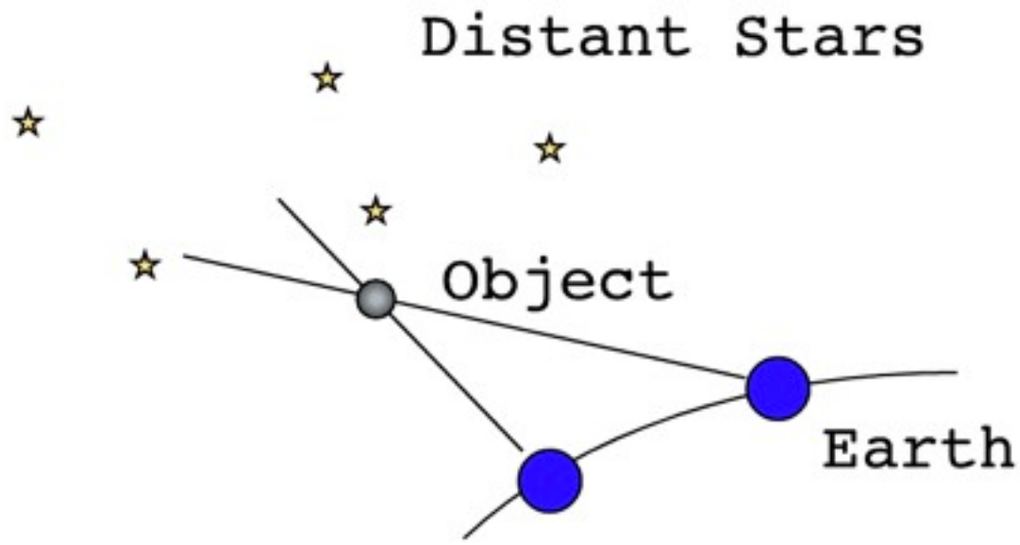
The 14-Nov-2003 Titan Occultation

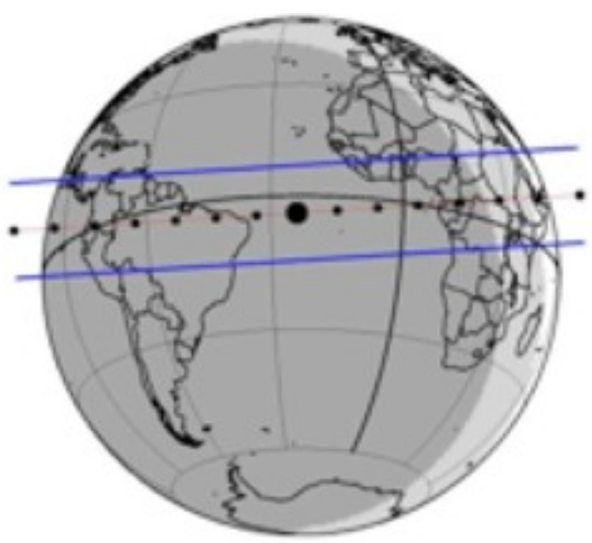
Eliot F. Young
Angela Zalucha

Occultations: background

For solar system bodies, stellar occultations occur when an object's parallactic motion intersects a star.

Velocity on the sky plane for the 14-NOV-03 event: ~11.25 km/sec

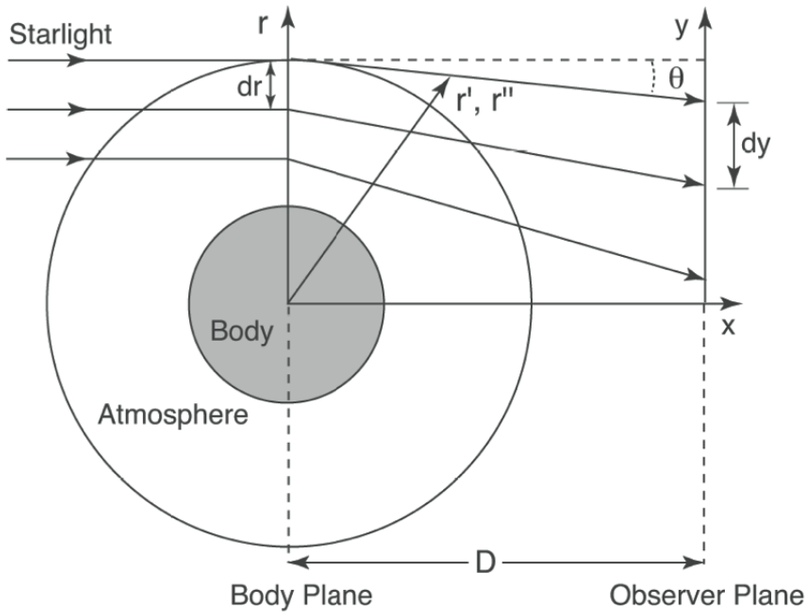




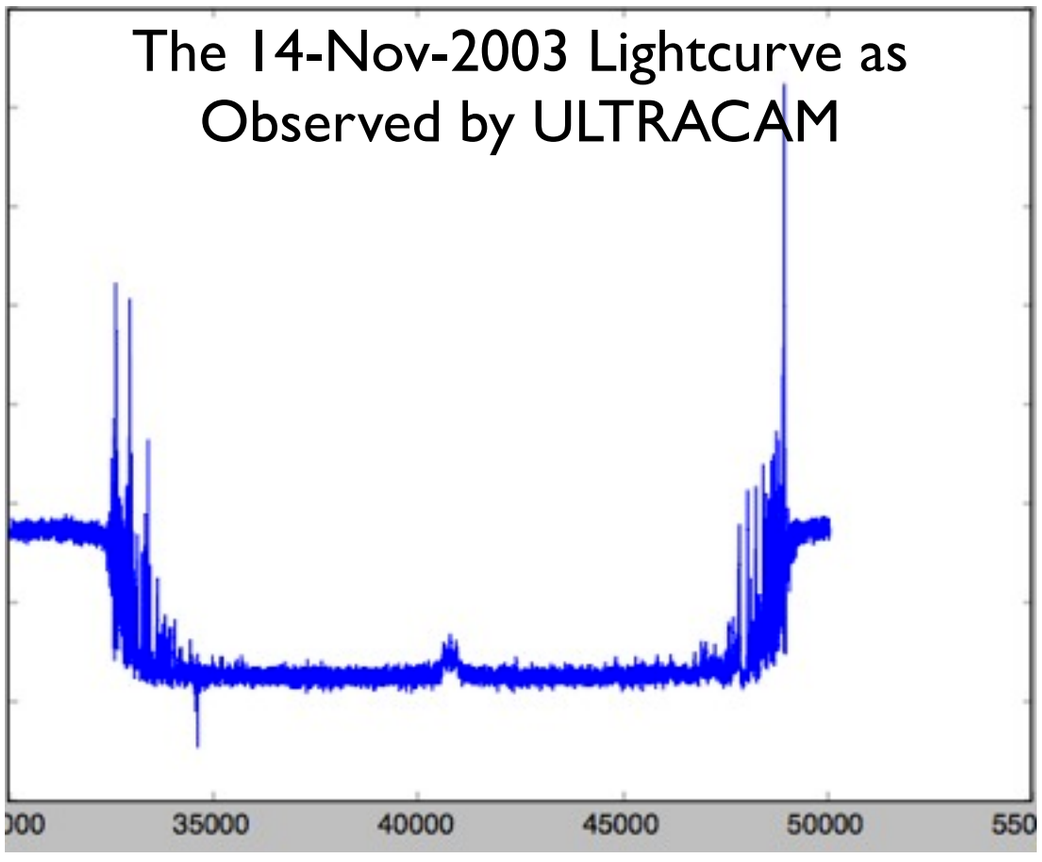
The *width* of the shadow path is the width of the occulting object, about 5150 km in the case of Titan – actually about 6200 km because of Titan's extended atmosphere.

Regions near the center of the shadow track can see a *central flash*, caused by a convergence of rays that are refracted by Titan's atmosphere.

Occultations: background



Occultations are extremely sensitive to the structure of an atmosphere. Reason: small deflections in ray angles translate to large excursions over 10 AU.



Differential refraction is caused by the exponential profile of the atmosphere. Rays that impact close to the surface are bent more than higher altitude rays.

However, if there is a temperature perturbation at a certain altitude, some focusing can occur.

The 14-NOV-2003 Event

- Actually two stars occulted on the same day.
- Three papers on these events (Sicardy et al. 2006; Zalucha et al. 2007; Fitzsimmons et al. (submitted 2006)).
- Central flashes observed for both events.
- Temperature profiles derived from the lightcurves showed an inversion at ~510 km, subsequently confirmed by HASI.

