THE WEAVE WIDE-FIELD MULTI-OBJECT SPECTROGRAPH ON THE WHT

And other WHT Spectroscopic Survey Opportunities

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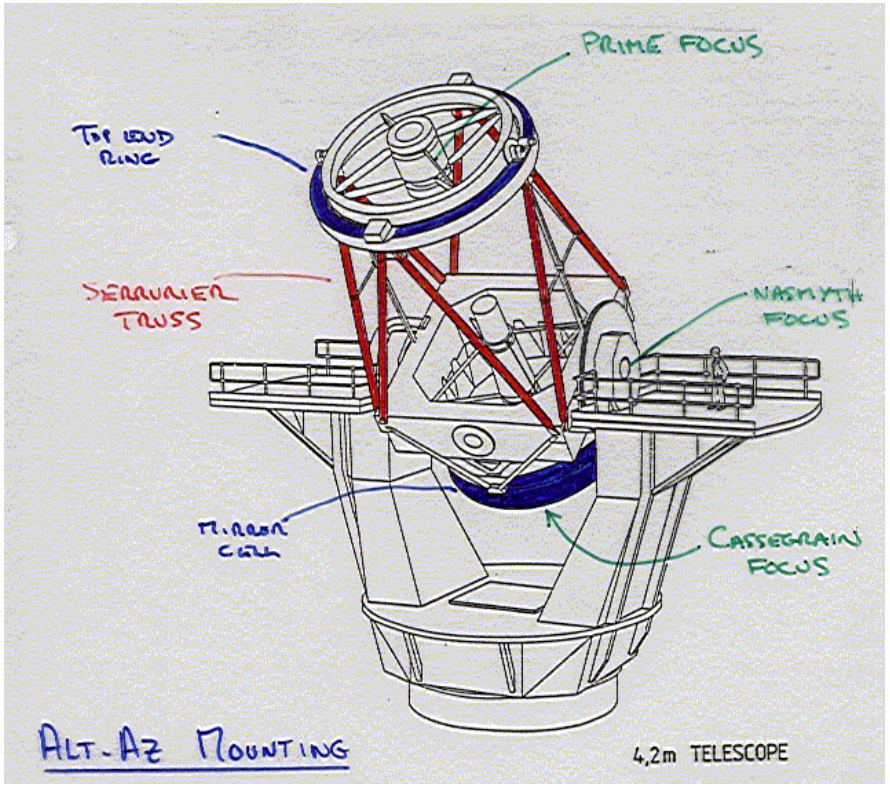
Contents

1. The WEAVE instrument for WHT
2. Plans for WEAVE surveys for Gaia follow-up
3. Plans at WHT for long-term programs pre-WEAVE

A new WF MOS for WHT: *WEAVE*

- *WHT Enhanced Aperture Velocity Explorer*
  - Proposed WHT Facility instrument
  - Prime Focus Multi-fiber MOS, spectrograph on Nasmyth platform
  - Multiplex ~1000, MOS, IFU, mini-IFU
  - FOV 2 deg diam
  - R=5,000 + 20,000



WEAVE Background

- **ASTRONET Science Vision 2007** made first suggestion
- ING Science Advisory Committee made initial proposal to ING Board (11/08)
- **GBFR** recommendation of continued access to WHT for wide-field MOS follow-up of Gaia and Northern Hemisphere access strategy (11/09)
- **ASTRONET ETSRC** report, 02/10: WHT optimal candidate for a Northern European wide-field MOS
- **Community** meetings London, 03/10 & Leiden, 04/10 ➔SPIE paper, 06/10 (Balcells et al 2010)
- WEAVE Concept Study, 06/10-01/11
- 03/11 **ASTRONET** partners recommend North(WHT)+South(ESO) MOS
- 06/11 UK, NL commit funding for WEAVE to PDR
- 09/11 IAC supports construction of WEAVE

