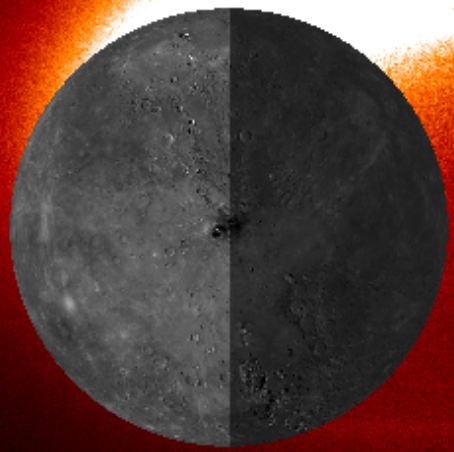
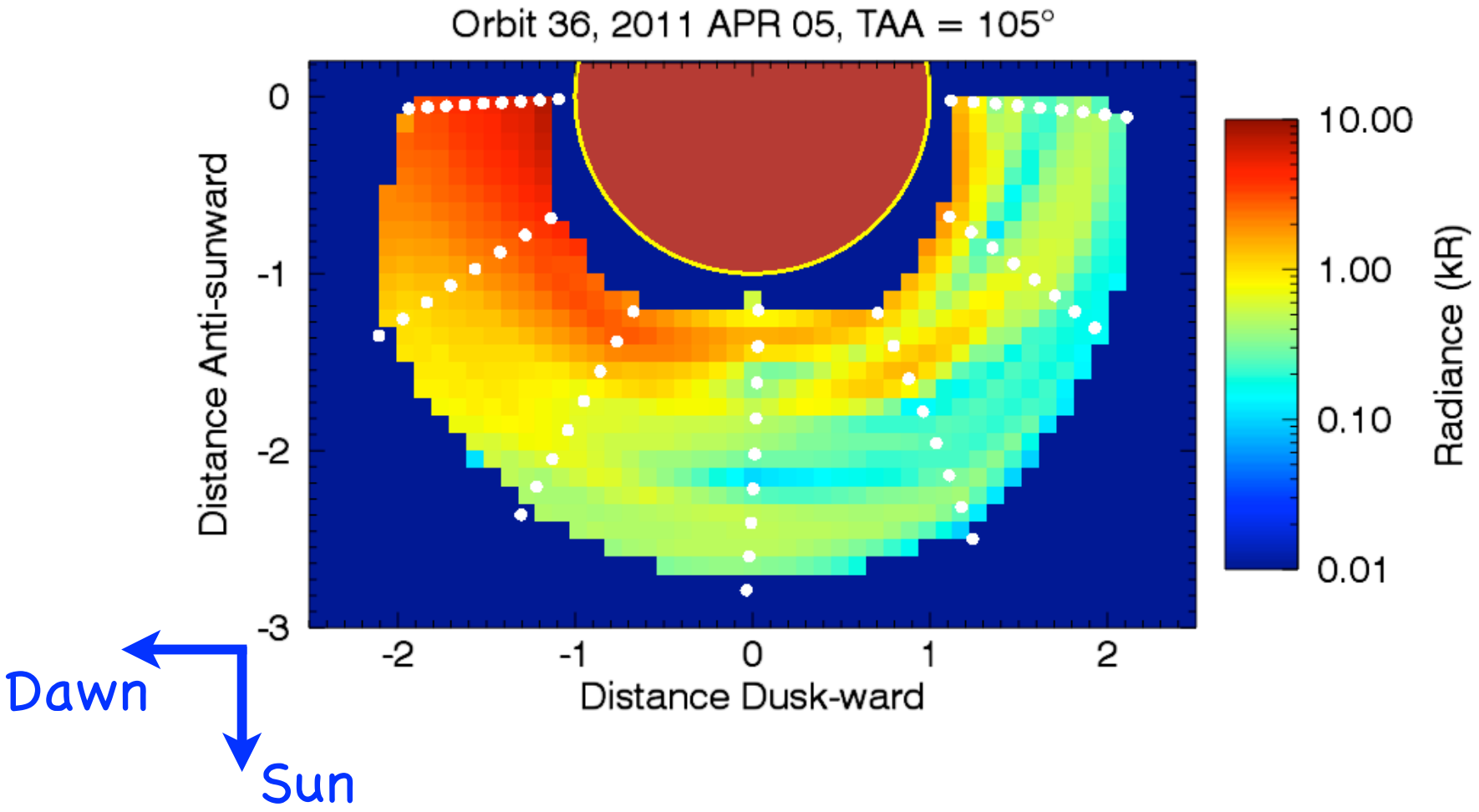
Mercury's Calcium Exosphere in the MESSENGER Era



