Top-level science drivers and possible instrumental considerations for wide-field spectroscopy on the WHT: The view from Groningen

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Top-level science requirements

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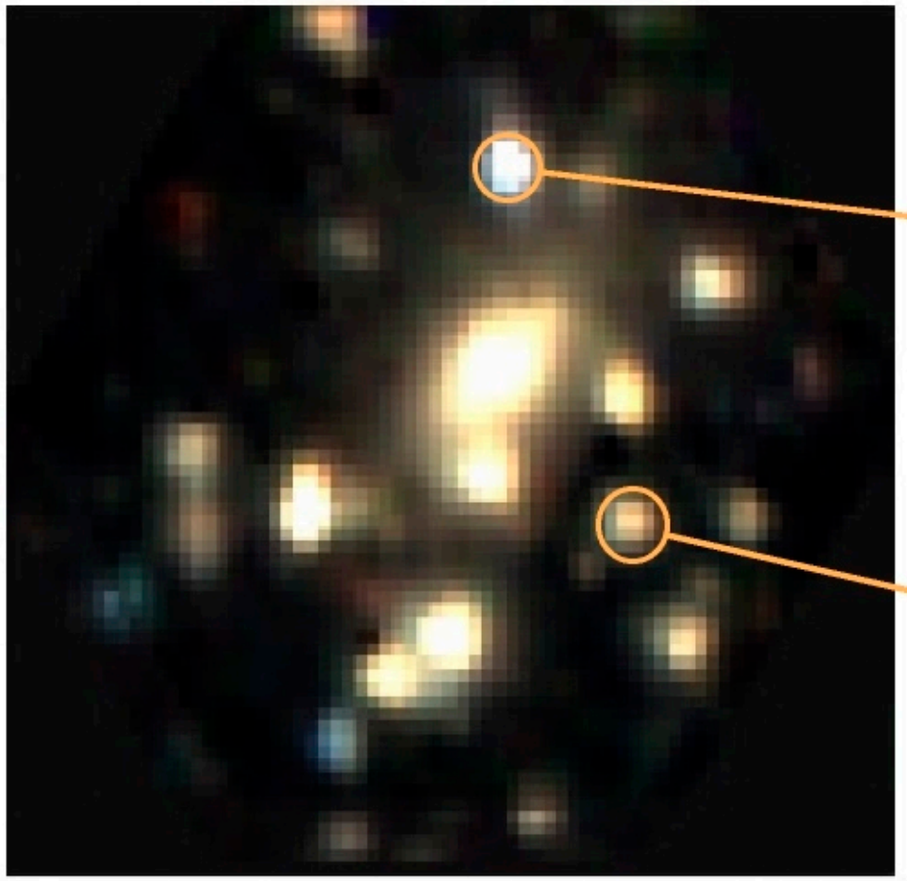
Wide-field stellar science in the *Gaia* era

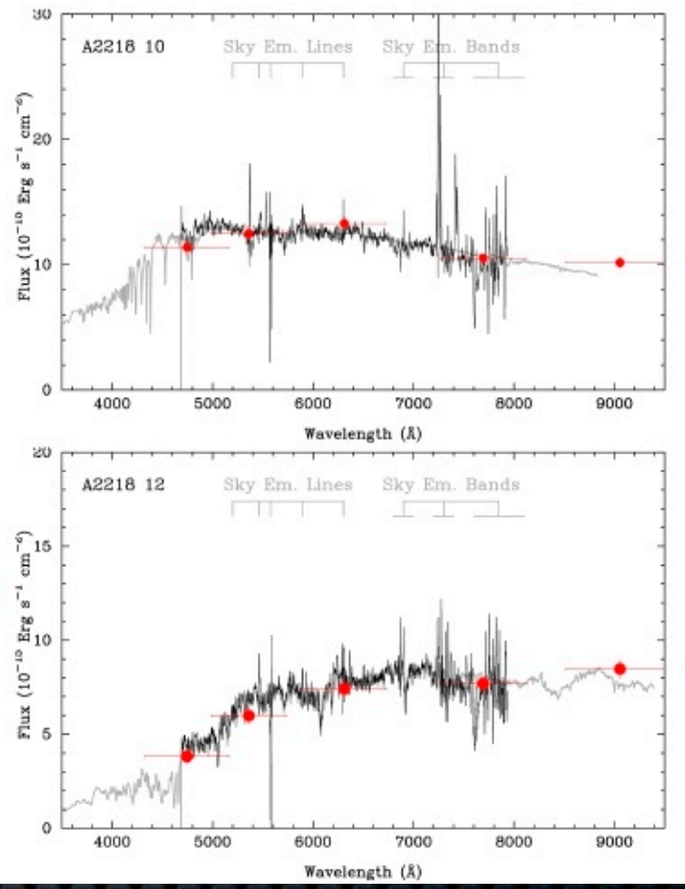
- Radial velocities of faint *Gaia* stars: 17 < V < 20
  - $\Re$~5000 (Δv_{cen}~6 km/s), low-to-moderate S/N
  - few x 10^6 stars
- Abundances of brighter *Gaia* stars: V < 14-16
  - $\Re$~20000 *for metal-poor stars* (much higher for metal-rich stars), high S/N
  - few x 10^5 stars

