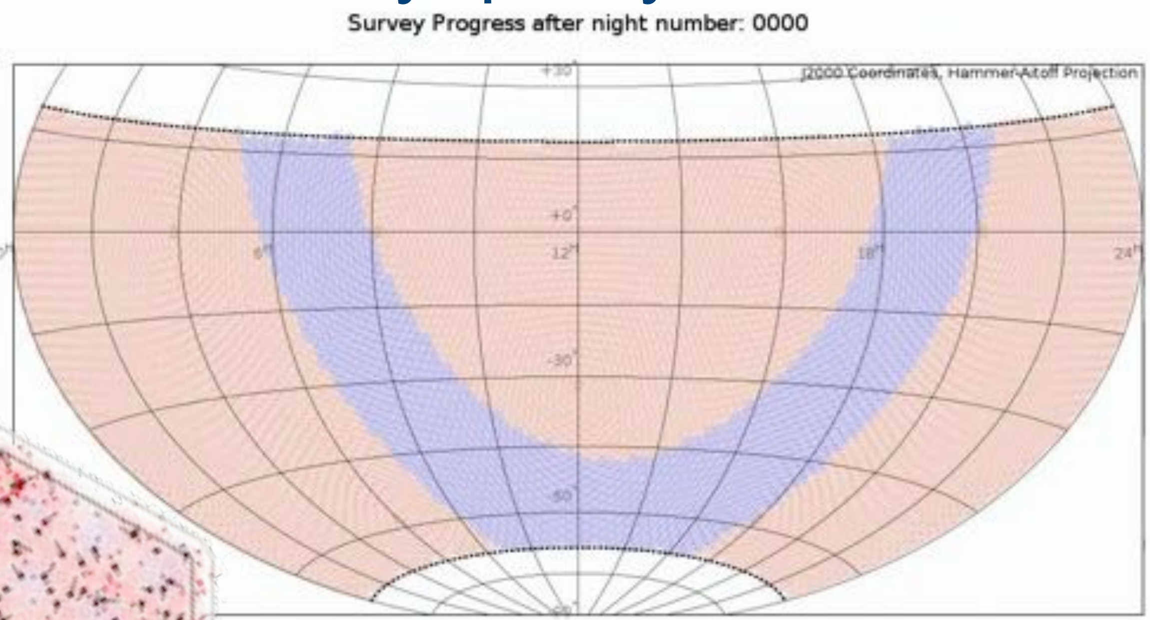
4MOST enables high quality statistical surveys of 10^3 to 10^7 objects, both all-sky and deep

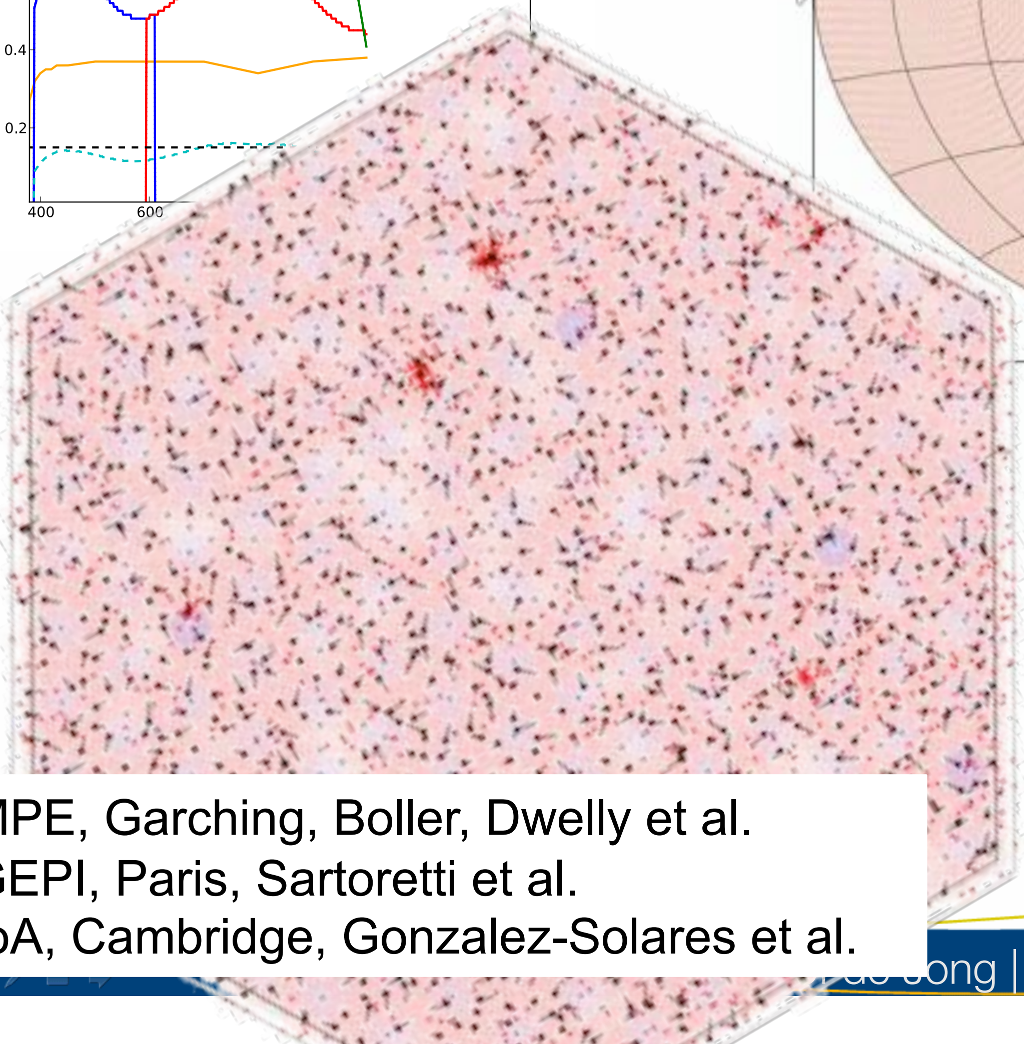
Other Science feasible with thousand to million object surveys