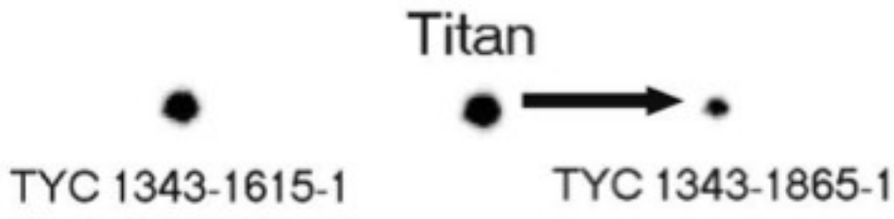
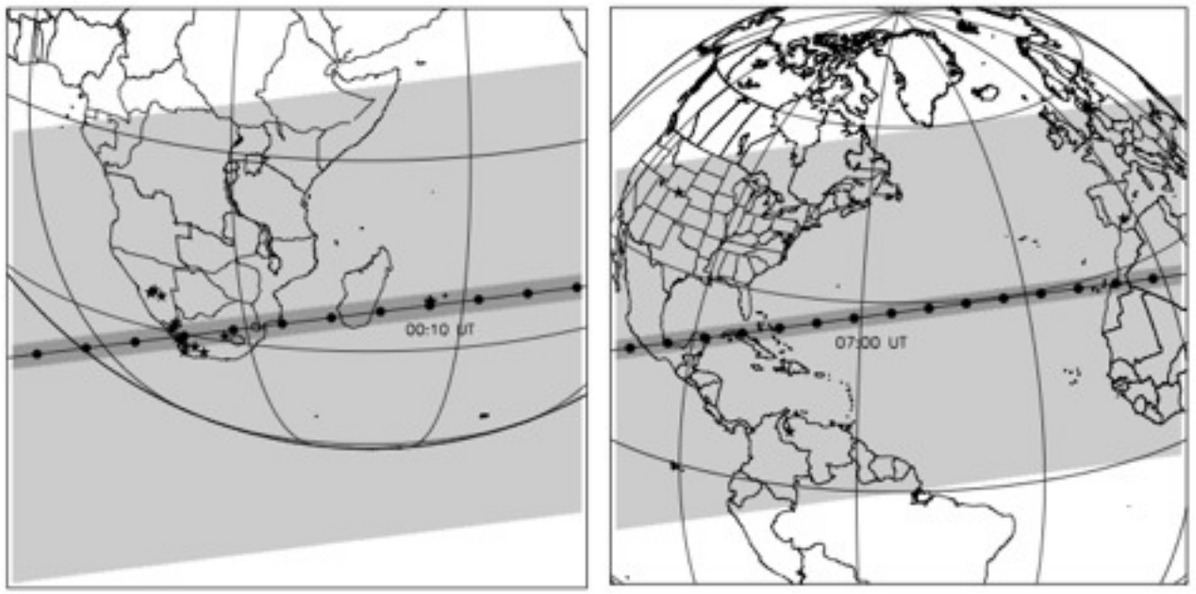
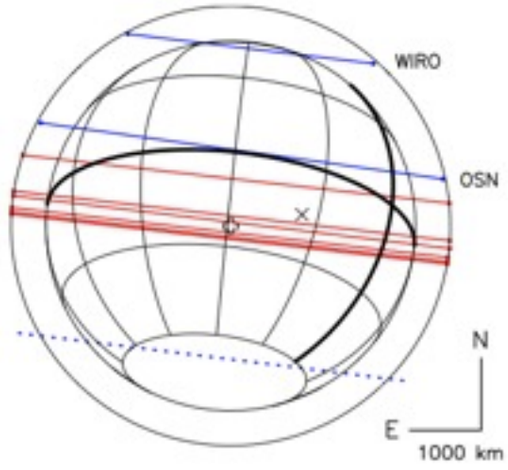


Image showing Titan and the occulted stars (Fig. 1 from Fitzsimmons et al. 2006).

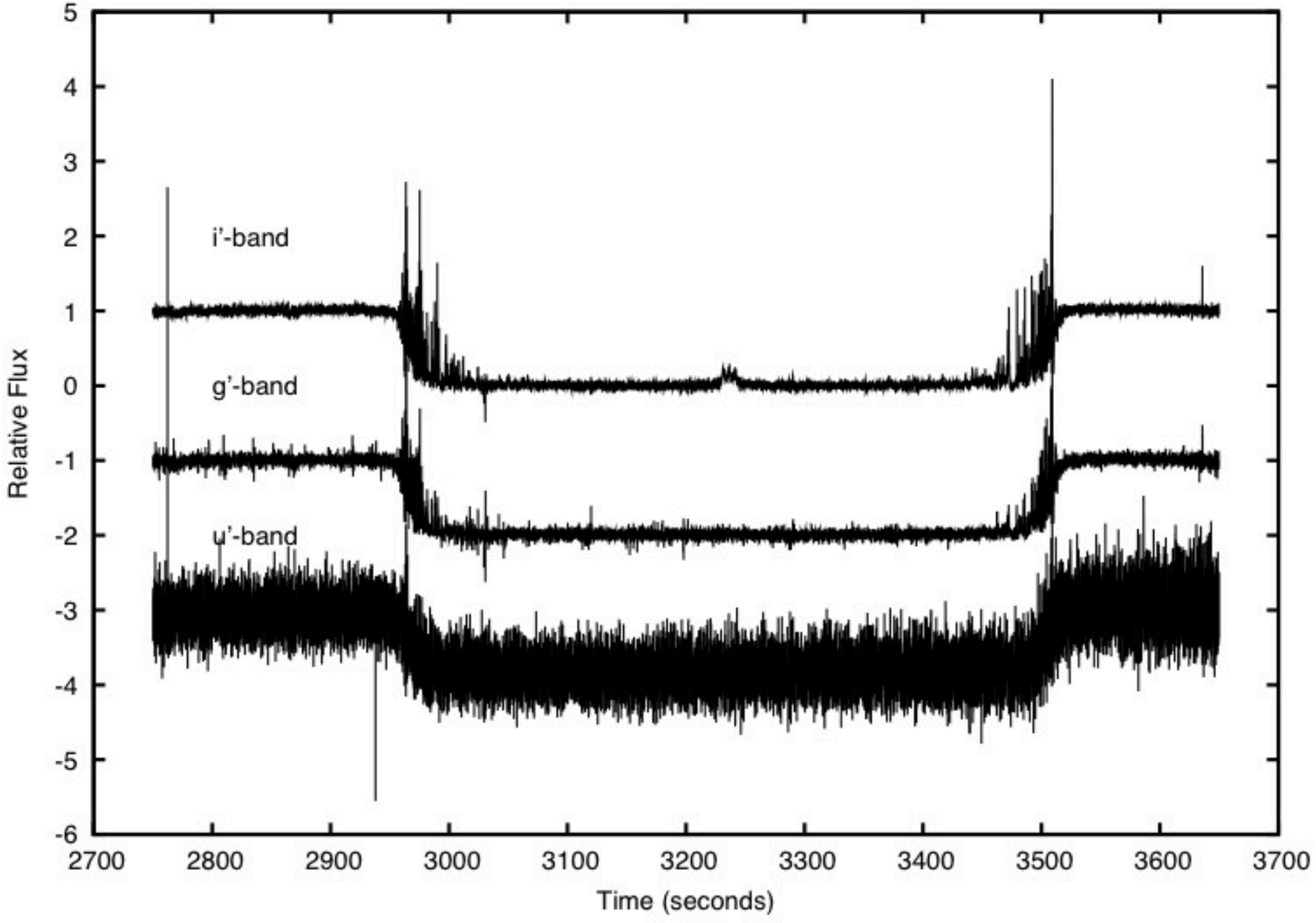


Shadow tracks (Fig. 2 & 3 from Sicardy et al. 2006) with the central flash region highlighted.



Chords observed across Titan (Fig. 6 from Sicardy et al. 2006) in the first (red) and second events.

