Cosmic Visions: Technology Developments

Aaron Roodman

Cosmic Visions Dark Energy Workshop, LBL

Nov 14, 2017

Cosmic Visions Dark Energy

Charge: collect & coordinate ideas from HEP community on:

- Enhancements to current program in Dark Energy, eg. DESI & LSST
- Motivation & Science reach of Future projects, beyond LSST
- Explore technology & instrumentation R&D relevant to such projects

Workshops:

- BNL October 2015
- FNAL November 2015
- SLAC November 2015
- Future Surveys - Chicago September 2016

White Papers:

- Programmatics
- Science reach: Dark Energy, neutrino mass, gravity arXiv:1604.07626
- Technology & instrumentation R&D arXiv:1604.07821

Office of HEP Support for Detector R&D

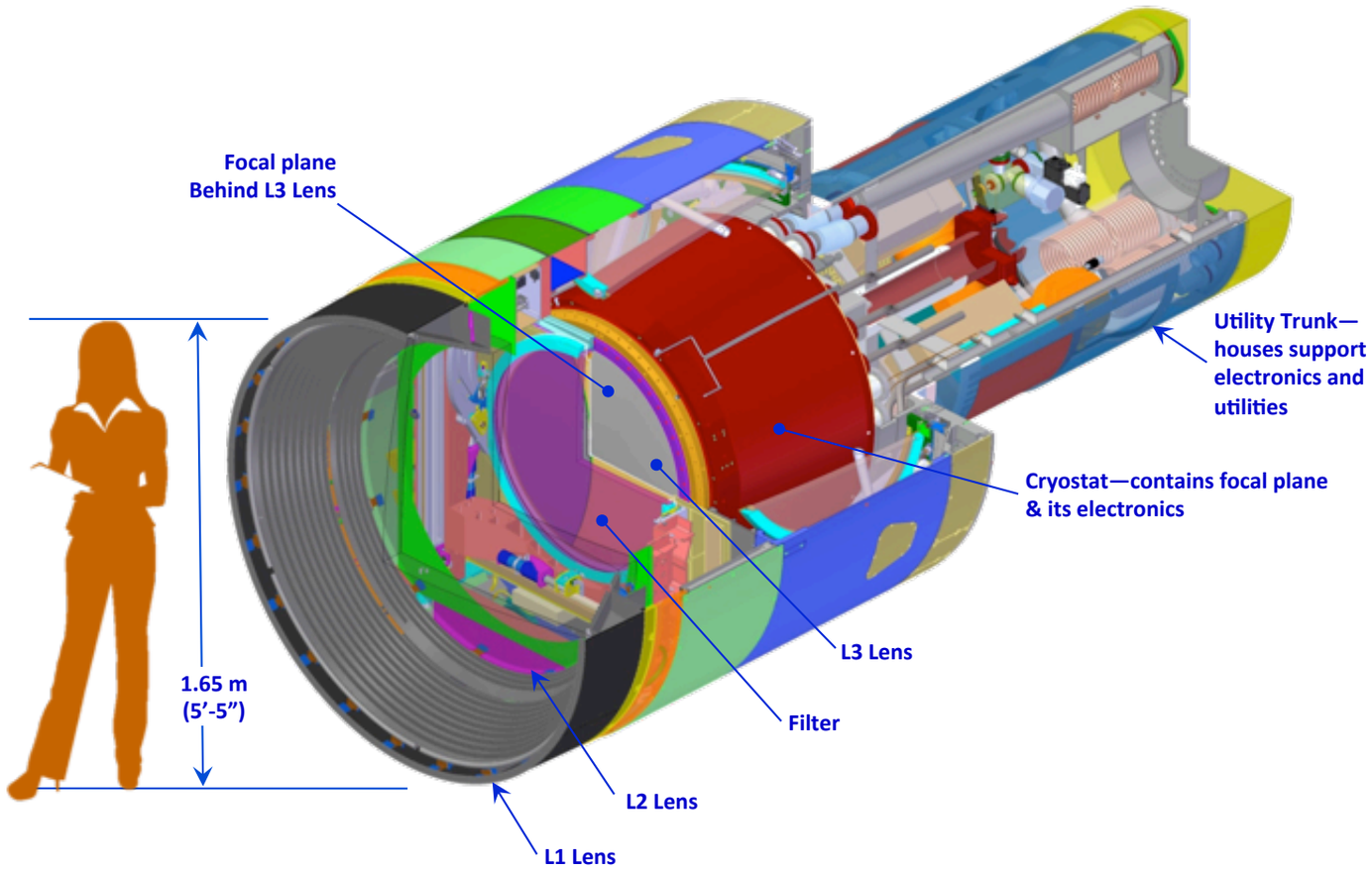
Detector R&D

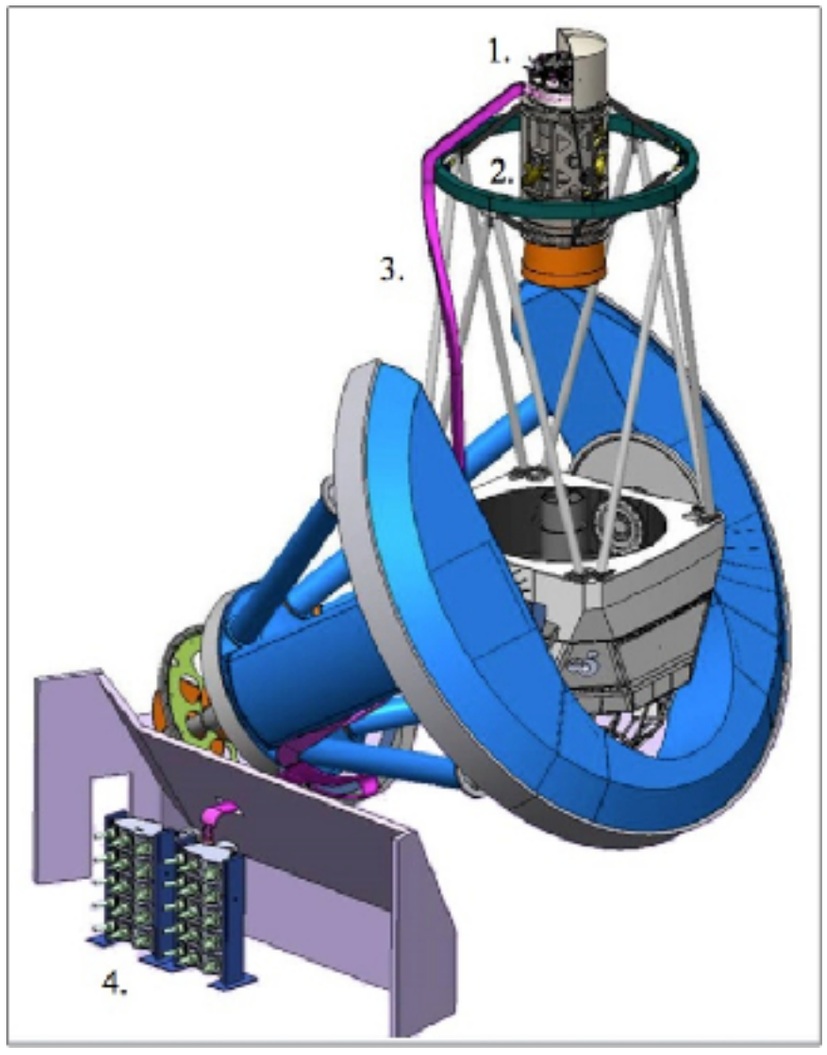
Detector R&D addresses the need for continuing development of the next generation instrumentation and particle detectors at the Energy, Intensity, and Cosmic Frontiers in order to keep scientific leadership in a worldwide experimental program that is broadening into new research areas. In order to meet this challenge, HEP aims to foster a program appropriately balanced between evolutionary, near-term, low-risk detector R&D and revolutionary, long-term, high-risk detector R&D, while training the next generation of experts. The Detector R&D subprogram consists of groups at U.S. academic and research institutions and national laboratories performing research into the fundamental physics underlying the interactions of particles and radiation in detector materials as well as the development of technologies that turn these insights into working detectors. The subprogram selects research efforts with the highest scientific impact and potential based on a competitive peer-review process. HEP conducted an external peer review of the Detector R&D laboratory research groups in 2016 and the next review will be in 2020. The findings of these reviews inform the funding decisions in intervening years.