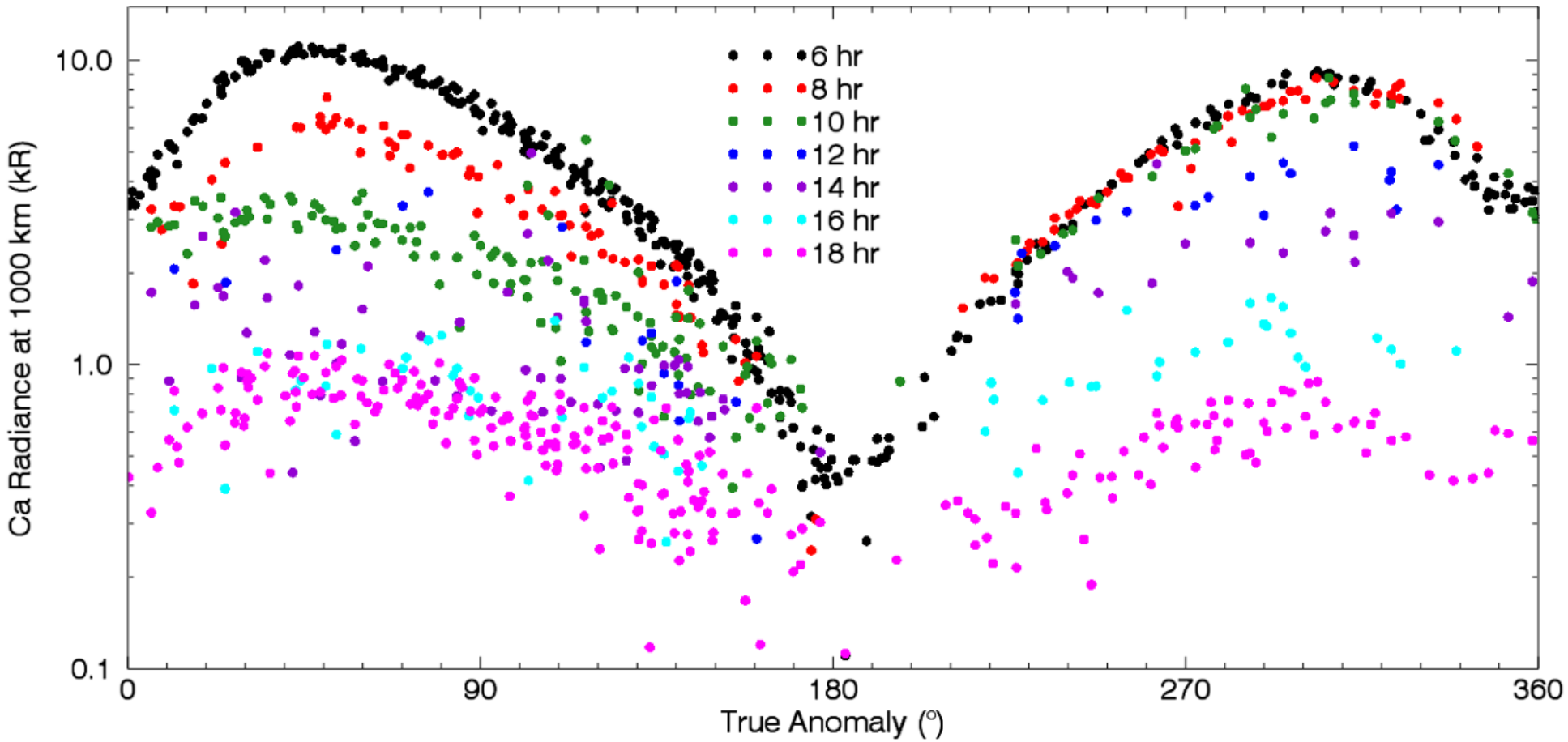
Matthew Burger, Rosemary Killen, Bill McClintock, Aimee Merkel, Ron Vervack, Jr., Tim Cassidy, Menelaos Sarantos

MESSENGER
Dawn Ca Enhancement

- **Dayside limb scans show persistent dawn enhancement (Burger et al. 2012, 2014)**



