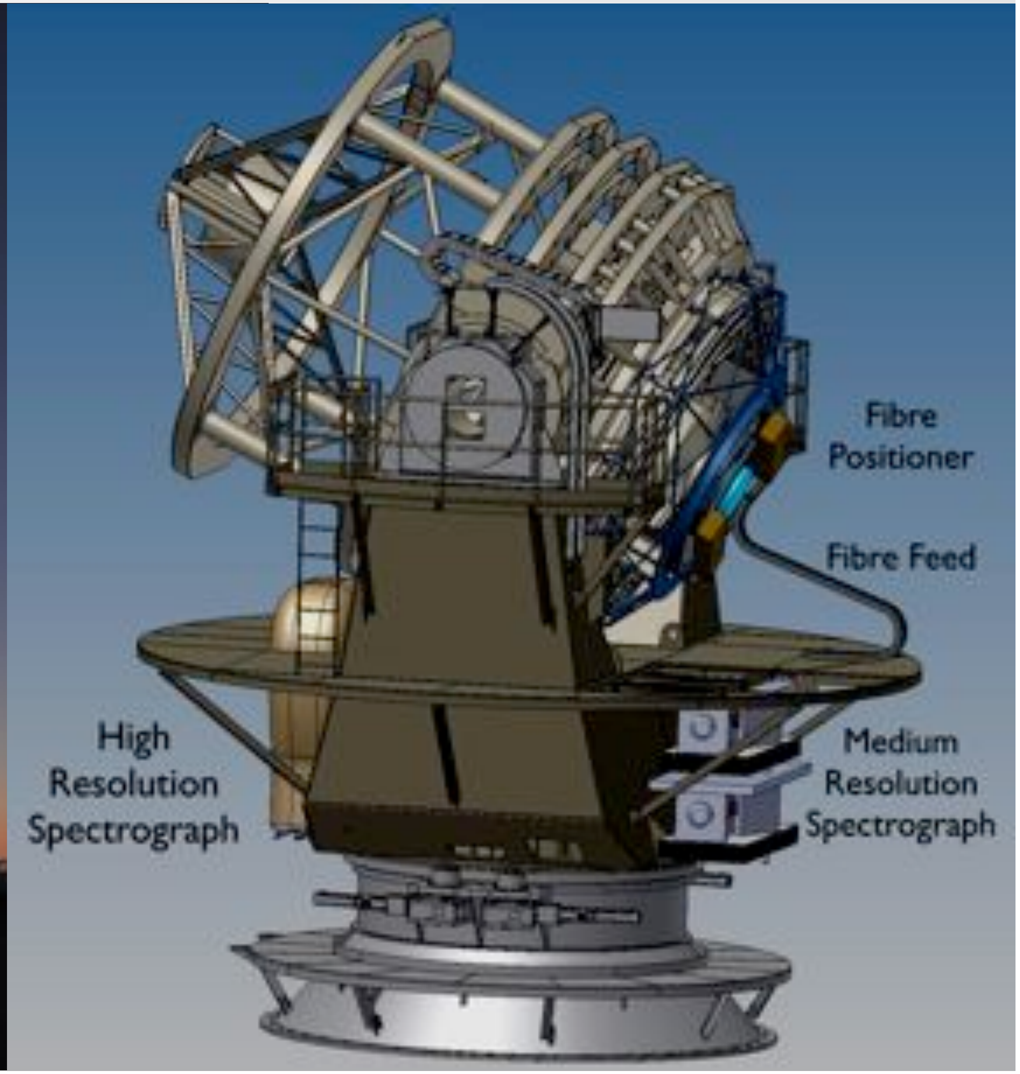
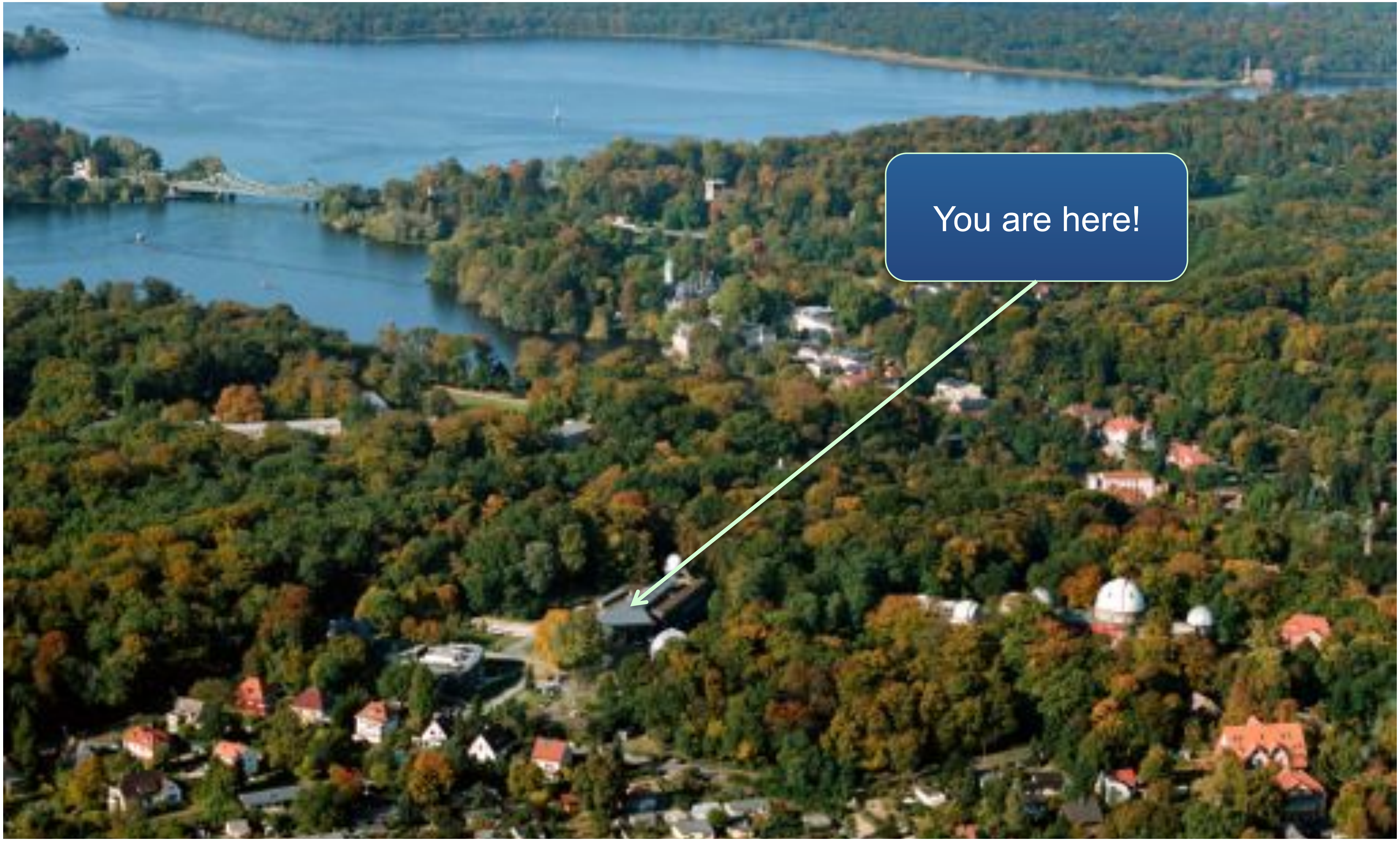
Large Area Spectroscopic Surveys Science with 4MOST