2018 oHEP Congressional Budget Justification

One focus area in FY 2018 is to use Quantum Information Science (QIS) and advanced computing for discovery along the P5 science drivers. Precision measurements using quantum sensors may yield information on fundamental Beyond the Standard Model physics and the dark sector. Technologies being developed for quantum computing are also candidates for sophisticated sensors for particle physics experiments.

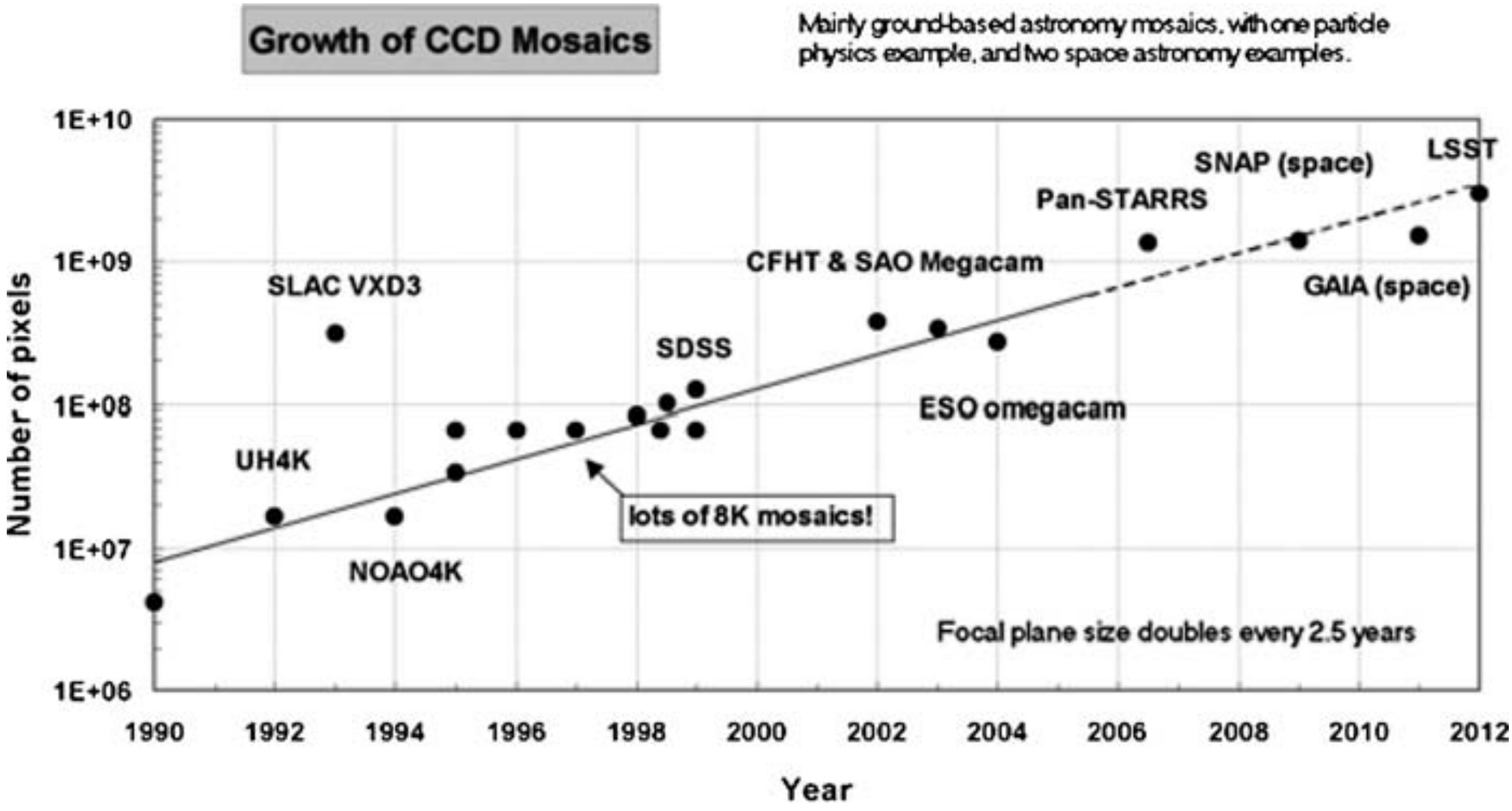
Technology Development Behind Stage 4 Dark Energy





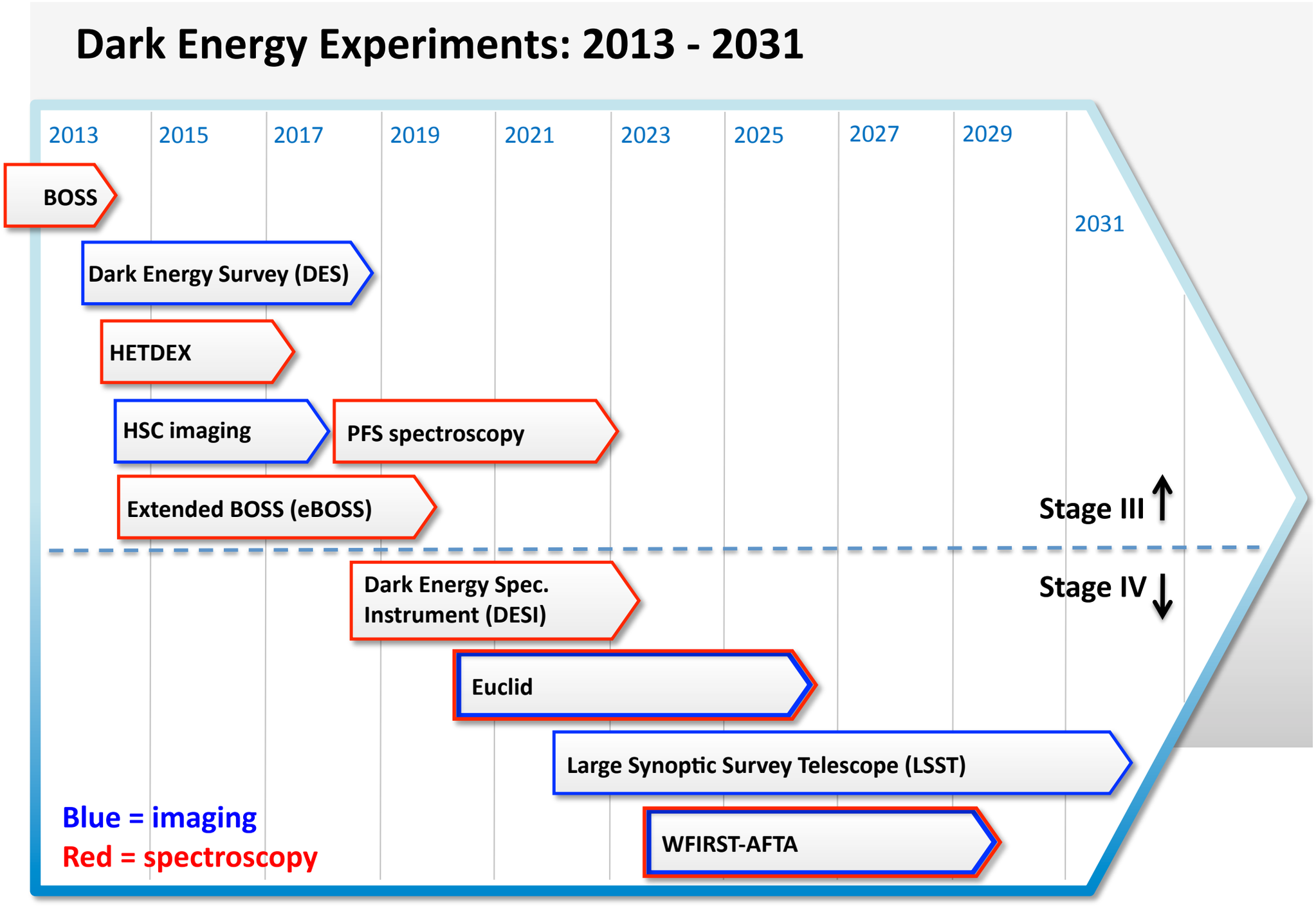
- Back-illuminated Deep-depletion CCDs
- Fiber Positioners
- Custom Analog ASICS
- Modular High Speed DAQ