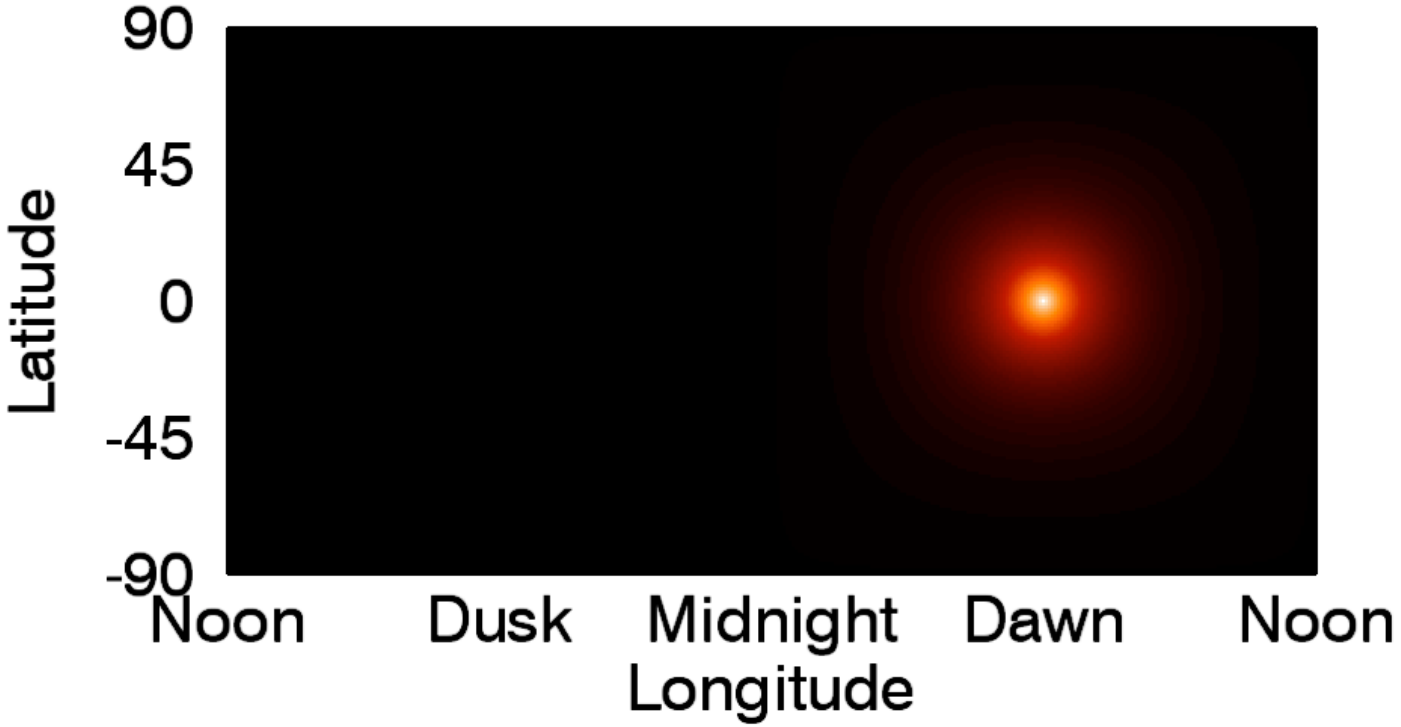
MESSENGER
Ca Radiance at 1000 km



MESSENGER
Dawn Calcium Source

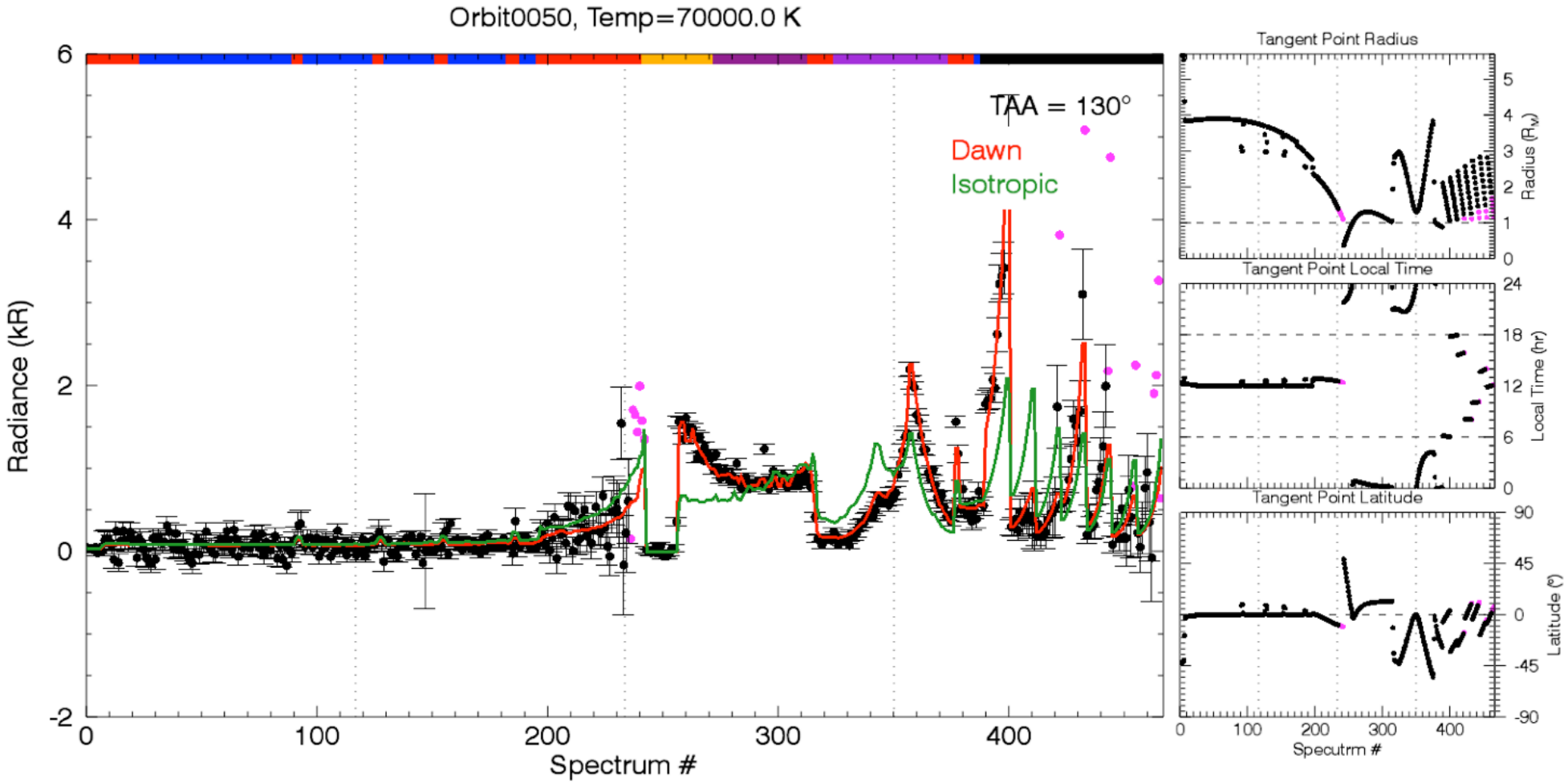
Source is centered at dawn equatorial point and drops off exponentially with width = σ

$$\mathbf{r} = (x, y, z) = (\cos\lambda\cos\mu, \sin\lambda\cos\mu, \sin\mu)$$
$$\cos\phi = \mathbf{r}\cdot\mathbf{r_0}$$
$$f(\lambda,\mu) = f_0 e^{-\phi(\lambda,\mu)/\sigma}$$

