Recent results on Chariklo's rings

Maryame El Moutamid

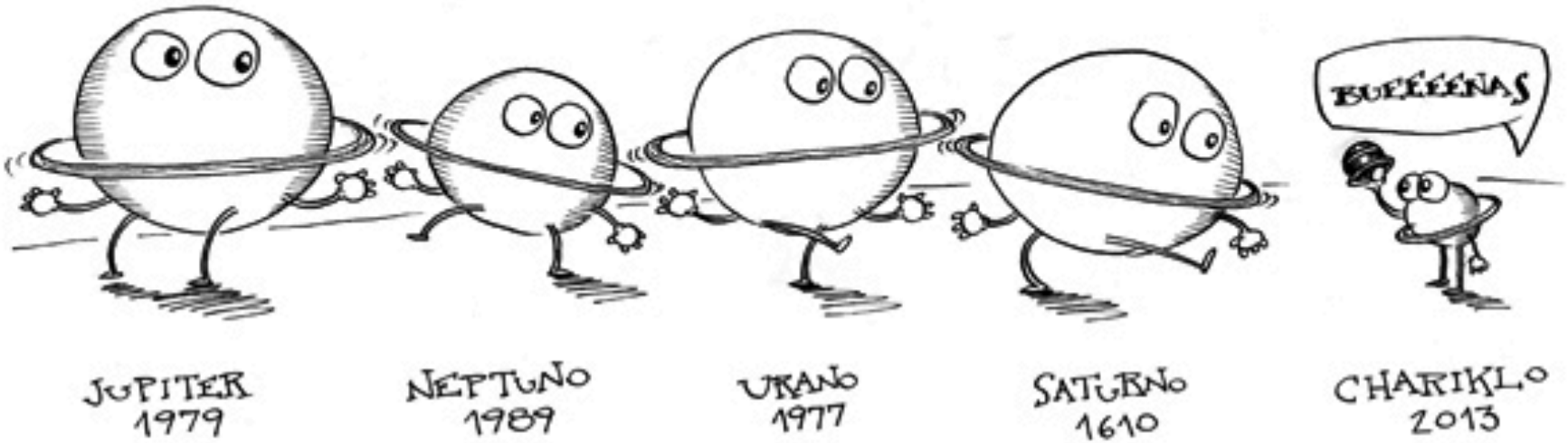
Cornell University

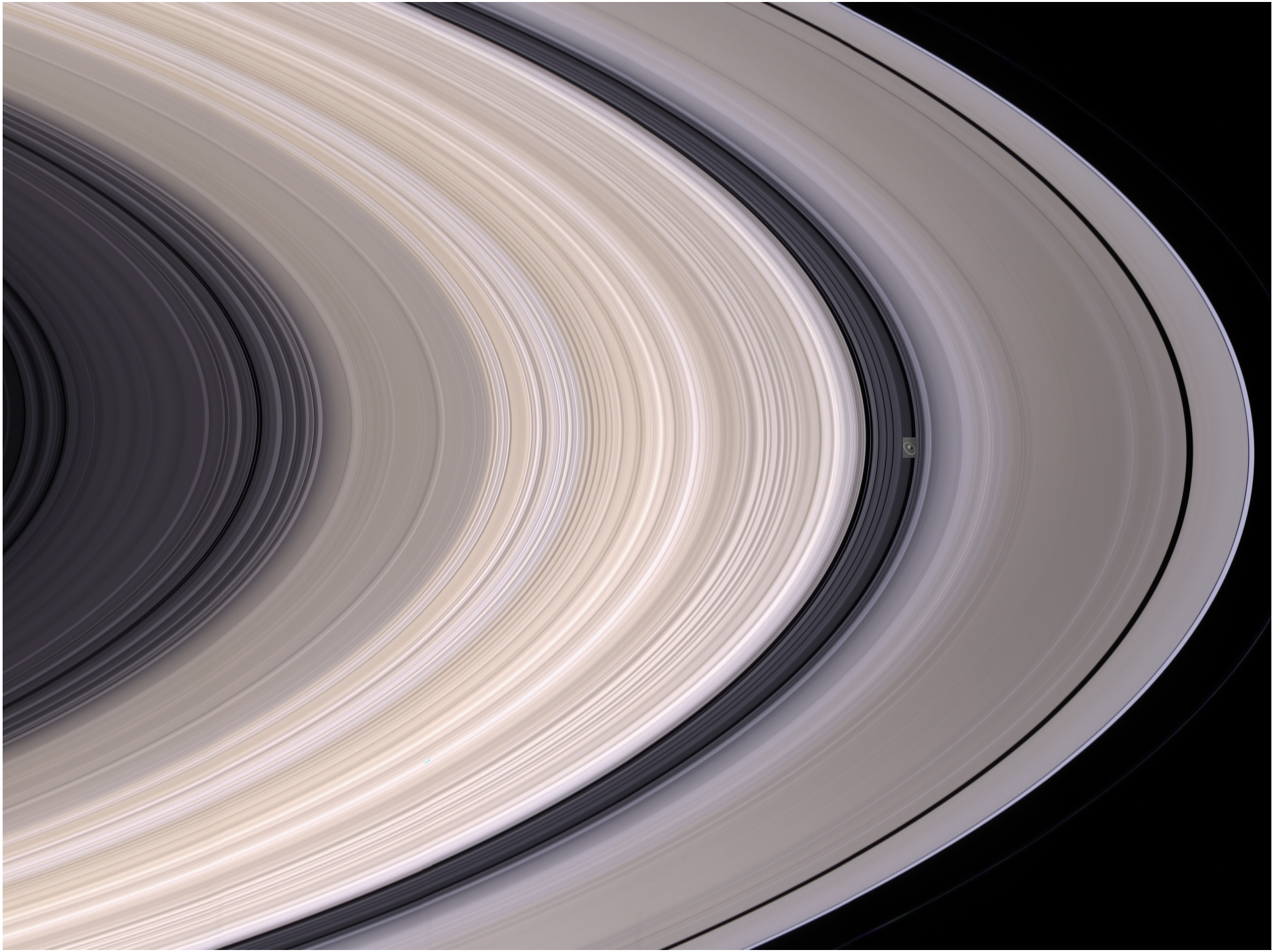
Bruno Sicardy (UPMC/OBSPM), Matt Hedman (Idaho Univ.), Matt Tiscareno (Cornell Univ.), Daniel Tamayo (Cornell Univ), Philip D. Nicholson (Cornell Univ.), Joseph A. Burns (Cornell Univ.)