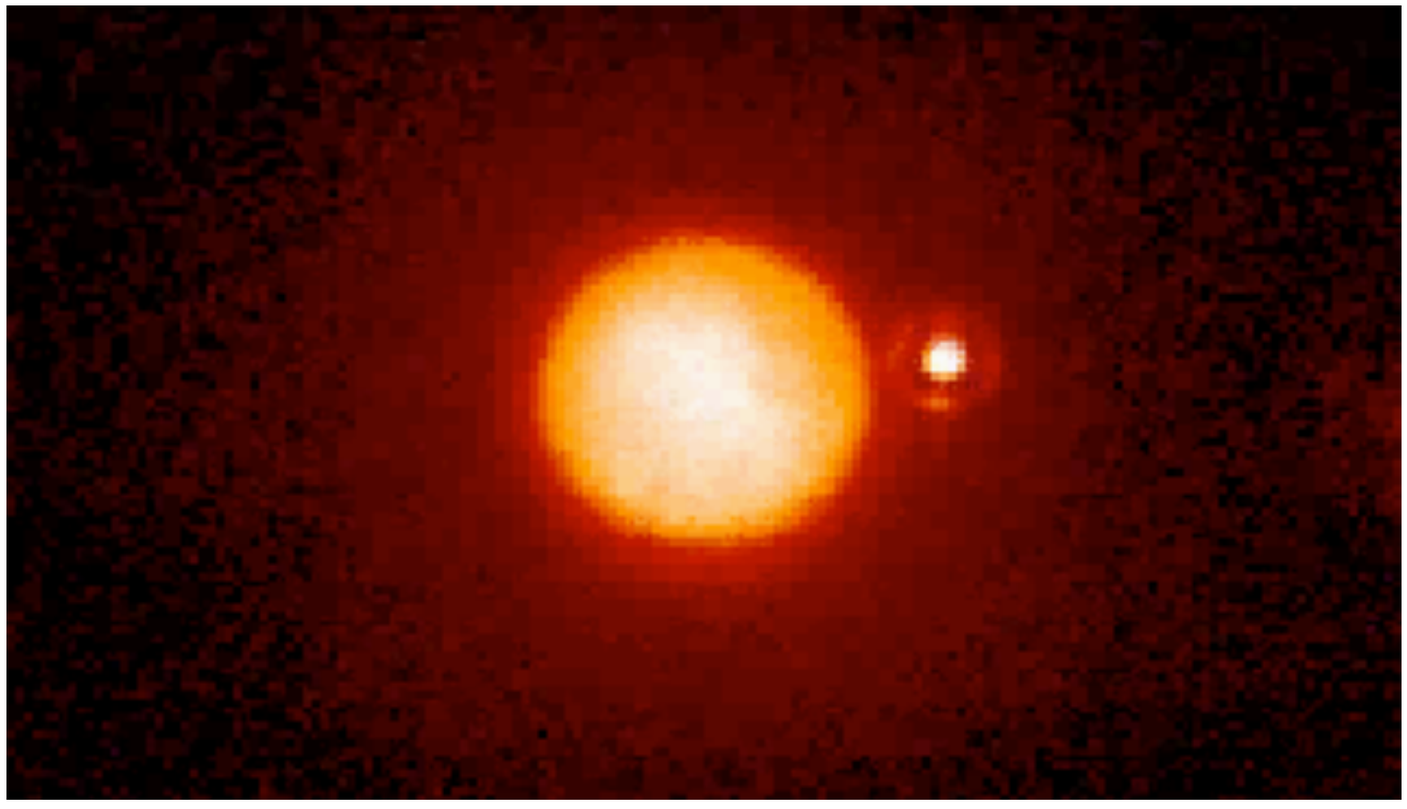
The ULTRACAM Lightcurves



Three simultaneous ULTRACAM lightcurves (offset for clarity; from Fig. 3 of Fitzsimmons et al. 2006). Observations were taken at ~30 Hz in three channels: u' (358 nm), g' (487 nm) and i' (758 nm). The time axis is in *seconds after 6:00 UT*.

The ULTRACAM Lightcurves

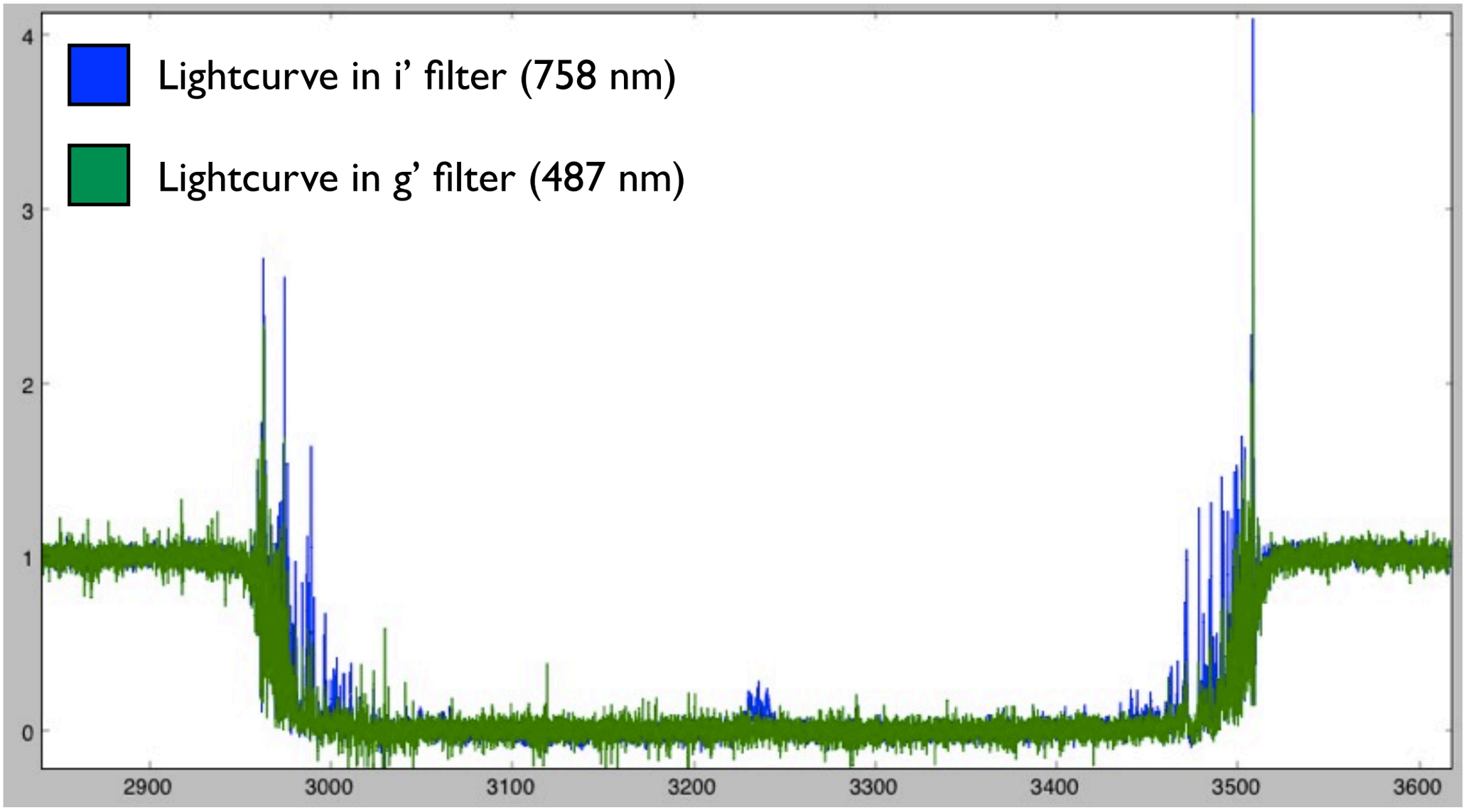
- Q1: Why all the spikes? Focusing events.
- Q2: Are the spikes real?
- Q3: Why is the central flash only seen in i'?



The 20-DEC-2001 double occultation (Bouchez et al. 2003), observed with AO from Palomar.

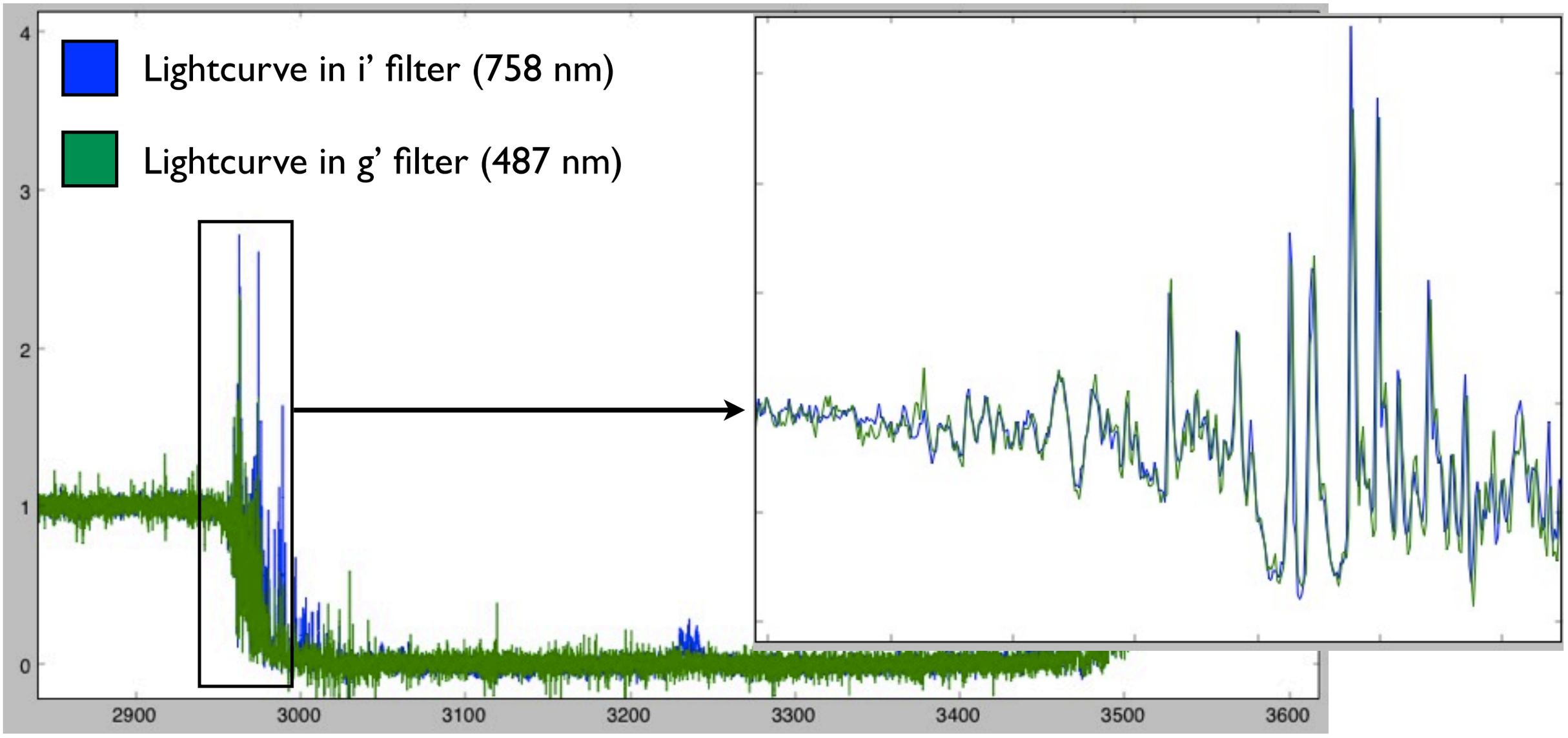
The ULTRACAM Lightcurves

- Q1: Why all the spikes? Focusing events.
- Q2: Are the spikes real? Yes - compare i' and g'.
- Q3: Why is the central flash only seen in i'?