- Follow-up of LSST and Euclid transients
- Support Euclid photometric redshift calibrations
  - (but not to 99.5% completeness at I=24.5)
- Star formation history of the Milky Way from 100,000 White Dwarfs
- Ages of astro-seismology objects from e.g. CoRoT, Kepler
- Nature of peculiar variable stars discovered by Gaia, LSST, Euclid
- High resolution spectroscopy survey of Open Clusters
- Radial velocities time series of low mass binary systems
- Galaxy evolution from redshift surveys to z~1.5
- Nature of radio galaxies from SKA
- Insert your idea here

Simulate throughput, fibre assignment, survey strategy and verify total survey quality







- Trade-off configurations:
  - Field-of-View
  - Fibre count
  - Positioner concepts
  - High/low resolution
  - Exposure time/overhead
  - Survey strategy

MPE, Garching, Boller, Dwelly et al.
GEPI, Paris, Sartoretti et al.
IoA, Cambridge, Gonzalez-Solares et al.

Large Area Spectroscopic Surveys Science with 4MOST **Workshop**

- Program:
  - 4MOST facility capabilities
  - Galactic, extra-galactic, cosmology science
  - Discussion of Consortium and Community science
- 13-15 November 2012

  at AIP, Potsdam
- Registration at **workshop.4most.eu**

  by Nov 1

Program

Session 1: 4MOST and spectroscopic surveys

- 4MOST instrument, technical capabilities
- Design Reference Surveys, survey strategies, and operational modes
- 4MOST Facility Simulator
- WEAVE and options for all-sky surveys
- Experience from RAVE, SDSS, Gaia-ESO, GAMA
- Discussion

Session 2: Galactic system surveys

- 4MOST Milky Way Halo & stellar streams Design Reference Surveys
- 4MOST Milky Way Disk, Bulge & Bar Design Reference Surveys
- Surveys (e.g., Gaia, VISTA, VST)
- Other Stellar Populations (White Dwarfs, X-ray luminous, variables, transients, Planetary Nebula, Open Clusters)
- Nearby galaxies (LMC, SMC)
- Discussion

Session 3: Extra-galactic and cosmology surveys

- 4MOST eROSITA AGN and Galaxy Clusters Design Reference Surveys
- 4MOST Large Scale Structure and Cosmology Design Reference Surveys
- Surveys (e.g., Euclid, VISTA, VST, DES, ASKAP, MeerKAT)
- Galaxy populations and their evolution (radio, sub-mm, IR, optical, UV, X-ray)
- Transients (supernovae and GRBs)
- Discussion

Conceptual Design Study for ESO

- Now: Conceptual Design study, completed by Feb 2013
- Selection: 4MOST/MOONS decided ~May 2013
- Goal: start all-sky *public* (consortium & community) surveys 2019
- Telescope: VISTA, 4m-class telescope
- Science: space mission follow-up: Gaia, eROSITA, Euclid
- Data: yearly public data releases with higher level data products
- Current specs:
  - Very high multiplex: ~2400 fibers
  - Full optical wavelength coverage: 390-950 nm
  - Large field-of-view: ⌀=2.6°
- 4MOST provides in a 5 year, all-hemisphere survey
  - $>20 \times 10^6$ spectra @ R~5000 to m_V~20 mag at S/N=20
  - $> 1 \times 10^6$ spectra @ R~20,000 to m_V~16 mag at S/N=50
- Your input welcome at this stage!