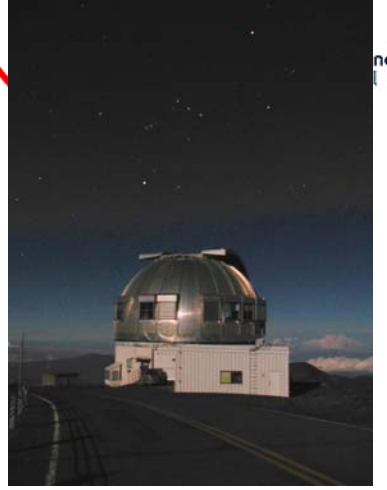
WEAVE: why

Purpose

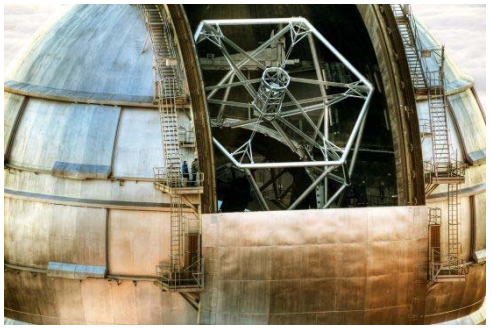
- Provide WHT with instrumentation that will be strongly productive in epoch when most PI science is done on 10m

Objectives

- A facility instrument for massive spectroscopic programmes in survey mode.
- Prepare teams to get organized to exploit new facility.
- Leadership in spectroscopic programmes of World relevance