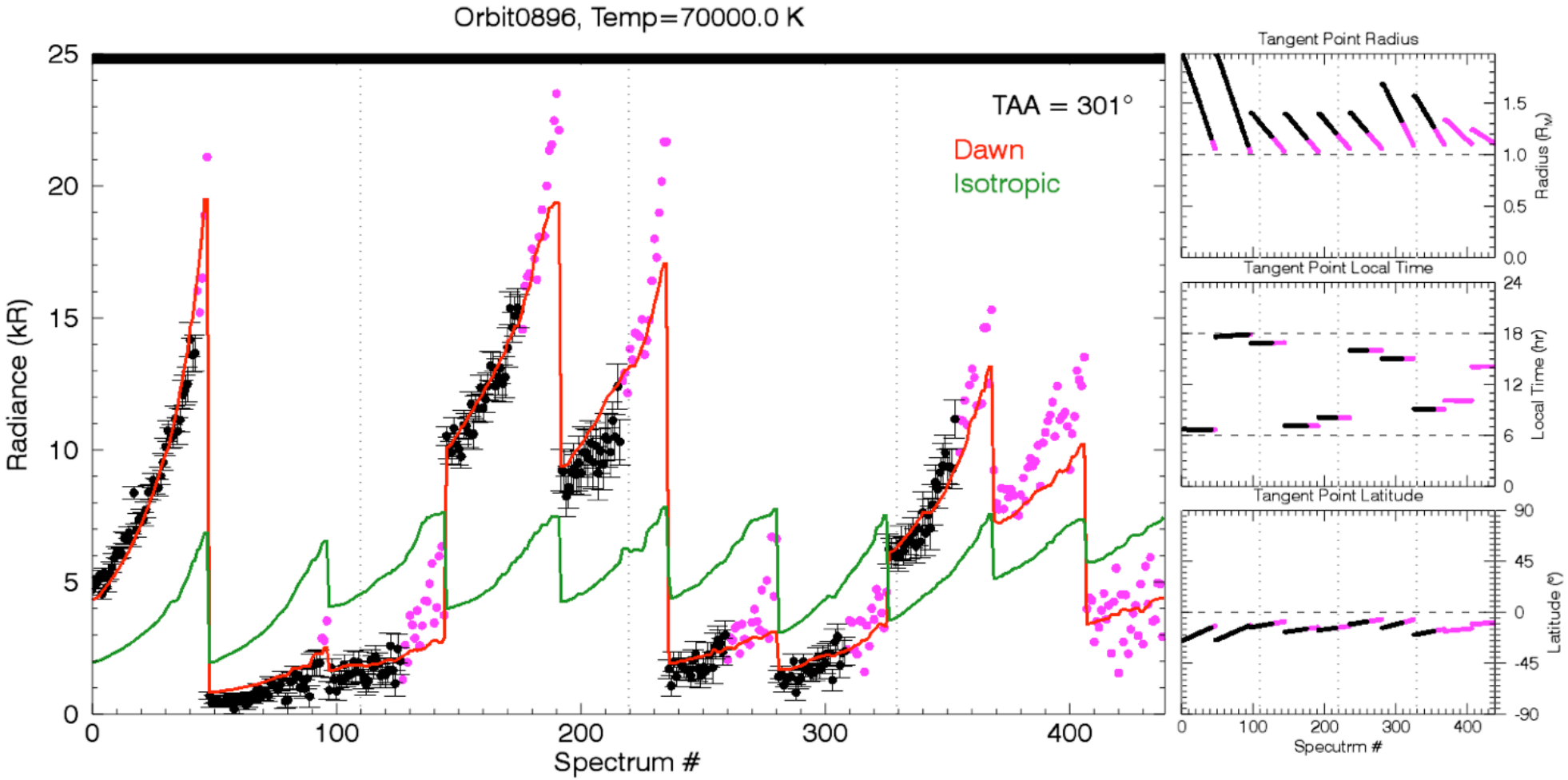


MESSENGER
Nominal Model

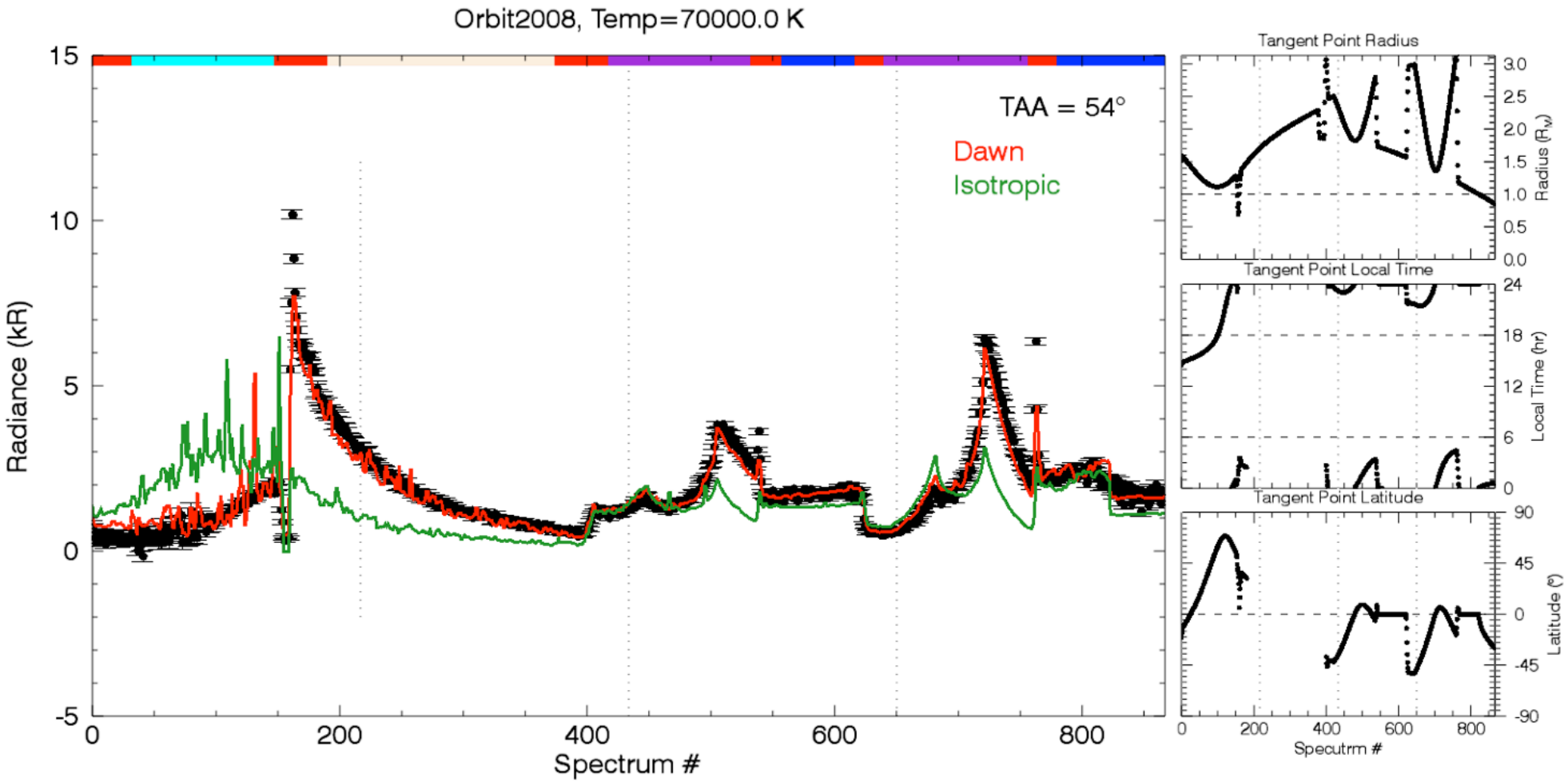
- **Our nominal Ca model uses a Maxwellian source distribution with T=70,000 K, σ=50°, centered on the**