Outline

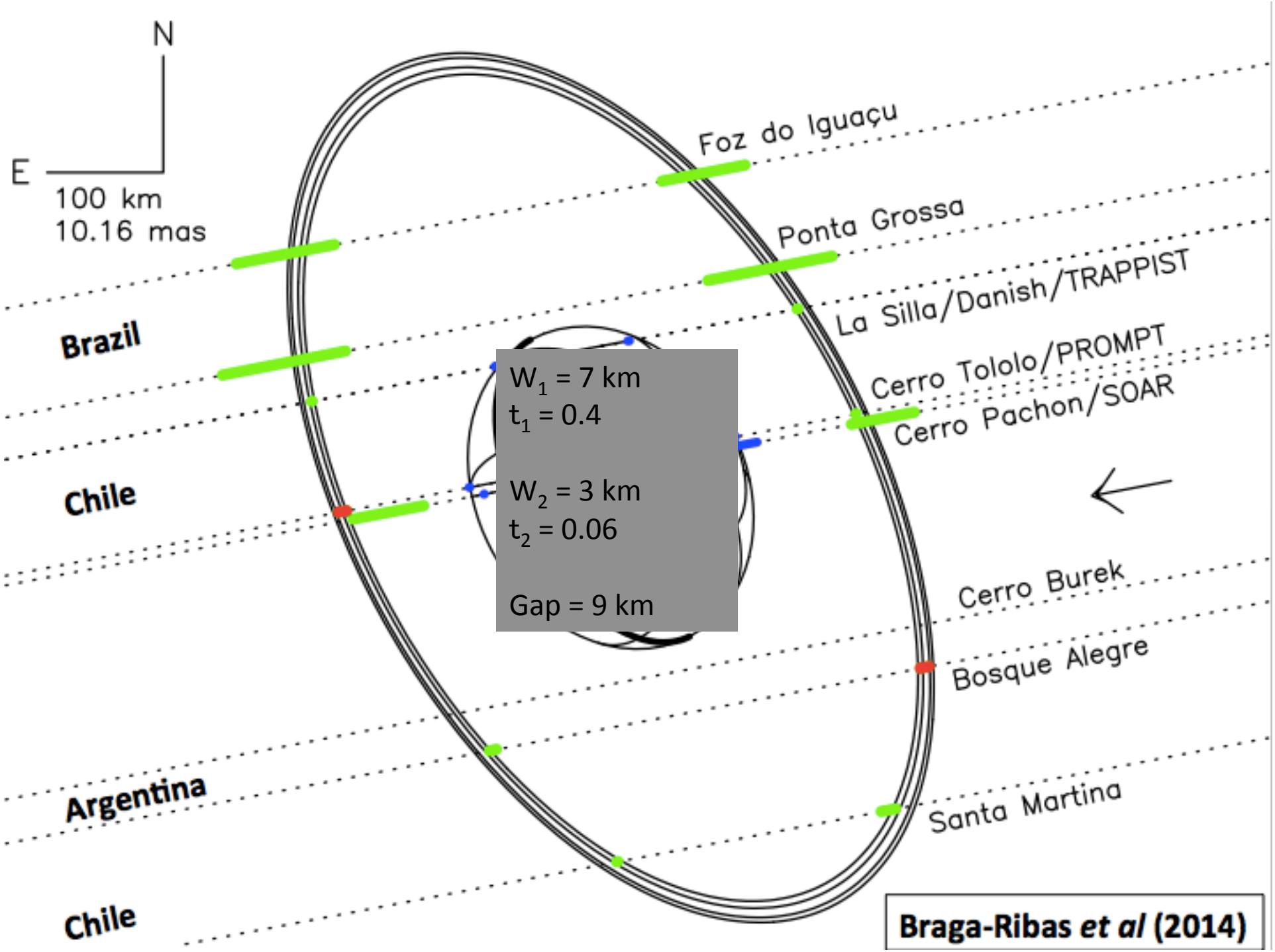
- The discovery
- Geometry and data processing
- Rings photometry and spectrometry
- Model
    - Photometry
    - Dynamics
- Results
- Origin
- Conclusion