- Large field of view:
  - Down to V~20:
    - ~10-20 halo stars/□°
    - ~100-200 thick disk stars/□°
    - 2° diameter ⇒ ~350 - 700 stars/field

Wide-field nearby galaxy science: the low-SB regime

- Dark matter & stellar populations in the outskirts of nearby galaxies: stellar kinematics & line strengths
  - For velocity dispersions need S/N~30 at
    - Elliptical galaxies: $\Re$<5000
    - Spiral galaxies: $\Re$~15000
  - at μ_B~24.5 mag/□″ (!)
    - For stellar pops, need 3x S/N at $\Re$/2 or $\Re$/3
- *Variable spatial resolution* allows for gaining spatial (and spectral) resolution in needed regions and science flexibility





- Other science also facilitated: centers of rich, intermediate-*z* clusters, ISM work, etc.

Wide-field moderate-redshift science: multi-IFUs

- Spatially-resolved kinematics and stellar populations of galaxies in large-scale structures at low-to-moderate redshift ($0.2<z<0.5$)

- For stellar kinematics need S/N~30 and for stellar populations need S/N~90, both at $\Re$~2000 - redshifts ‘come for free’

  - Note that R_e of a massive early-type galaxy at z~0.4 is 10 kpc=2″

- Single fibers (like SDSS) give *unresolved* information and *aperture bias*
  - Consider many “mini-IFUs”, small, movable fiber bundles, for efficient surveys *with spatial information*
- Accurate spatially-resolved kinematics of galaxies *and their environments*
  - As high multiplexing as possible

- Other survey projects with mini-IFUs
  - LOFAR surveys follow-up
  - APERTIF follow-up (~50 galaxies/FOV)
  - Lyα-emitter searches and kinematics
  - star-formation regions
  - etc.