Moore's Law for CCD Mosaics

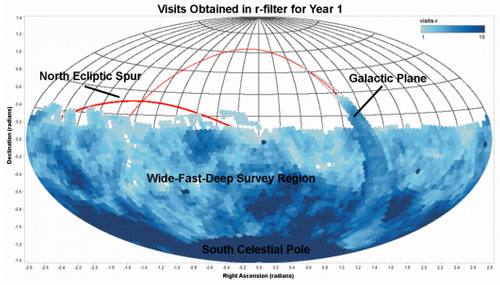


Burke, Jorden, Vu 2005

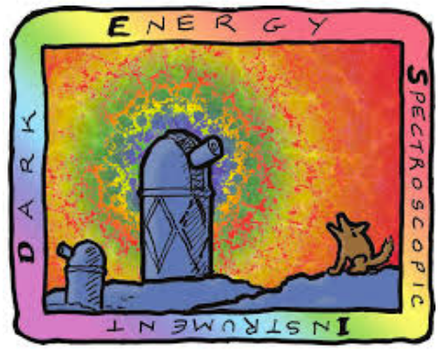
Current Roadmap for Cosmic Surveys



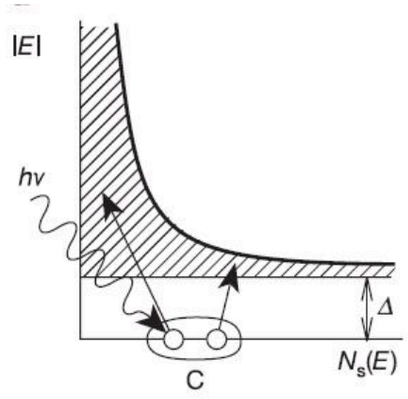
Possible Future Survey Projects



SSSI

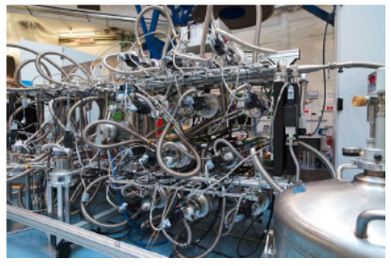


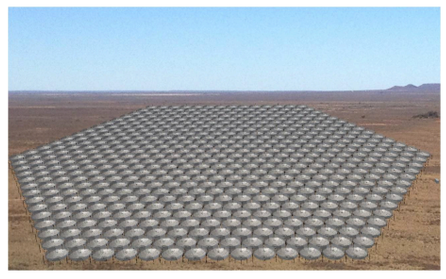
DESI-2



Low Resolution Spectroscopy

Billion Object Apparatus





21 cm

K. Honscheid summary slide

Technology R&D: Grand Challenges?

Current state of the art Optical/NIR sensors

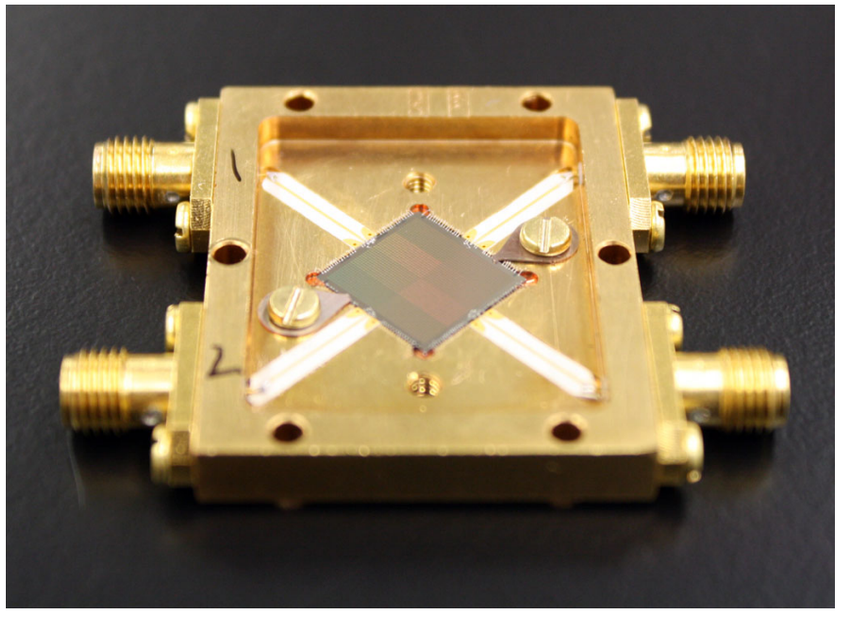
- High Q.E.
- Wide wavelength band
- Few Electron read noise
- Pixel size well matched to PSF
- Very Large Field of View possible
  - 4 side buttable, minimal uninstrumented area
  - Excellent cosmetics