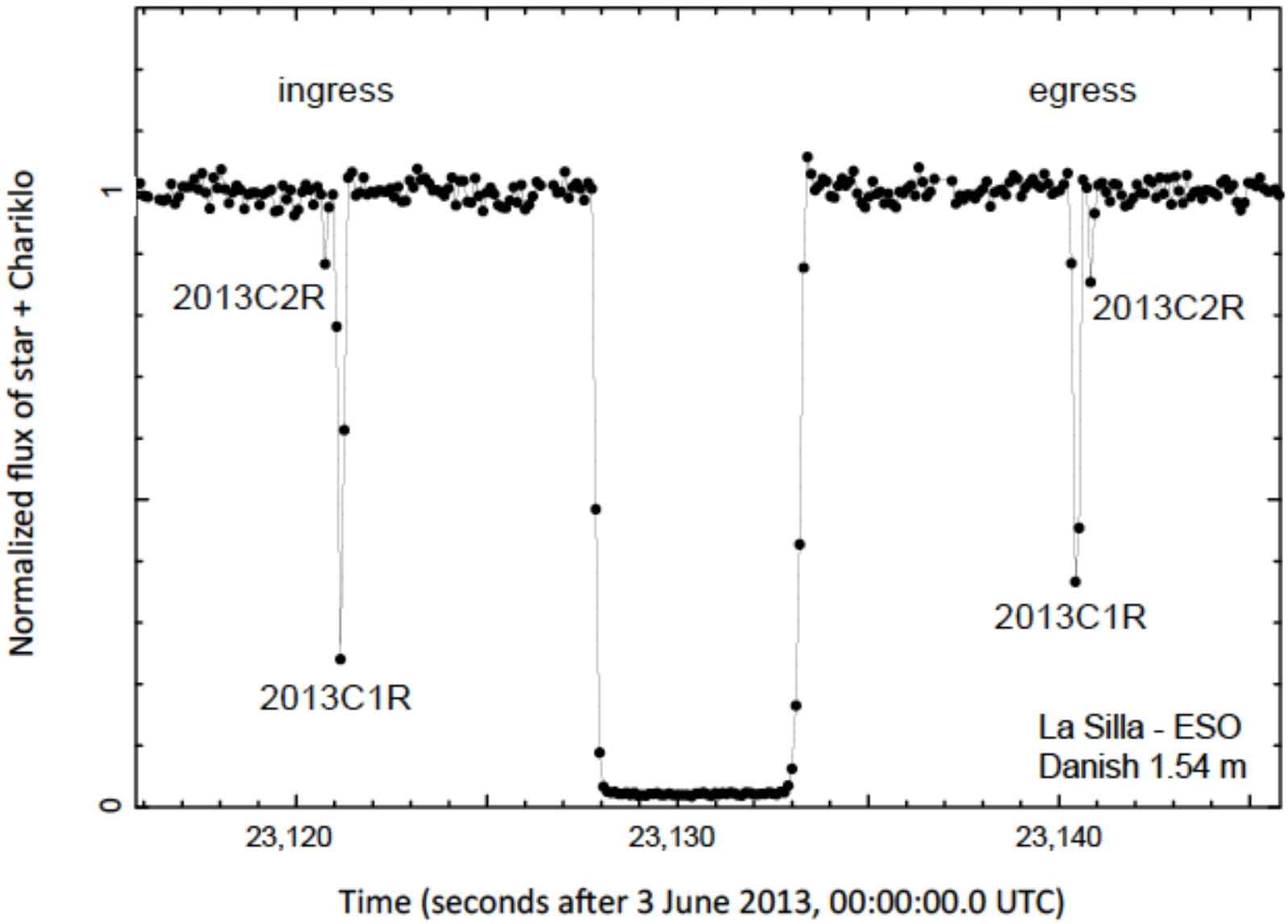
CONCURSO DE HULA-HULA





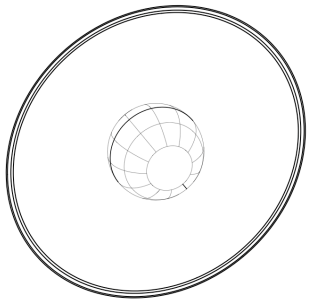
- The discovery
- Geometry and data processing
- Rings photometry and spectrometry
- Model
    - Photometry
    - Dynamics
- Results
- Origin
- Conclusion


N
E
100 km
10.16 mas
Foz do Iguaçu
Ponta Grossa
La Silla/Danish/TRAPPIST
Cerro Tololo/PROMPT
Cerro Pachon/SOAR
Brazil
Chile
W_1 = 7 km
t_1 = 0.4
W_2 = 3 km
t_2 = 0.06
Gap = 9 km
Cerro Burek
Bosque Alegre
Argentina
Santa Martina
Chile
Braga-Ribas *et al* (2014)

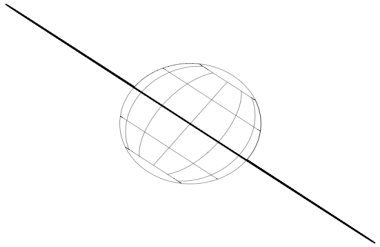

ingress
egress
2013C2R
2013C1R
2013C2R
2013C1R
La Silla - ESO
Danish 1.54 m
Normalized flux of star + Chariklo
1
0
23,120
23,130
23,140
Time (seconds after 3 June 2013, 00:00:00.0 UTC)

