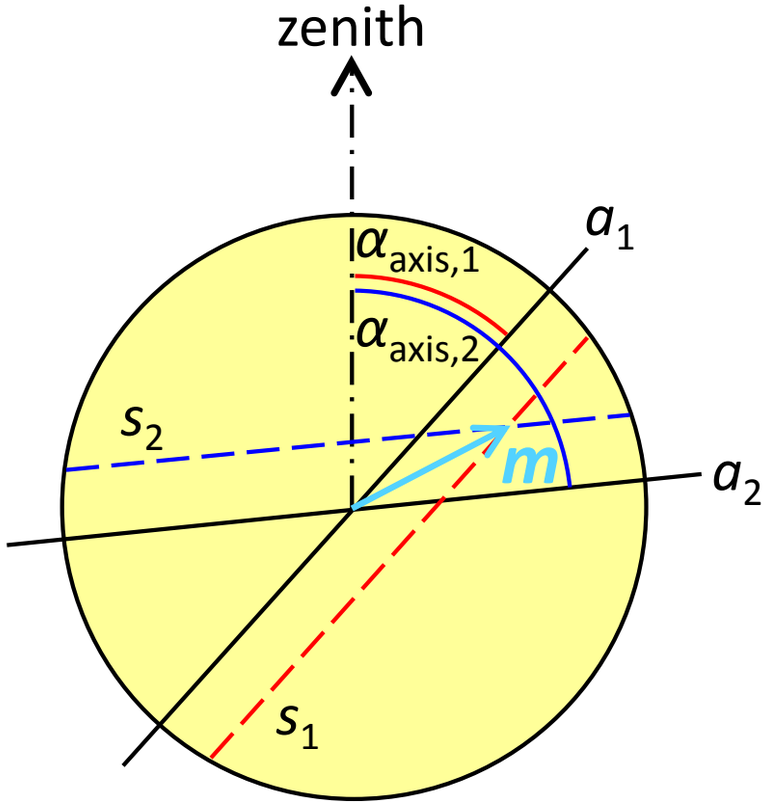
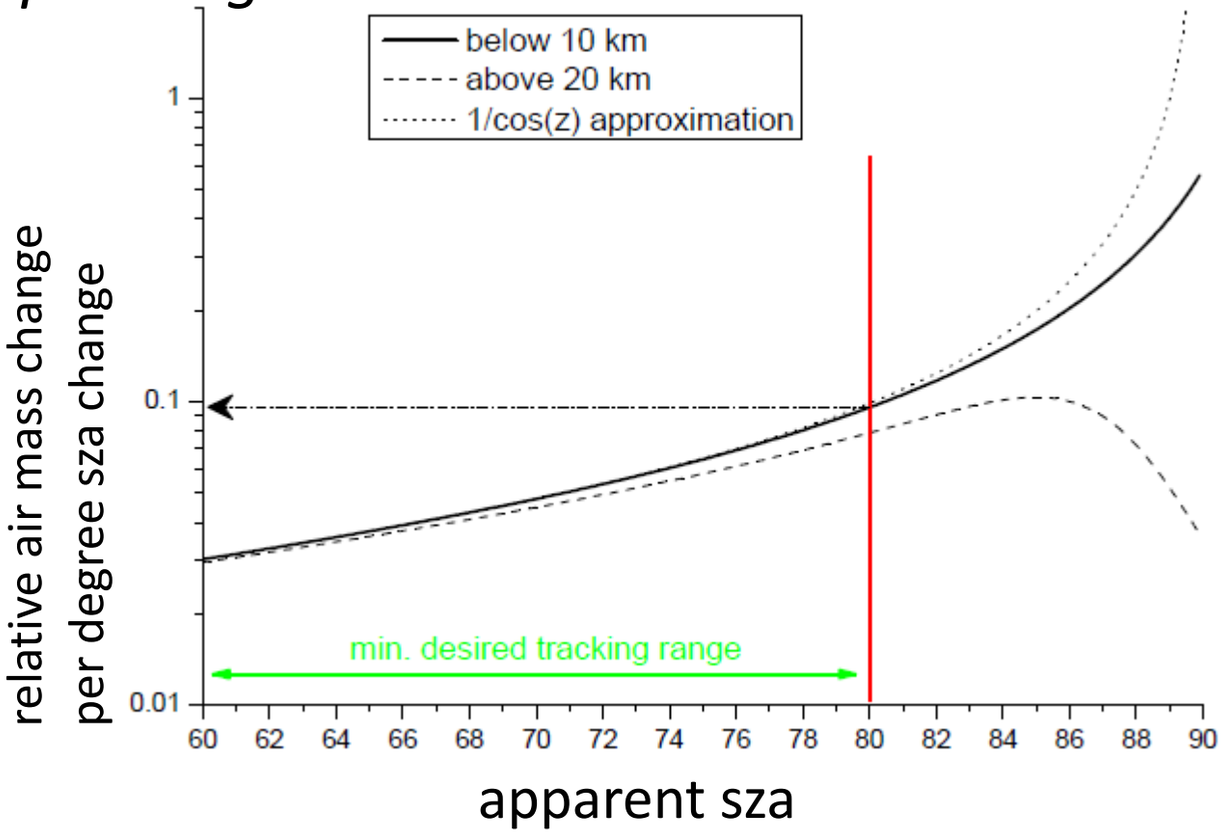
Determination and correction of pointing errors in solar FTIR spectrometry