Roelof de Jong (AIP)
4MOST PI

www.4most.eu



Welcome in Potsdam!
Welcome at the AIP



Goal of the meeting

- Inform the broader (ESO) astronomical community about the 4MOST facility development
- Foster feedback on the Key Science Surveys that have been developed by the 4MOST consortium
- Identify additional science cases that can be done with 4MOST
- Checking whether the current design and operations model fits many (4most) other science cases
- Develop paths for further community involvement in 4MOST

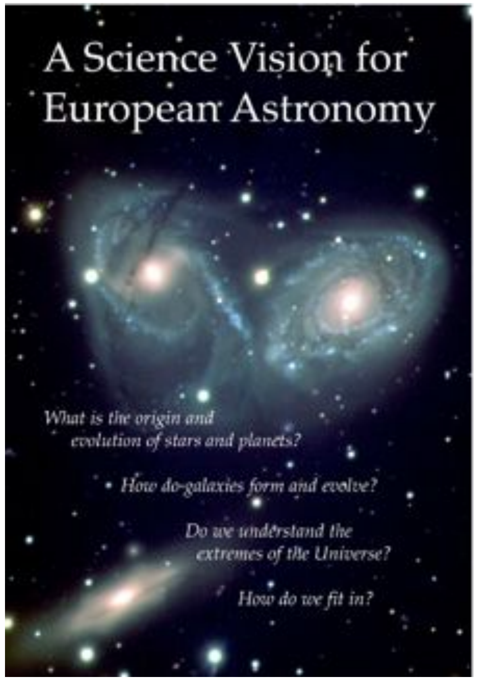
Conceptual Design Study for ESO

- Now: Conceptual Design study, completed by Feb 1, 2013
- Selection: 4MOST/MOONS decided ~May 2013
- Science: space mission follow-up: Gaia, eROSITA, Euclid
- Telescope: VISTA, 4m-class telescope
- Goal: start all-sky parallel *public* surveys 2019
- Data: yearly public data releases with higher level data products

- Current concept design:
  - Very high multiplex: ~2400 fibers
  - Full optical wavelength coverage: 390-950 nm
  - Large field-of-view: ⌀=2.5°
- 4MOST provides in a 5 year, all-hemisphere survey
  - >20 $\times 10^6$ spectra @ R~5000 to m_V~20 mag at S/N=10
  - > 1 $\times 10^6$ spectra @ R~20,000 to m_V~16 mag at S/N=50

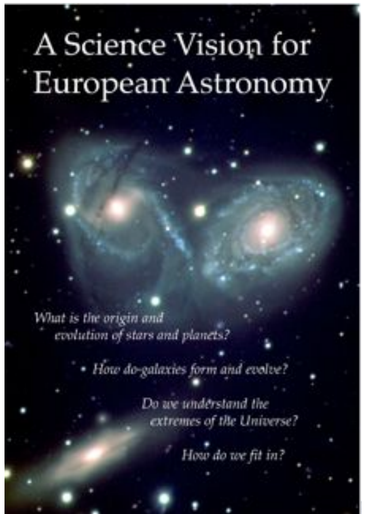
Background: EU strategic docs

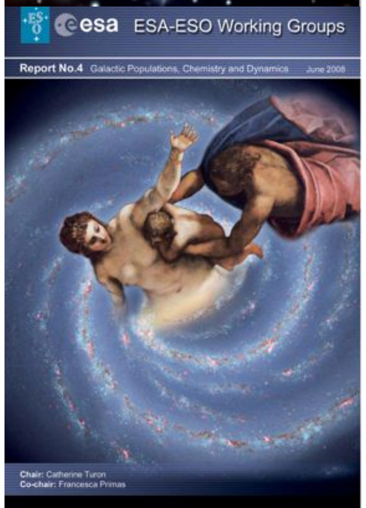
- De Zeeuw & Molster 2007: A Science Vision for European Astronomy (ASTRONET)
  - Extreme Universe (Dark Energy & Matter, Black holes)
  - Galaxy Formation & Evolution
  - Origin of Stars and Planets
  - Solar System



