Half Wave Plate pros and cons
# Half Wave Plate requirement

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Planck experience

- In Planck HFI 2013 paper:
  - "at the present state of the reconstruction, polarization maps are dominated at large scales by systematic effects"
    - Detectors miscalibration
    - Dipole leakage
    - Differential spectral transmission

Planck 2013 results. VI. High Frequency Instrument data processing

- This must be in better control, by design:
  - HWP
  - Scanning strategy

Idealized Polarimeter

Source

Rotating HWP
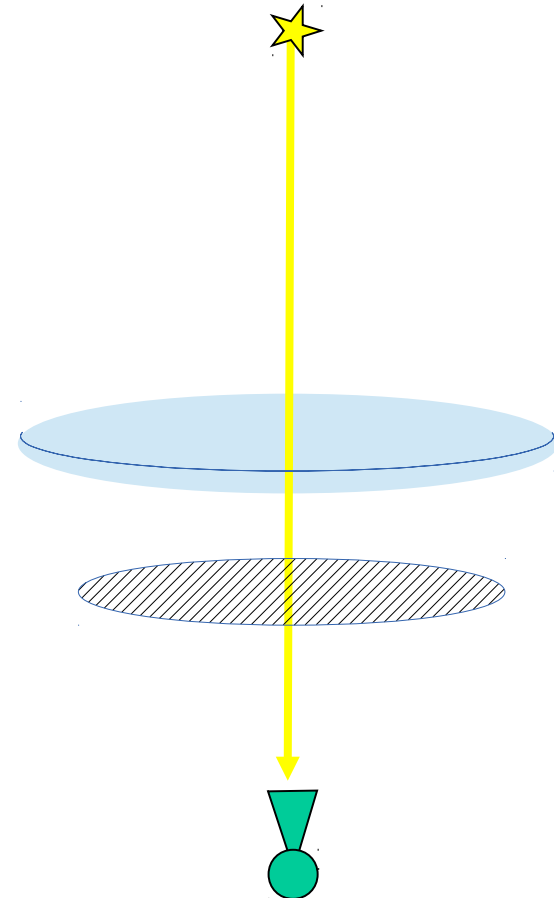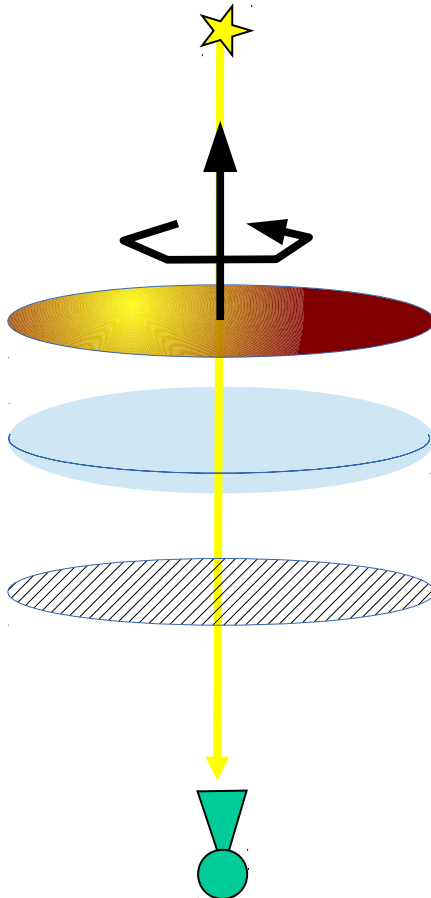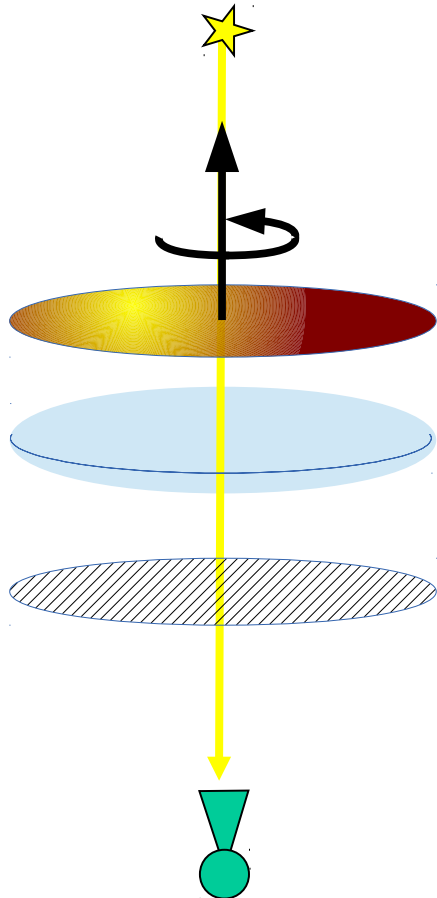
Telescope