A. Reichert, P. Hausmann, and R. Sussmann



Mispointing determination:

impact of mispointing

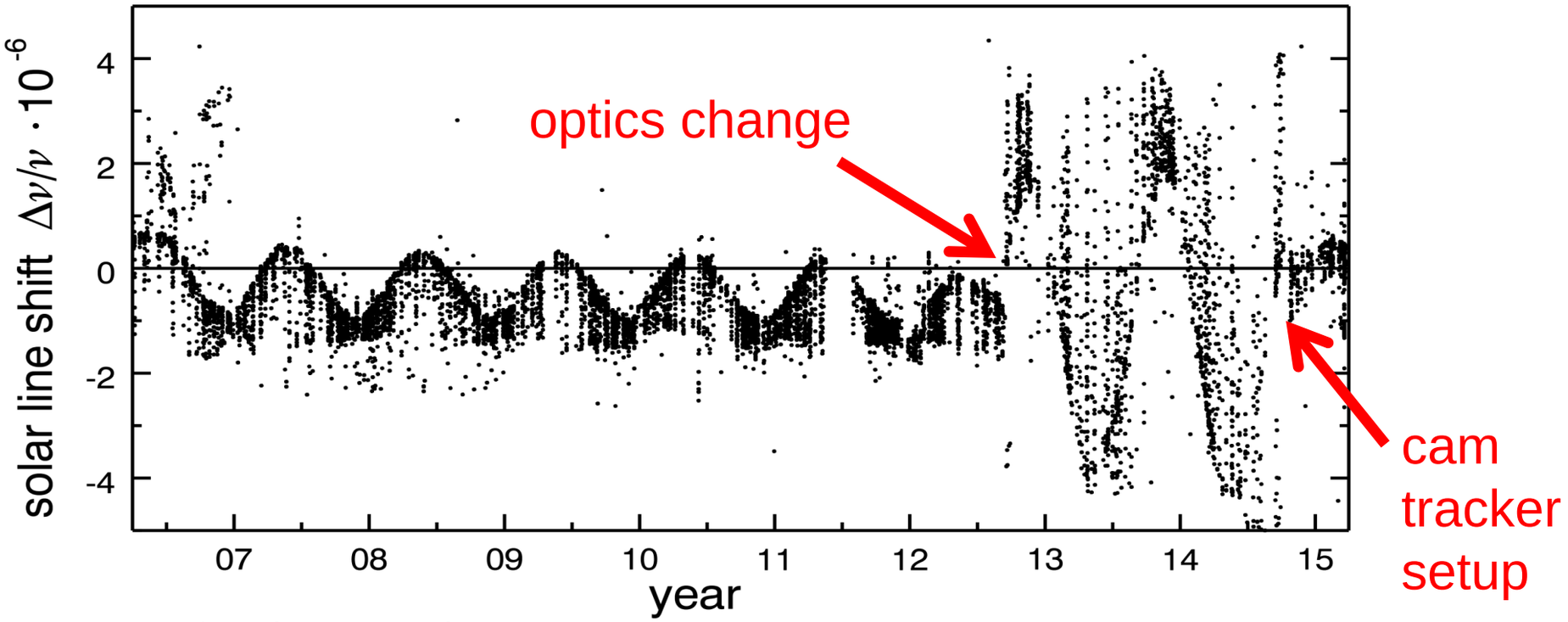


from: Hase, 2000

- Inaccurate alignment of FTIR line of sight with the solar disc center causes errors in trace gas retrievals
- Errors are approximately proportional to mispointing in zenith direction
- These errors may exceed accuracy requirements
  → error diagnosis and correction necessary

Mispointing determination:

solar line shift measurements

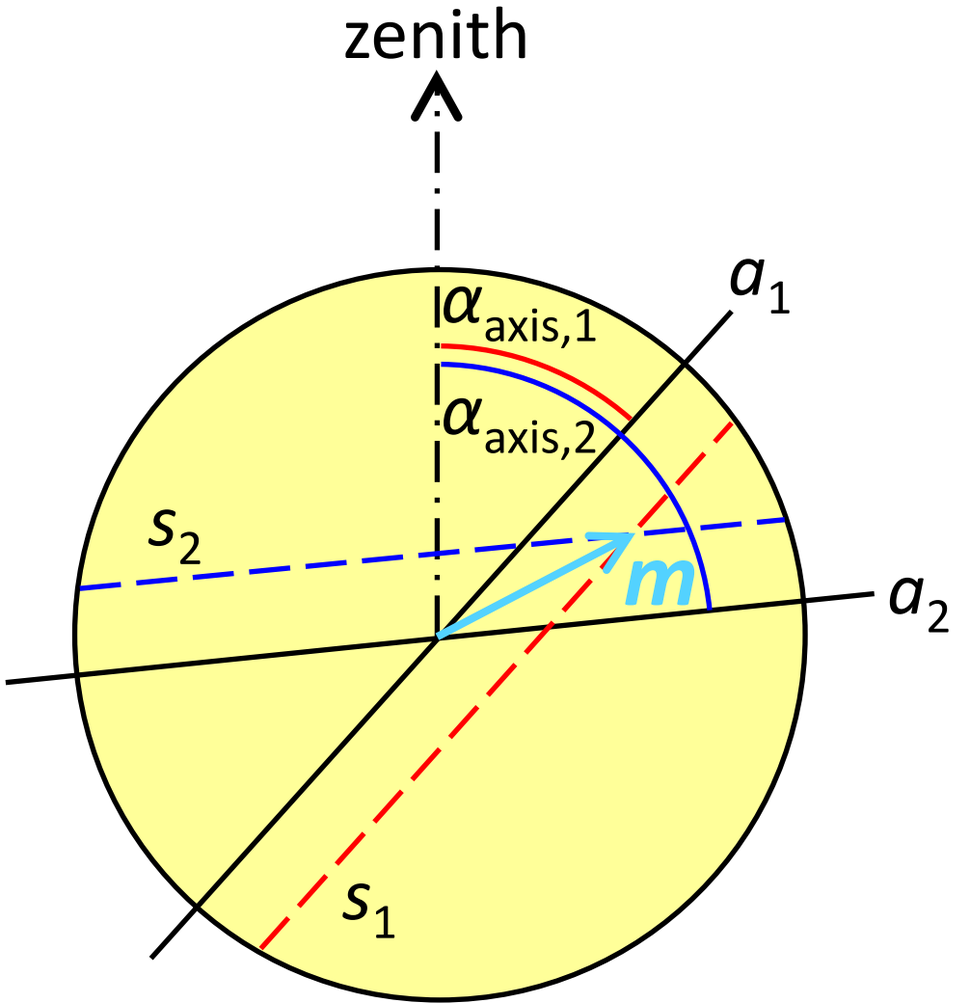


- Mispointing perpendicular to solar rotation axis
  → rotational Doppler shift in solar lines
- Neglecting differential rotation, measured shift is proportional to radial mispointing:

$$s\,[^\circ] = \frac{\Delta\nu/\nu \cdot 1^\circ}{3.9 \cdot 10^{-7} \cdot 60}$$ (Gisi et al. 2011)

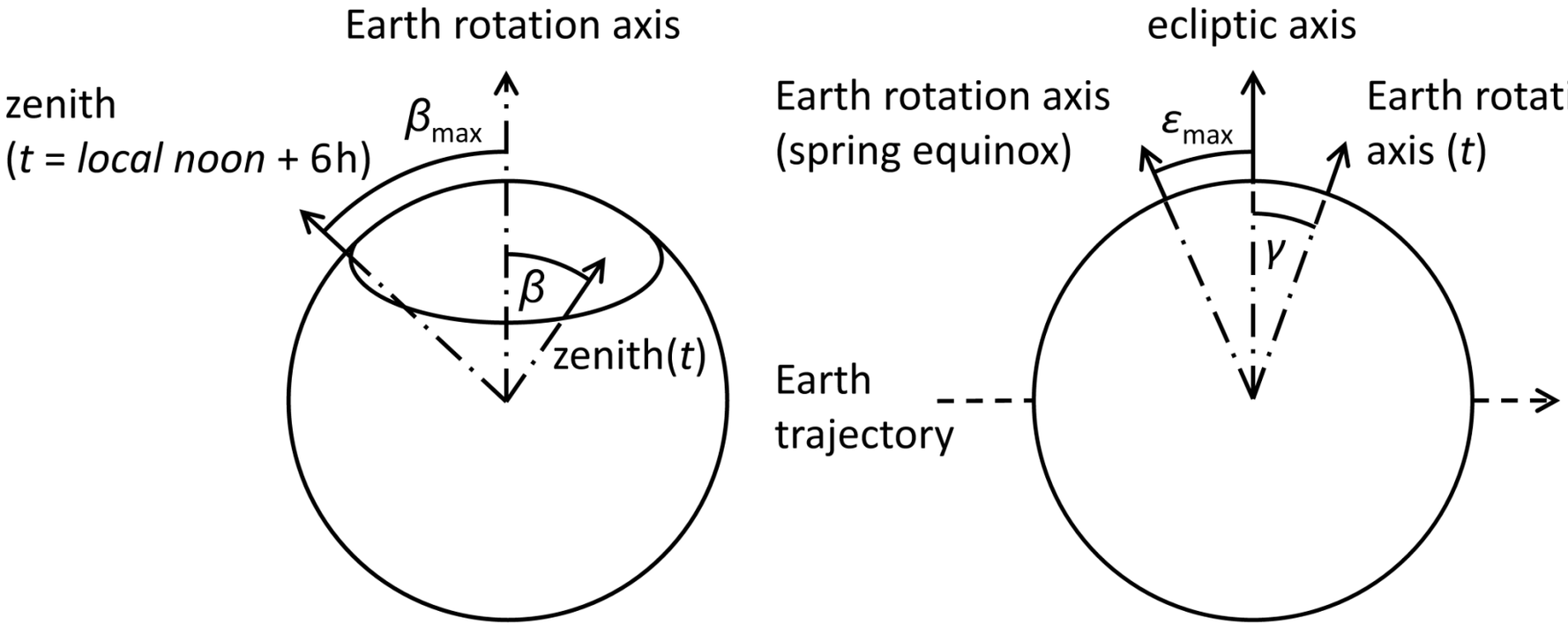
- **But:** No mispointing error correction directly possible from shift measurements since mispointing parallel to solar axis can not be determined