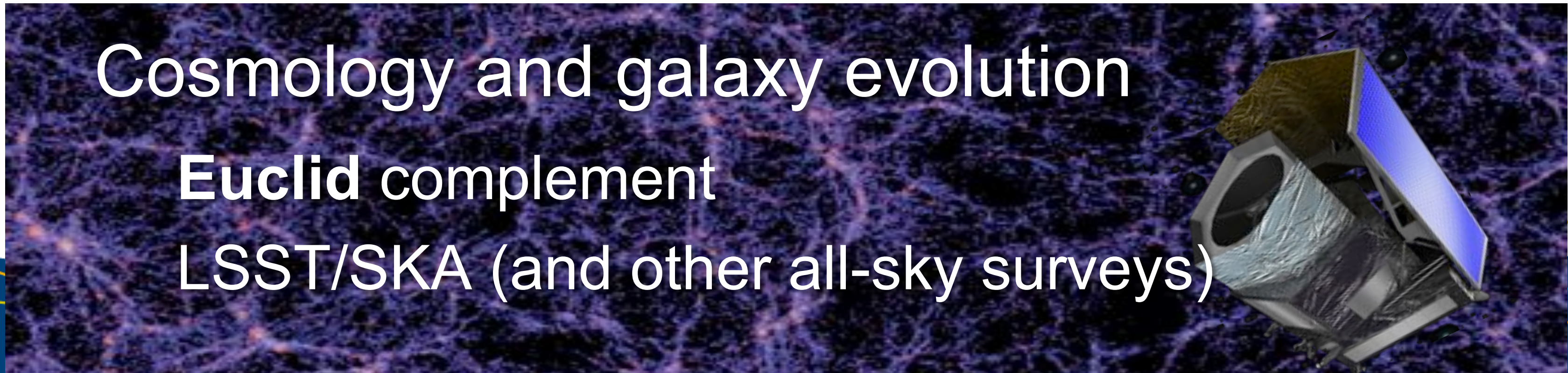
Background: EU strategic docs

- De Zeeuw & Molster 2007: A Science Vision for European Astronomy (ASTRONET)
  - Extreme Universe (Dark Energy & Matter, Black holes)
  - Galaxy Formation & Evolution
  - Origin of Stars and Planets
  - Solar System
- Turon et al. 2008: ESA-ESO Working Group on Galactic populations, chemistry and dynamics
  „Blue multiplexed spectrograph on 4 or 8m class telescope“
- Bode et al. 2009: ASTRONET Infrastructure Roadmap
  „A smaller project, but again of high priority, is a wide-field spectrograph for massive surveys with large optical telescopes.“
- Drew et al. 2010: Strategic Review on Europe’s 2-4m telescopes over the decade to 2020 (ASTRONET/OPTICON)
  „Optical wide-field spectrograph on 4m telescopes (N+S)
  R ~ 5000 for 500+ objects/ sq.deg over a field ≥ 1 sq.deg
  R ≥ 30000 for 100+ objects over a field ≥ 2 sq.deg.

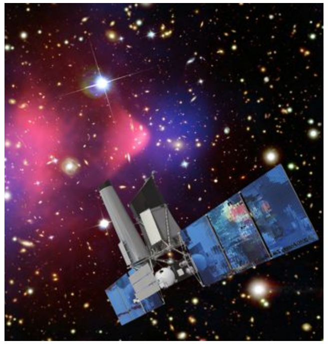


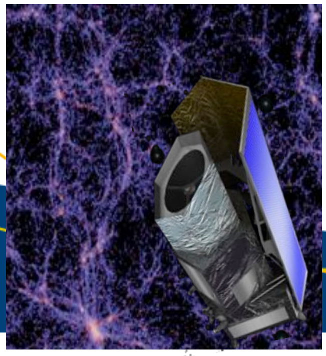


Main science drivers



Design Reference Surveys
(drive requirements on facility)





- 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

Running in parallel all the time!

What shall 4MOST deliver?

- 4MOST shall be able to obtain:
  - *Abundances* of up to 15 chemical elements
    - R~20000 spectra of 15.5 r-mag stars with S/N=140 per Ångström in <2h
  - *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 in <1h
  - *Redshifts* of AGN and galaxies (also in clusters)
    - R~500 spectra of 22 r-mag targets with S/N=5 in <1h, >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

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

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

  minimal instrument changes, no significant time sharing

- ***4MOST runs experiments***:

  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:***

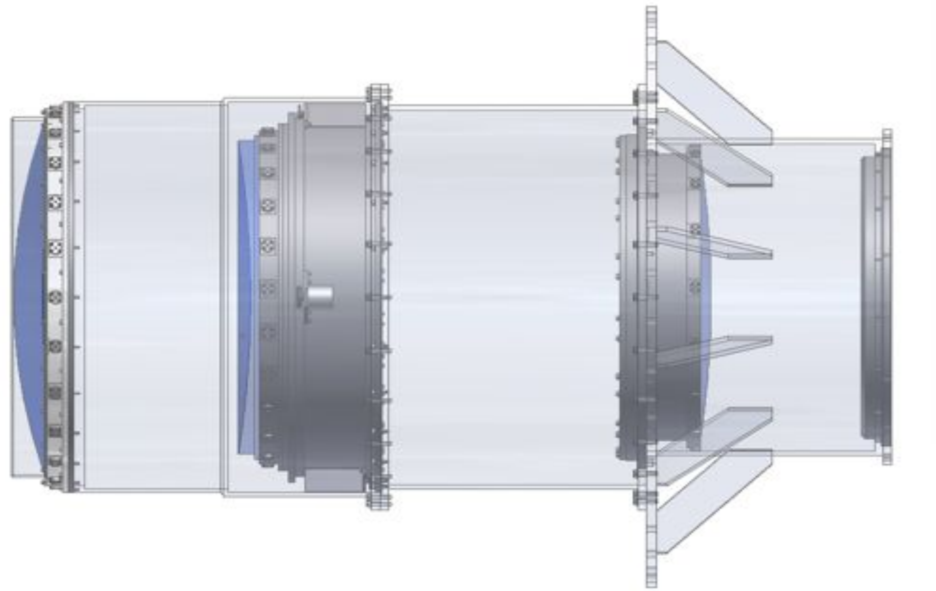
  all surveys public: raw data published immediately, higher-level data products in yearly Data Releases