Polarizer (wire grid)
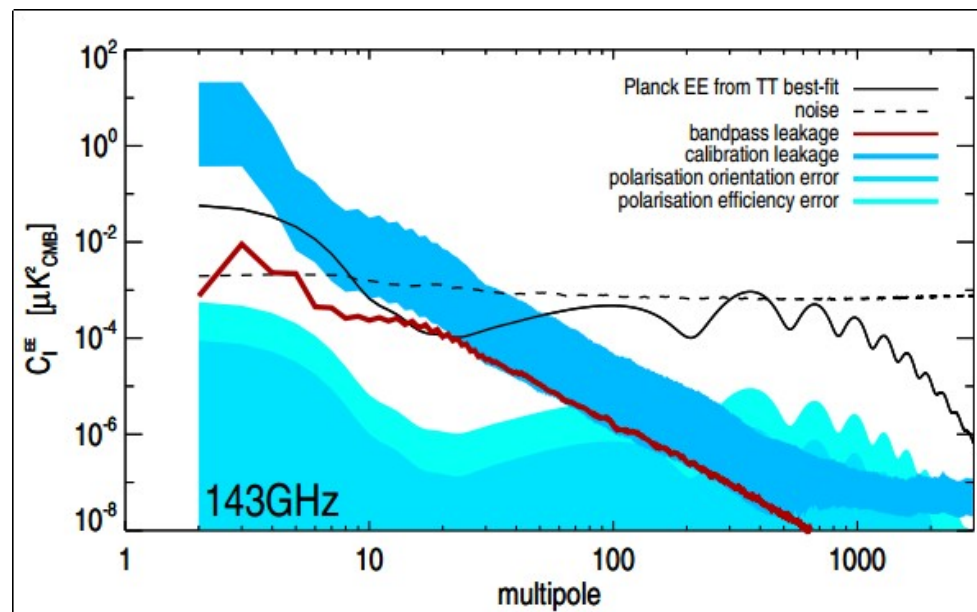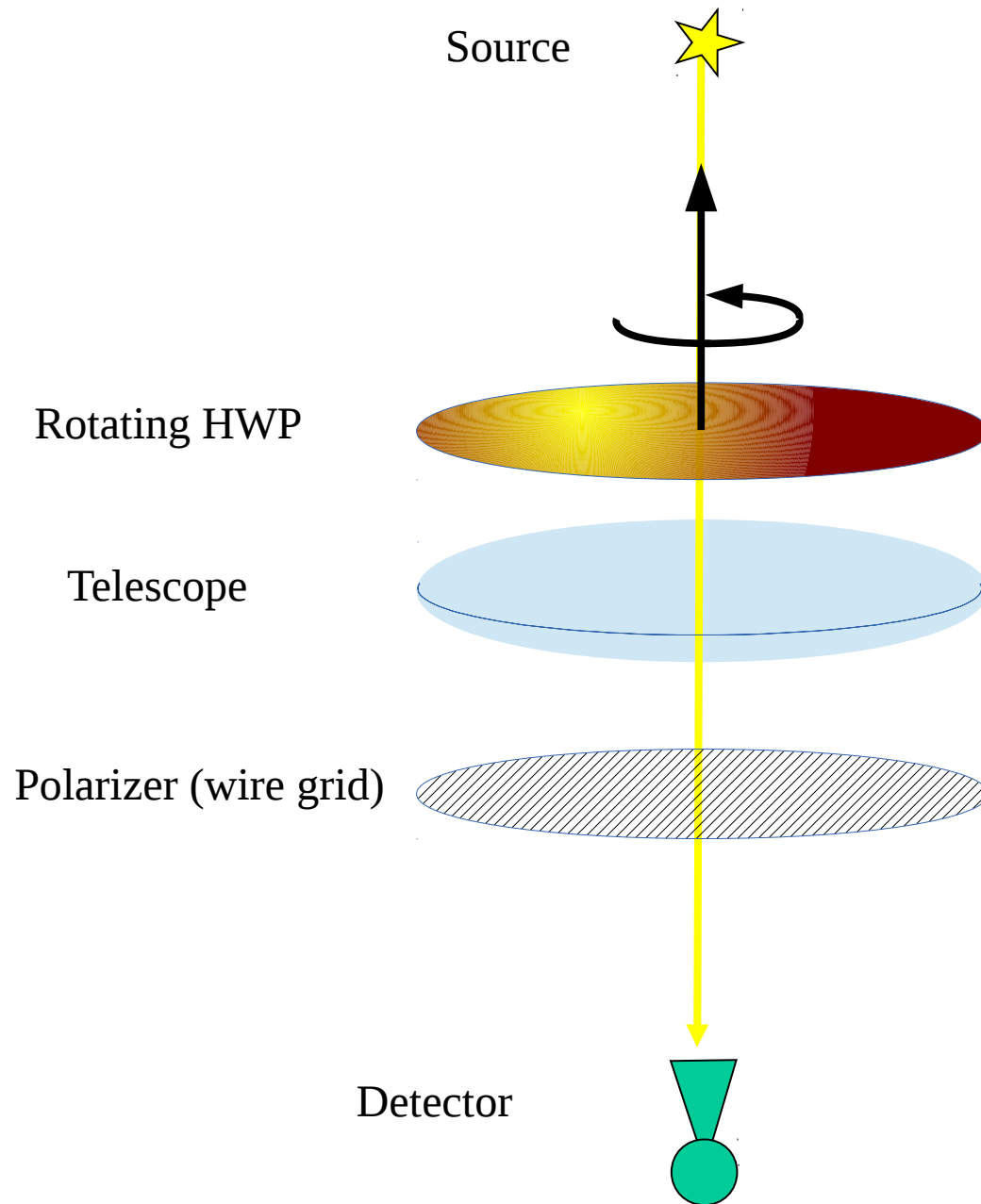
Detector