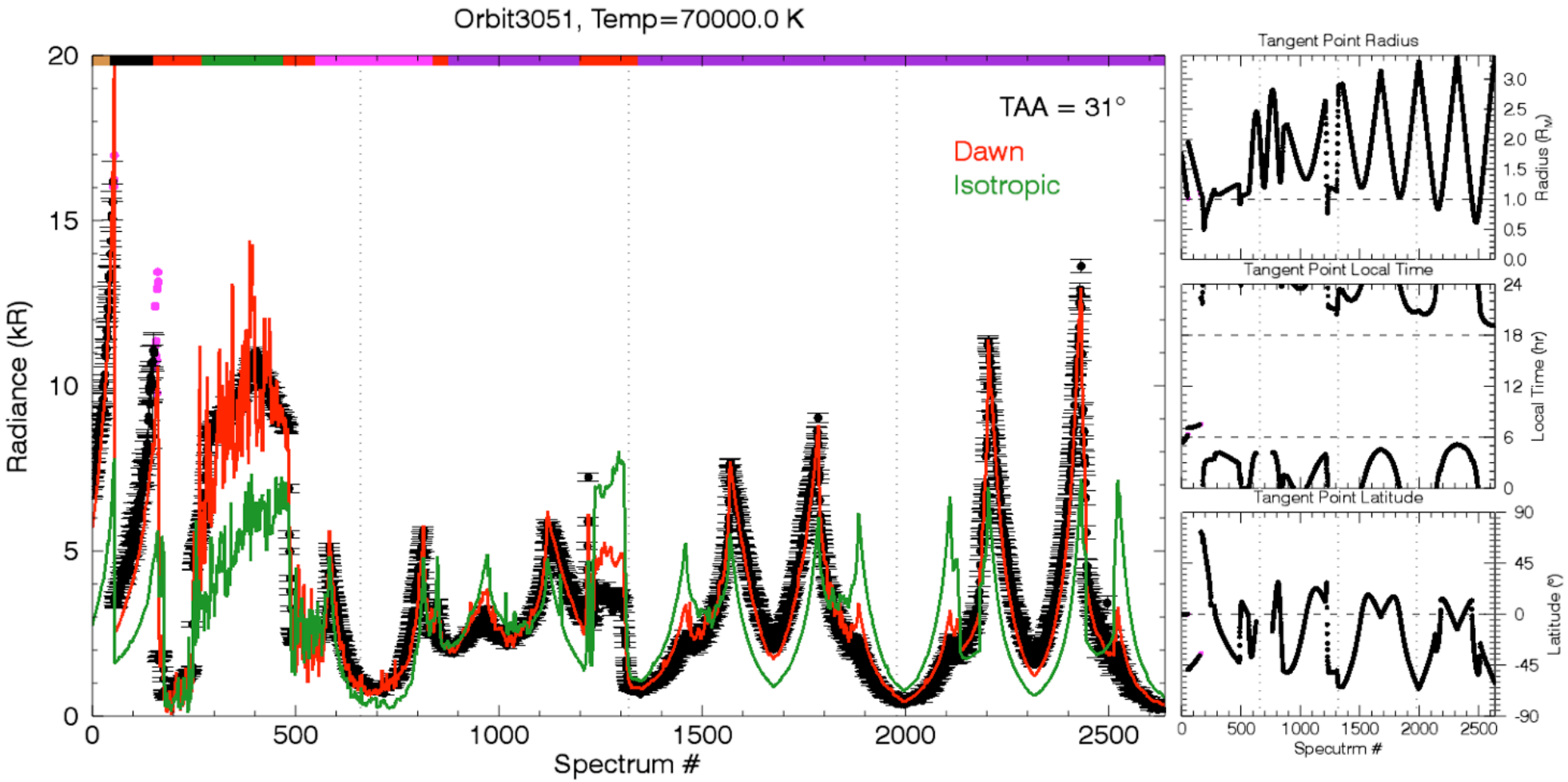
MESSENGER
Nominal Model



MESSENGER
Nominal Model



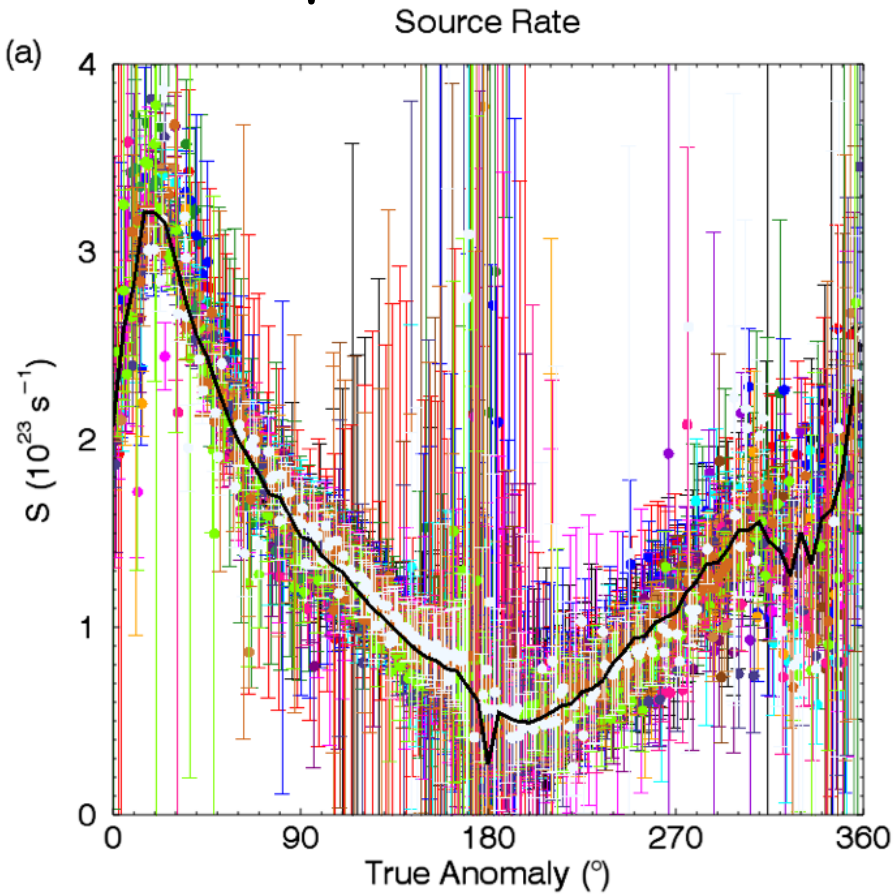
MESSENGER
Nominal Model

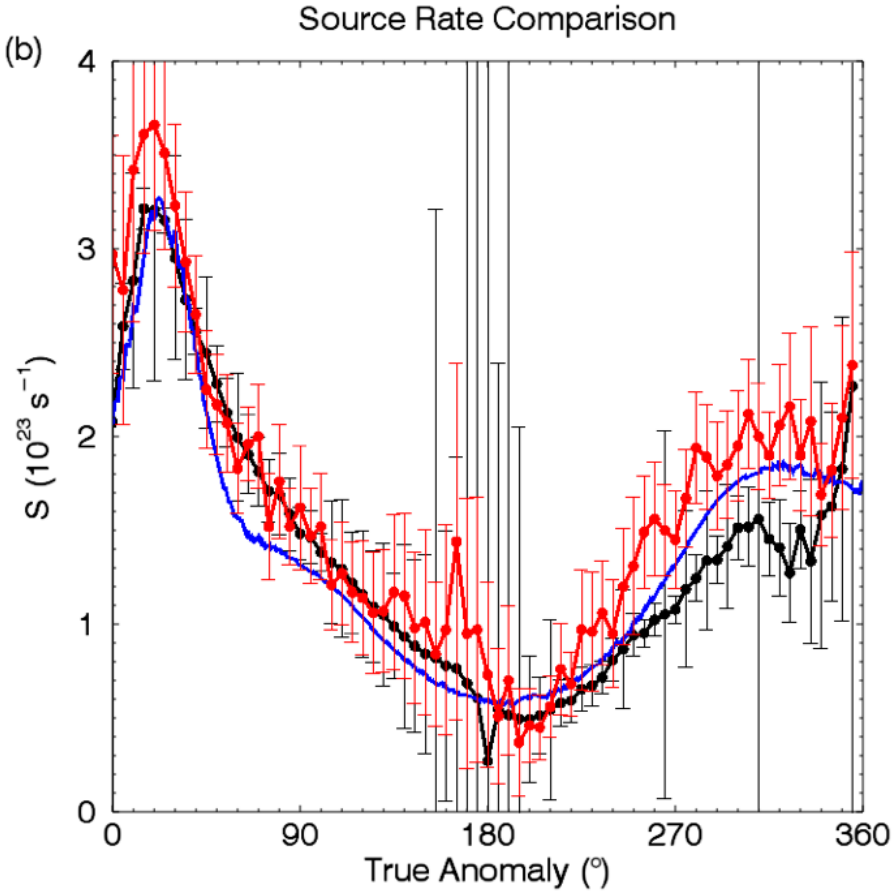