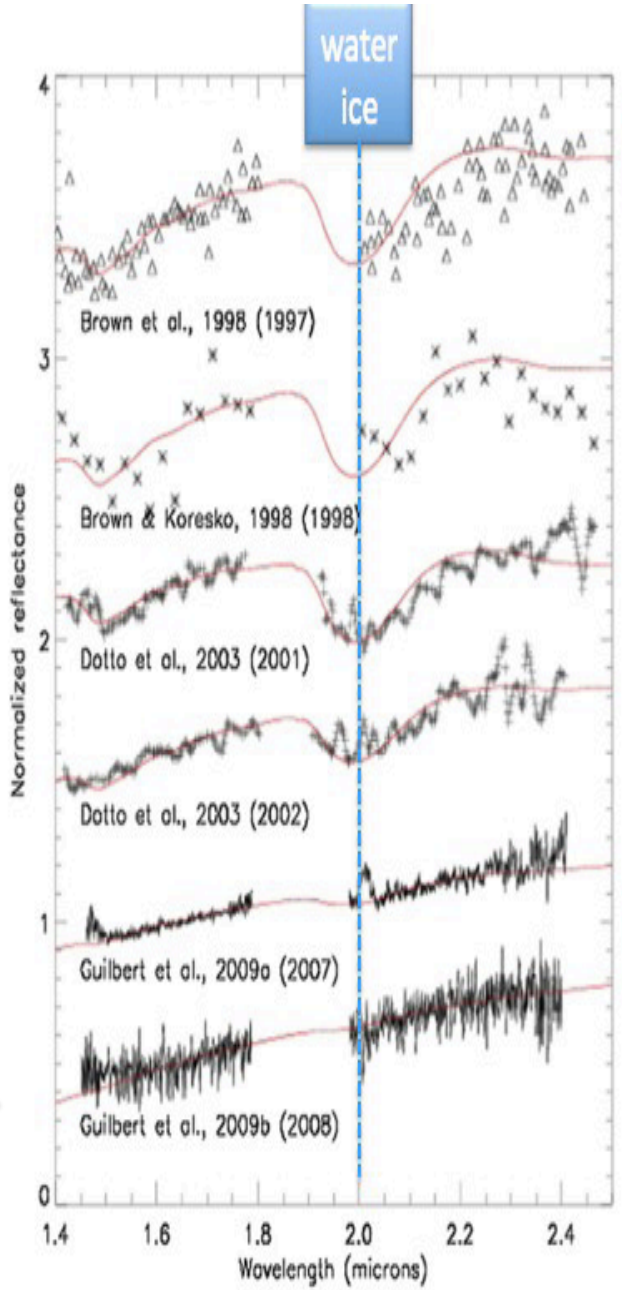
- The discovery
- Geometry and data processing
- Rings photometry and spectrometry
- Model
    - Photometry
    - Dynamics
- Results
- Origin
- Conclusion

maximum opening plane: end of 1995



ring plane crossing: end of 2007



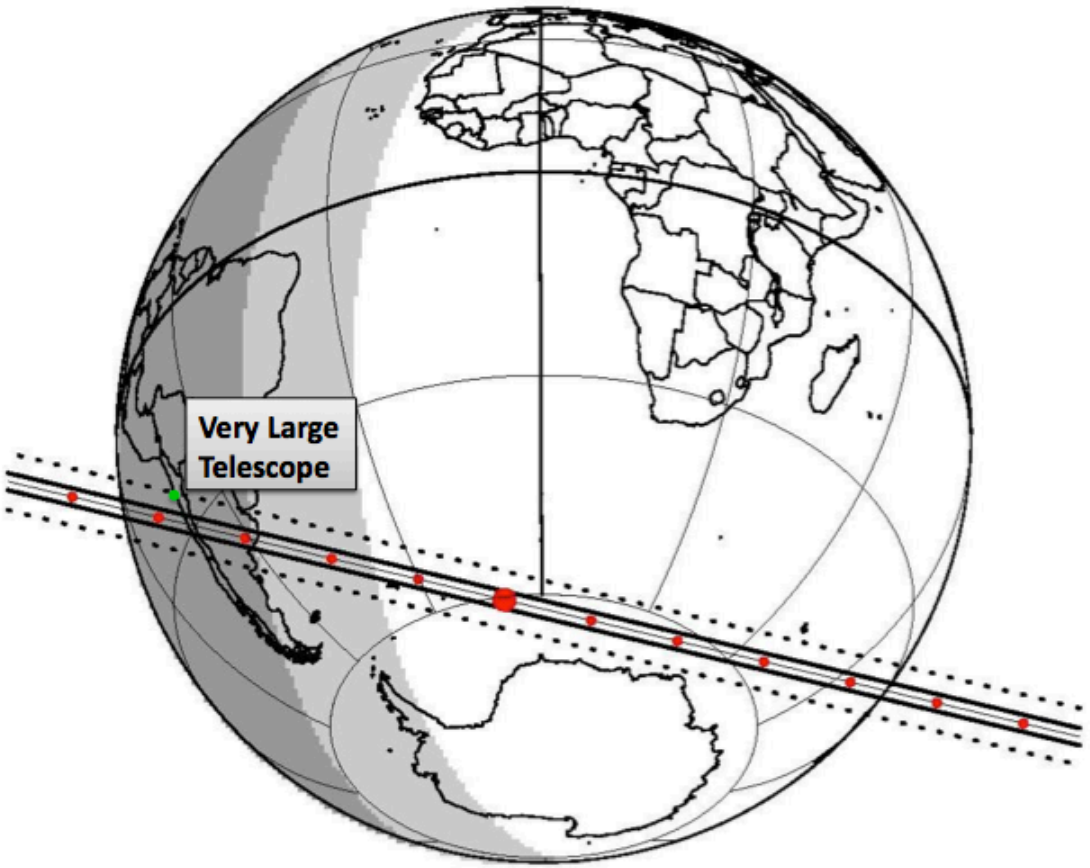


rings wide-open (B~50°)

rings edge-on (B~0°)