3 options

- Spinning HWP
- Stepping HWP
- No HWP

Spinning HWP

- **Operation**
  - The HWP spins fast with respect to scanning speed
  - Polarization is modulated at 4 ω
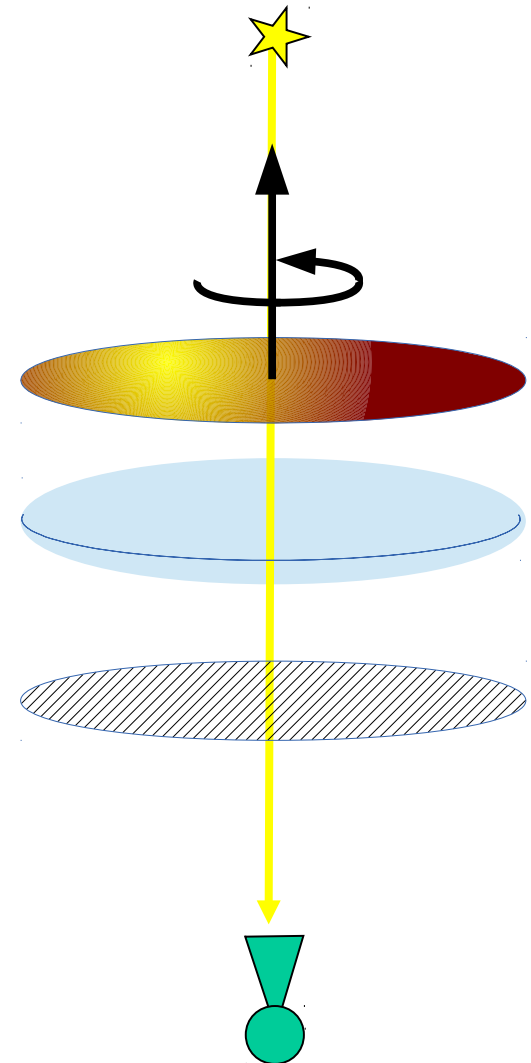
- **Experience**
  - Quijote, EBEX, MaxiPOL