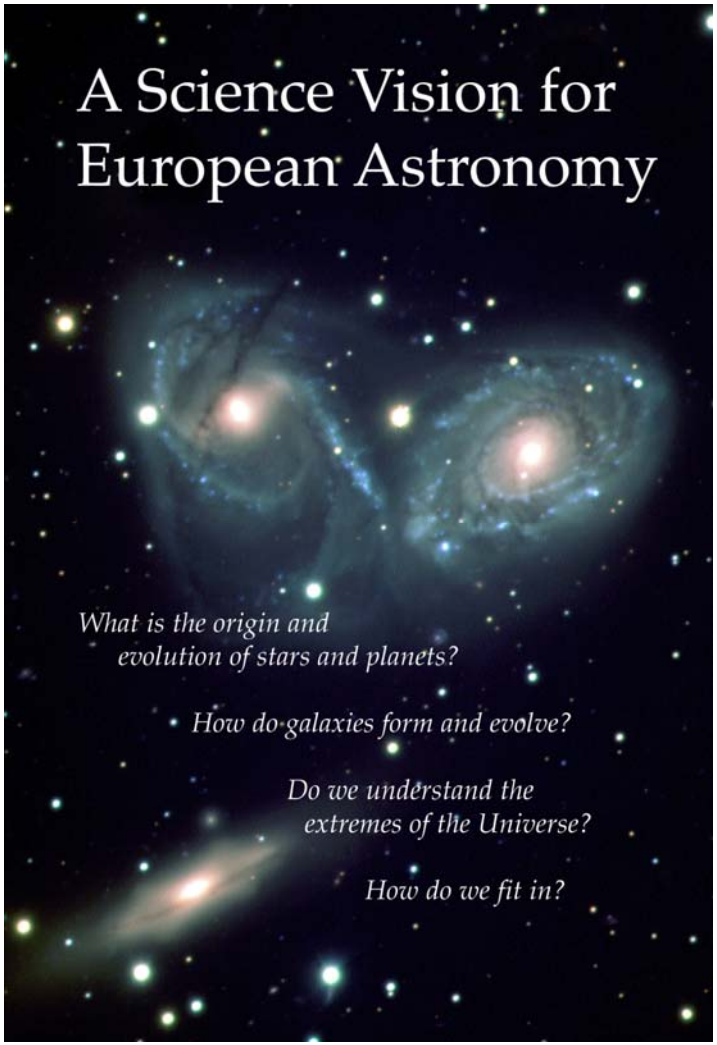

www.atacamaphoto.com



Science Overview

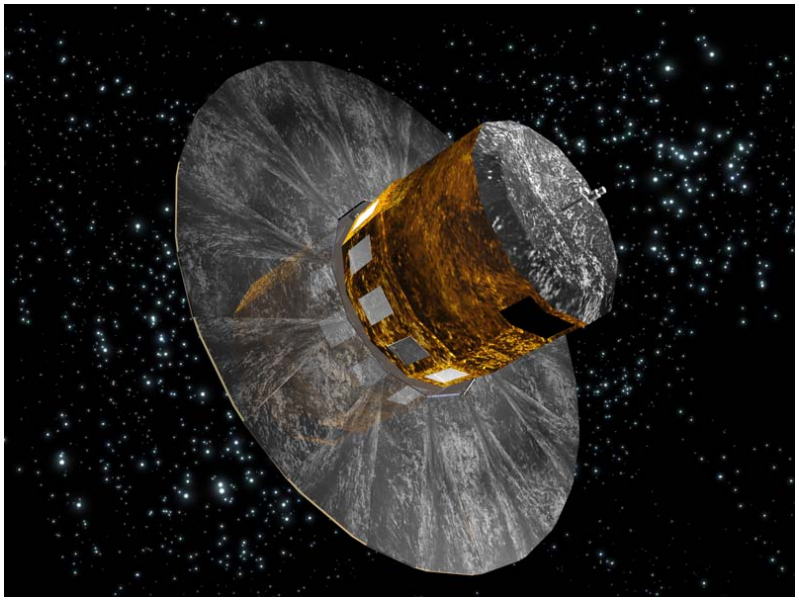
Addresses three themes from ***ASTRONET2007 Science Vision:***

- What are the stellar content and stellar distribution in the Milky Way?
- How do galaxies form and evolve?
  - What are the contents, internal structures, and mechanisms of galaxies?
  - What is the role of environment and interactions in galaxy evolution?
- The extremes of the Universe
  - What is the nature of dark matter and dark energy?



Gaia

- Gaia launch March 2013
- 10^9 stars, I<20



Measurement	Accuracies
Astrometry	7 μarcsec at $V = 10$
	$12 - 25$ μarcsec at $V = 15$
	$100 - 300$ μarcsec at $V = 20$
Photometry	low resolution prism spectra to $V = 20$
Radial velocities	$1 - 15$ km s^{-1} to $V \lesssim 17$

Property	Limiting magnitude	Number of stars
Radial velocities	$V < 17$	150×10^6
Rotational velocities	$V < 13$	5×10^6
Atmospheric parameters	$V < 13$	5×10^6
Gross elemental abundances	$V < 12$	2×10^6
Interstellar reddening	$V < 13$	5×10^6

Gaia Science Questions

- Dynamics of the Milky Way
  - Velocity distributions along the disk; resonance maps; coupling of dark halo, bar and disk
  - Halo shape, density and granularity
  - Streams as tracers of mass distribution and evolution

- Structure and history of the disks
  - Characterization of star formation and chemistry as f(R)
  - Models of the formation of thick disk
  - Inter-relation between various components

- Metal-poor components
  - Streams in the halo to trace merger history
  - Constrain the IMF, and star formation in the early Universe