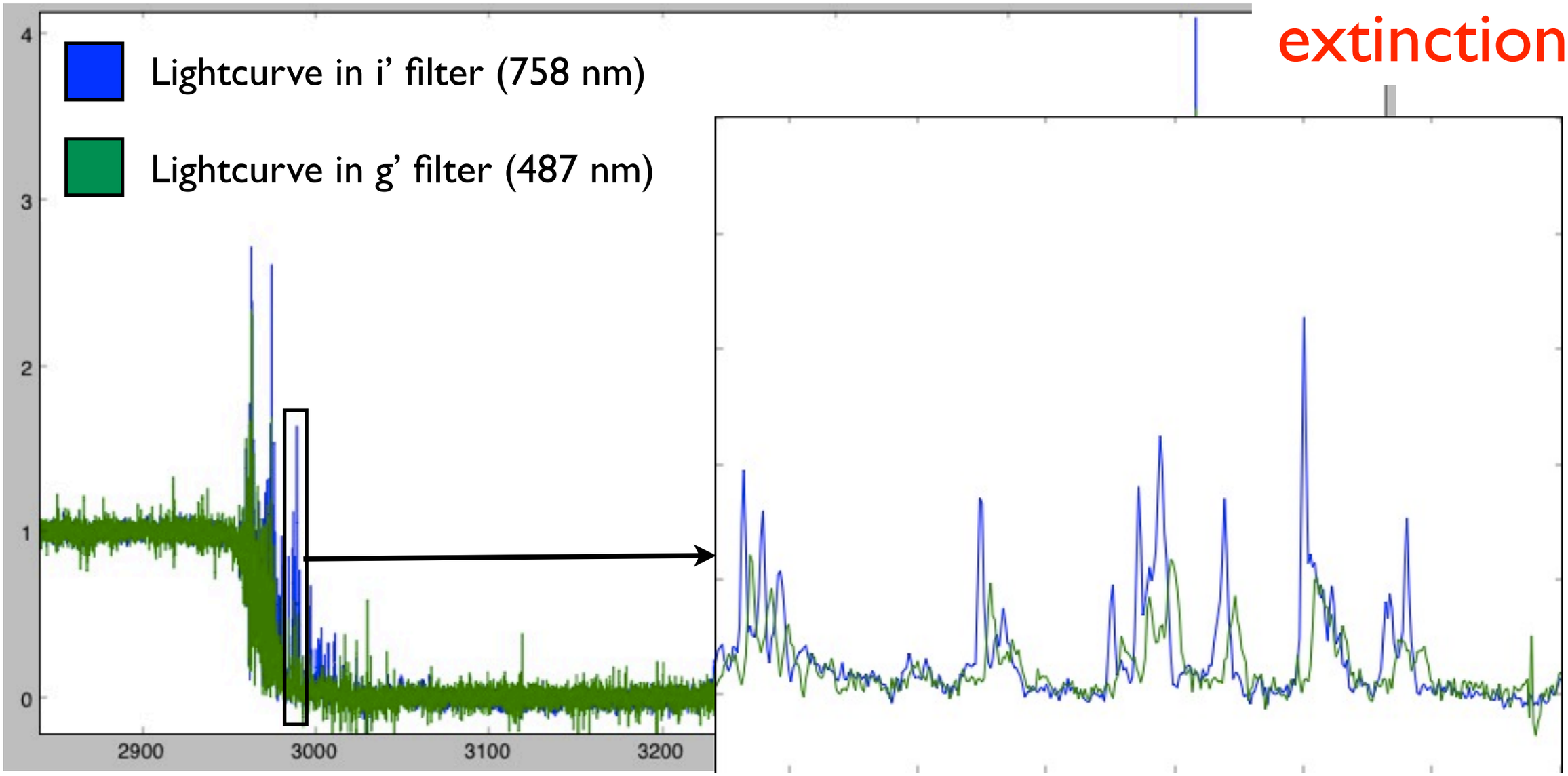
The ULTRACAM Lightcurves

- Q1: Why all the spikes? Focusing events.
- Q2: Are the spikes real? Yes - compare i' and g'.
- Q3: Why is the central flash only seen in i'?



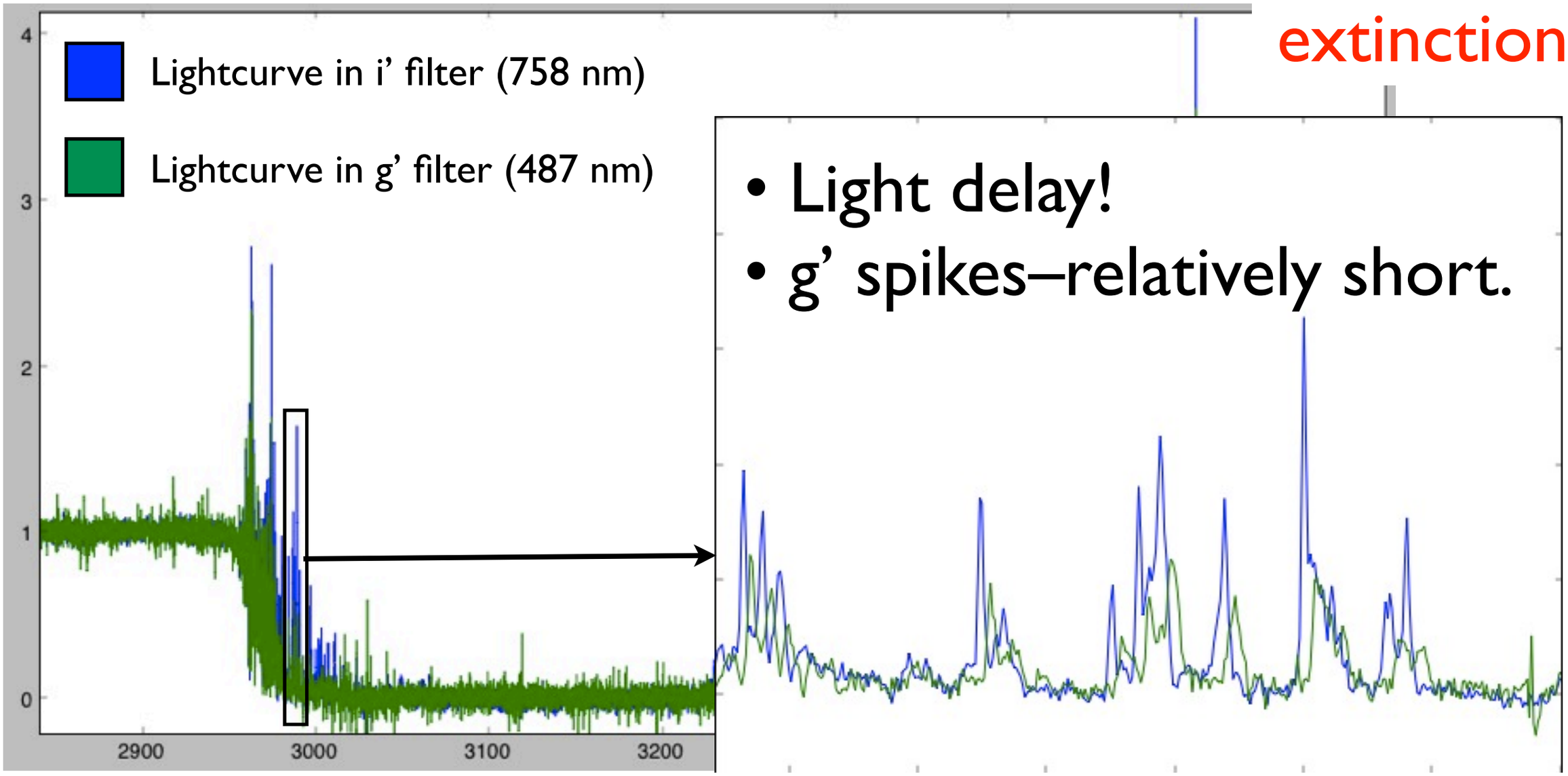
The ULTRACAM Lightcurves

- Q1: Why all the spikes? Focusing events.
- Q2: Are the spikes real? Yes - compare i' and g'.
- Q3: Why is the central flash only seen in i'? More haze extinction in g'.