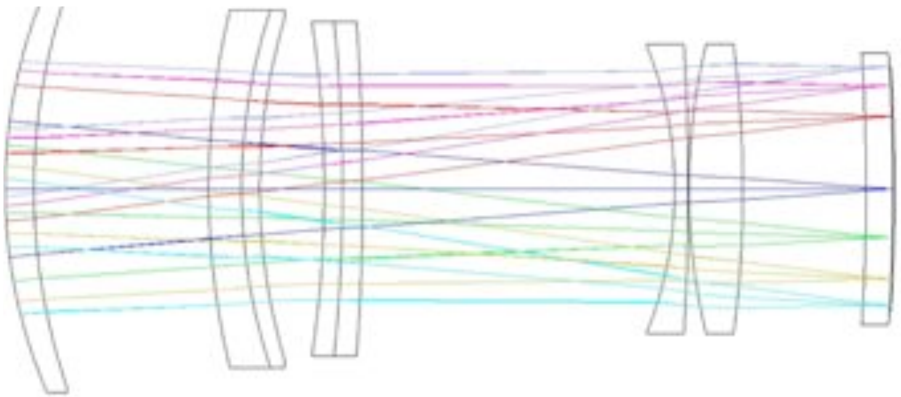
Instrument Specification

Specification	Concept Design
Field-of-View (hexagon)	4.25 degree^2 (⌀>2.5°)
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	>3
Area (5 year survey)	>2h x 20,000 deg^2
Objects (5 year survey)	>20x10^6
Start operations	Mid 2019

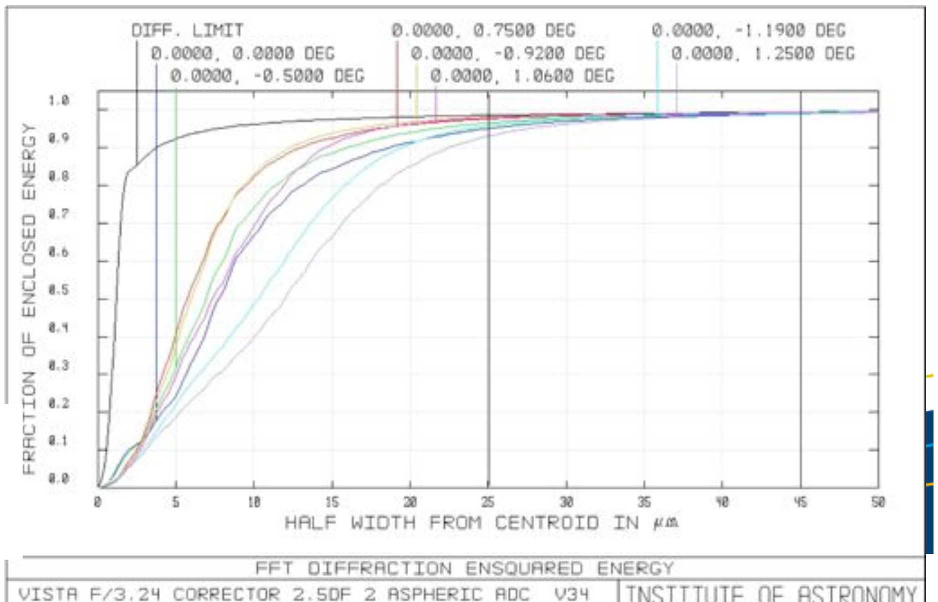
Wide-field corrector can be inserted into VISTA like IR camera