- **Pros**
  - No combination of detectors is required to measure polarization
  - Instrumental polarization not mixed with sky polarization
  - Relaxed constraints on calibration and stability
  - Relaxed requirements on beam knowledge

- **Cons**
  - Limited experience at the current time
  - Thermo-mechanical design, Power dissipation
  - Telescope size limited by HWP size
  - HWP calibration critical
  - Non-idalities of the HWP have different coupling with different sky emissions (see Bryan et al, arXiv:1006.3359, O'Dea et al. arXiv:1102.0559 on SPIDER)
  - Bandwidth limitations induced by the HWP

Stepping HWP

- Operation
  - Signal is modulated by scanning (T+Q)
  - Polarization is rotated at 4 θ
 - Stepping the HWP modifies the response to polarization, keeping the same optical system
- Experience
  - **SPIDER**r, BLASTpol, Polarbear, Keck array, PILOT
- Pros
  - No combination of detectors is required to measure polarization
  - Relaxed constraints on calibration and stability, and beam knowledge
  - Instrumental polarization not mixed with sky polarization
  - HWP angle synchronous systematics are just offsets in the data
  - Study, design and prototype in preparation within ITT Pisano
- Cons
  - Limited experience at the current time
  - Moving parts, mechanical design
  - Telescope size limited by HWP size
  - HWP calibration critical (transmission, phase shift, cross-pol)
  - Non-idalities of the HWP have different coupling with different sky emissions (see Bryan et al, arXiv:1006.3359, O'Dea et al. arXiv:1102.0559 on SPIDER)
  - Bandwidth limitations induced by the HWP
  - 1/f more critical than with spinning HWP
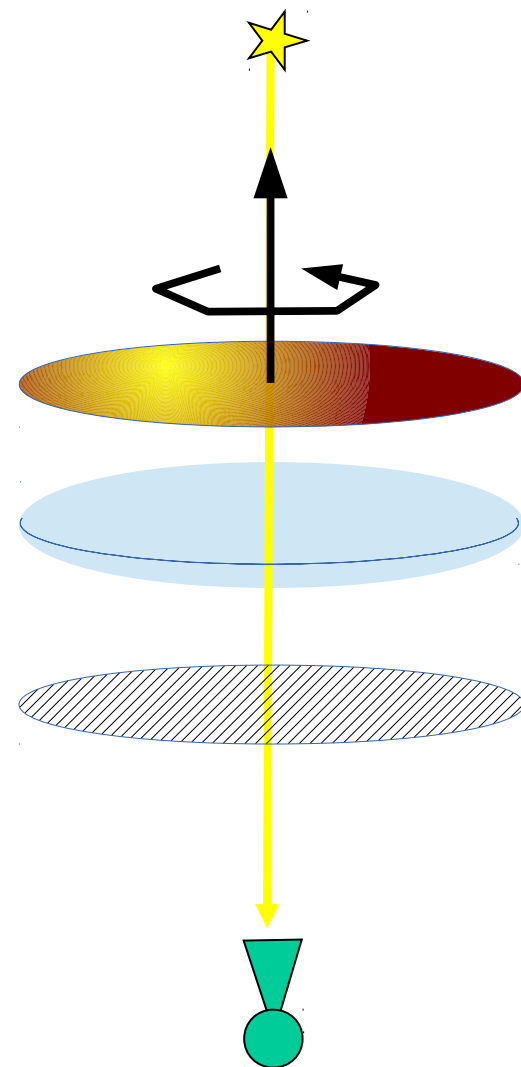
No HWP