The ULTRACAM Lightcurves

- Q1: Why all the spikes? Focusing events.
- Q2: Are the spikes real? Yes - compare i' and g'.
- Q3: Why is the central flash only seen in i'? More haze extinction in g'.



ASIDE into Central Flashes

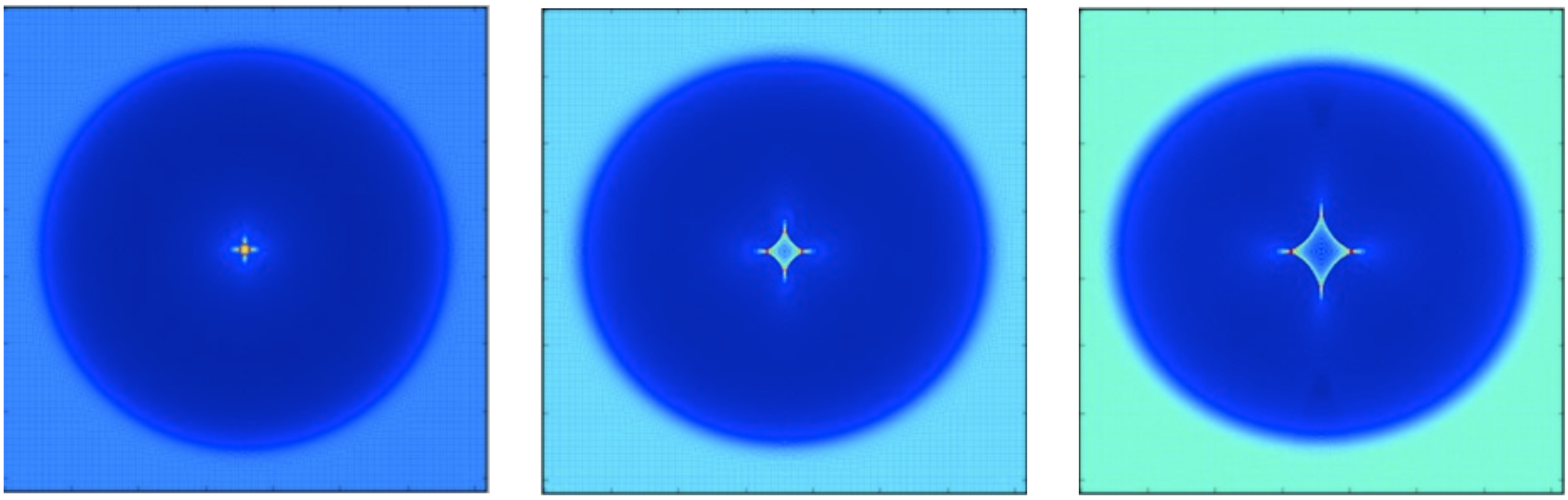
- Central flashes are extremely sensitive to the shape (the oblateness, the figure) of the atmosphere.
- The 3-JUL-1989 Titan occultation by 28 Sgr mapped the central flash from 15 different sites and suggested zonal winds near ±60° at ~100 m/s (Hubbard et al. 1993).
- Sicardy et al. (2006) recorded some central flash lightcurves with the 14-NOV-2003 event and recovered a new zonal wind profile.
- The ULTRACAM site (La Palma) was very close to the shadow center (19 - 45 km).

ASIDE into Central Flashes

- Central flashes are extremely sensitive to the shape (the oblateness, the figure) of the atmosphere.
- The 3-JUL-1989 Titan occultation by 28 Sgr mapped the central flash from 15 different sites and indicated zonal winds near ±60° at ~100 m/s (Hubbard et al. 1993).
- Sicardy et al. (2006) recorded some central flash lightcurves with the 14-NOV-2003 event and recovered a new zonal wind profile.
- The ULTRACAM site (La Palma) was very close to the shadow center (19 - 45 km).

ASIDE into Central Flashes

- Oblate atmospheres: caustics are equatorial diamonds.
- The ULTRACAM central flash: three main peaks (over ten seconds) with two smaller intermediate peaks.
- Zonal winds are required to fit the three peaks.

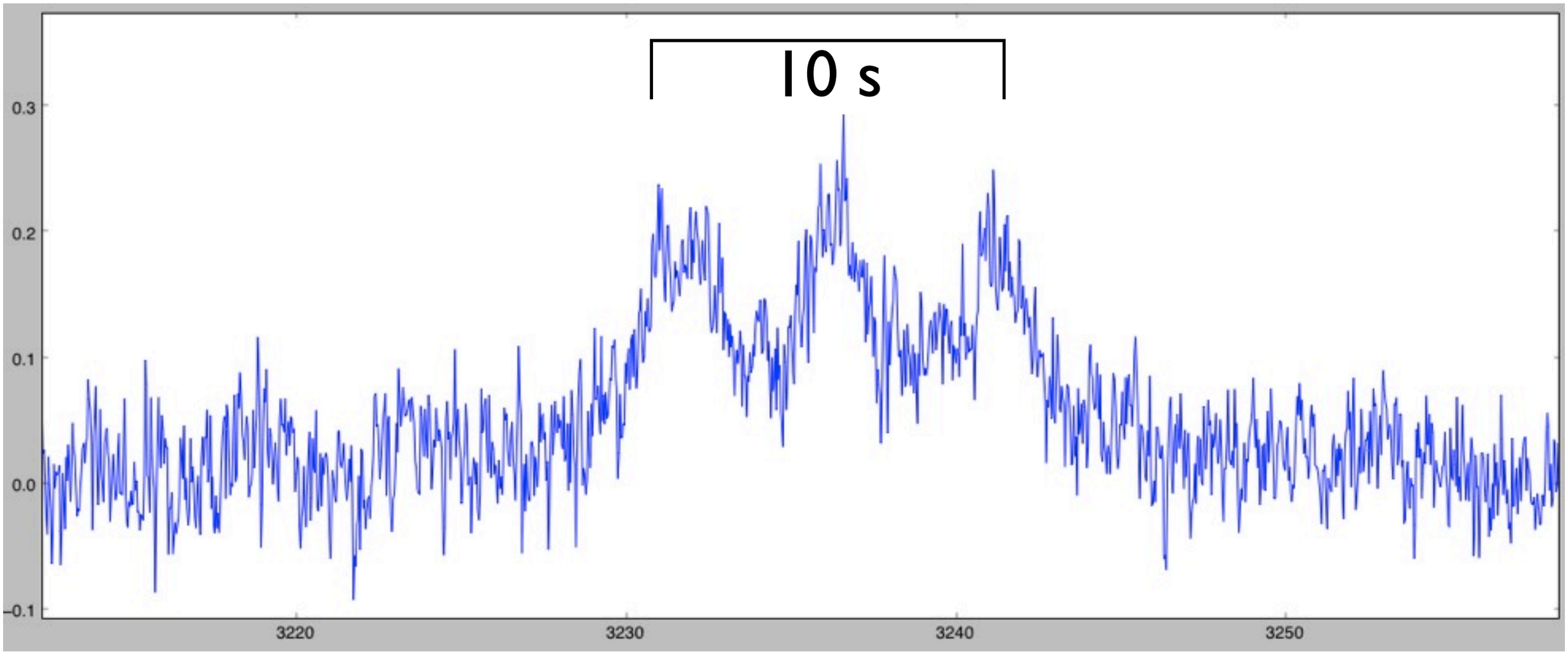


Oblateness = 1% Oblateness = 3% Oblateness = 5%

Observer's plane intensity fields generated with a nominal Titan atmosphere but no haze.

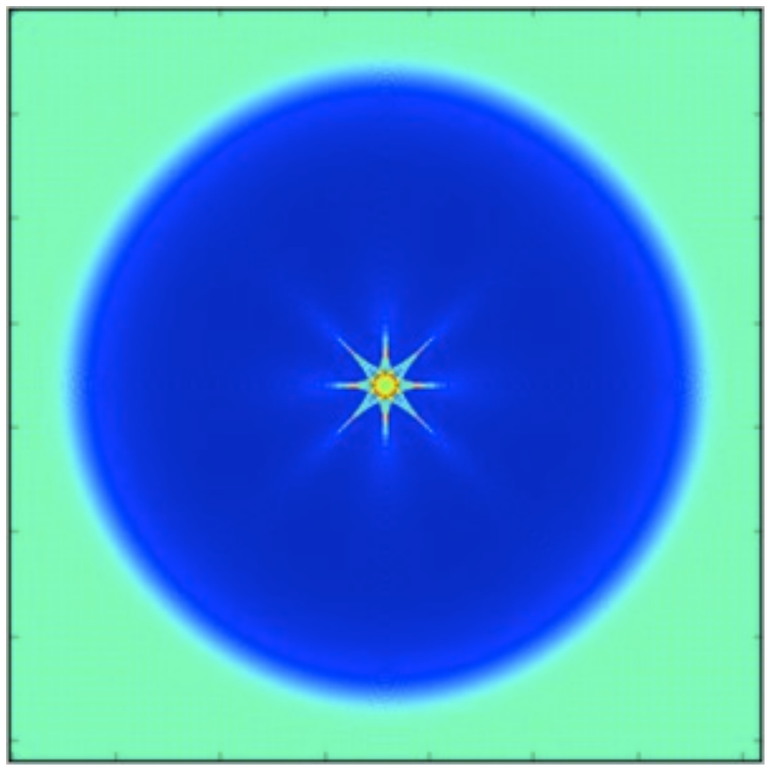
ASIDE into Central Flashes

- Oblate atmospheres: caustics are equatorial diamonds.
- The ULTRACAM central flash: three main peaks (over ten seconds) with two smaller intermediate peaks.
- Zonal winds are required to fit the three peaks.