Wide-field corrector VISTA ⌀=2.5°

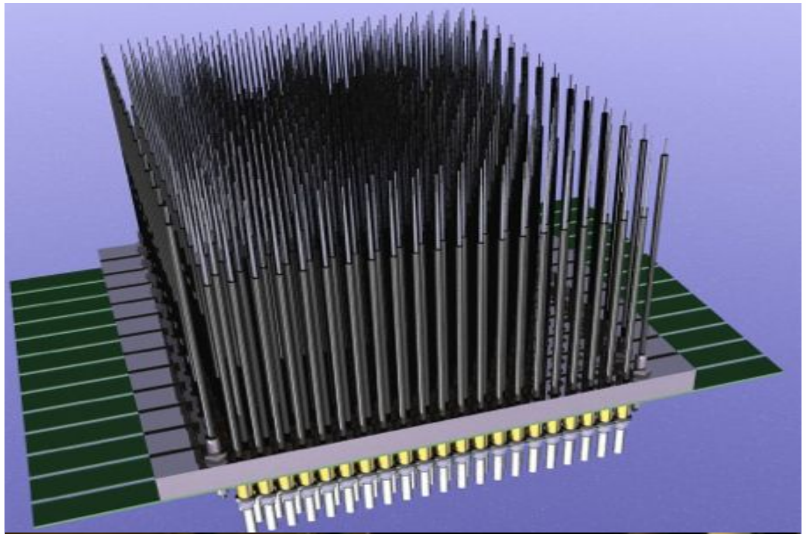


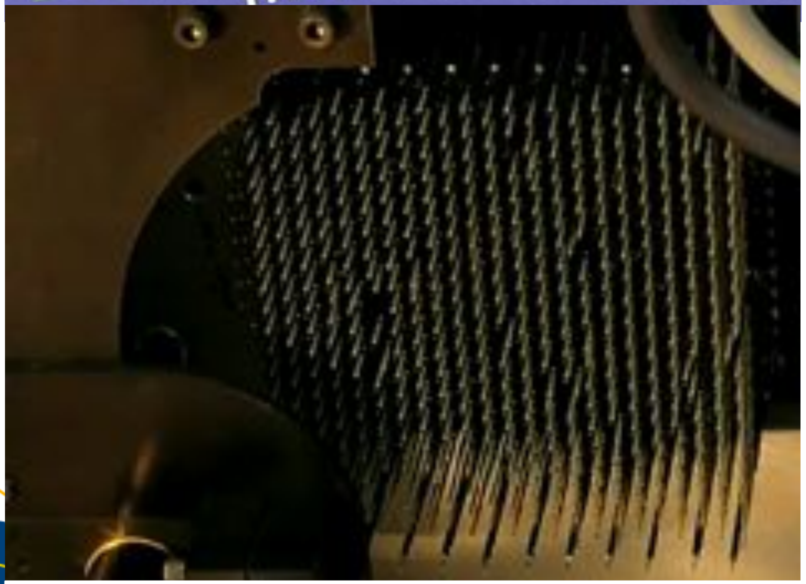


IoA Cambridge, King, Parry, Sun, et al.



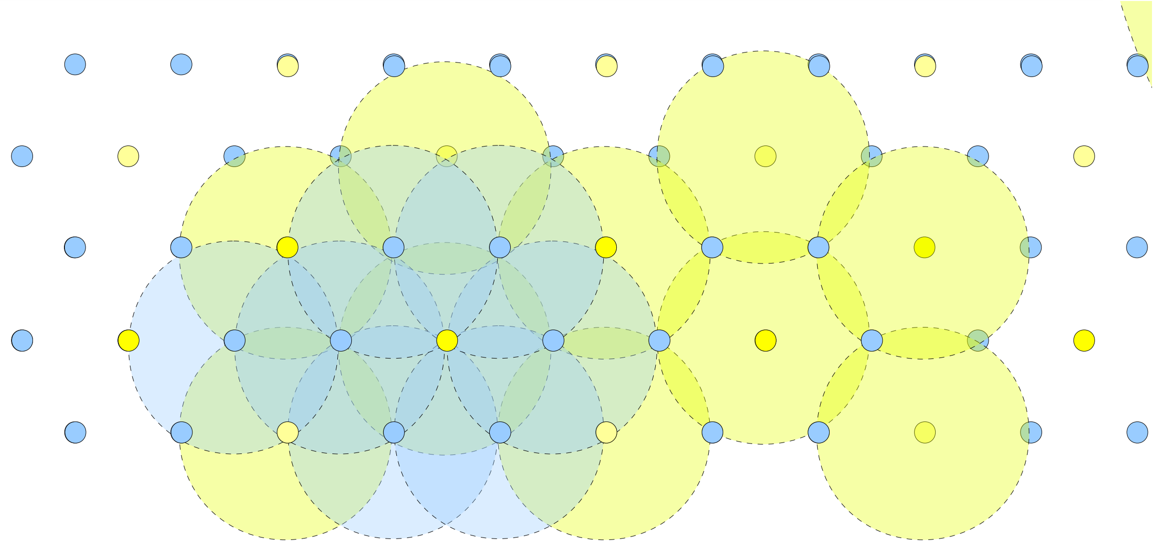
Echidna style positioner





FMOS Echidna on Subaru

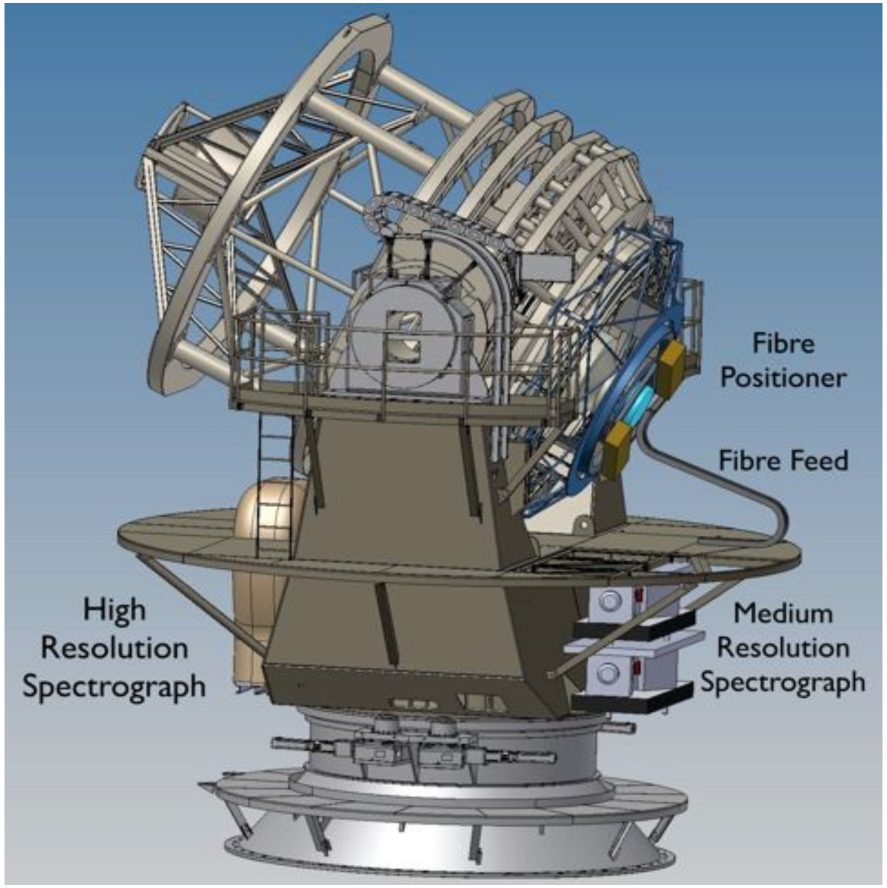
- Large, overlapping patrol areas enables
  - sparse fibres for high resolution spectrograph
  - clustered fibres (e.g. galaxy clusters)
- Pitch ~10 mm, Patrol R: ~1.2x pitch
- Reconfiguration time <1 min
- Proven technology