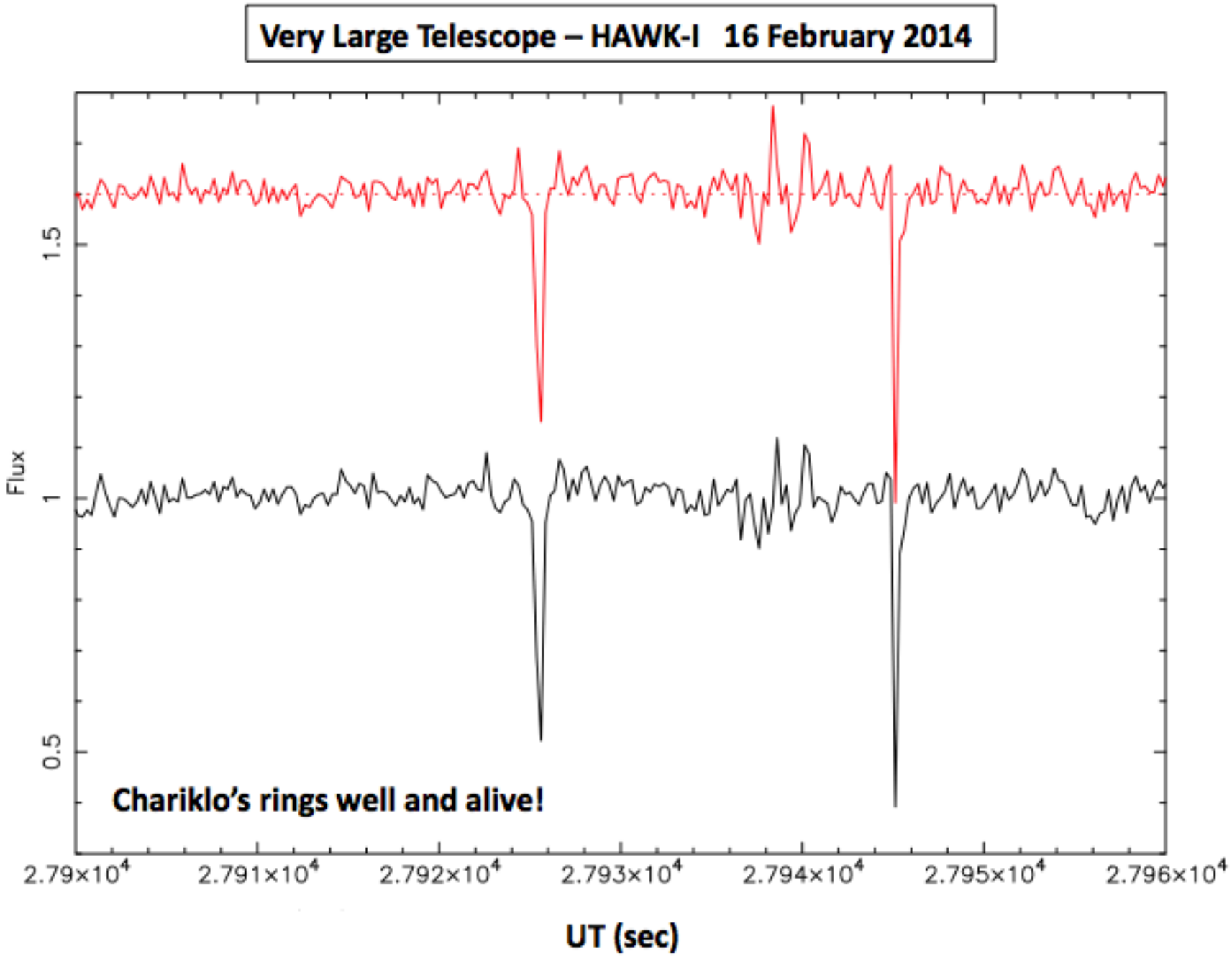
Guilbert-Lepoutre 2011

Chariklo: Star OPD08sep13_T60cm, NIMAv2 ephem. Offset (mas): 0.0 0.0

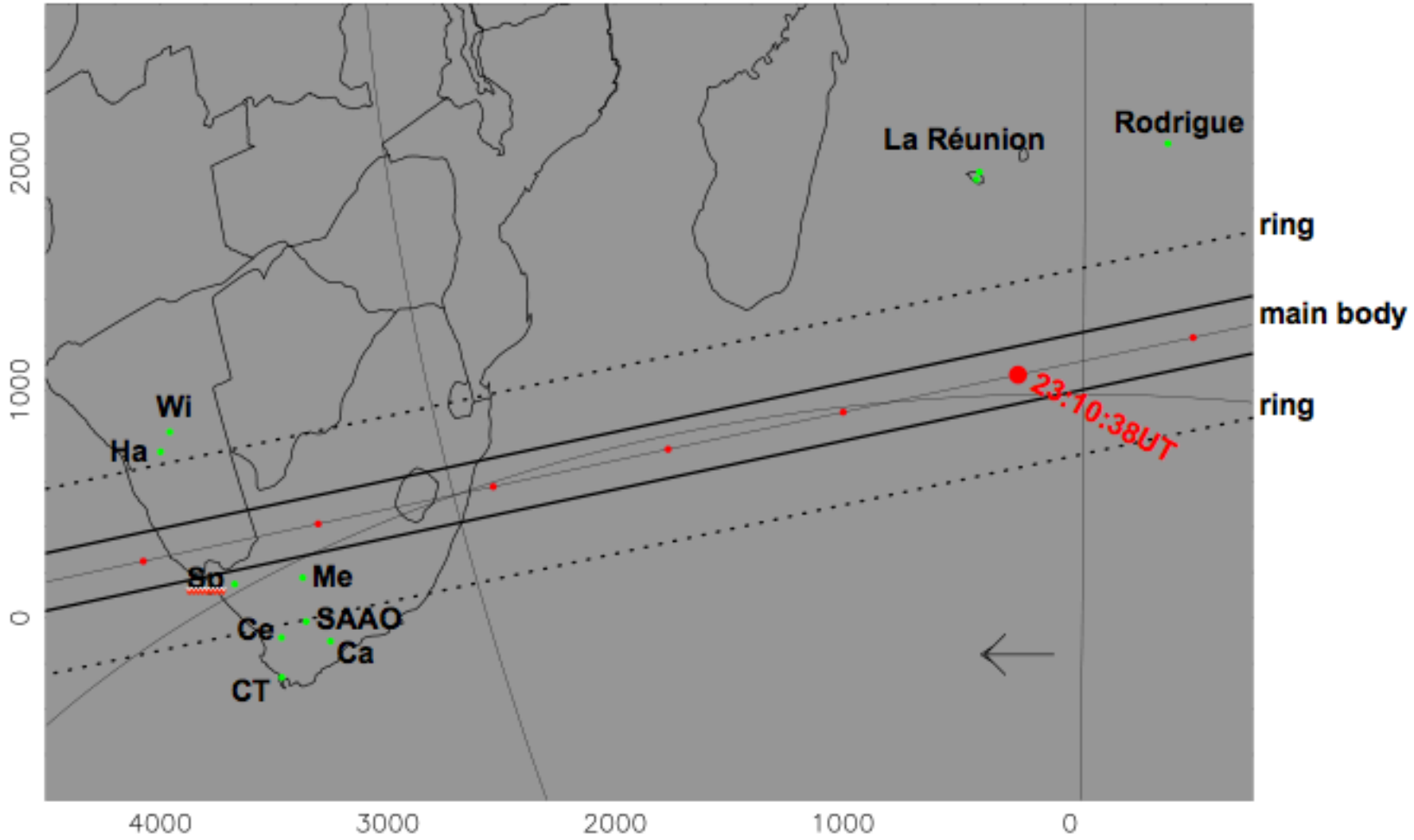


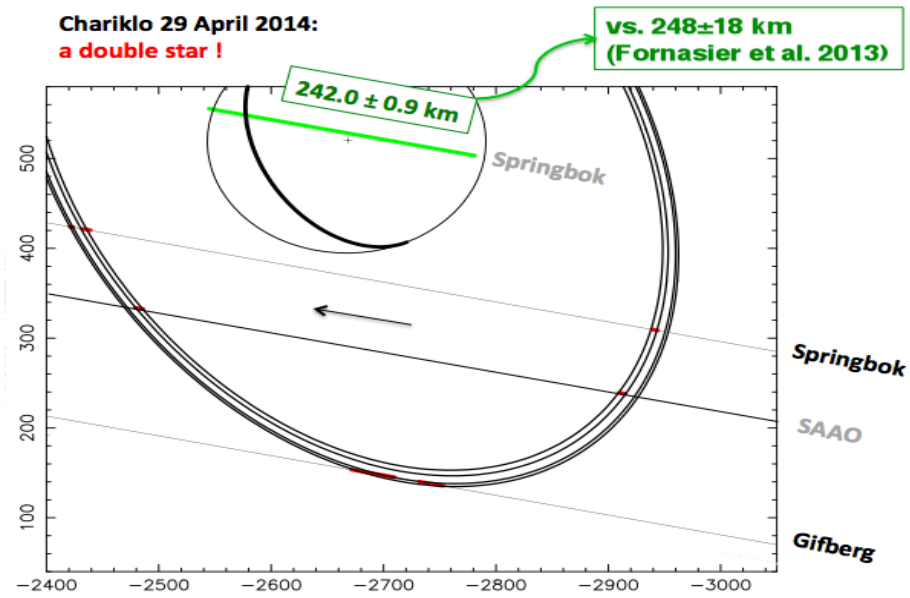
16 February 2014 Chariklo stellar occultation

d	m	year	h:m:s	UT	ra___dec___J2000_candidate	C/A	P/A	vel	Delta	R*	K*	long
16	02	2014	07	49	13. 17 35 55.3333 −38 05 17.184	0.230	193.40	22.12	15.15	16.9	12.0	0.