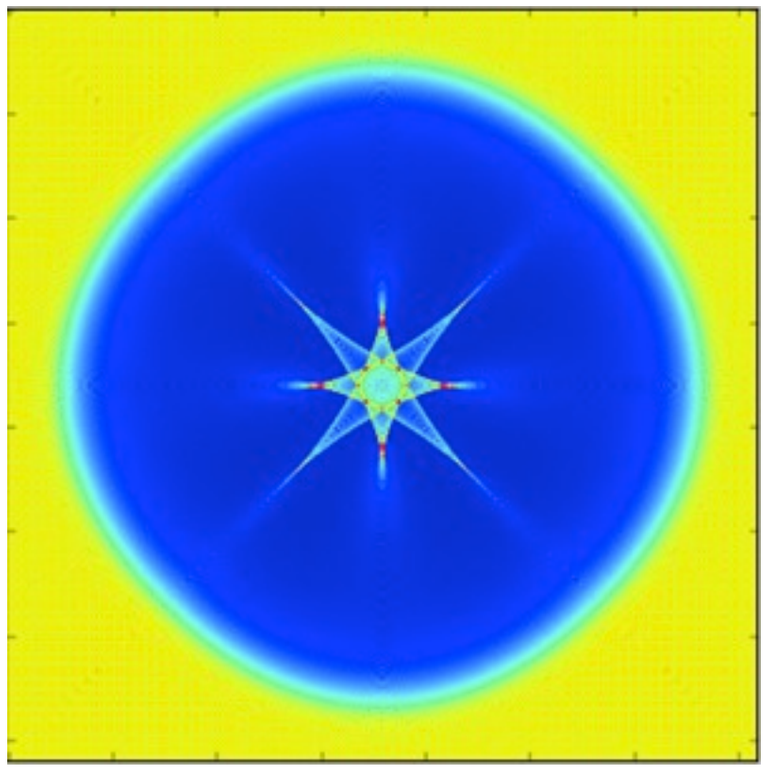


ASIDE into Central Flashes

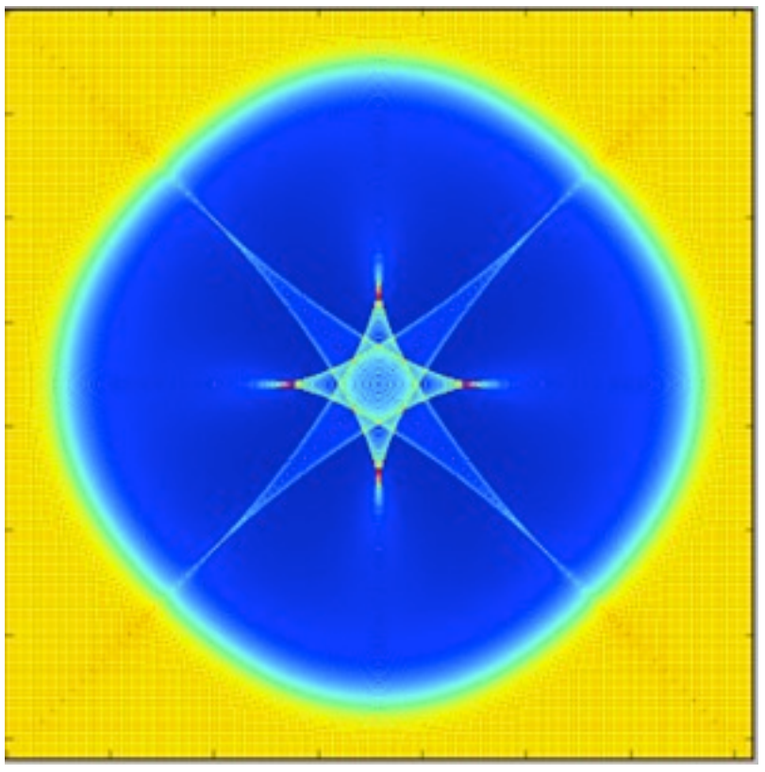
- Oblate atmospheres: caustics are equatorial diamonds.
- The ULTRACAM central flash: three main peaks (over ten seconds) with two smaller intermediate peaks.
- Zonal winds are required to fit the three peaks.