Positioner: AAO, Metrology & Control: AIP

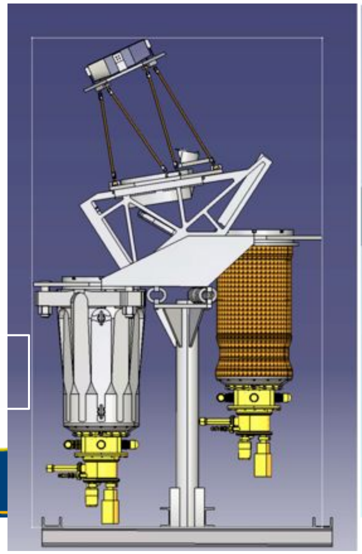
Fibre routing and spectrographs

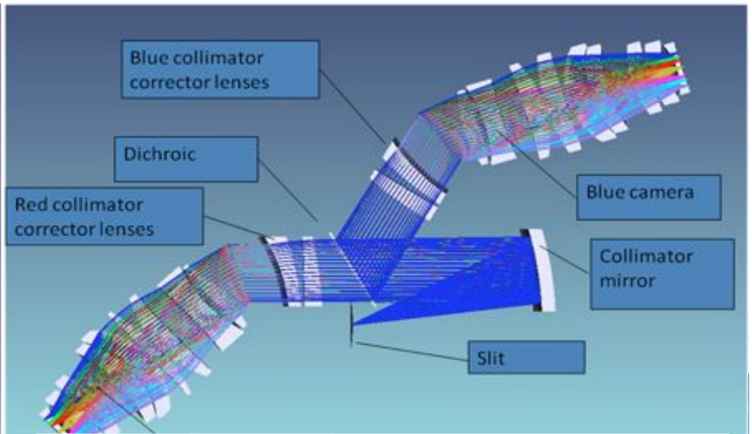
- Spectrographs gravitation invariant and outside dome environment
- Short fibre run (~10–15 m)
- Location High and Medium Resolution Spectrographs may be swapped (TBD)
- Fixed configuration spectrographs, high throughput with VPH gratings
- Two arm spectrographs, two 3k x 8k CCDs per arm



Fibres: AIP

High-Res Spectrograph: GEPI

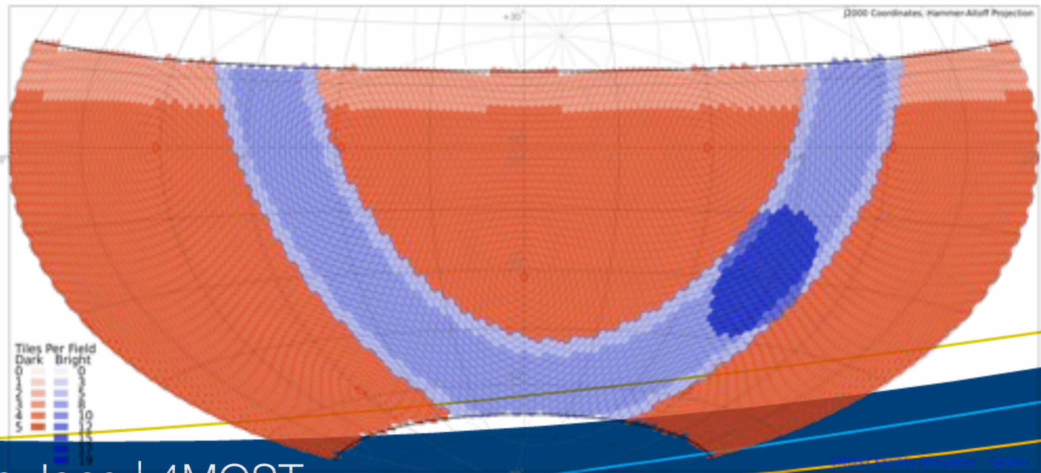




NOVA/ASTRON & RAL/Oxford, LSW

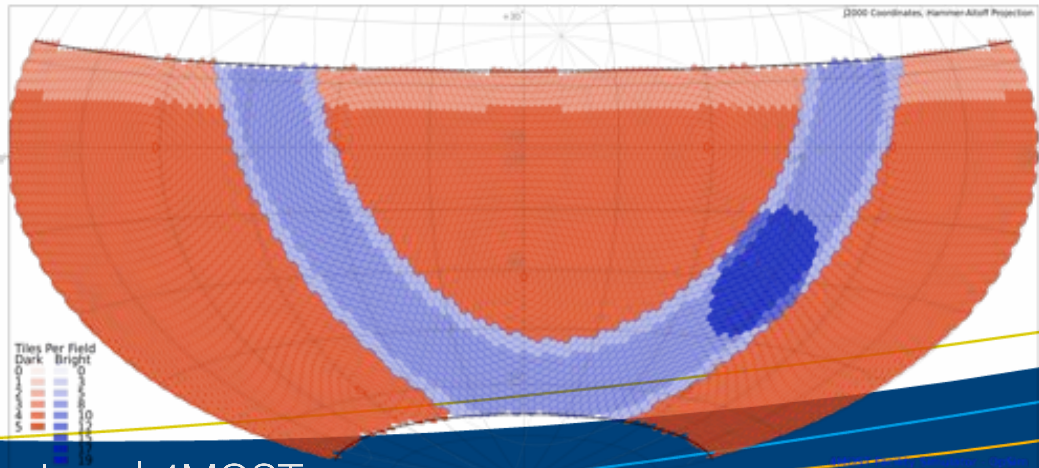
How are we going to run 4MOST?