- Operation
  - Polarization is detected by observations with different payload angles
  - Scanning strategy is tuned so to observe each pixel with several different orientation
 - Different detectors can be combined to remove common mode
- Experience
  - Planck and other CMB experiments designed for temperature anisotropy
- Pros
  - Simples system, in terms of technological development and operations
  - Large telescope
  - No moving parts
- Cons
  - Mix of beam shape and polarization, to be correct by scanning strategy + data analysis techniques
  - Instrumental polarization mixed with sky polarization
  - Strong calibration requirements
    - Gain, beams, time response, ...
  - Stability
  - Scanning strategy design
  - Beam knowledge requirements
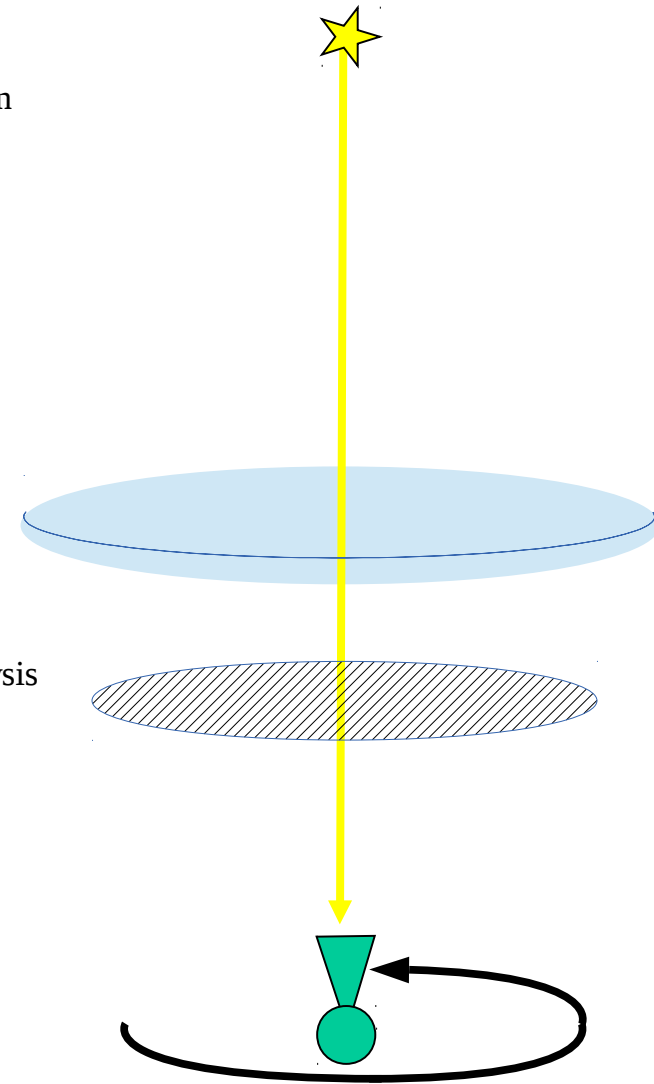
Pros / Cons summary

	Spinning	Stepping	No-HWP
Modulation	P only	T+P	T+P
Pol measure	demodulation	Same detector with different HWP position	Same detector with different Payload positions
Beam knowledge	Not critical	Not critical	critical
Power dissipation	Critical	Not critical	Not critical
Moving parts	Critical	Mid	Not present
Cooling	Critical	Mid	No
Angular resolution	Limited by HWP	Limited by HWP	Not limited by HWP
Instrumental polarization	Not critical	Not critical	Critical
Required stability	Low	Mid	High
Scanning strategy	Simple	Simple	Complex
Experience	Limited	Limited	Mid
Tech. development	Required	Required - ITT	Limited
HWP calibration	Critical	Critical, a few positions	Not critical
Beam calibration	Not critical	Not critical	Critical
Gain Calibration	Not critical	Mid	Critical
Stability	Not critical	Mid	Critical
Bandwidth	Constrained	Constrained	Unconstrained