Distortion = 1%



Distortion = 2%

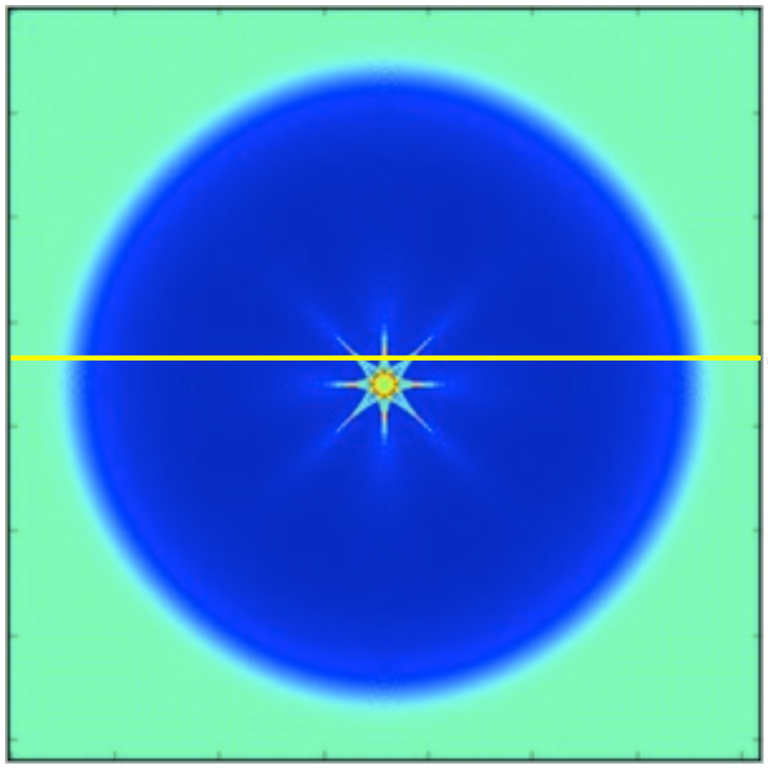


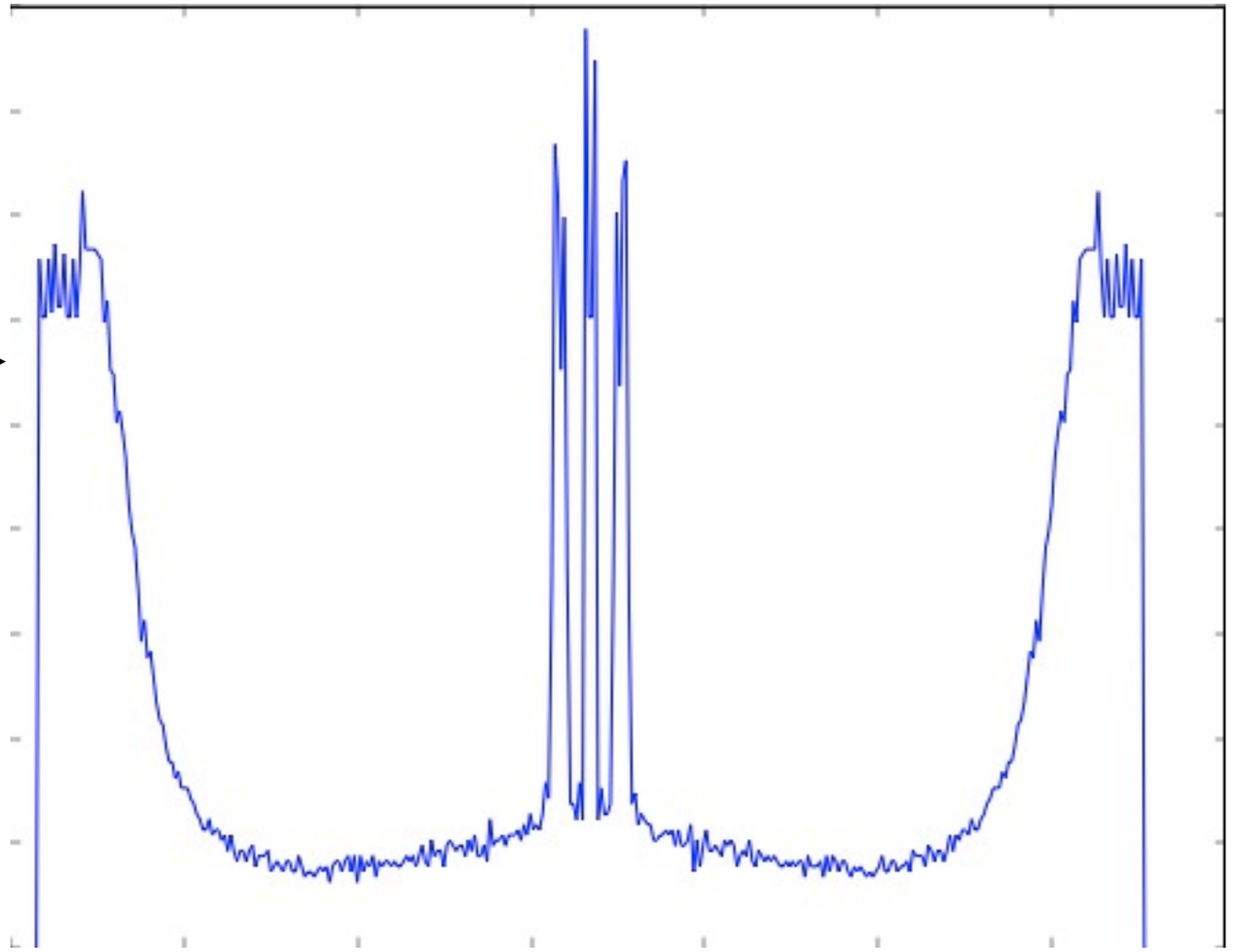
Distortion = 3%

Fast zonal winds at 50° give rise to 8-pronged caustics which produce 3-peaked central flashes for chords above/below the center.

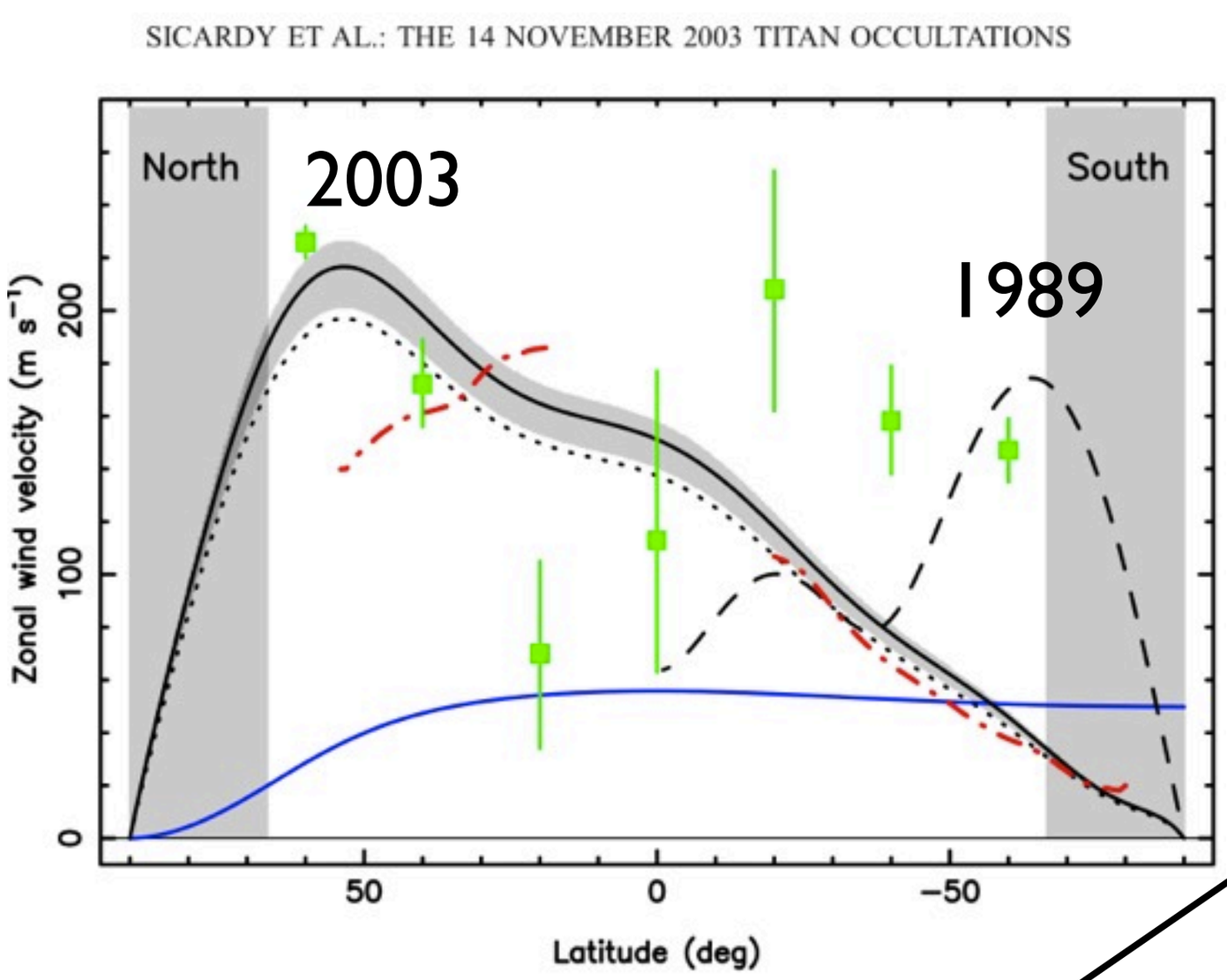
ASIDE into Central Flashes

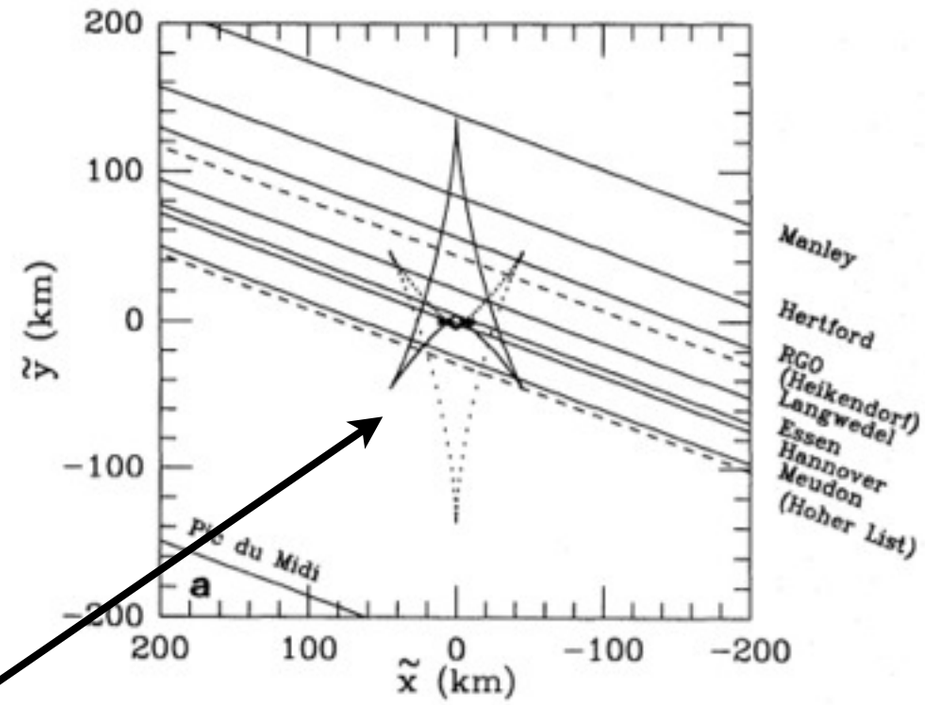
- Oblate atmospheres: caustics are equatorial diamonds.
- The ULTRACAM central flash: three main peaks (over ten seconds) with two smaller intermediate peaks.
- Zonal winds are required to fit the three peaks.