Mispointing determination:
basic idea of our method



- Multiple solar shift measurements at different solar axis orientations enable constraining both components of mispointing vector
- Each shift measurement constrains mispointing to lie on straight line, mispointing vector defined by intersection of lines with different axis orientations
- **Underlying assumption:** Mispointing does not vary significantly between measurements

Implementation:
orientation of solar rotation axis

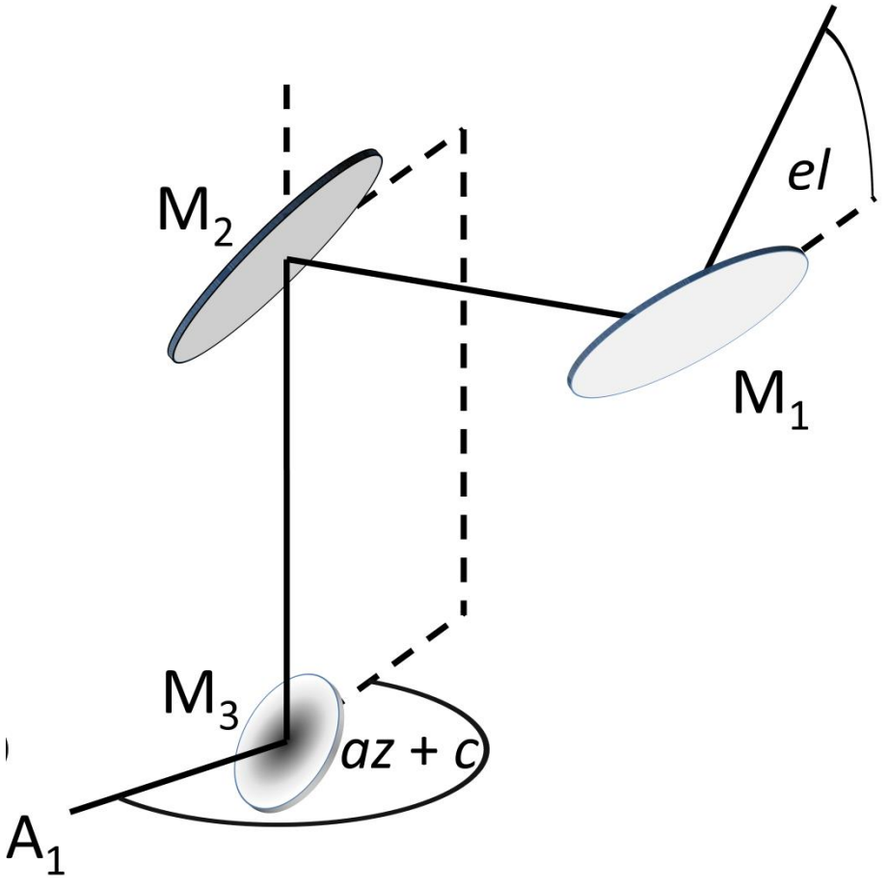


- Orientation of solar rotation axis:
  apparent angle between zenith direction and solar axis

- Orientation has annual/daily cycle, sum of 3 contributions:
  1) zenith → Earth axis, **2)** Earth axis → ecliptic axis,
  3) ecliptic axis → solar axis

Implementation:

transfer from sky to spectrometer coordinates

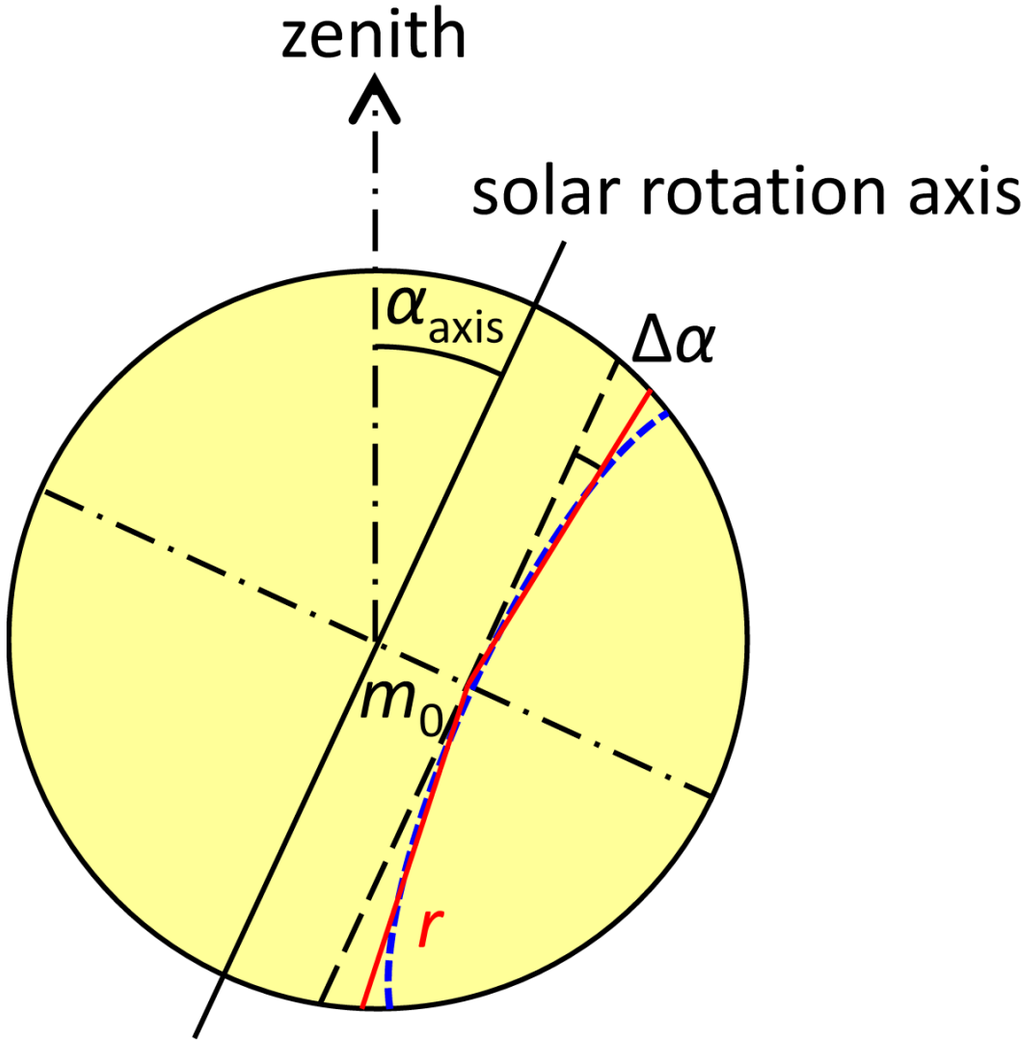


- Typical source of mispointing: non-ideal geometry of optical elements in the spectrometer

→ Approximately constant mispointing for spectrometer coordinates, **not** for sky coordinates

- Change of orientation of solar image due to tracker optics is calculated before mispointing calculation

Implementation:
differential solar rotation

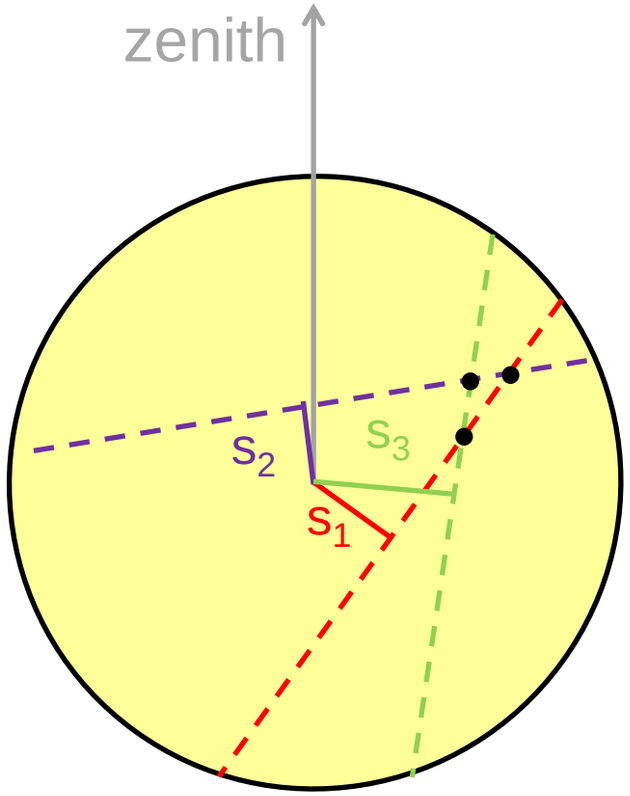


- Angular velocity of solar rotation depends on solar latitude: **differential rotation**

→ solar shift measurement does not constrain mispointing on straight line parallel to axis but on line with constant ω(ϕ) (blue)

- For mispointing determination scheme: linear approximation (red)