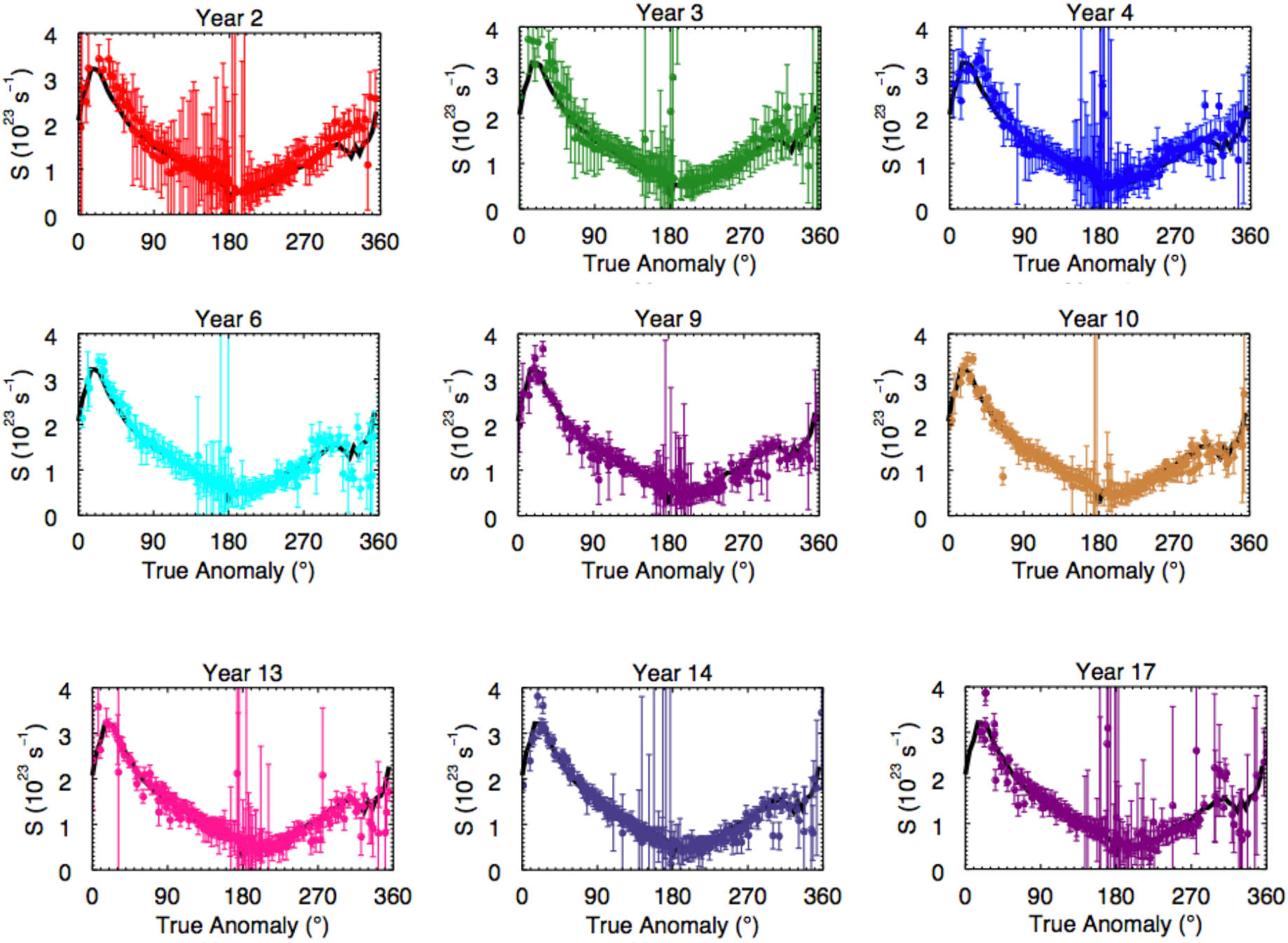
MESSENGER
Ca Source Rate

- Strong seasonal variation in source rate
- Year-to-year variability is small
  - 89% of points w/in 1σ of the black line
  - 97% of points w/in 2σ of the black line

