CCAT Polarimetry Technique

Darren Dowell

JPL

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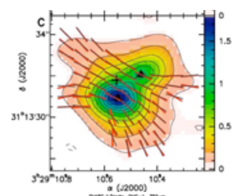
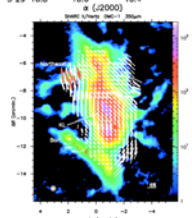
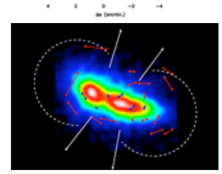
Why were we thinking of doing polarimetry with CCAT?





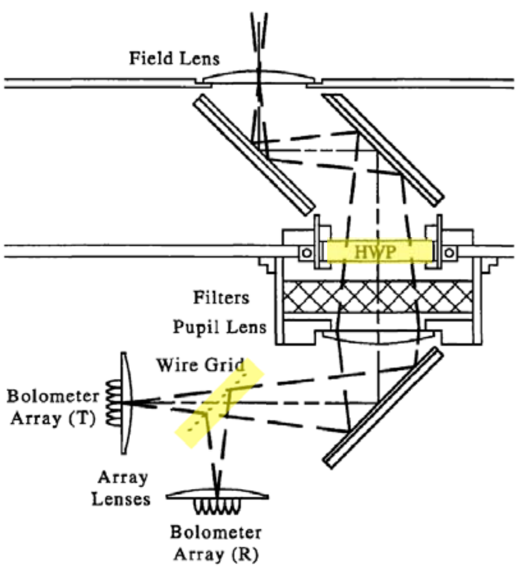


- magnetic fields in the envelopes of young stellar objects, which test models for the formation of individual stars (resolved out by ALMA?)
- polarization maps of clouds with thousands of vectors in them, which test models of turbulence (resolved out by ALMA)
- polarization variability at 200 μm and 350 μm in Sgr A*, which is sensitive to jets and accreting plasma very near the event horizon (higher frequency than ALMA)
- magnetic field patterns in galaxies 10-100 Mpc away (resolved out by ALMA?)
- polarization of more distant objects, which help quantify the contamination in lower-resolution CMB polarization measurements (faster surveying than with ALMA?)

How do other people do polarimetry in (sub)mm?

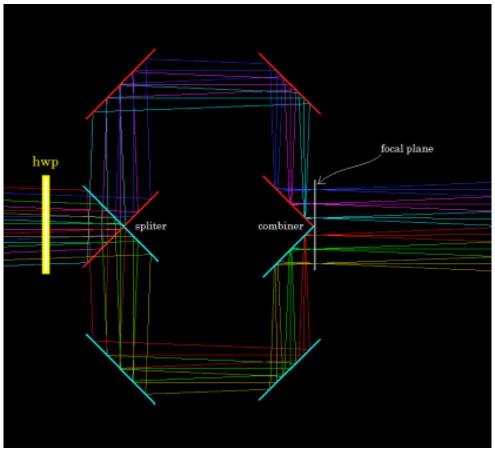
- cold stepped wave plate with dual-polarization detector: Hertz/CSO, Stokes/KAO
- warm stepped wave plate with dual-polarization detector: SHARP/CSO
- warm stepped wave plate with single-polarization detector: SCUBA/JCMT
- **rotating wave plate (warm) with single-polarization detector: POLKA/SMTO**
- **variable delay reflective modulator: Hertz/SMTO**
- no modulator whatsoever, just scanning: Boomerang, QUAD, BICEP

Cold stepped wave plate with dual-polarization detector: Hertz/CSO, Stokes/KAO



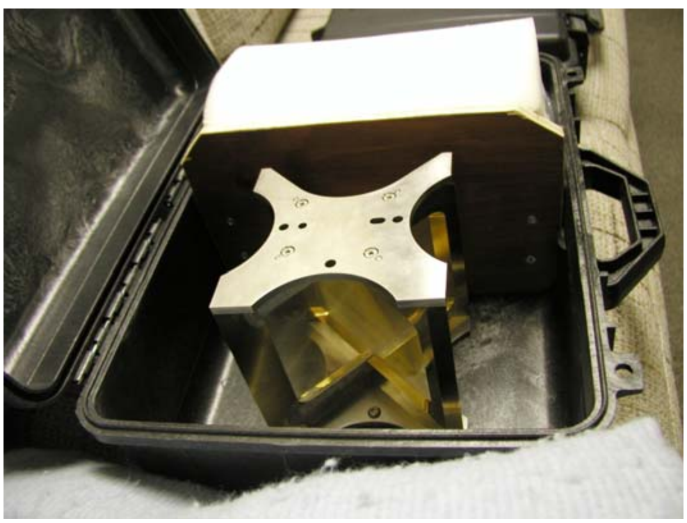
- observing mode: chopping + nodding
- Dual-polarization detection reduces effects of sky noise and atmospheric transmission variations. ⇒ Photon-noise limited in almost all conditions.
- $\sigma(P)$ = 0.2% systematic errors
- Platt et al. (1991); Schleuning et al. (1997); Dowell et al. (1998)