Science requirements: summary

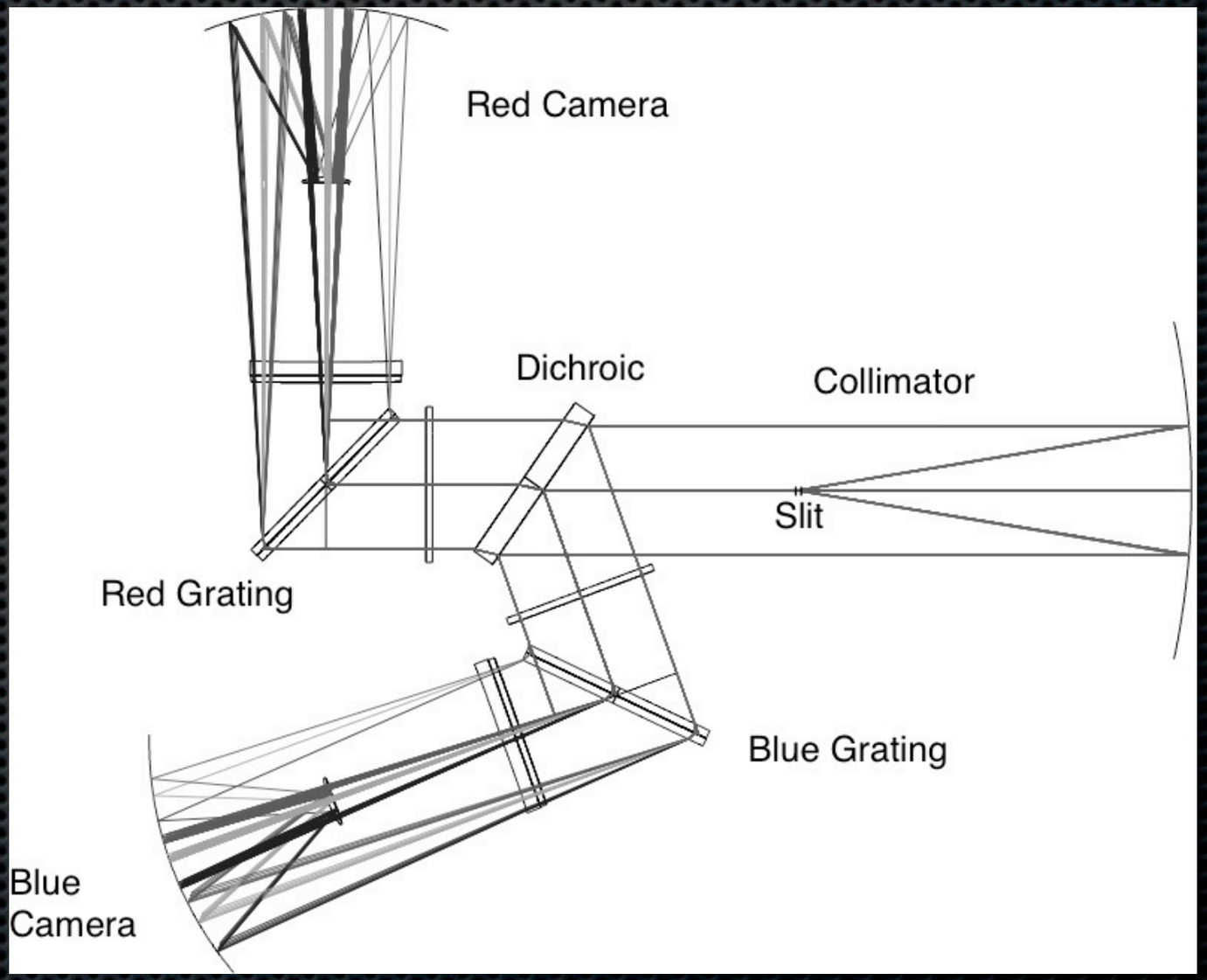
	spectral resolution	spatial scale	multiplexing
stellar science	20000/5000	~1.3″	~300-500
low-SB science	15000/3000	~1.3″-~4″/ spaxel, ~2′ field	1
resolved mod-*z* science	>2000	~1.3″/spaxel, ~10″/IFU	≳30-50

- High efficiency!
  - 50% peak efficiency through entire system (i.e., >65% through spectrograph alone!) turns WHT into >6.5m telescope compared with ISIS
  - even bigger gain compared with WYFFOS!

“Straw man” concept: CHEIFS

- We (Trager, Verheijen, Groot, Venema, Peletier, et al.) have designed a spectrograph + IFU that does some of this already: CHEIFS
  - Very high through-put spectrograph coupled to Cassegrain-mounted monolithic IFU with variable fiber sizes

- Very-high-throughput VPH-grating-based spectrograph with *very fast* camera: faster than *f*/1.3
  - AAOmega design is excellent starting place
- *f*/2.8 collimator to match Prime Focus



