Secondary Calibrators at sub-mm wavelengths

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Outline

- Challenges
- Ideal calibrators
- Reality
- Current JCMT calibrators
- Where do we go from here?
- Future (SOFIA, Herschel)

Challenges

- Stellar photospheres too faint
  - Flux density scale based on Mars model (accuracy ~ 5%, larger deviations possible during dust storms)
- Sky ‘never’ photometric, transparency poor (even at very good sub-mm sites), additionally we get sky noise and anomalous refraction
- Telescopes have relatively poor efficiency, may vary (varies) as a function of elevation, temperature (day/night or even winter/summer)
- Very few celestial sources suitable as calibrators

An ideal calibration source

- Bright
- Point-like
- Non-variable (or variability systematic and predictable, e.g. a planet)
- Featureless spectrum, well behaved SED
- Located in a region with low background and no confusion from nearby sources or extended emission

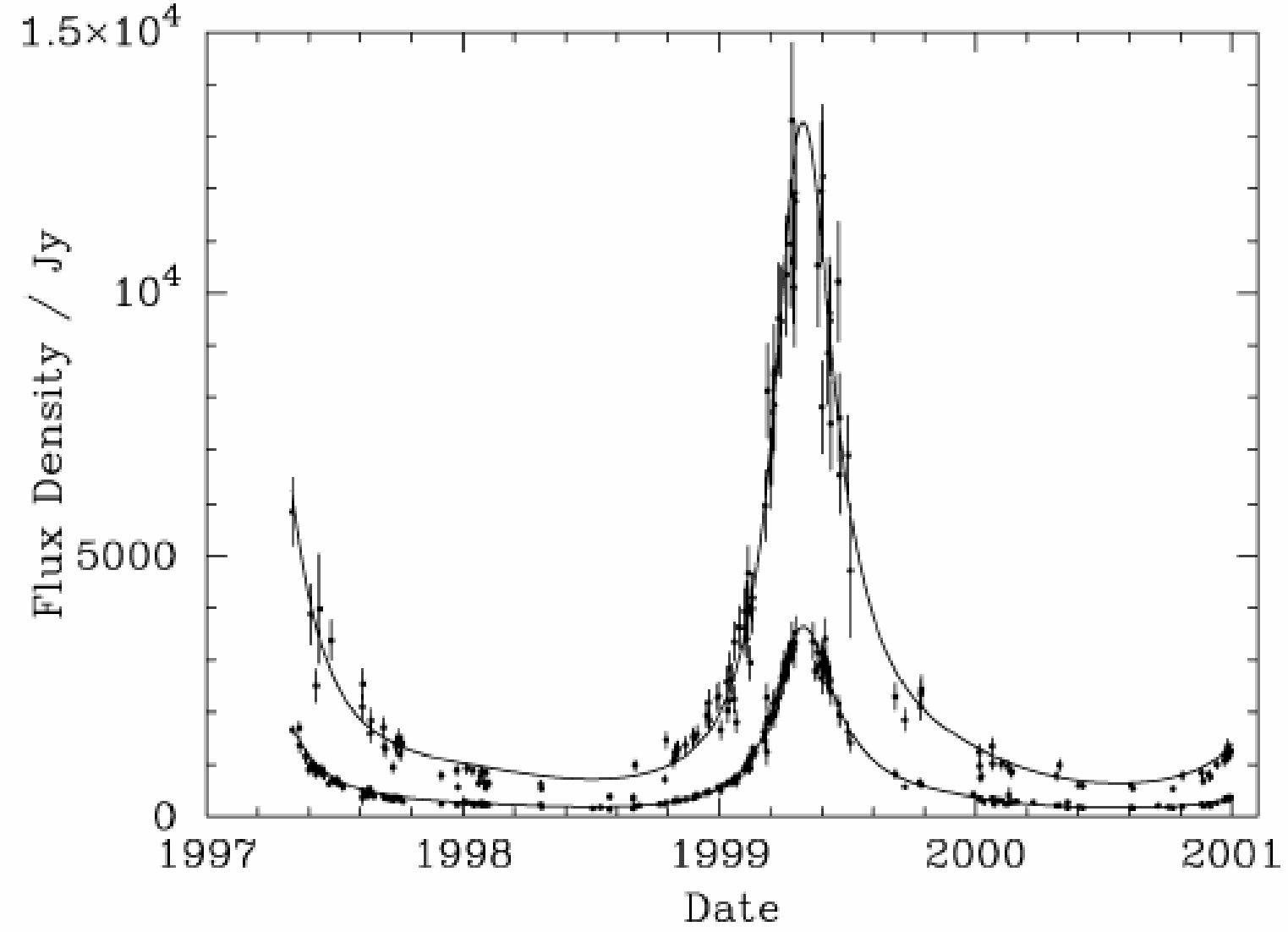
Reality

- Very few sources in the sub-mm/FIR fullfill these criteria
  - UCHII regions - no - always associated with extended emission
  - Planets, yes, but only three
  - Protostars - no - always associated with extended emission
  - Protoplanetaries - yes, but very few and all have strong emission lines
  - AGB stars - no - always variable, strong emission lines
  - Young stars - some - (maybe one FU Ori star, one T Tauri star and a handfull of isolated HAEBE stars
  - Asteroids - yes, but not as many as we would need
  - AGNs - yes, a few, but strong emission lines