Warm stepped wave plate with dual-polarization detector: SHARP/CSO



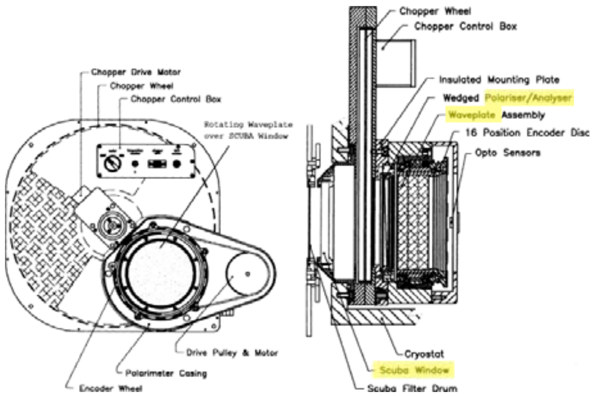
- Doesn't have to be that complicated if the dual-polarization splitting is in the cryostat.
- observing mode: chopping + nodding
- Novak et al. (2004); Li et al. (2006)

Warm stepped wave plate with dual-polarization detector: SHARP/CSO



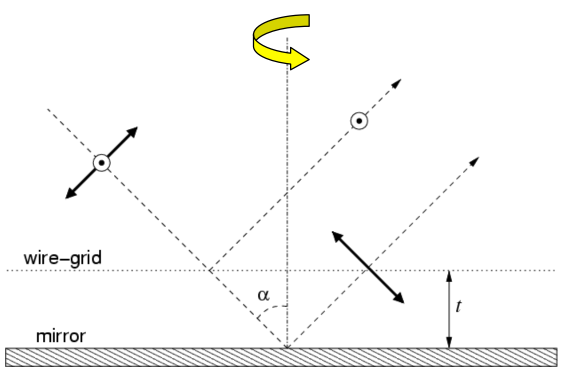
- Crossed polarizer (QMC Instruments)

Warm stepped wave plate with single-polarization detector: SCUBA/JCMT



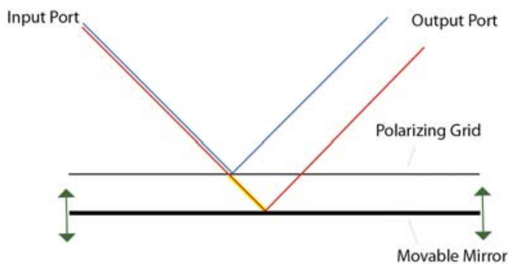
- observing mode: chopping + nodding
- Single polarization detection is vulnerable to atmospheric fluctuations, but wasn't a big problem at 850 μm.

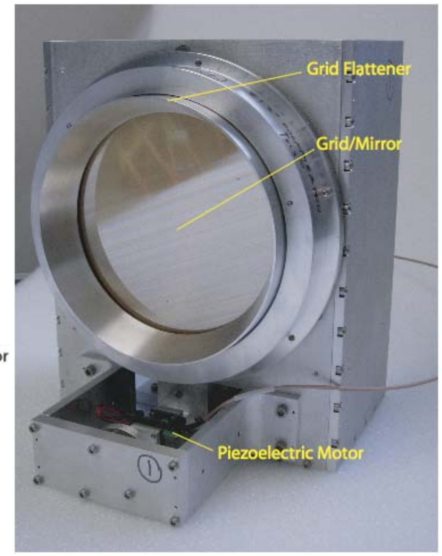
Rotating wave plate (warm) with single-polarization detector: POLKA/SMTO



- reflective half-wave plate
- rotation at 4 Hz ⇒ modulation at 16 Hz
- observing mode: nodding or on-the-fly mapping
- separate observation to recover the total intensity
- Siringo et al. (2004)

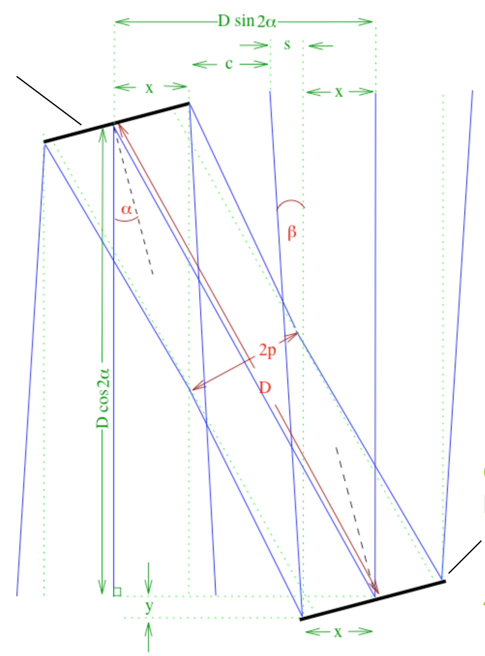
Variable delay reflective modulator: Hertz/SMTO