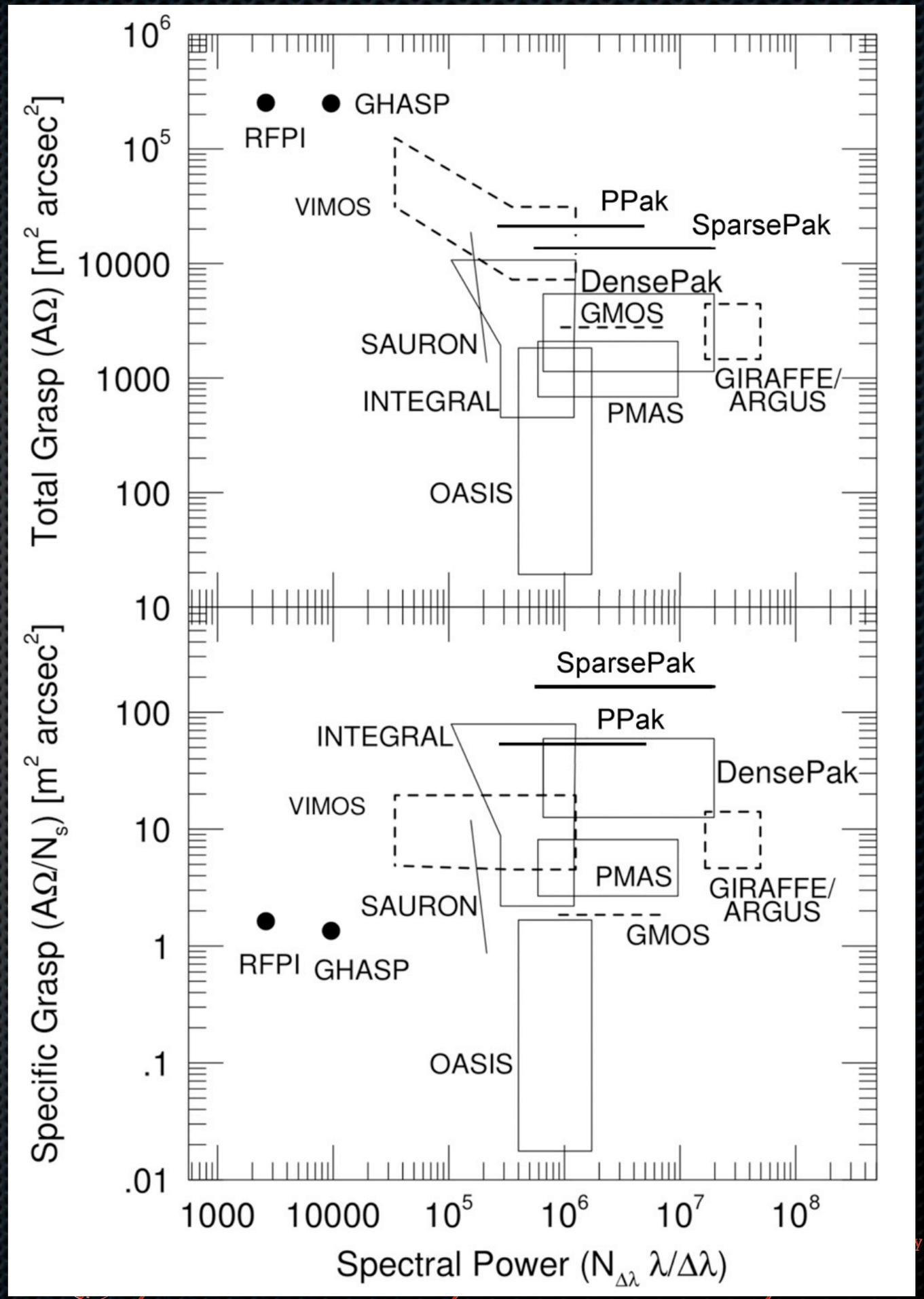
AAOmega optical design: Saunders+04

- **Multiple** front ends:
  - Single-fiber MOS mode
  - Monolithic IFU mode with multiple fiber sizes (CHEIFS)
  - Mini-IFU mode
- Note that different front ends do *not* necessarily need to be at same focal stations
  - e.g., monolithic IFU can be mounted at Cassegrain (with a focal reducer), as in CHEIFS

- By combining VPH gratings with careful choice of optics, dichroic, coatings, fibers, and detectors, can reach *total system efficiencies* of >40% over the range 450-850 nm
  - dual-beam spectrograph
  - 4x higher than WYFFOS, 2x higher than ISIS
    - note that these efficiencies *do not include* microlens arrays

- High multiplexing:
  - At PF: 75 µm fibers (1.3″ on sky): **821 single fibers** over 4k pixels (132 mm slit) or **43 mini-IFUs** (19 fibers) each covering **10″x9″**
  - At Cassegrain (or Nasmyth): **single IFU** with coverage of **2′x1.7′** and **total étendue of >25000 m²□″**

- For IFUs, important metric is (specific) **grasp**, the total collecting area x area on sky (per fiber for specific grasp): *this is where 4m telescopes win*
  - fibers are well-matched to plate scales!