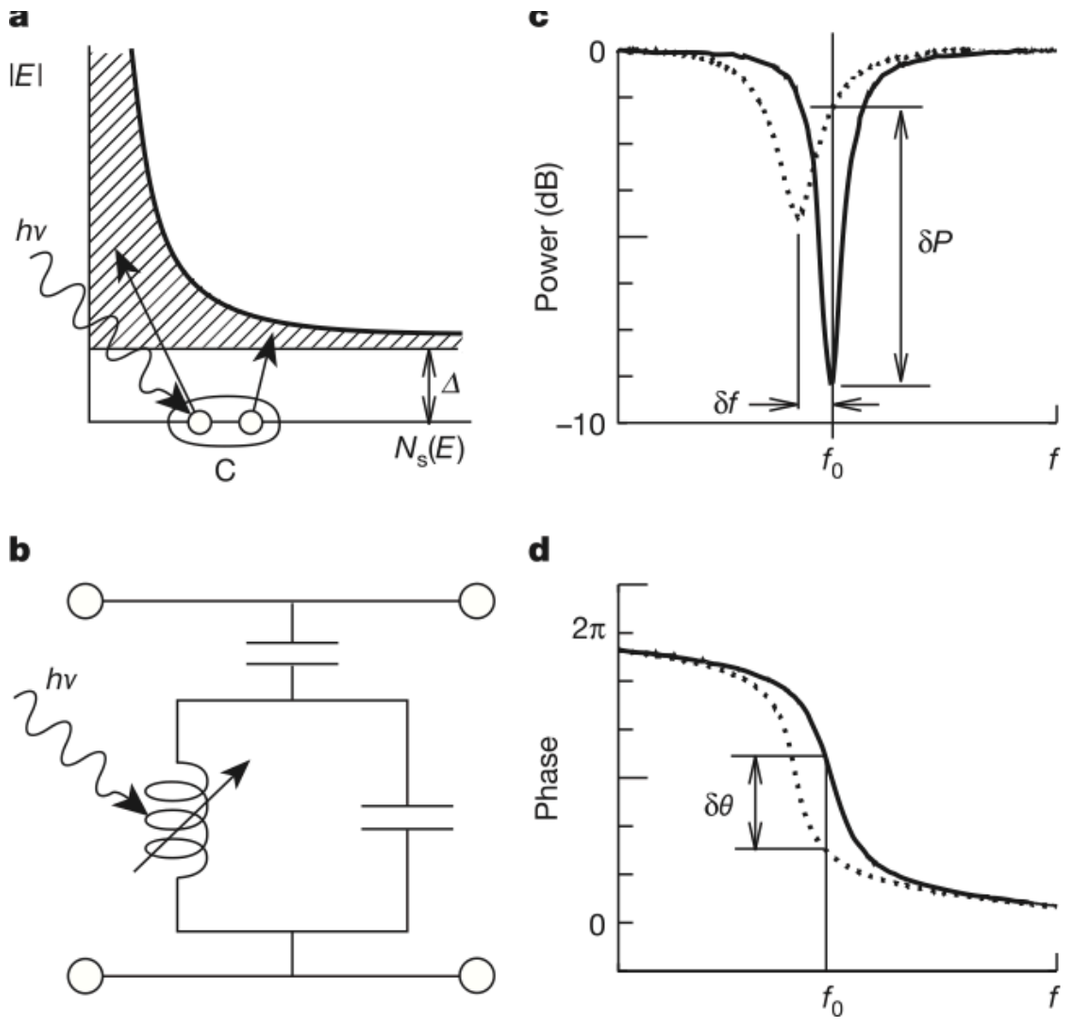
Ideal optical/NIR photon sensors?

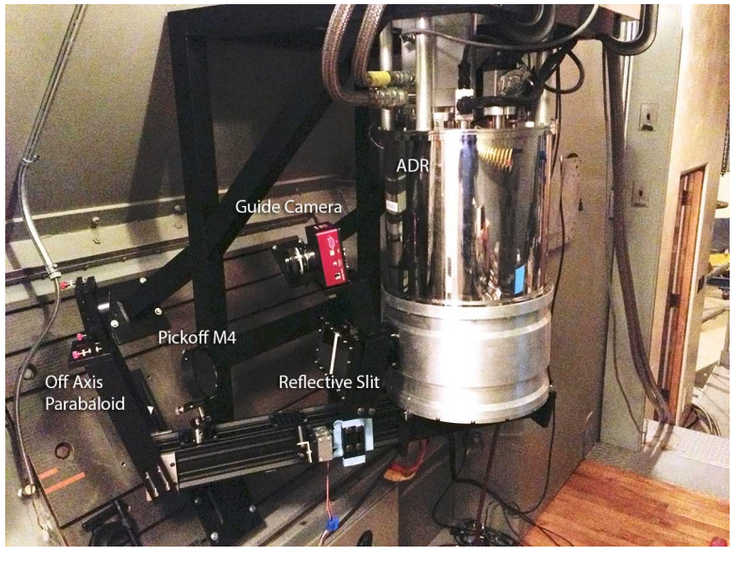
- Wavelength Sensitive
- Time Sensitive (msec or better resolution)
- Single Photon detection or Ultra-low noise