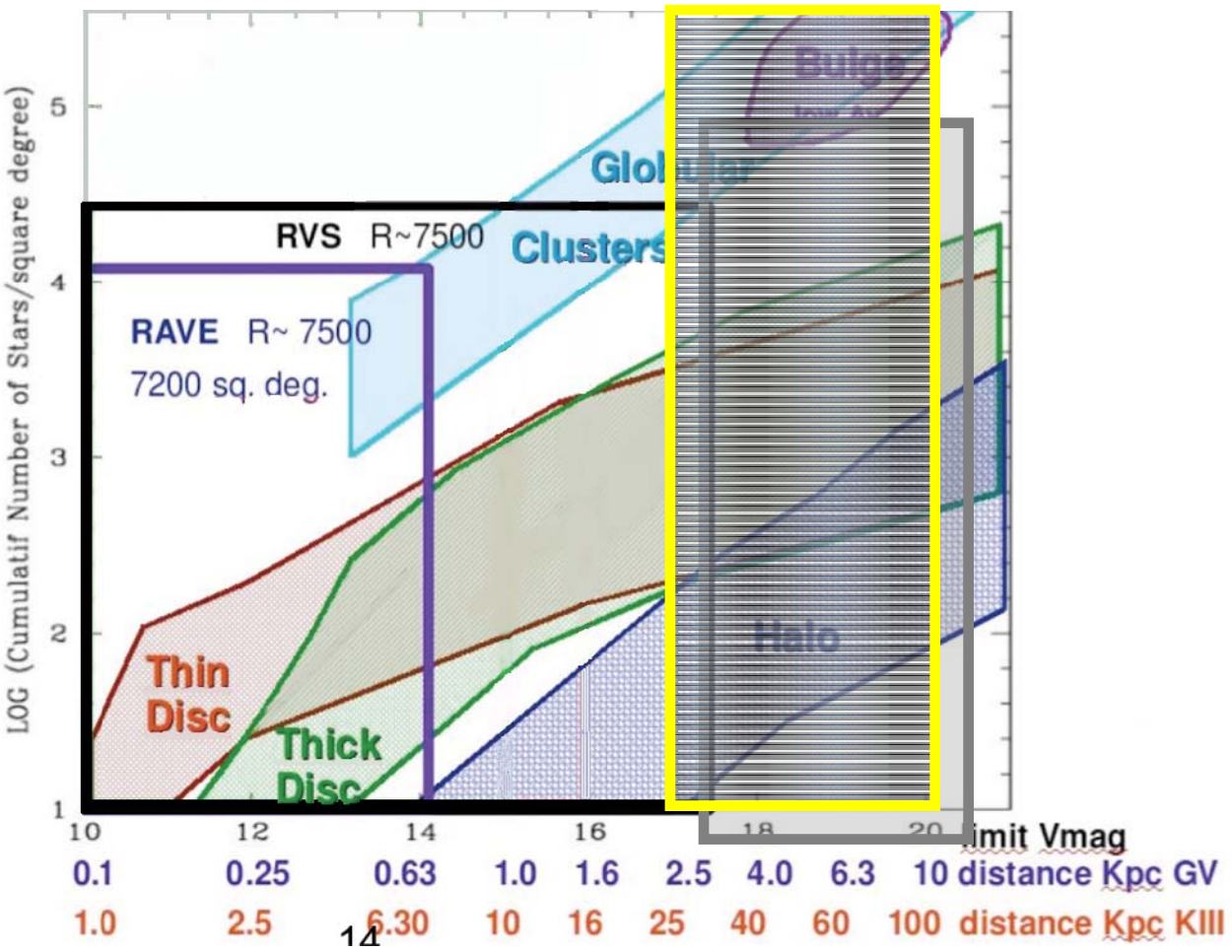
Gaia needs ground-based spectra

- Gaia provides
  - (x,y) angular coordinates
  - (vx,vy) angular velocities
  - Vr for Mag<17
- Ground-based 4m spectroscopy can provide
  - Vr for 17<Mag<20
- Gaia+4m together:
  - 6 phase-space coordinates for Milky Way dynamics

WEAVE/Gaia Survey Space

WEAVE, R~5000
370-1000nm
$\delta v_r < 5 kms^{-1}$
δ[Fe/H] < 0.2 dex
$>10^6$ stars
10000 deg^2