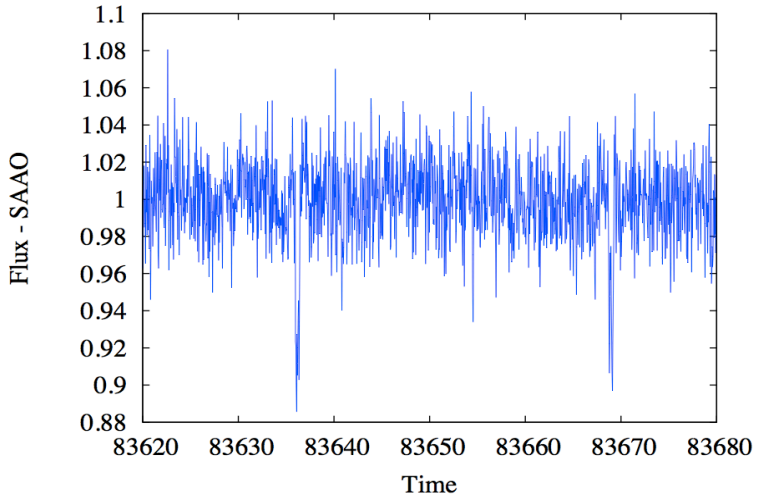

Very Large Telescope – HAWK-I 16 February 2014
Flux
1.5
1
0.5
Chariklo's rings well and alive!
2.79×10^4
2.791×10^4
2.792×10^4
2.793×10^4
2.794×10^4
2.795×10^4
2.796×10^4
UT (sec)

the 29 April 2014 Chariklo stellar occultation

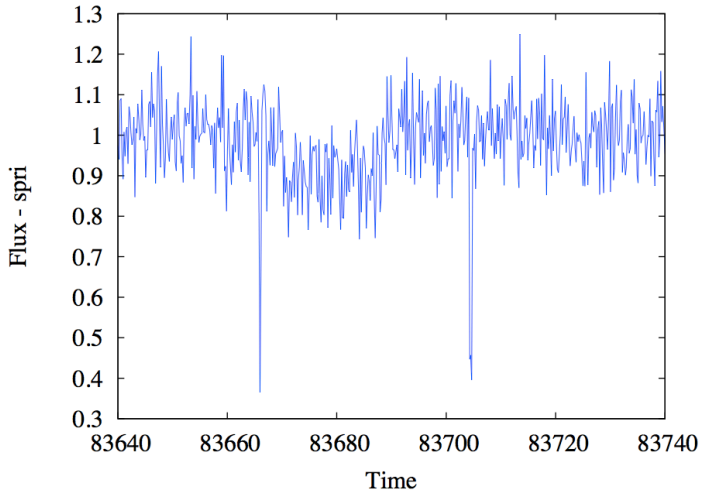




Saao



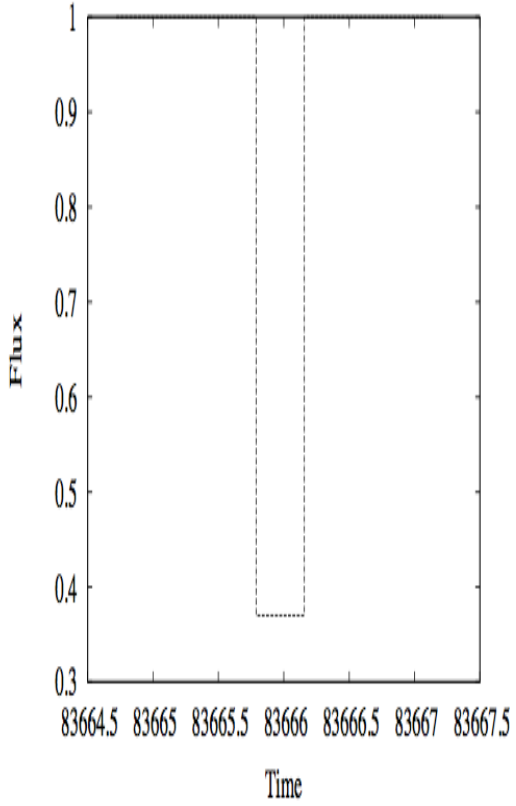
Springbok



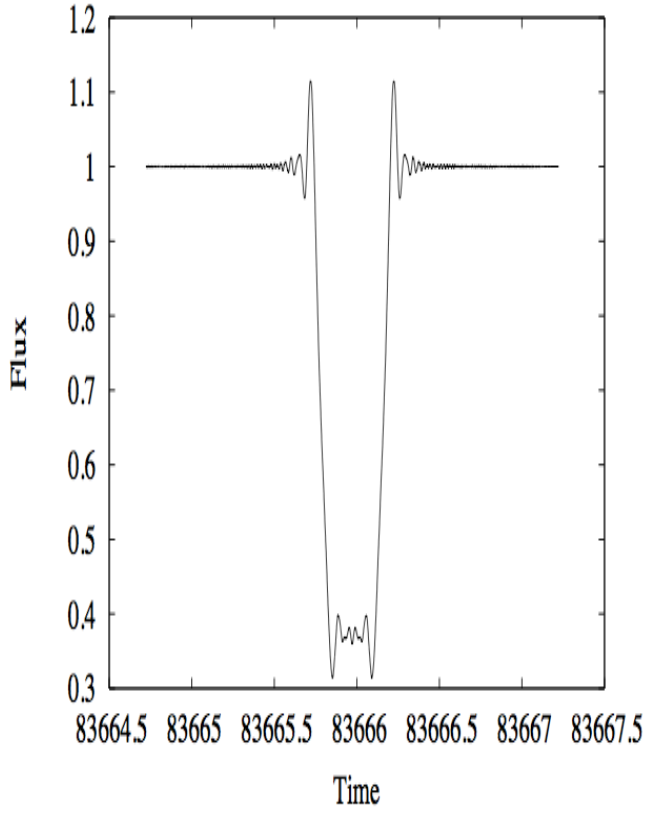
- The discovery
- Geometry and data processing
- Rings photometry and spectrometry
- Model
    - Photometry
    - Dynamics
- Results
- Origin
- Conclusion