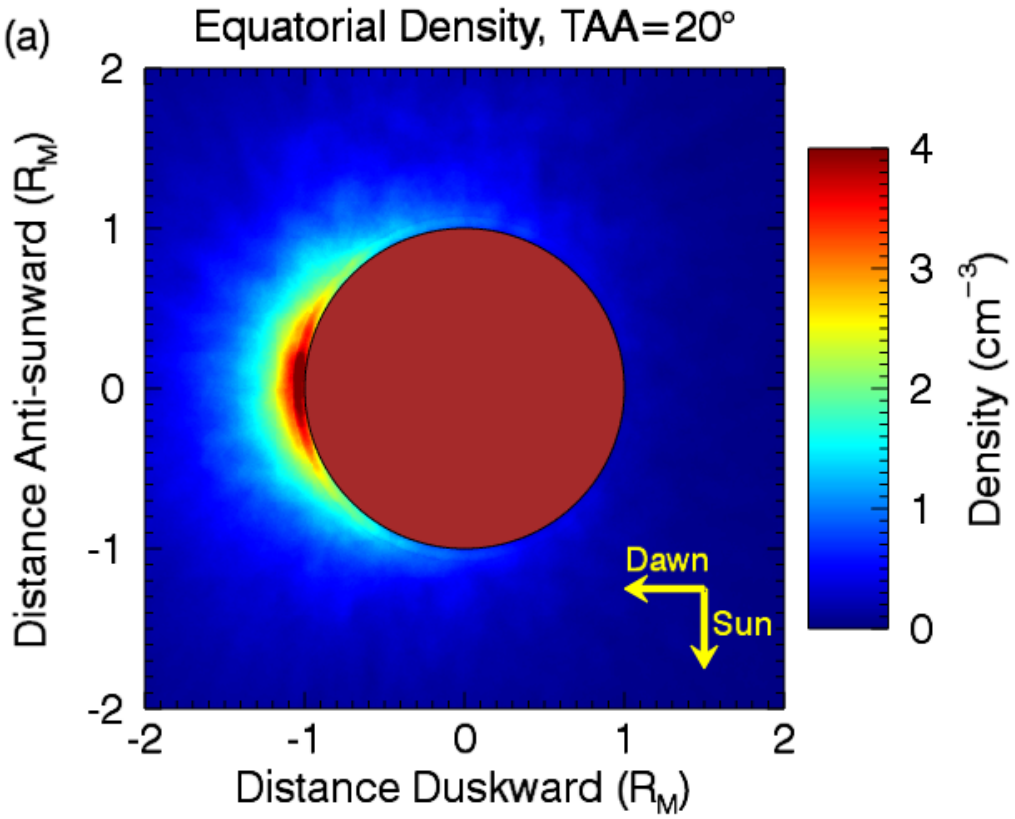
All data
Burger et al. (2014)
Killen & Hahn (2015)

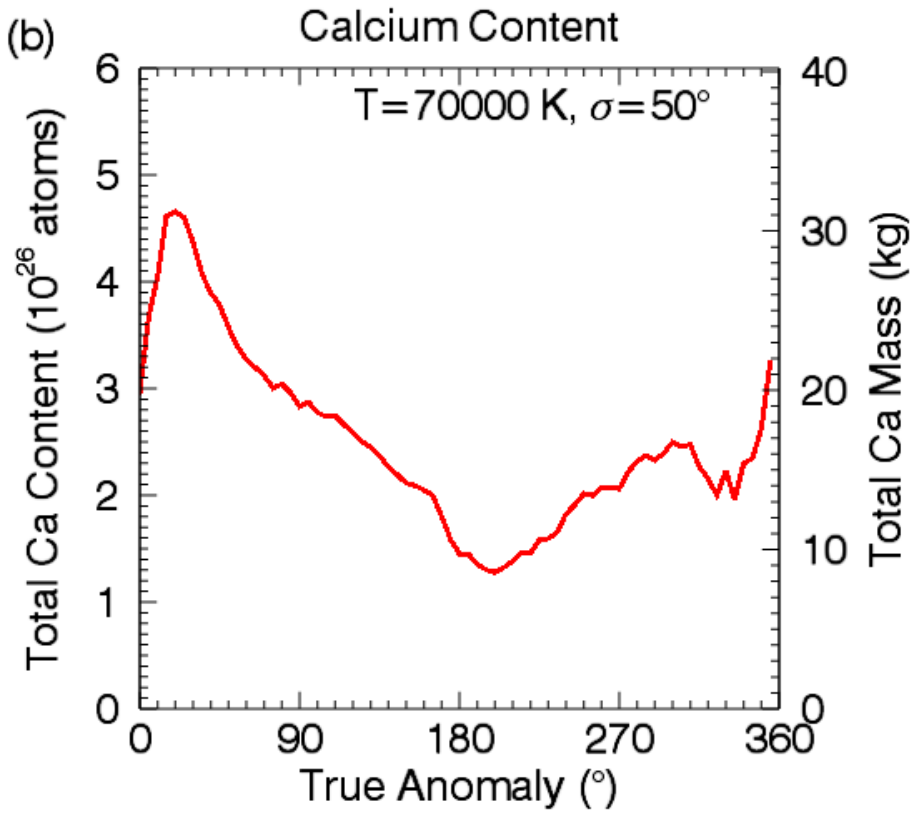





Year 2
Year 3
Year 4
Year 6
Year 9
Year 10
Year 13
Year 14
Year 17
S (10^{23} s^{-1})
True Anomaly (°)
0
90
180
270
360
1
2
3
4