Technology R&D: Sensors with Wavelength Sensitivity

MKIDs





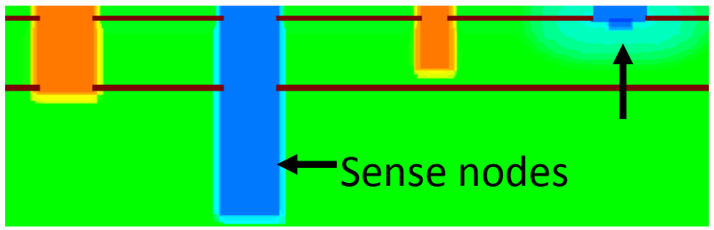


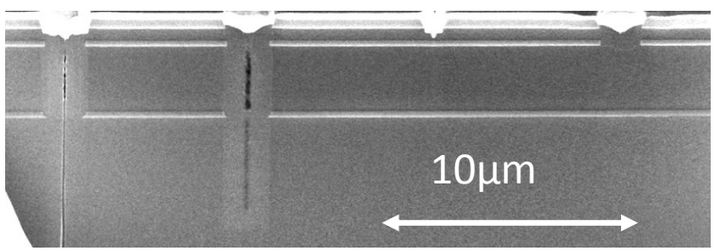
ARCONS
R ~ 8

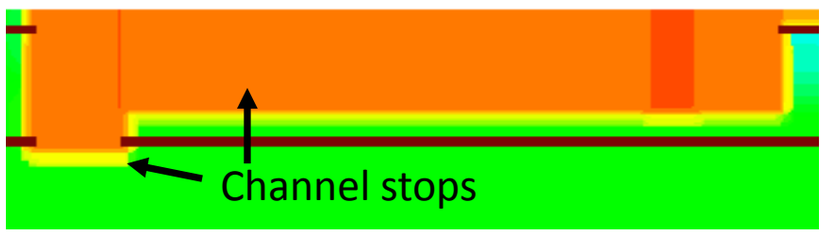
B Mazin

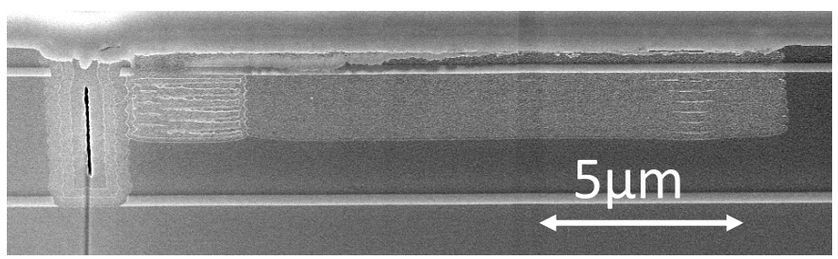
Technology R&D: Sensors with Wavelength

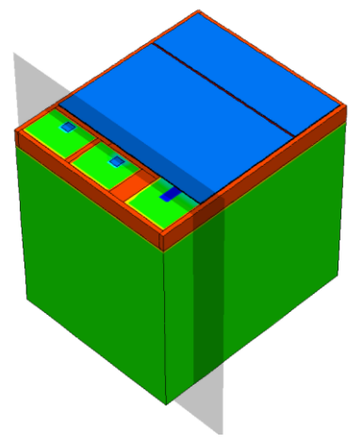
Multi-Band CCDs

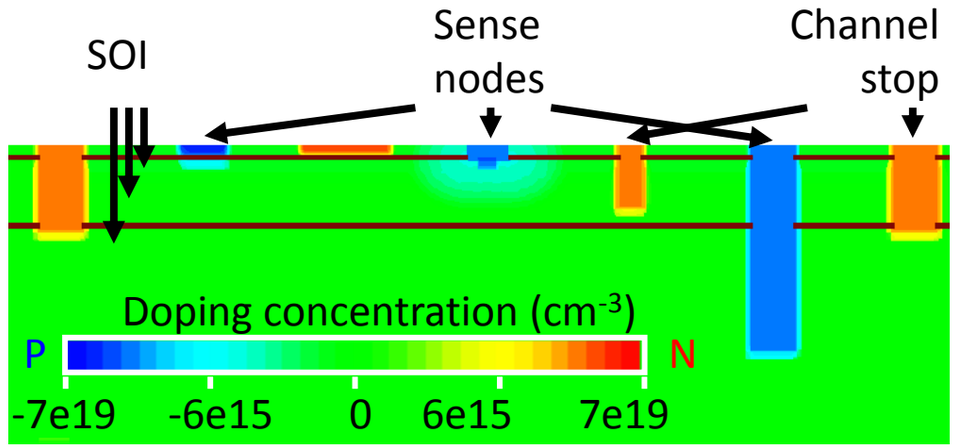


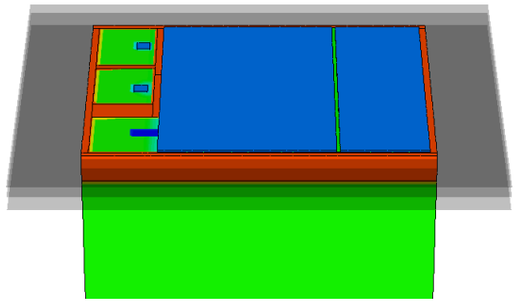