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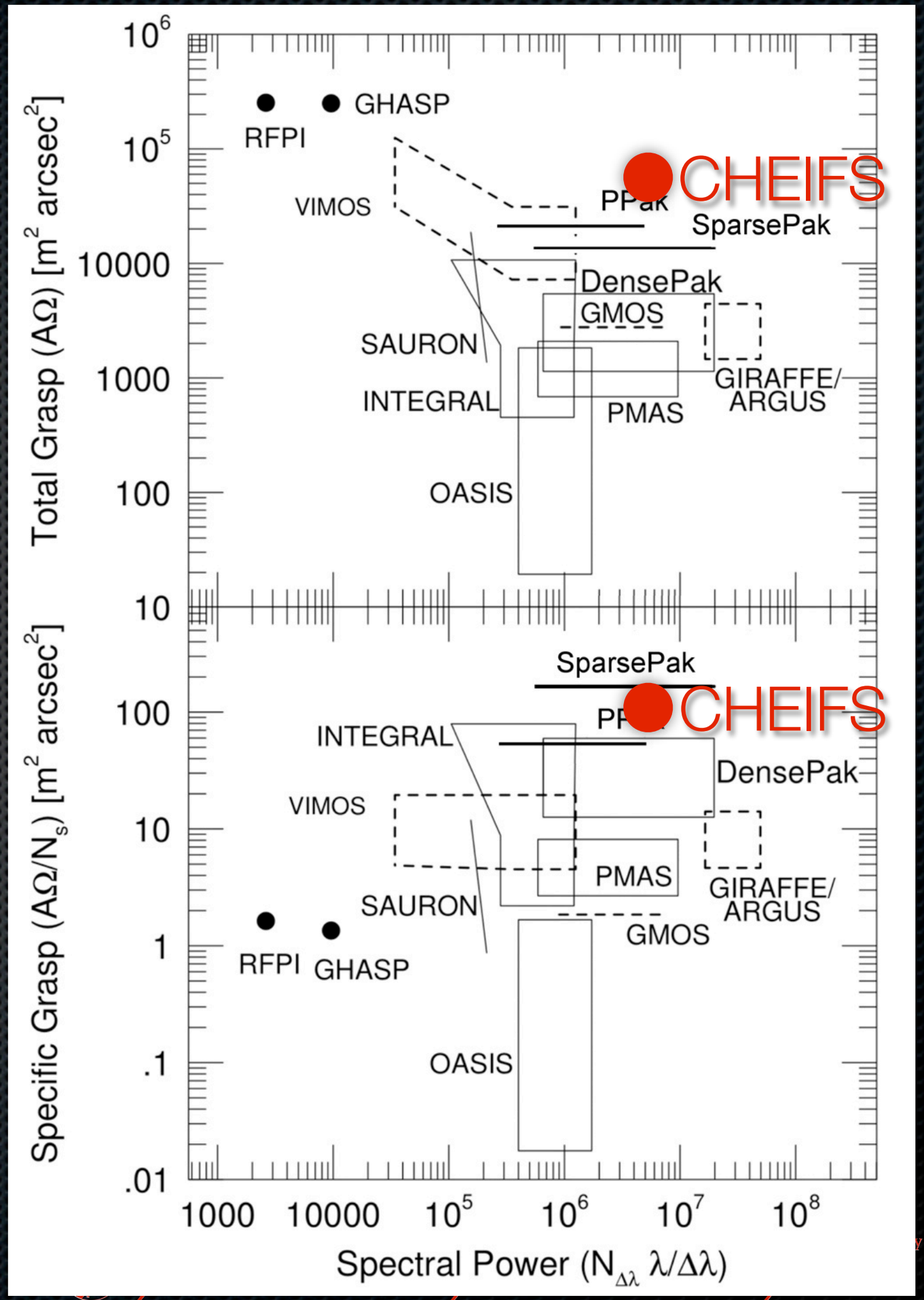

Conclusions

- Most wide-field MOS and IFU science cases for WHT *possible* with **one dual-beam VPH-based spectrograph** and **multiple front-ends**
  - front ends are cheap! (except for PF corrector & possibly fiber positioner)

“Paving the sky”

- Survey *entire sky in spectroscopy*
- Cover, say, 0.5° x 0.5° in one point with *complete spectral coverage*
  - Very tough with conventional techniques: paving full-moon area with 5″-diameter fibers at WHT PF requires 360x360=129600 fibers ⇒ 45.36 *meters* of slit length!
- Need a better idea: perhaps single-fiber spectrographs as in Konidaris+ 2008?