The 4MOST Facility Simulator (4FS)

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Large Area Optical Spectroscopic Surveys: Science with 4MOST
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The 4FS philosophy

- Model all relevant 4MOST sub-systems and interactions between them, including:
  - focal plane layout/positioner geometry
  - targeting (fiber -> target assignments)
  - scheduling algorithms (optimal field selection)
  - observing constraints and survey strategy
- Parameterize (more or less) everything
- Survey operations are dynamic
  - night-by-night simulation of survey
  - respond to conditions and survey progress
- Simulator outputs must be user friendly
- Efficient coding (1 simulation runs in ~1 hour)
Operations Simulator (MPE)
- Interpret survey strategy
- Layout sky tiling
- Process catalogues
- Model a 5 year survey
  - Maintain target and observation DB
  - Sky observability
- Run fiber allocator

4FS
- Updated target catalogues

Graphical Flowchart:
- Input
  - Target 1
  - Target 2
  - Target 3
  - Target 4
- Simulation Parameters
- Output
  - Catalogues
  - FoMs
  - Sky maps
  - Progress reports
  - Statistics

Telescope Throughput Simulator (GEPI)
- Measure required exposure time for each target

Data Quality Tools (IoA)
- Folded Spectra
Baseline Input Catalogues

- Design Reference Surveys:
  - eRosita AGN
  - eRosita Clusters
  - Gal. Halo LoRes
  - Gal. Halo HiRes
  - Gal. Disk LoRes
  - Gal. Disk HiRes
  - Galaxy redshift survey (BAO)
Instrument Configuration

- FOV = 4.06deg² (2.5° diameter)
- Echidna-style positioner
- 2437 positioners (filled hexagon with 28 per side)
  - 812 hi-res fibers
  - 1625 lo-res fibers
- Pitch = 9.6mm
- Patrol radius = 11.5mm
- Plate scale = 59.5µm/arcsec

- High Res
- Low Res
Fiber ↔ Target Allocation

- Reconfigure for each Tile
- Assign high priority targets first
- Avoid fiber collisions
  - Positioner geometry (Echidna, PotzPos ...)
- Assign sky fibers
- Collision mitigation routine
  - to be added

- High Res
- Low Res
Night-by-night operations

Example night in mid-December 2020
Survey Strategy

• Constraints:
  – Airmass limit (<1.624)
  – Moon avoidance (>15°)
  – Time lost to poor weather
  – Consider -70°<Dec<+20°
    • Total ~ 26 000 deg²
  – 12k Bright, 20k Dark+Grey Tiles
    – + LMC/SMC observations?

• Segregate sky about $b=\pm15^\circ$
  – Dark/grey moon:
    – $|b| > 15^\circ$
    – goal: $n_{dg} \times 20\text{min per field}$
  – Bright moon:
    – $|b| < 15^\circ$
    – goal: $n_b \times 20\text{min per field}$
    – + extra on Gal. Bulge
    – - fewer v. near Gal. Plane

• Geodesic tiling pattern
Impact of changing Survey Strategy

- **Option 1:** Cover sky to minimum depth
  - require at least 6x20mins/pointing
  - cover -70°<Dec<-10° of extragalactic sky
  - cover full visible Galactic Disk
    - + extra tiles on Galactic Bulge

- **Option 2:** Go as wide as possible
  - cover full -70°<Dec>+20° sky
  - 4-5x20min/pointing on extragalactic sky
  - 6x20mins/pointing on Galactic Disk
    - + extra tiles on Galactic Bulge
Option 1: Depth over Area

FoM

Completeness
Option 1: Depth over Area
Option 2: Area over Depth

Completeness

FoM
Option 2: Area over Depth

Survey Progress after night number: 0000

J2000 Coordinates, Hammer/Altoff Projection
Comparison: Completeness

Option 1: Deeper

Low Res Targets

High Res Targets

Option 2: Wider

Low Res Targets

High Res Targets
Comparison: Survey Figure of Merit

Option 1: Deeper

Option 2: Wider
Impact of adding SMC/LMC survey

- Repeated observations spanning 5 years
- SMC
  - 6 pointings, each with 6x20mins/epoch
  - with 40 epochs
  - 480hrs + overheads
  - \(\sim 3\) million spectra
- LMC
  - 16 pointings, each with 6x20mins/epoch
  - with 40 epochs
  - 1280hrs + overheads
  - \(\sim 9\) million spectra
Effect of adding SMC/LMC surveys
4MOST Facility Simulator: Summary

- The 4FS is a versatile tool for instrument design verification and survey planning
- First results suggest 4MOST will be a very powerful tool for a wide range of science projects
  - Balancing interests of competing surveys is possible, but complex
  - Realistic simulations of survey outcomes are vital to make most efficient use of 4MOST time
  - Surveys must clearly define their success criteria
- Additional surveys can be examined with the 4FS
  - estimate success of additional surveys
  - quantify adverse impact (if any) on reference surveys
Positioner statistics