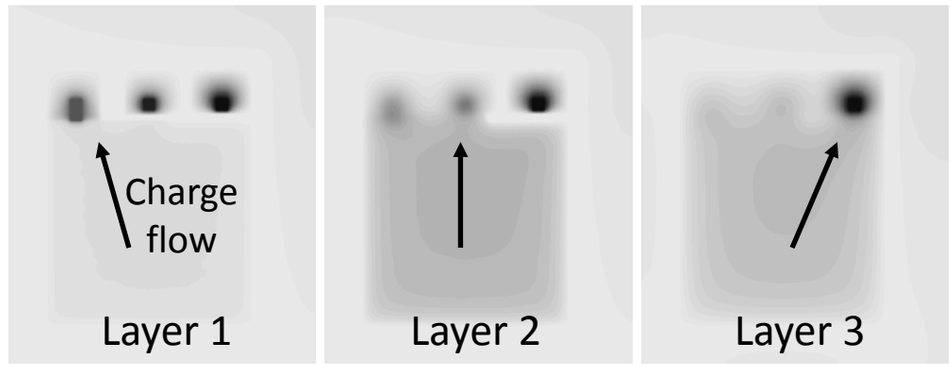


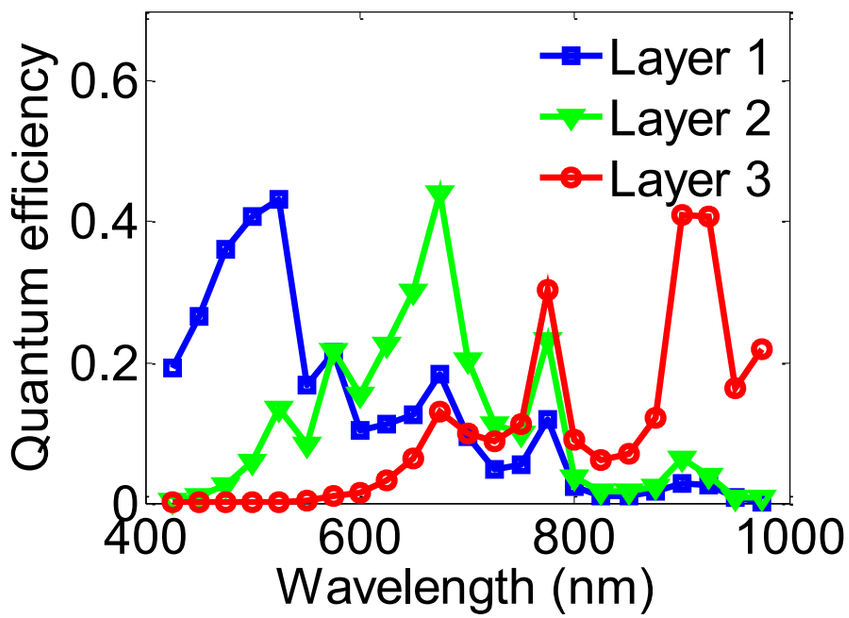








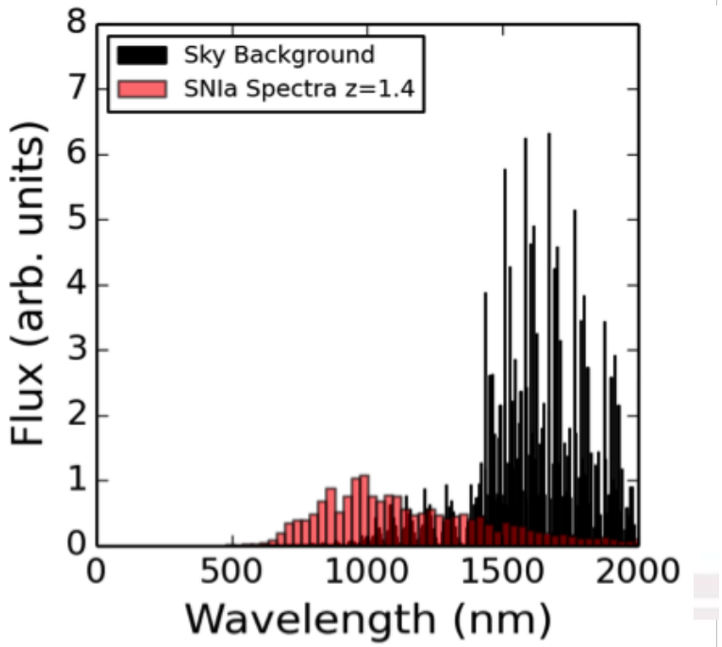


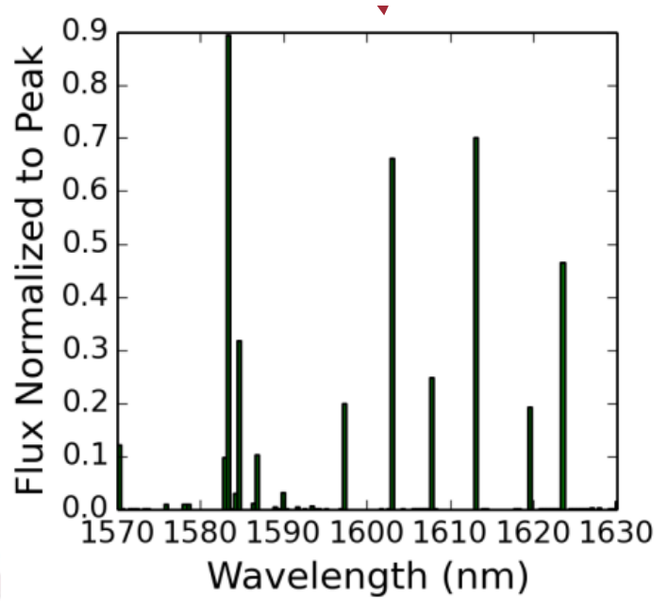


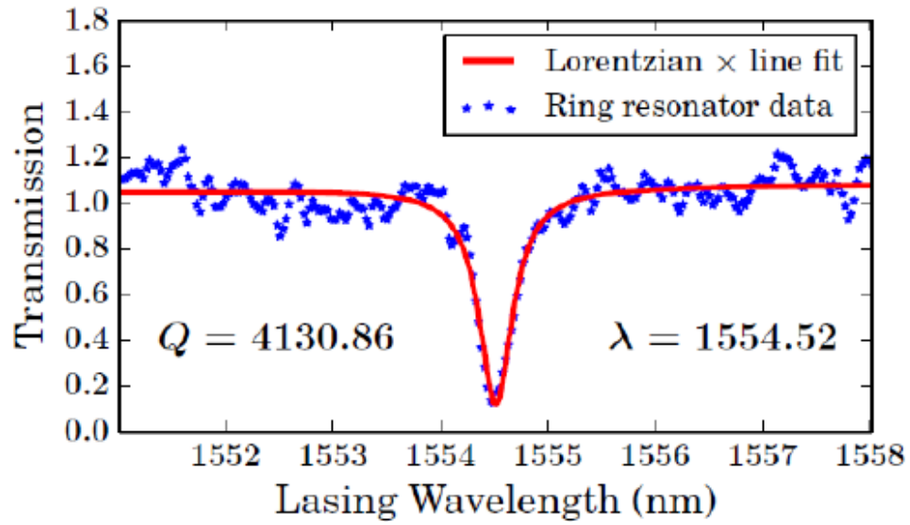
C. E. Chang

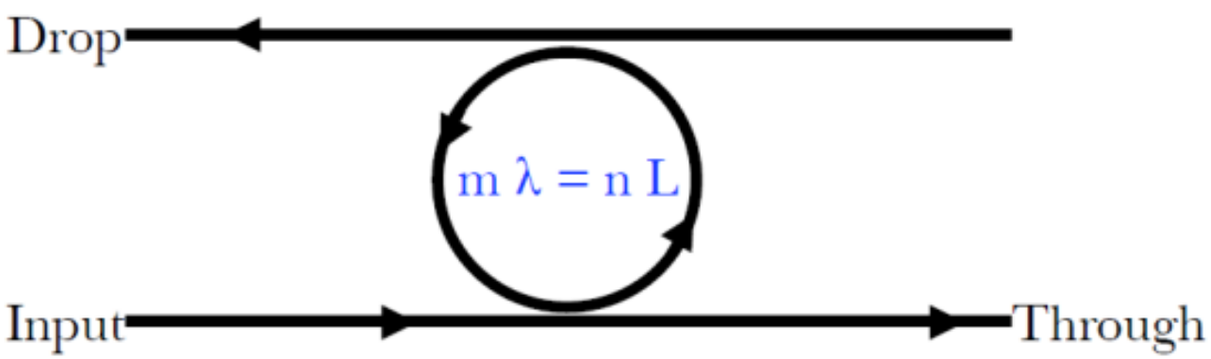
Technology R&D: IR Spectroscopy

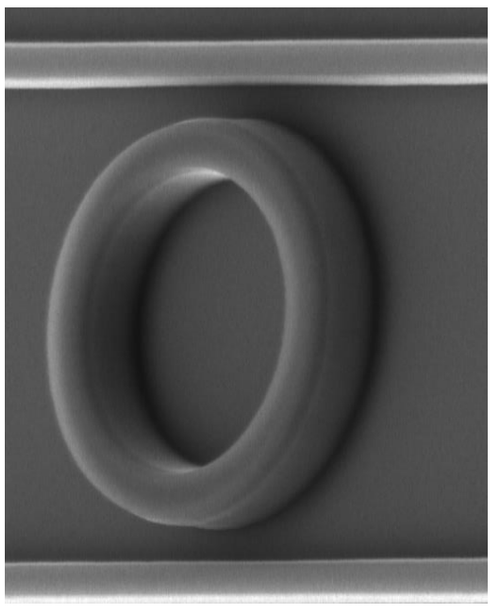
Optical Ring Resonators: Notch Filters