- 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 targets all sky
- ***Add-on Surveys*** for smaller surveys
  - Small fraction fibers all sky
  - Dedicated small area

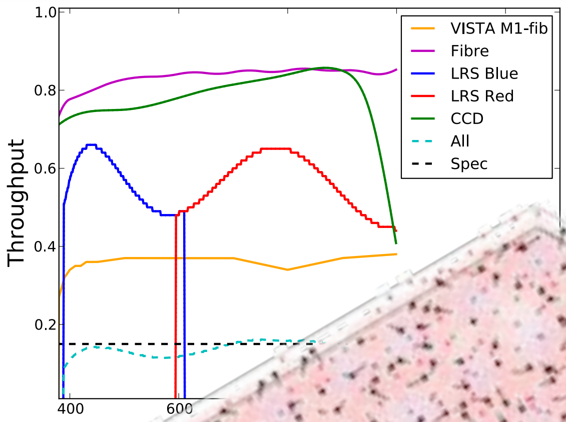


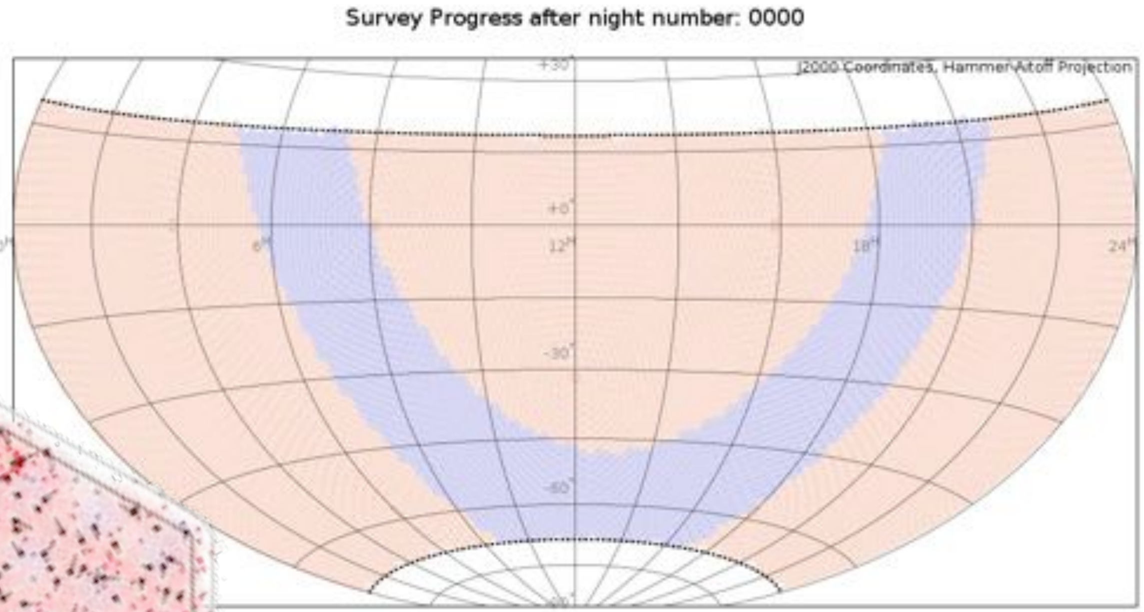
How are we going to run 4MOST?

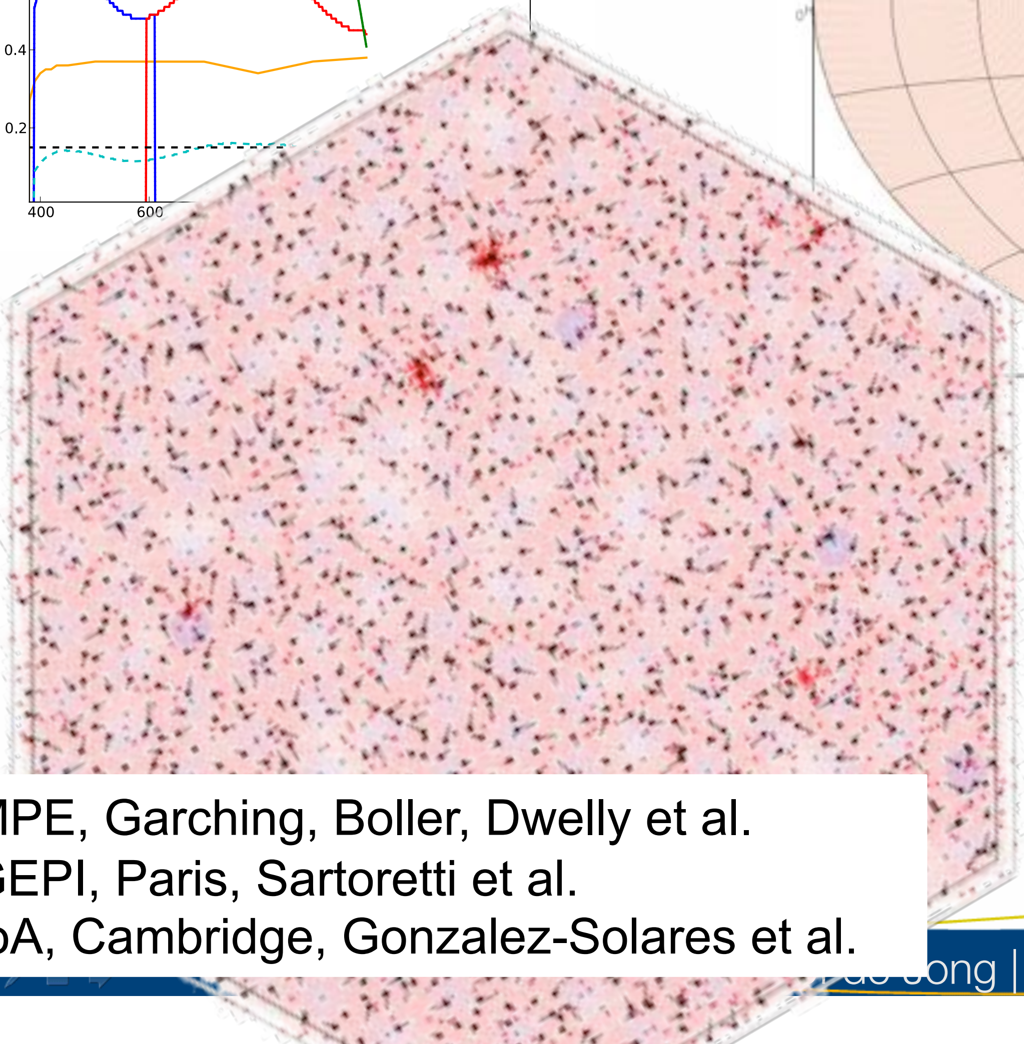
- Consortium Surveys will ensure whole hemisphere covered with at least ~120 minutes total exposure time
- Each exposure 20 minutes, repeats possible
- Total exposures times per target between 20 and 120 min (and more) possible
- Areas with more targets visited more than 120 min