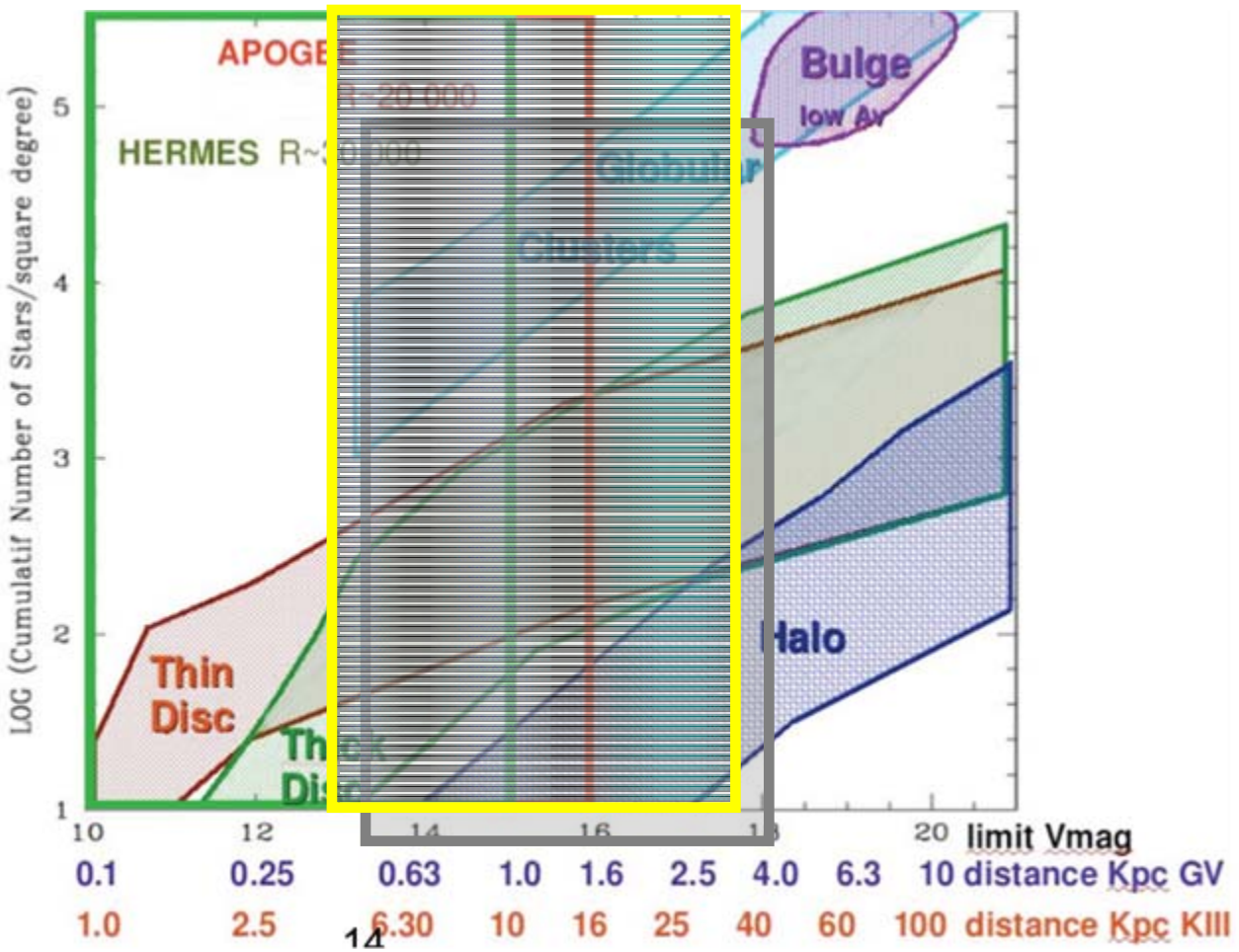
Enough to measure
Metallicity
Distribution
Function



WEAVE/Gaia Survey Space

WEAVE, R~20000
$\delta v_r < 1 kms^{-1}$
δ[Fe/H] < 0.1 dex
500 streams
50,000 halo giants
2500 deg^2