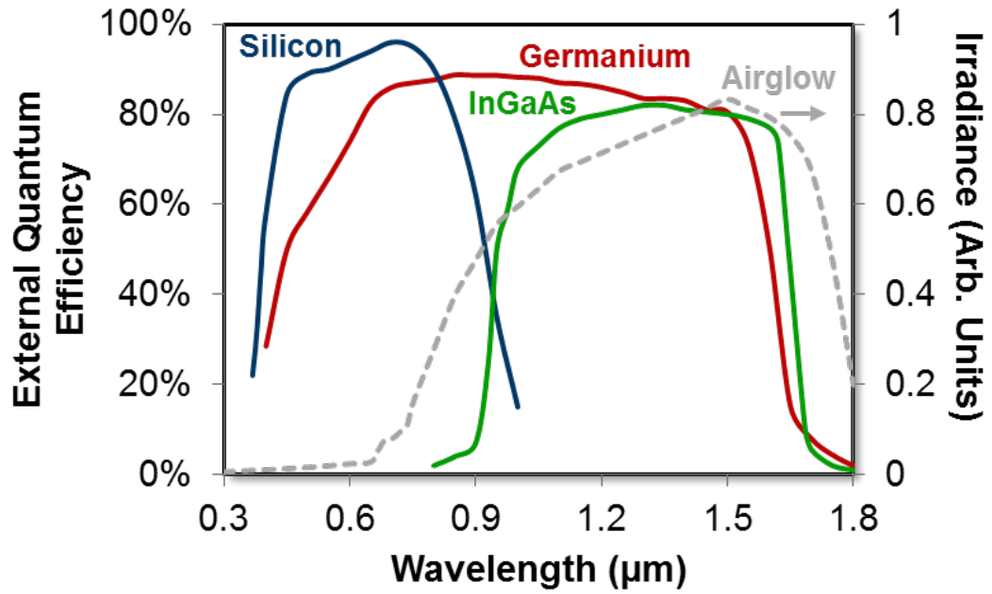


SEM pic: 3um scale

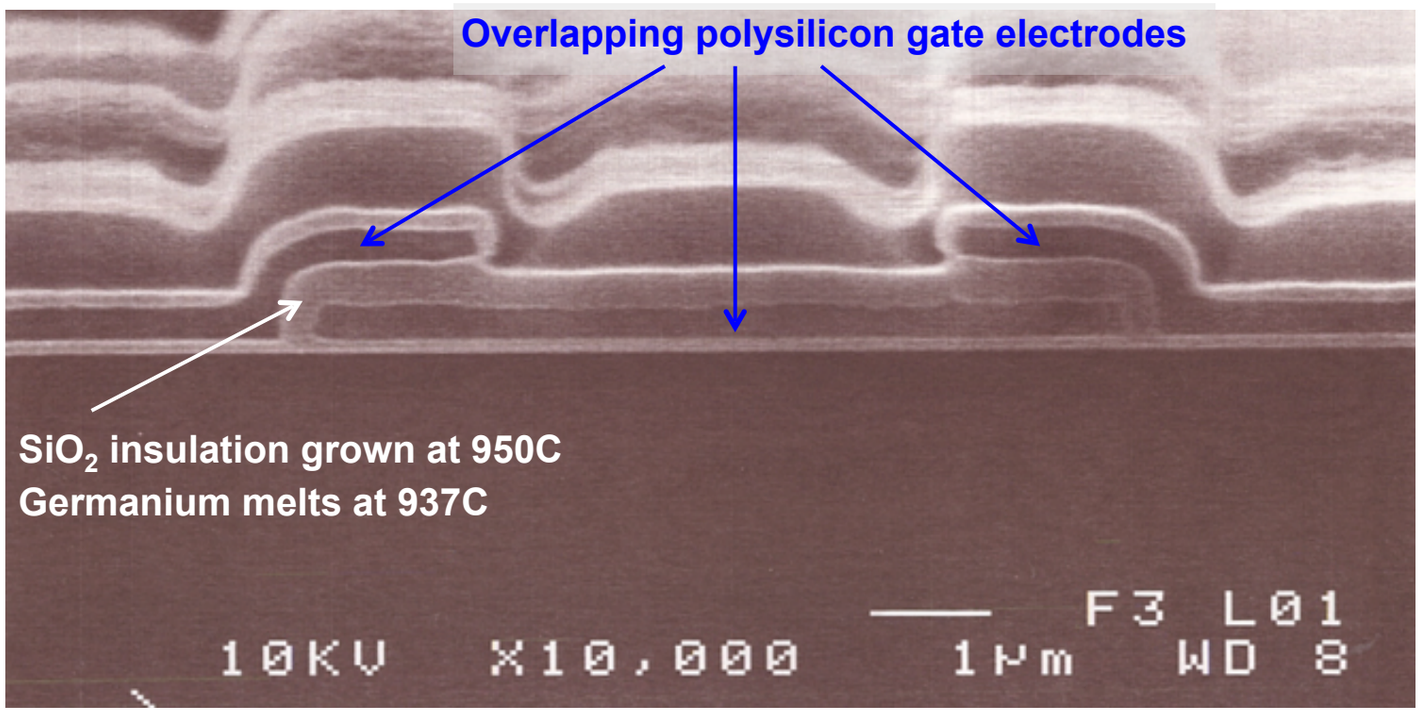
S. Kuhlmann

Technology R&D: IR Spectroscopy

Germanium CCDs

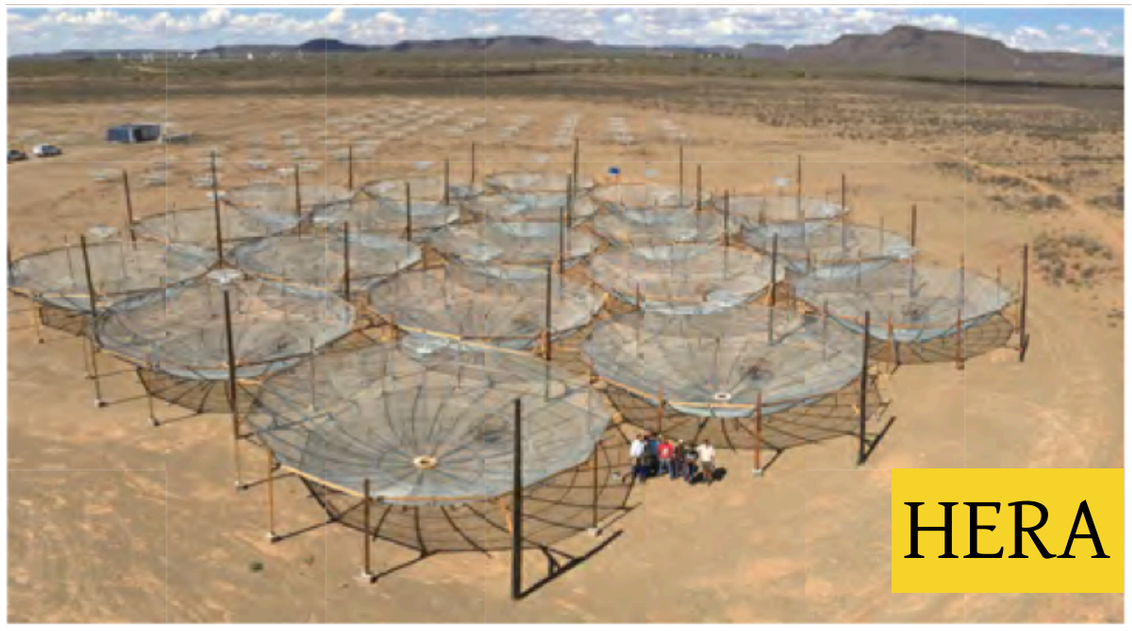


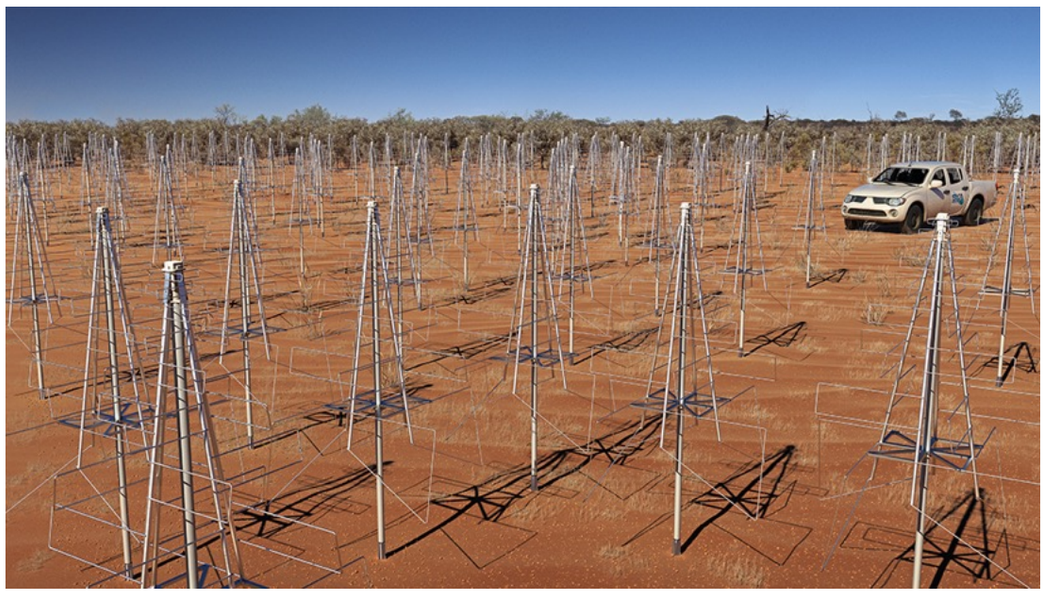
Metric	2016 Goal
Frame Rate	4 fps
Read Noise	10 e^-
QE	> 60% (400-1600 nm)
Well capacity	> 100 ke^-
Features	• TDI / Pushbroom easily implemented • On-chip binning w/o read noise penalty