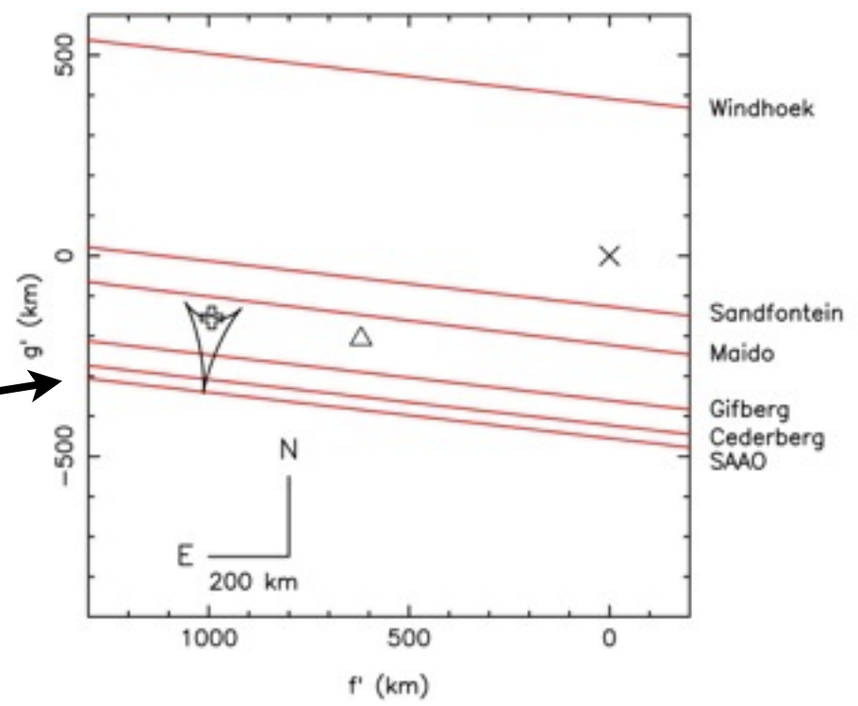




ASIDE into Central Flashes





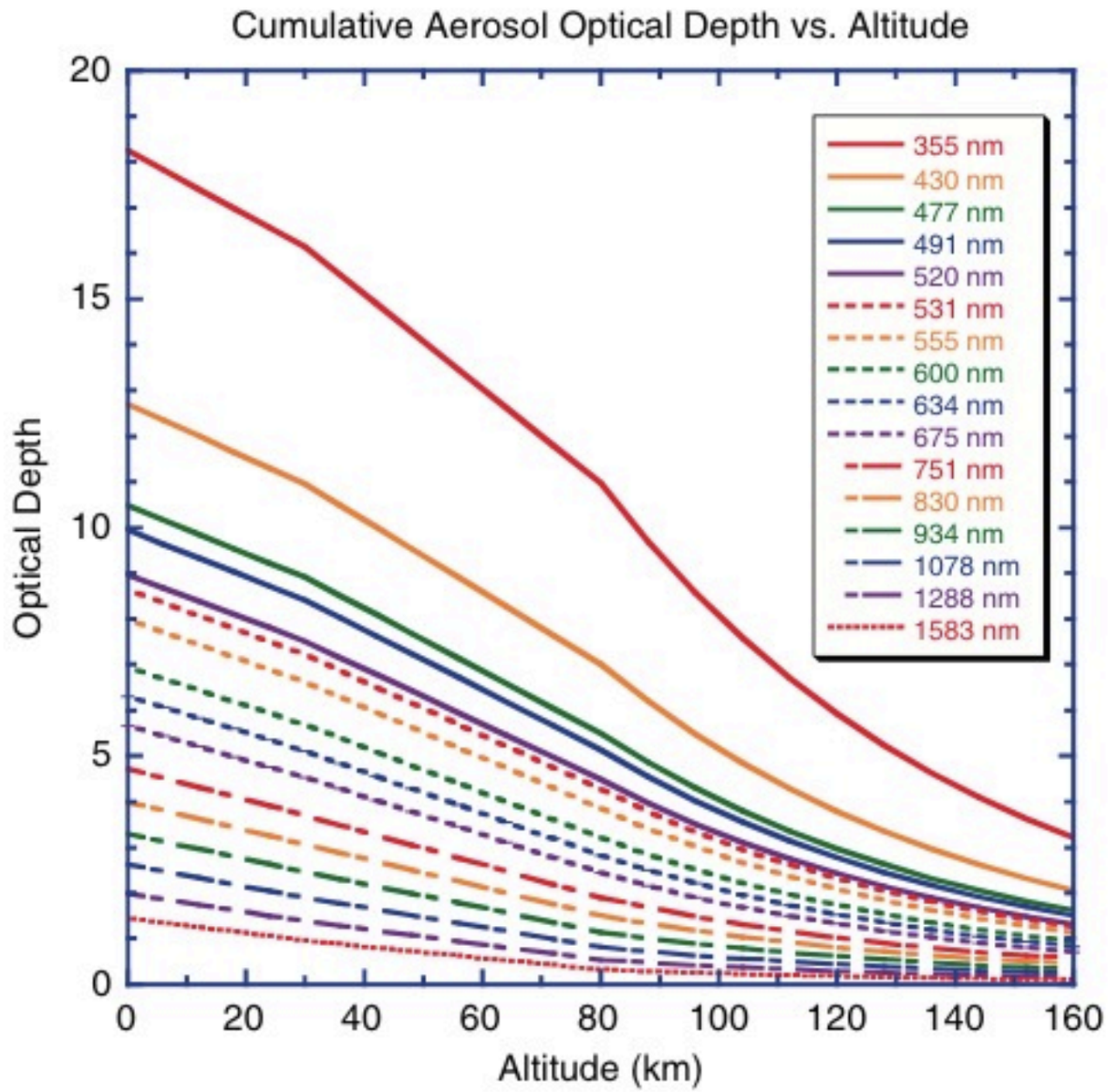


- Hubbard et al. (1993) fit this caustic to the 1989 central flash lightcurves.
- Sicardy et al. (2006) fit this profile to the 2003 lightcurves.

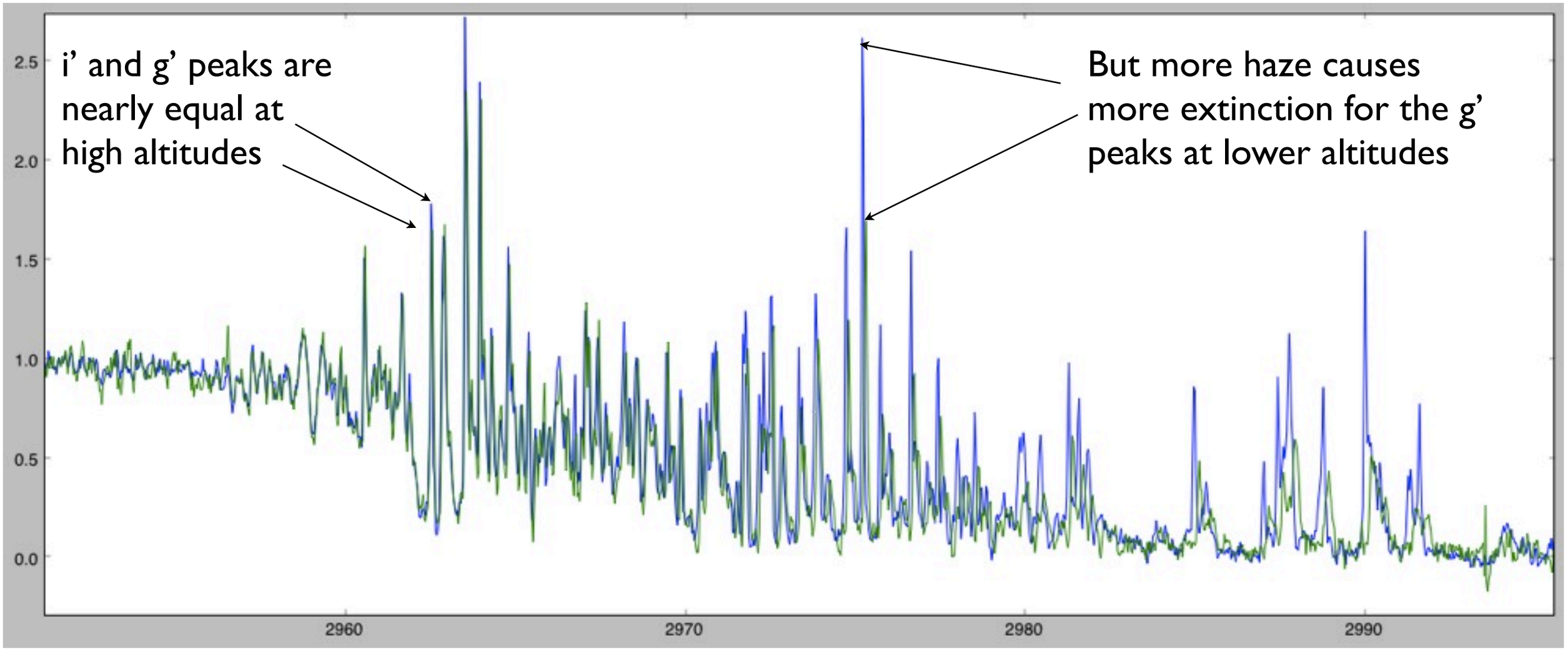
Scintillations

- The multi-color ULTRACAM scintillations give an independent check on the temperature profile (from the light delays between colors; Zalucha et al. 2007 gets profile that is a little warmer than HASI).

- They ALSO provide a very sensitive measure of haze number density in the 300 - 550 km region (but we have to assume extinction cross sections from the DISR observations, i.e., cumulative optical depths above 160 km).



Scintillations



Because the scintillation spikes are very distinct (thanks to the high SNR and 30 Hz frame rate of ULTRACAM in this case), the precise differences between spike amplitudes in different colors gives haze number densities at altitudes up to 550 km.

Upcoming Occultations

- 24-OCT-2014.
- VERY bright star (R=7.6, K = 4.5).
- Path goes right over Australia
- But very close to the Sun - an IR event, most likely.