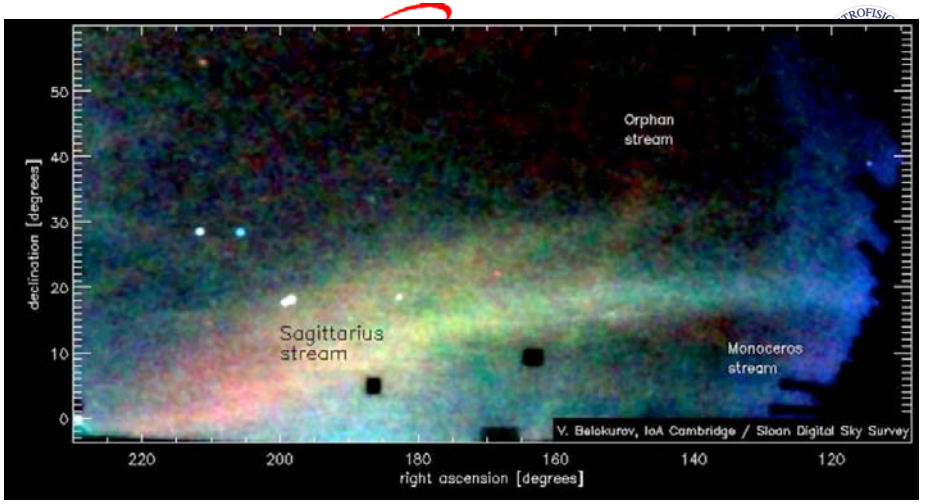
Chemical tagging of stars to formation events