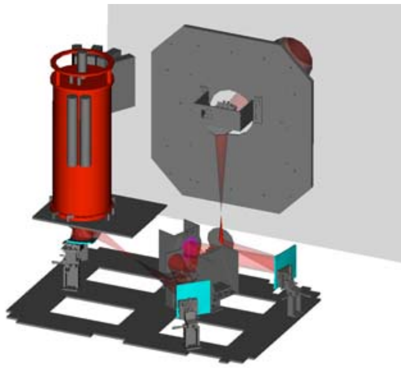
- under development
- Chuss et al. (2004)

QVI 1: Selects Between Q & U (Grid wires at 22.5 degrees)

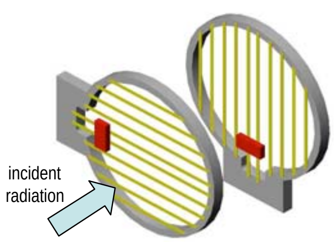


QVI 2: Toggles Roles of detectors (Q ⇒ -Q) (Grid wires at 45 degrees)

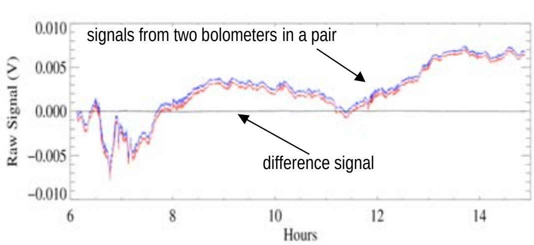
Hertz on the SMTO- April 2006



No modulator whatsoever, just scanning: Boomerang, QUAD, BICEP



- Matching of detectors within a pair is key:
  - beam shape
  - transfer function
- All of these instruments operate at sites and wavelengths where the atmosphere is very stable.



What makes the most sense for CCAT?

- Assumptions:
  - No funds for a dedicated polarimeter at the start; instead converting the cameras.
  - Not a lot of room to redirect wide, low f/ # beams through a reflective system.
- <u>Baseline plan</u>: transmissive single-polarization polarimeter
  - wire-grid polarizer parallel to camera window (undetected polarization reflected into cold dewar)
  - crystal quartz mosaic HWP, polyethylene AR coating
    - rotation at a few Hz
    - λ = 200 μm: 2 mm thick
    - λ = 2000 μm: 2 cm thick
  - Ideally, the HWP would be near a pupil (Gonatas et al. 1989). If not, will need to check for systematic effects.
- Other plans worth considering:
  - Some detector designs or camera configurations could be dual polarization.
    - stepped HWP
    - maximum sensitivity for small fields
  - If there is room, the variable delay modulators could be used instead in a reflective system.
    - In principle, can be tuned over a wide band.

Camera pairs

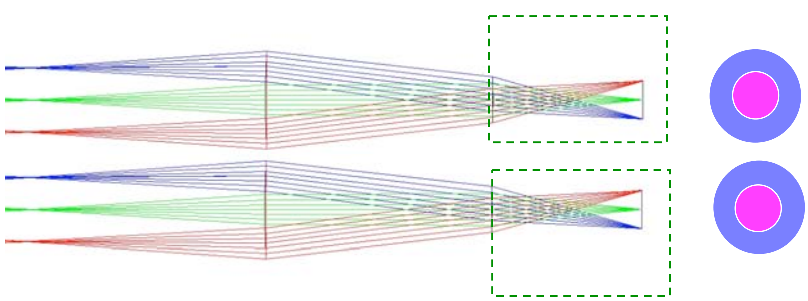


Figure 6.14. Four identical SWCam and fore-optics systems can deliver good field coverage for CCAT. The total field covered would be ~ 102 square arcminutes.

Dual-polarization camera pairs

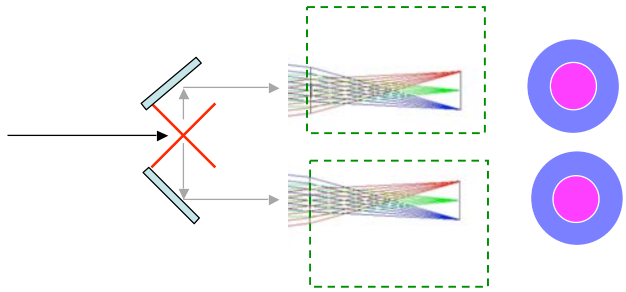


Figure 6.14. Four identical SWCam and fore-optics systems can deliver good field coverage for CCAT. The total field covered would be ~ 102 square arcminutes.