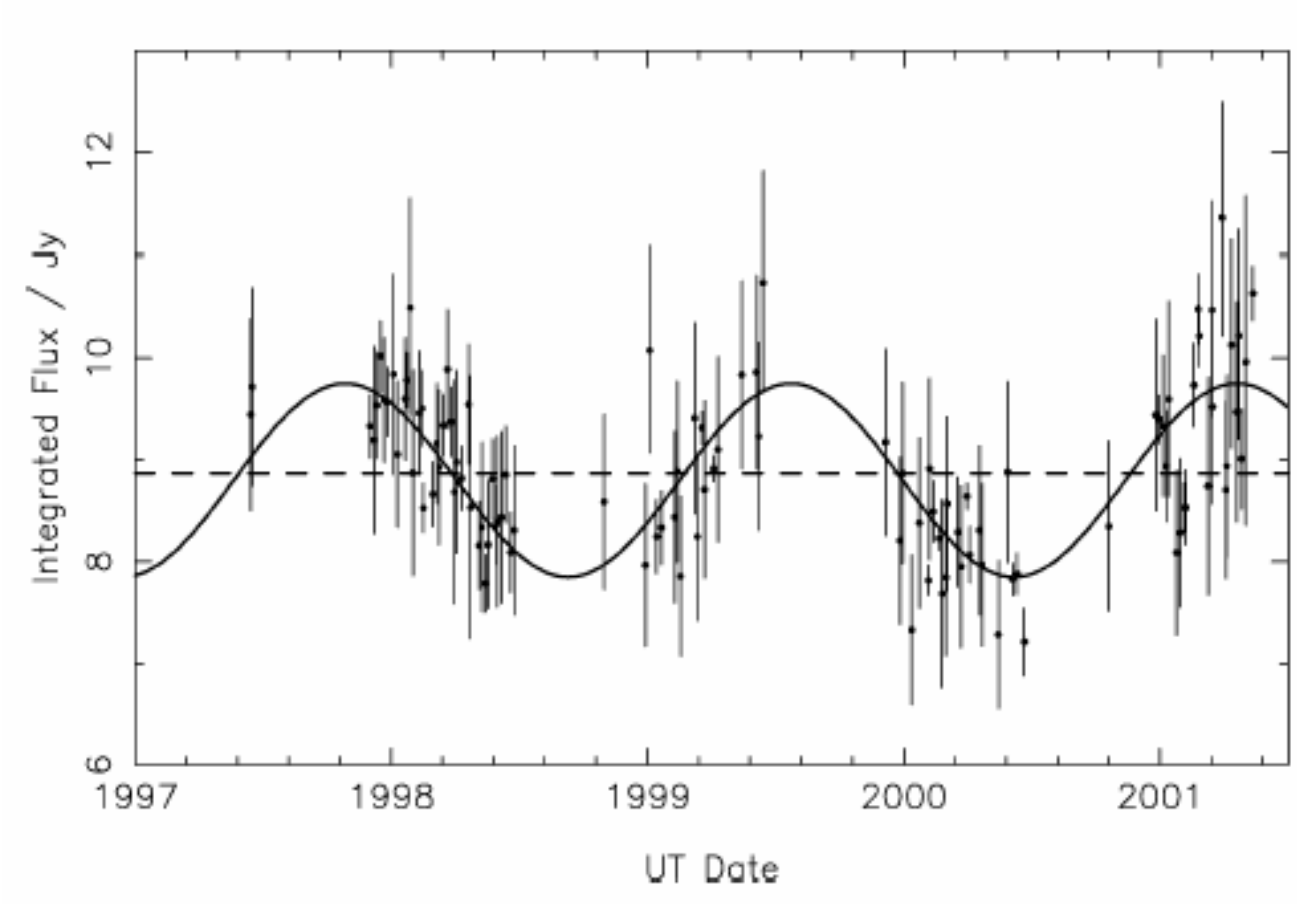
Photometric calibrators for SCUBA

- Primary calibrators
  - Mars (fundamental standard), Uranus, Neptune
- Secondary standards
  - CRL618, CRL2688 (protoplanetary nebulae)
  - IRC+10216 & OH231.8+4.2 (variable)
  - HL Tau
  - IRAS 16293-2422
- (insufficient list, and several far from ideal, IRAS16293 is too extended and cannot be used at all with small chop throws (>100”)

Mars model (Wright et al. 1976) validated from Uranus observations (Jenness et al 2002)