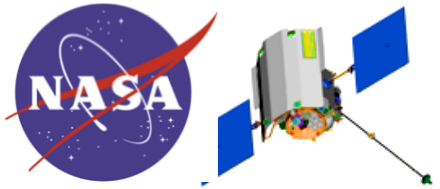
MESSENGER
8.5-31 kg Ca





MESSENGER
Summary of Observations

- The calcium source is concentrated on the dawn hemisphere
  - may move around a little bit, but not much
- Comes off very hot (T>50,000 K)
  - Nominal model has T=70,000 K
- Source size and temperature don't change much if at all
- Source strength varies with Mercury's true anomaly (position in orbit)
  - Source strongest just after perihelion
  - Source weakest just after aphelion

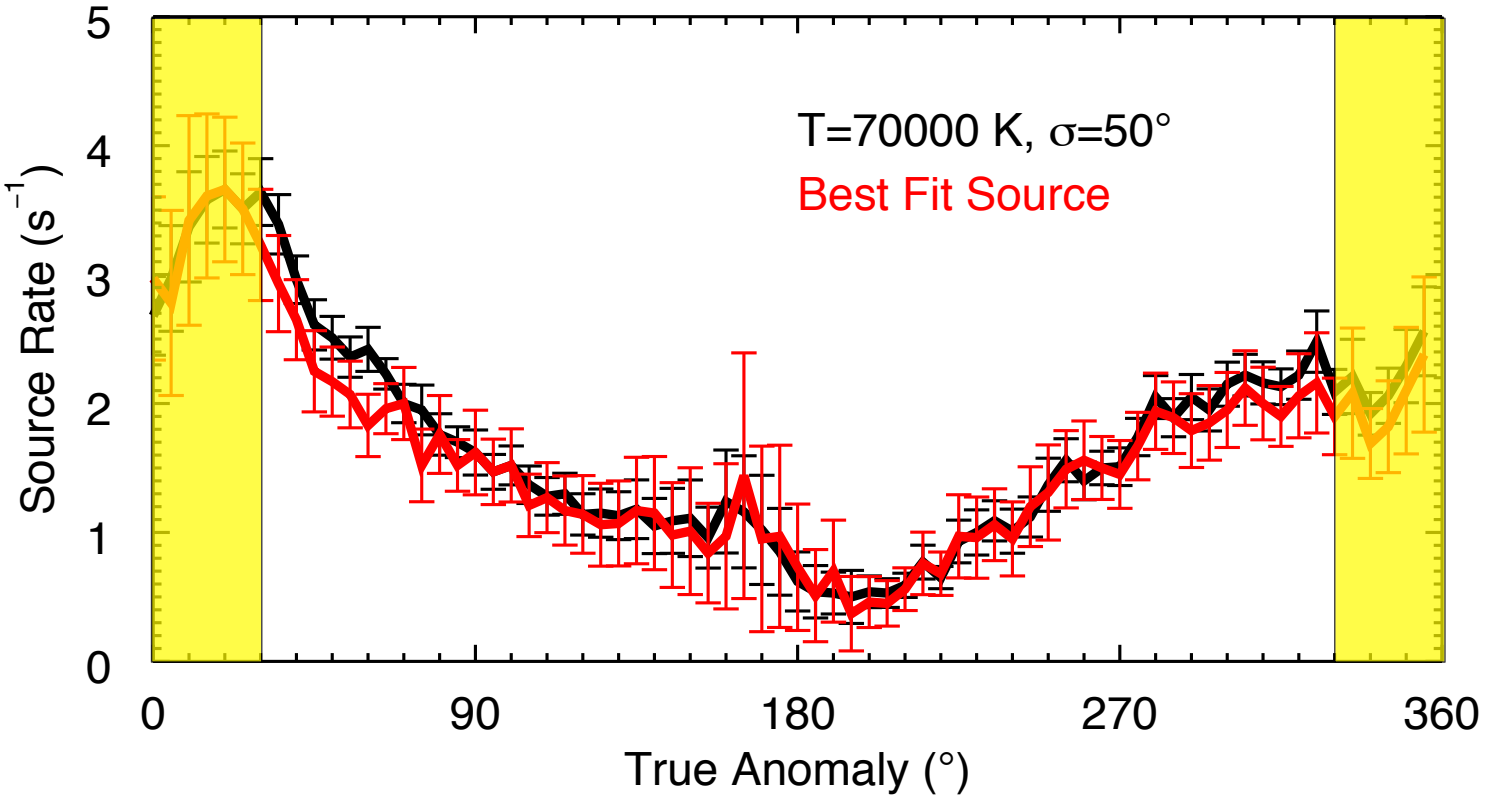


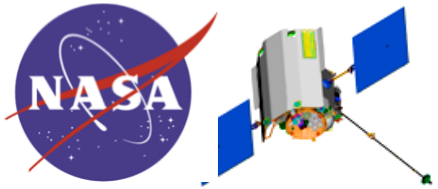
MESSENGER
What is the Source?

- Not related to the surface geology
  - Source is (approximately) fixed in local time and does not rotate with Mercury
- Not related to the magnetosphere (ion sputtering or electron stimulated desorption)
  - Magnetosphere is highly variable
  - Wouldn't produce a source at dawn
  - There are possible sporadic sources that may be associated with the magnetosphere (still trying to understand these)
- Not related to Ca freezing on the nightside and vaporizing as it moves into sunlight

MESSENGER
Sun Reverses in Sky

- **The motion of the Sun in Mercury's sky reverses near perihelion, where the source is strongest**





MESSENGER
Current Hypothesis

- Micrometeoroid impact vaporization and molecular dissociation
  - Interplanetary Dust bombards the surface producing vapor plumes containing CaO and $Ca(OH)_2$ at ~5000 K (Berezhnoy 2013)
  - Ca-bearing molecules quickly dissociate producing hot Ca that escapes Mercury (Killen et al. 2005)
- Pros:
  - Models at Earth suggest dust impacts peak at dawn (Janches et al. 2006, Pifko et al. 2013)
  - CaO and $Ca(OH)_2$ are more likely to be produced in plumes than atomic Ca (Berezhnoy & Klumov 2008; Berezhnoy 2013)
  - Source rate consistent with dust disk + comet stream (Killen & Hahn 2015): See Rosemary's talk later
- Cons:
  - No evidence of a dawn/dusk asymmetry in impacts at Mercury
  - Plume chemistry is very uncertain
  - Not clear that dissociation produces the >50,000 K Ca the model requires