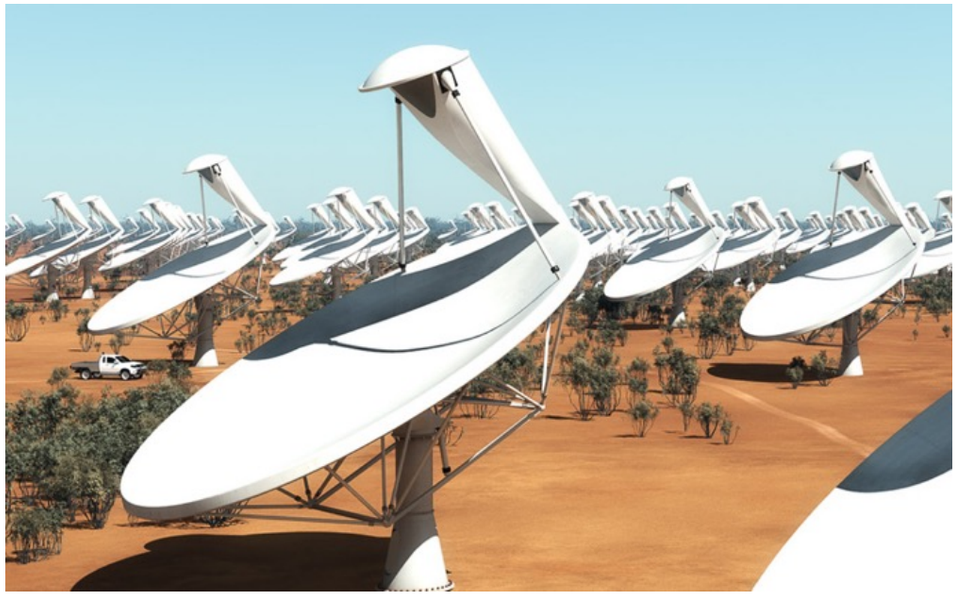
K Honscheid
D Schlegel

Technology R&D: 21cm





SKA-Low



SKA-Mid

Technology R&D: 21cm

Challenges of Low-Frequency Radio Astronomy

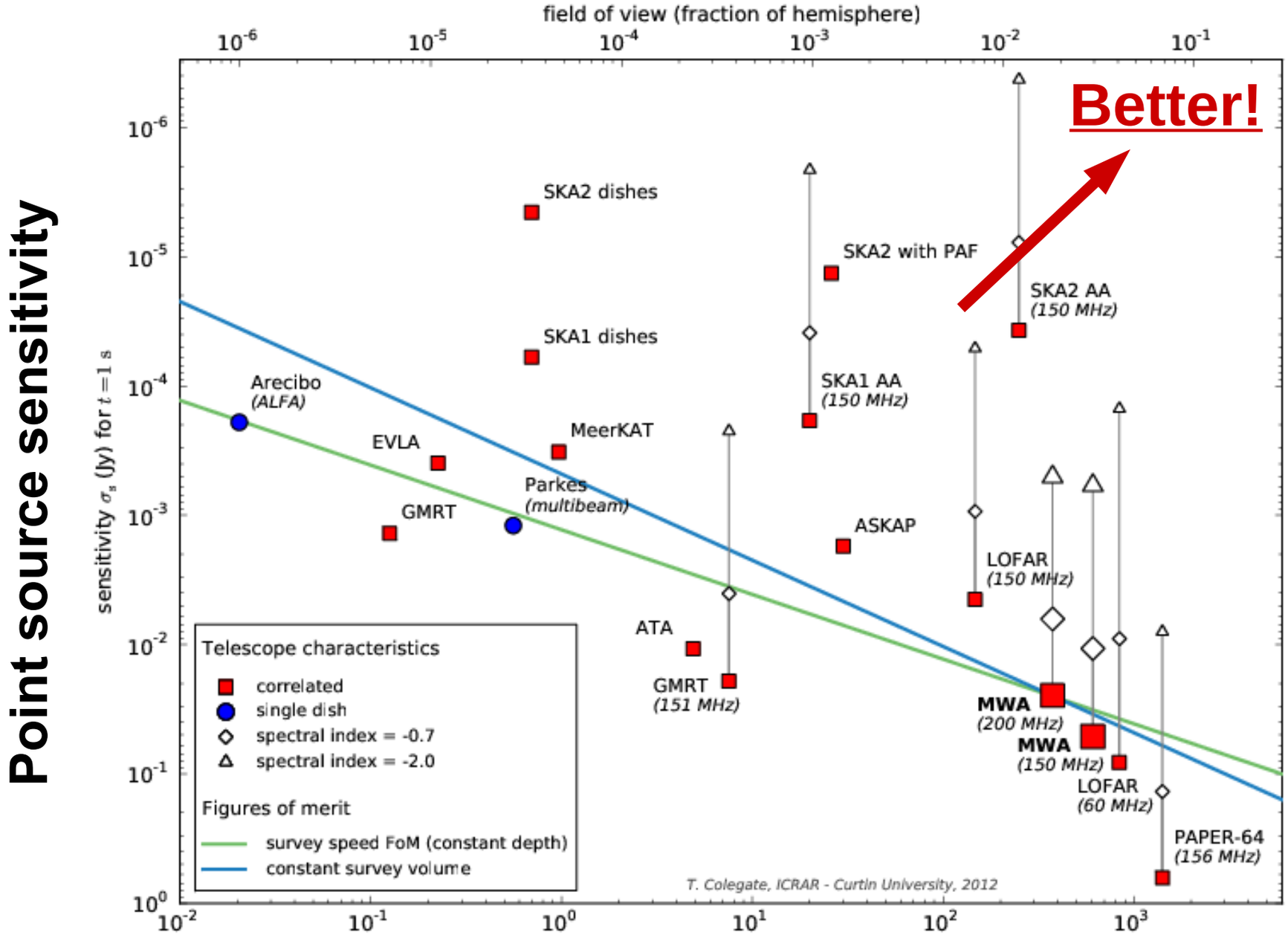
- Sky noise
- Foregrounds
- RFI
- Ionospheric fluctuations
- Calibration difficult

Require high speed computation to address – starting to be affordable only now
Instrument design must incorporate calibration requirements

J Hewitt

Technology R&D: 21cm

Survey telescopes



Tingay et al. (2013)

Technology Parallel Sessions

Tuesday, 14 November 2017

15:00 - 17:00 **Parallel Session: New Technology Developments for the Future Summary**

Meeting ID: 162 492 955

Conveners: Dr. David Schlegel (Lawrence Berkeley National Lab), Prof. Aaron Roodman (SLAC)

Material: **Zoom link**

15:00 **Ring Resonators** *30'*
Speaker: Dr. Ravi Gupta

15:30 **Wide-field adaptive optics** *30'*
Speaker: Jessica Lu

16:15 **Fiber positioners** *15'*
Speaker: Tom Diehl (FNAL)

16:30 **Future fiber positioners** *30'*
Speaker: Joe Silber

Wednesday, 15 November 2017

08:30 - 10:30 **Parallel Session: New Technology Developments for the Future Summary**

Meeting ID: 162 492 955

Conveners: Prof. Aaron Roodman (SLAC), Dr. David Schlegel (Lawrence Berkeley National Lab)

Material: **Zoom link**

08:30 **LSST CCDs** *30'*
Speaker: Paul O'Connor

09:00 **Germanium CCDs** *30'*
Speaker: Steve Holland (Lawrence Berkeley National Laboratory)

09:30 **Quantum sensors** *30'*
Speaker: Swapan Chattopadhya (TBC)

Technology R&D Comments

My own comments:

- Novel technology like MKIDs or Ring resonators could be essential in a special purpose instrument
- Ambitious, highly multiplexed spectroscopic project may require some new technology: eg. micro-shutters, Germanium CCDs, etc.
- 21cm?
  - SKA Phase II - $$$
  - can advances in electronics/computer reduce cost?