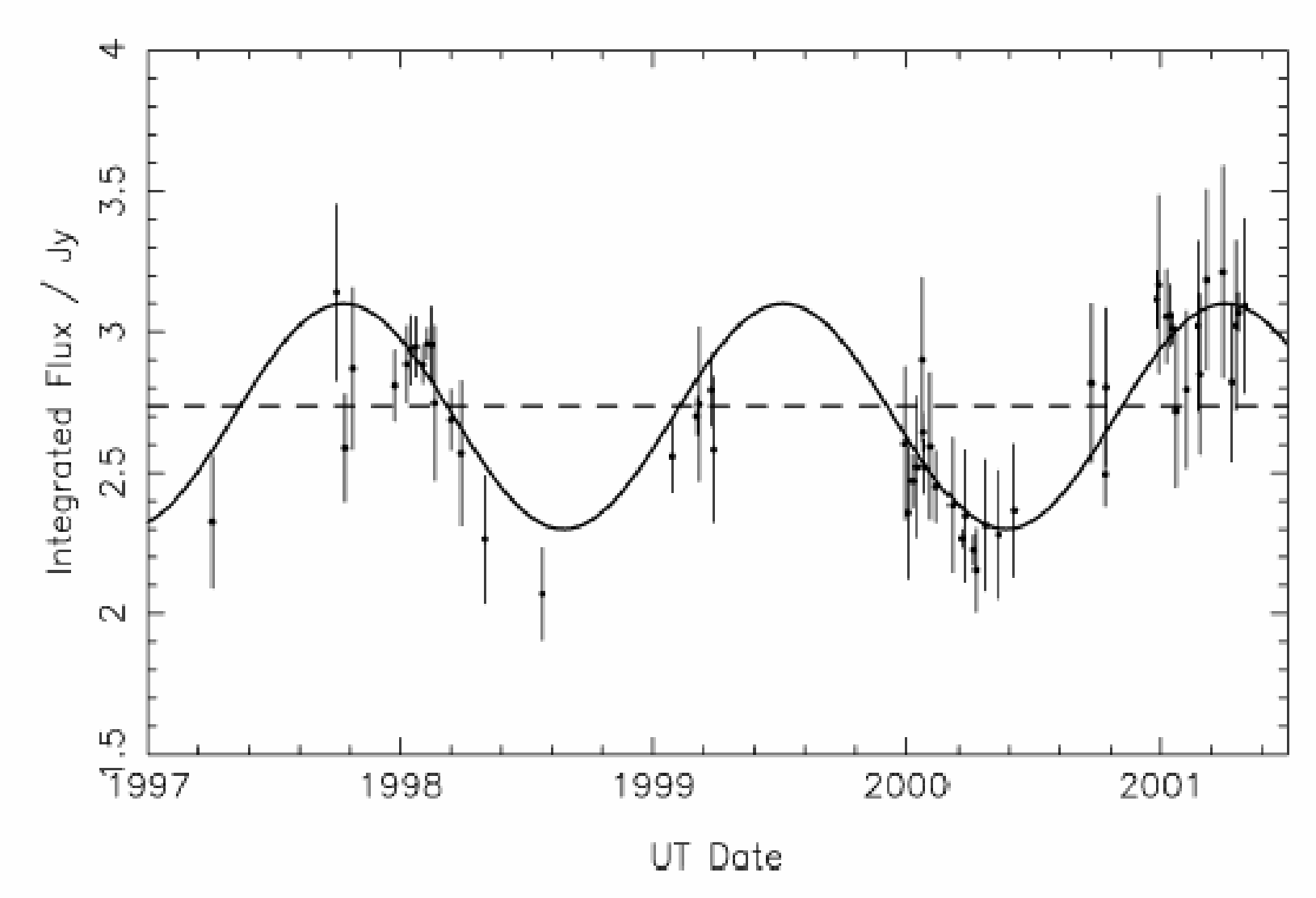


Light curve for IRC+10216 (Jenness et al. 2002)



$$S(\mathrm{Jy}) = 8.8 + 0.95 \sin\left(2\pi \frac{Y - 1999.125}{1.74}\right)$$

Lightcurve for OH231.8+4.2 (Jenness et al. 2002)



What's next

- We need to find, evaluate and establish more well-characterized secondary calibrators:
  - MWC349, NGC7027 ;both possible, but CRL2688 is brighter
  - Need to look for more protoplanetaries in the sub-mm
  - PMS stars (V833 Ori 1.4/9.5, TW Hya), isolated HAEBE stars, mostly spectral class A - F, gas poor, shallow SEDS: > 10 in the brightness range 0.3 - 0.8 Jy @ 850 um, 1 - 9 Jy @ 450 um, mostly ~ 5h, but some around 15 - 18 h.
  - Asteroids (ongoing program at JCMT lead by D. Hughes); data only on Ceres, Pallas & Hygiea

Why isolated HAEBE stars?

- Isolated >> no confusion from extended emission
- Emission at sub-mm and FIR dominated by protoplanetary dust disk. Progenitors to debris disks, but still young
- they are strong enough as calibrators, marginally so for SCUBA, but okay for SOFIA and Herchel
- Large dust grains, gas poor
- Beta-index ~ 0 - 1

Asteroids

- We need asteroids for sub-mm and FIR calibration
- We would greatly benefit from preparatory ground based mm/sub-mm observations
- We can select asteroids with:
  - Small or moderate optical lightcurves
  - No albedo variations
  - Approximately spherical; a/b < 1.2 b/c <1.2
  - Size > 200 km
- Very little luck with ground-based programs
  - Ceres 9 epochs, Pallas 7 epochs, Hygiea 2 epochs (not sufficient, but at least a start)
- May get more data from SOFIA before Herschel flies