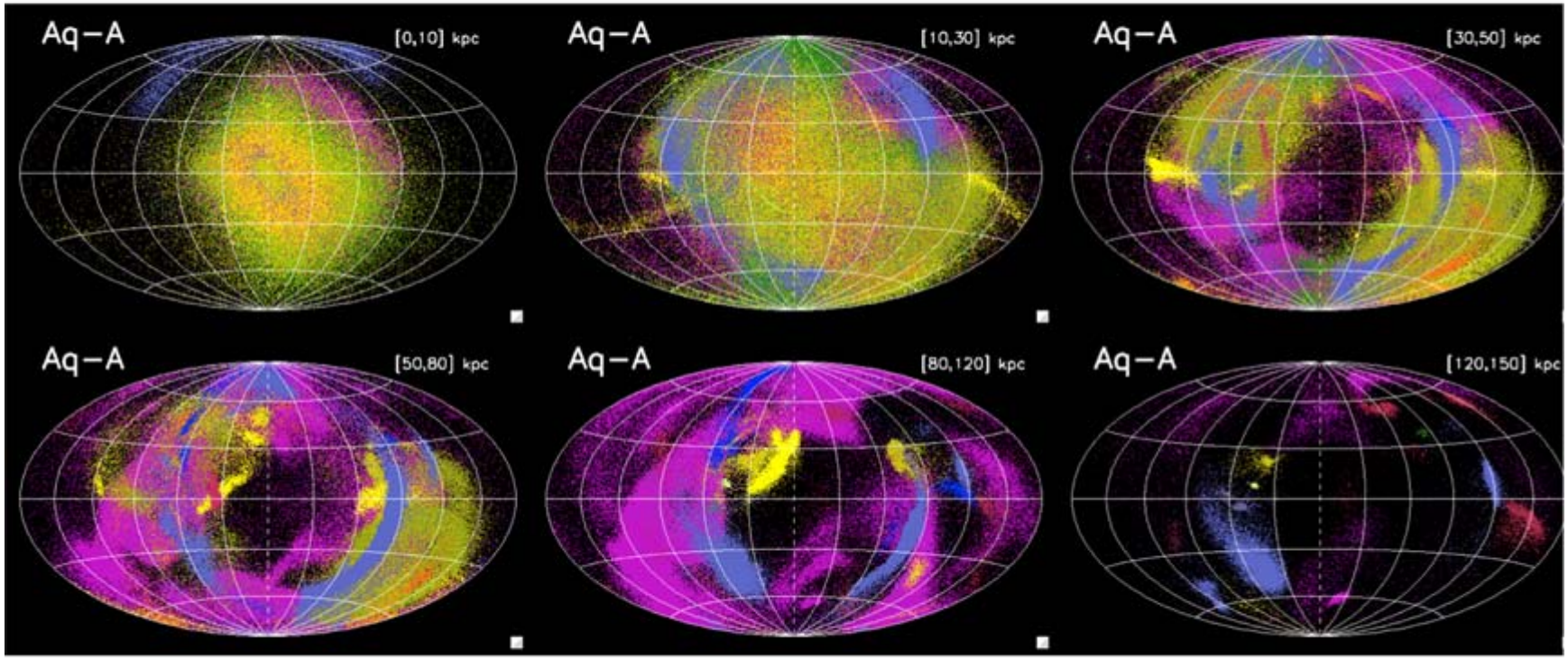


Mapping the Halo

Simulations suggest the distribution of merger remnants is highly anisotropic.

Northern Hemisphere required to sample thick disk and outer halo.





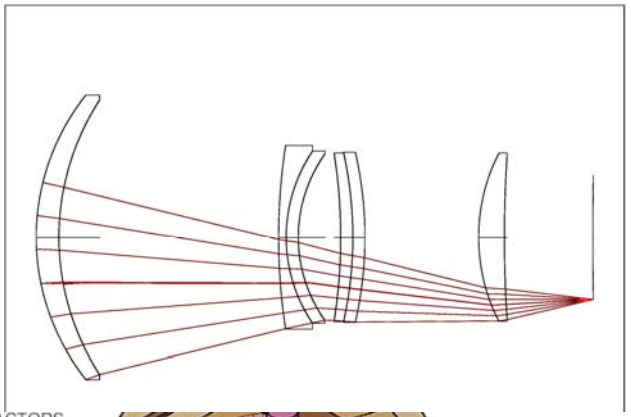
Aquarius simulations of recent MW mergers. (Helmi et al. arXiv:1101.2544)

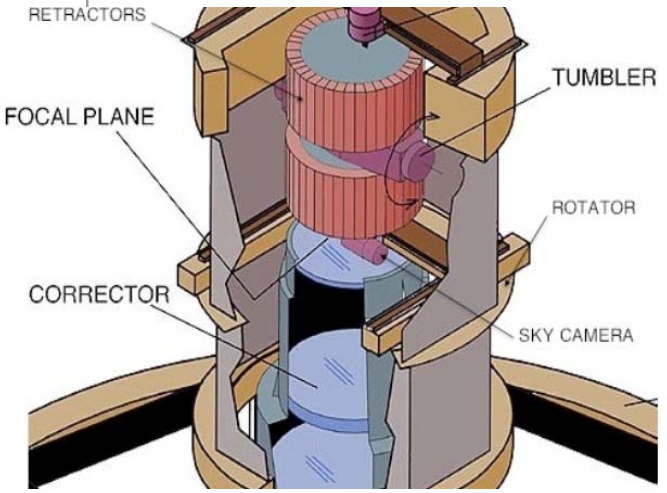
Other WEAVE science…

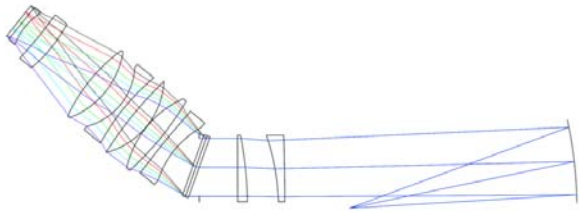
- Galaxy evolution studies
  - Galaxy properties since z=1
  - Physical properties of LOFAR galaxies
  - Physical properties of many other surveys
    - UKIDSS, VISTA, eROSITA, PanSTARRS
- Cosmology
  - Redshift surveys: LSS vs z, constrain Dark Energy equation of state
  - Again, LOFAR unique surveys
- More Gaia-related (clusters, stellar evolution)