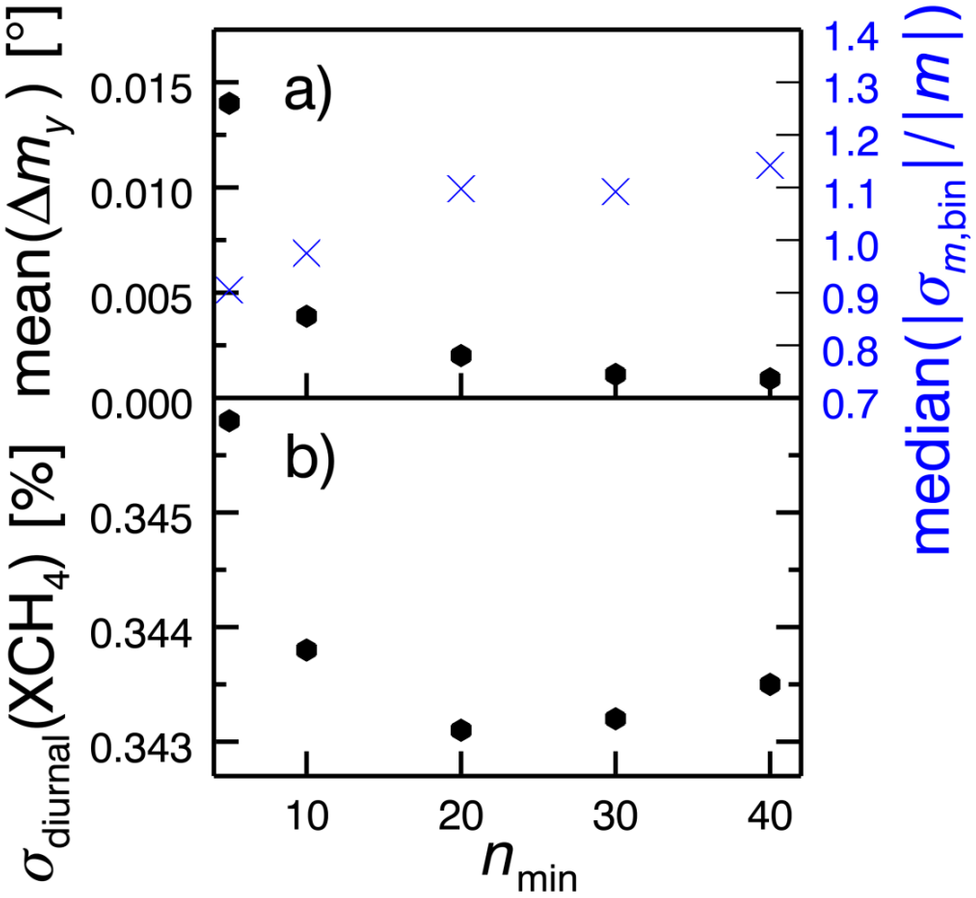
Implementation:
mispointing calculation



- Combine multiple measurements in time bin + calculate mean mispointing for bin → reduced mispointing error
- Mean mispointing = weighted mean of intersection coordinates
- Intersection error: solar shift error from difference of shift fit in adjacent filters + difference of axis orientation for measurement pair

Implementation:

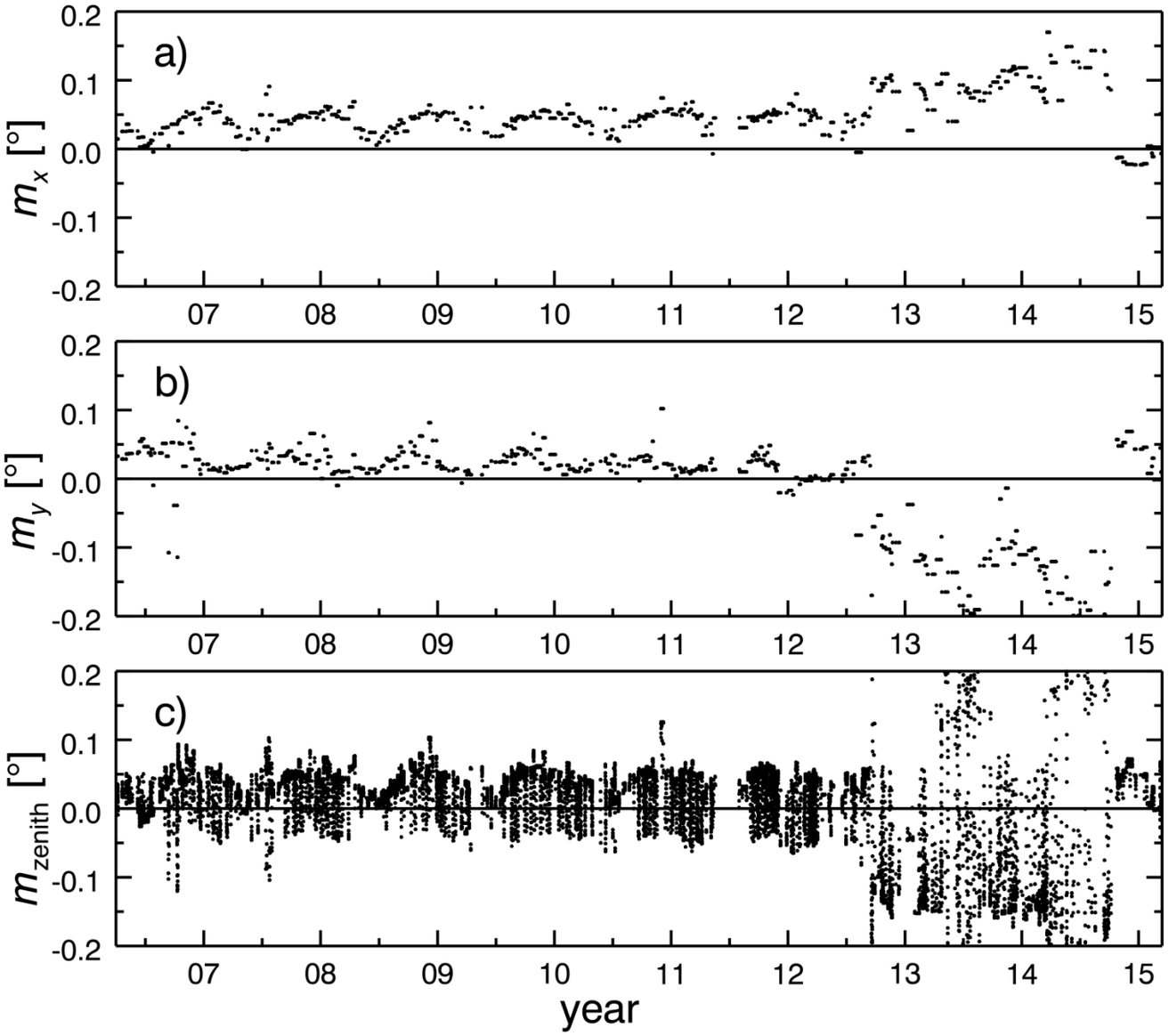
binning of measurement time series



- Tradeoff between constant mispointing within bin vs. mispointing uncertainty
- Selection of binsize for Zugspitze time series:
  minimum of XCH_4 diurnal variability

Results:

Zugspitze mispointing results

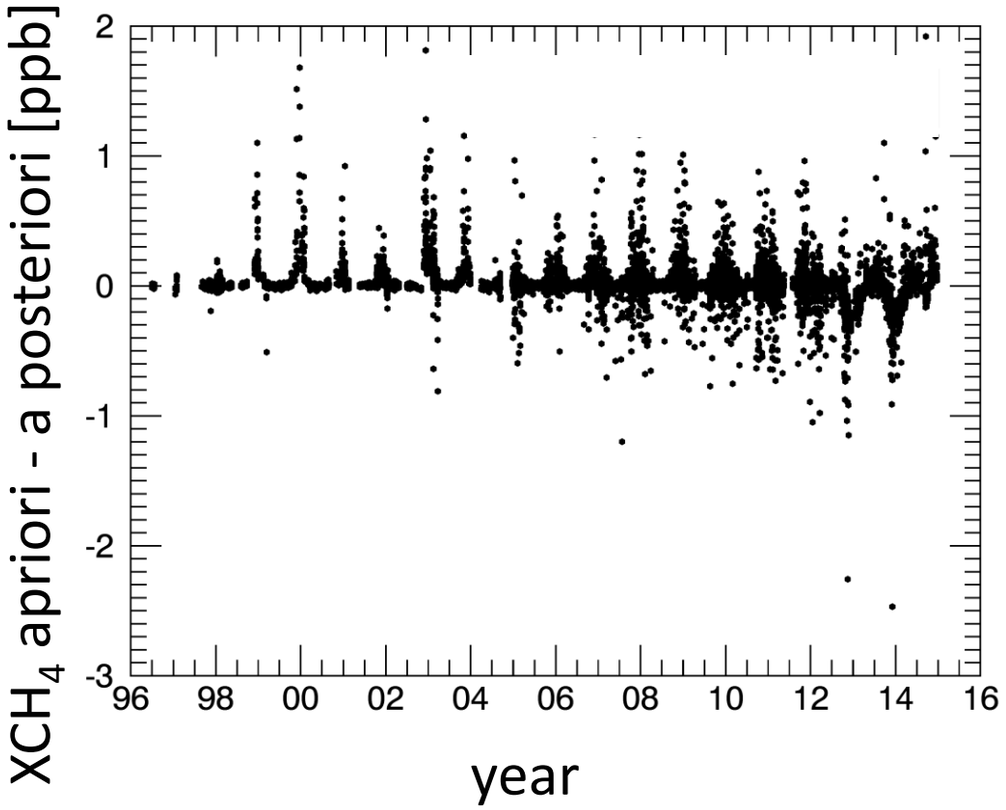


← Mispointing in spectrometer coordinates, *x* and *y* component

← Mispointing in sky coordinates, zenith component

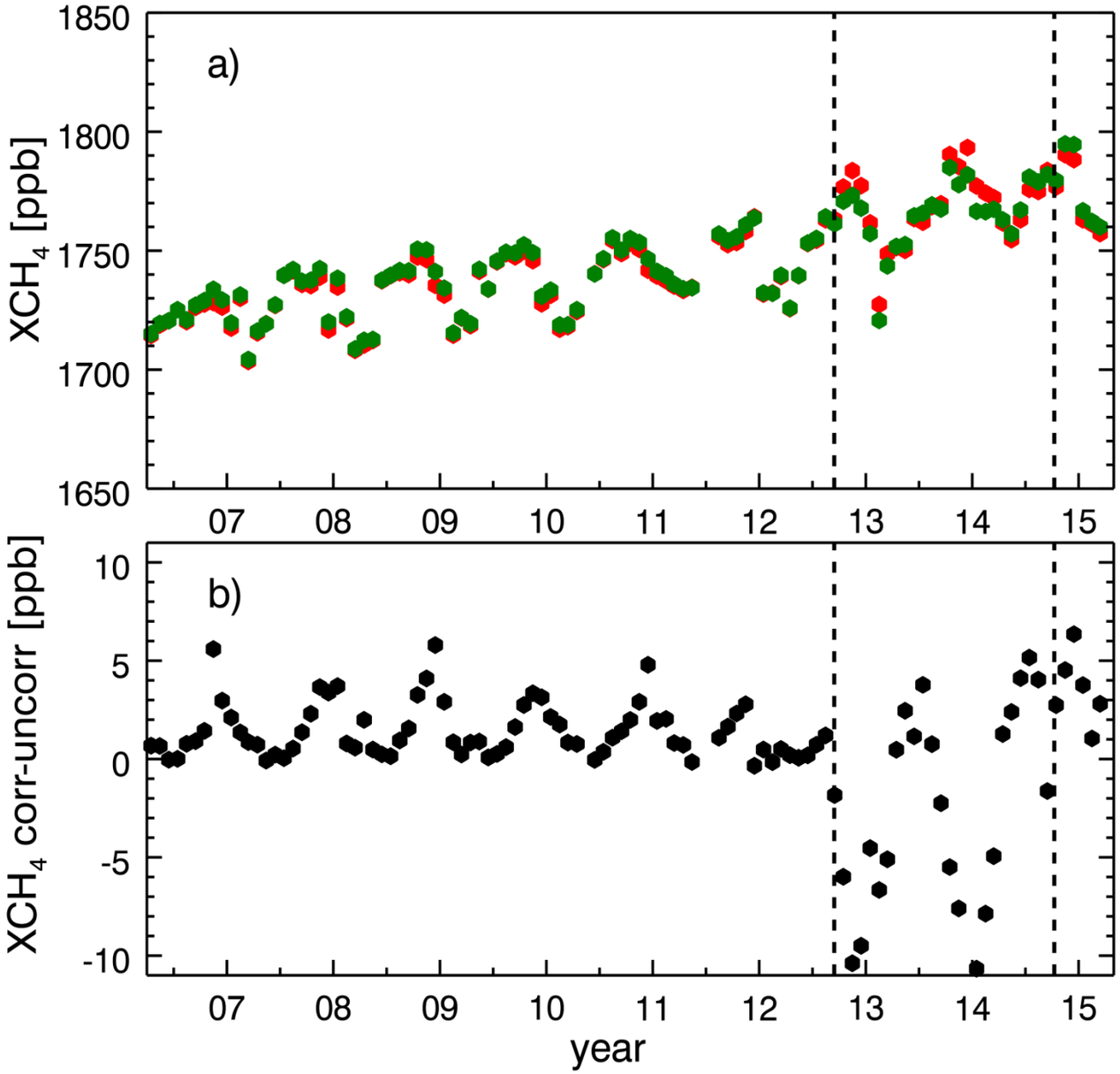
Implementation:
mispointing correction of retrieval results

- **a posteriori method:** calculate corrected airmass, multiply retrieved column by $airmass_{org}$ / $airmass_{corr}$
- **a priori method*:*** repeat retrieval using corrected sza
- a priori method: 5 % bias in mispointing/ ~0.02 % bias in XCH_4 → fair approximation for column retrievals
- For profile retrievals: a priori correction preferable



Results:

corrected methane time series/trend



- XCH_4 trend [ppb/yr]
  Apr 06 - Mar 15
  Zugspitze/Garmisch

	uncorrected	**a posteriori corrected**
Zugspitze	6.45	6.07
	[5.84, 7.04]	[5.55, 6.59]
Garmisch	5.22	5.20
	[4.77, 5.65]	[4.74, 5.64]

Summary and Conclusions

- Method to determine mispointing in solar FTIR measurements, enables correction of mispointing-induced errors in retrieval results
- Method relies on measurement of solar line shifts from multiple spectra at different orientations of the solar rotation axis
- Constraining zenith component of mispointing enables correction of retrieval results

Summary and Conclusions

- Mispointing correction for Zugspitze XCH_4 time series:
  effects of non-optimum tracking period are removed, trend consistency with nearby Garmisch site restored
- Benefit of presented method for refining other existing solar FTIR measurement time series
- **More details:** see Reichert et al., 2015, accepted for AMTD

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