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.

Other Science feasible with surveys with thousands to millions of objects

- Follow-up of LSST and Euclid transients
- Support Euclid photometric redshift calibrations
- 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
- Chemo-dynamics of Magellanic Clouds and other satellites
- 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

Strengths of 4MOST

- Dedicated spectroscopic survey facility
- Full, continues optical wavelength coverage at R>5000
- All-sky coverage
- High multiplex
- Power of 4m-class telescope exposing for several hours

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

Consortium effort

4MOST – 4-metre Multi-Object Spectroscopic Telescope

Roelof S. de Jong[a], Olga Bellido-Tirado[a], Cristina Chiappini[a], Éric Depagne[a], Roger Haynes[a,n], Diane Johl[a], Olivier Schnurr[a], Axel Schwope[a], Jakob Walcher[a], Frank Dionies[a], Dionne Haynes[a,n], Andreas Kelz[a], Francisco S. Kitaura[a], Georg Lamer[a], Ivan Minchev[a], Volker Müller[a], Sebastián E. Nuza[a], Jean-Christophe Olaya[a,n], Tilmann Piffl[a], Emil Popow[a], Matthias Steinmetz[a], Uğur Ural[a], Mary Williams[a], Roland Winkler[a], Lutz Wisotzki[a], Wolfgang R. Ansorge[b], Manda Banerji[c], Eduardo Gonzalez Solares[c], Mike Irwin[c], Robert C. Kennicutt, Jr.[c], David King[c], Richard McMahon[c], Sergey Koposov[c], Ian R. Parry[c], David Sun[c], Nicholas A. Walton[c], Gert Finger[d], Olaf Iwert[d], Mirko Krumpe[d], Jean-Louis Lizon[d], Mainieri Vincenzo[d], Jean-Philippe Amans[e], Piercarlo Bonifacio[e], Mathieu Cohen[e], Patrick Francois[e], Pascal Jagourel[e], Shan B. Mignot[e], Frédéric Royer[e], Paola Sartoretti[e], Ralf Bender[f], Frank Grupp[f], Hans-Joachim Hess[f], Florian Lang-Bardl[f], Bernard Muschielok[f], Hans Böhringer[g], Thomas Boller[g], Angela Bongiorno[g], Marcella Brusa[g], Tom Dwelly[g], Andrea Merloni[g], Kirpal Nandra[g], Mara Salvato[g], Johannes H. Pragt[h], Ramón Navarro[h], Gerrit Gerlofsma[h], Ronald Roelfsema[h], Gavin B. Dalton[i,o], Kevin F. Middleton[i], Ian A. Tosh[i], Corrado Boeche[j], Elisabetta Caffau[j], Norbert Christlieb[j], Eva K. Grebel[j], Camilla Hansen[j], Andreas Koch[j], Hans-G. Ludwig[j], Andreas Quirrenbach[j], Luca Sbordone[j], Walter Seifert[j], Guido Thimm[j], Trifon Trifonov[j], Amina Helmi[k], Scott C. Trager[k], Sofia Feltzing[l], Andreas Korn[m], Wilfried Boland[n]

[a]Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, D-14482 Potsdam, Germany, [b]RAMS-CON Management Consultants, Assling, Germany, [c] University of Cambridge, United Kingdom, [d] European Southern Observatory, Garching bei München, Germany, [e] GEPI, Observatoire de Paris-Meudon, CNRS, Univ. Paris Diderot, France, [f] Universität-Sternwarte München, Germany, [g] Max-Planck-Institut für extraterrestrische Physik, München, Germany, [h]NOVA-ASTRON, Dwingeloo, the Netherlands, [i] Rutherford Appleton Lab., United Kingdom, [j]Zentrum für Astronomie der Universität Heidelberg, Germany, [k] Kapteyn Astronomical Institute, Groningen, the Netherlands, [l] University of Lund, Sweden, [m] University of Uppsala, Sweden, [n]innoFSPEC, Potsdam, Germany, [o]University of Oxford, United Kingdom, [n]NOVA, the Netherlands

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

High-res spec http://arxiv.org/abs/1211.1406

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

Conceptual Design Study for ESO

- Now: Conceptual Design study, completed by Feb 1, 2013
- Science: space mission follow-up: Gaia, eROSITA, Euclid
- Selection: 4MOST/MOONS decided ~May 2013
- Telescope: VISTA, 4m-class telescope
- Goal: start all-sky *public* (consortium & community) surveys 2019
- Data: yearly public data releases with higher level data products
- Current design:
  - Very high multiplex: ~1600 fibers R>5000, ~800 fibres R~20,000
  - Full optical wavelength coverage: 390-950 nm
  - Large field-of-view: ⌀=2.5°
- 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!