Instrument Overview

- New top end and 2° FOV prime focus corrector
- Pick-and-place fiber positioner (2dF-like)
- IFUs incorporate naturally into this design
  - LIFU (1.5'x1.5')
  - 30 miniIFUs
- 1000 fiber dual-beam VPH spectrograph optimised for R=5000
- R=20000 from grating change and rotation







Survey Profile

- Gaia low-res survey in grey/bright. (700 nights)
- High Res survey in bright time. (80 nights)
- LOFAR/APERTIF surveys in dark time, but combine with outer halo stars (800 nights)
- 5 year programme
  - Simultaneous execution all surveys + PI projects
  - Each country could retain a bit of time for small projects

WEAVE Cost

- Hardware €5270k, including corrector and top-end modifications.
- Effort: 47 FTEs
- Total instrument: €12M
- Funding:
  - UK, NL, ES,
  - Non-ING partners: France, Germany (ongoing discussions)
  - ASTRONET planning schemes for cross-European funding schemes
- Current funding status:
  - To PDR (NL; STFC; ING)

WEAVE

Name	Affiliation	Post
Gavin Dalton	*Oxford/RAL*	P.I.
David Carter	*Liverpool J.M.*	Deputy P.I.
Don Carlos Abrams	*ING*	Project Manager
Scott Trager	*Groningen*	Project Scientist
Chris Evans	*UK ATC*	Instrument Scientist
Phil Rees	*UK ATC*	Systems Scientist

Package	Institute
Spectrograph optics	*Oxford/RAL*
Spectrograph mechanics	*NOVA*
Fibres	*Paris?*
Positioner robot	*Oxford*
Advanced positioners	*UK ATC*
Detectors, electronics	*Liverpool J.M.*
Systems engineering	*UK ATC*
WHT top end, PF corrector	*ING, Nice (?)*
Electronics, Software	*IAC*

WHT Science Vision: four pillars

1. WF MOS
   - Gaia
   - Cosmology
   - Galaxy evolution
2. Access to Northern Hemisphere
   - LOFAR; Gaia
3. Complementarity with 10.4m GTC
4. Technology test-bed for E-ELT

Spanish participation in WEAVE

- Unique opportunity to join key Scientific/instrumental project early on
- Science
  1. Spanish GAIA teams
  2. Galaxy evolution groups
  3. Cosmology dark energy groups
- Control developments for instrument on Spanish telescope

Spain needs to increase participation in WEAVE science team

- Check www.ing.iac.es/weave/team.html
  - España: all membership is from IAC
- Visibility: *Red Española de Gaia* should join WEAVE science team
  - UB simulations team – essential for WEAVE capture of requirements
- WEAVE PDR kick-off meeting
  - Thursday, Friday THIS WEEK

Gaia surveys BEFORE weave 2013-2016

- ESO/VLT survey – ongoing

- Opportunities for WHT surveys with current instrumentation
  - AF2/WYFFOS
  - Tentative Plan for WHT long-term programs
    - Upgrading of key instruments if requested

Surveys in the WEAVE epoch 2017+

- Bring experience Gaia-ESO surveys

- Spain: scientific complementarity WHT – GTC
  - Classical : WHT – imaging, GTC – Spectroscopy??
  - Alternative:
    - Spectroscopy, WHT: V=17=20 // GTC: V=20-23
    - WHT/WEAVE combined with GTC/MEGARA
- Powerful opportunities for Spanish astronomy

Conclusions

- WEAVE covers fundamental need of European astrophysics in North for next decade
  - WHT to remain center-stage of European astronomy in next decade
- Spain to boost its participation in WEAVE
  - Gaia-Spain called to play key role in science team
  - WEAVE needs REG members!
- Upcoming program WHT long-term programs, pre-WEAVE