Data analysis

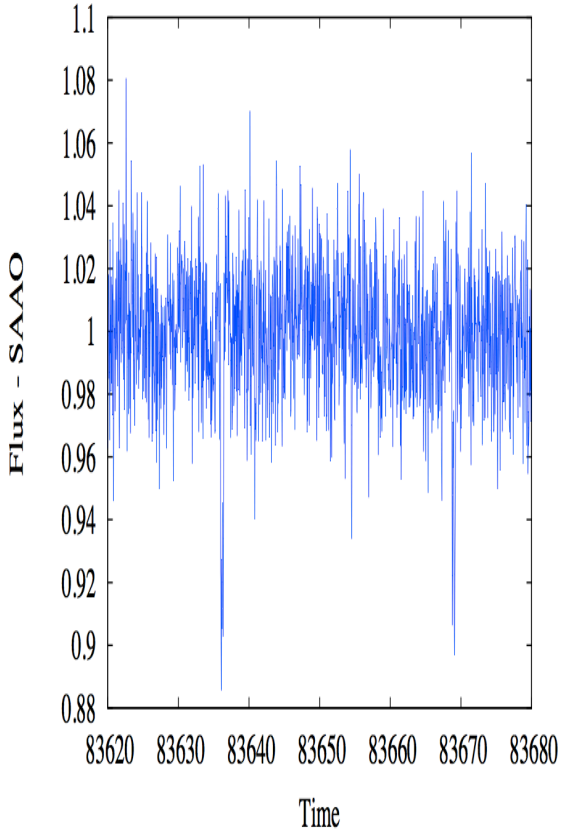
Square model

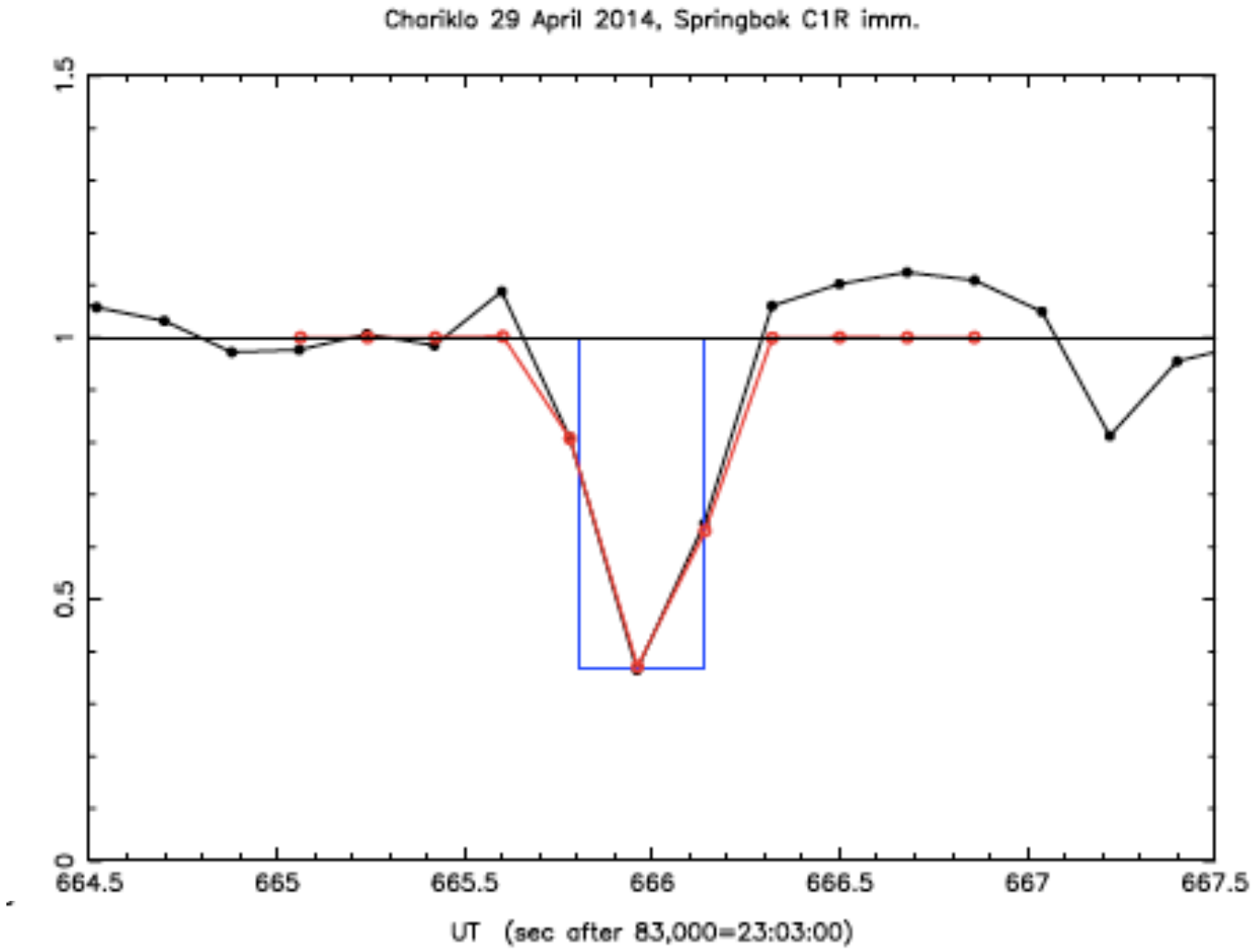


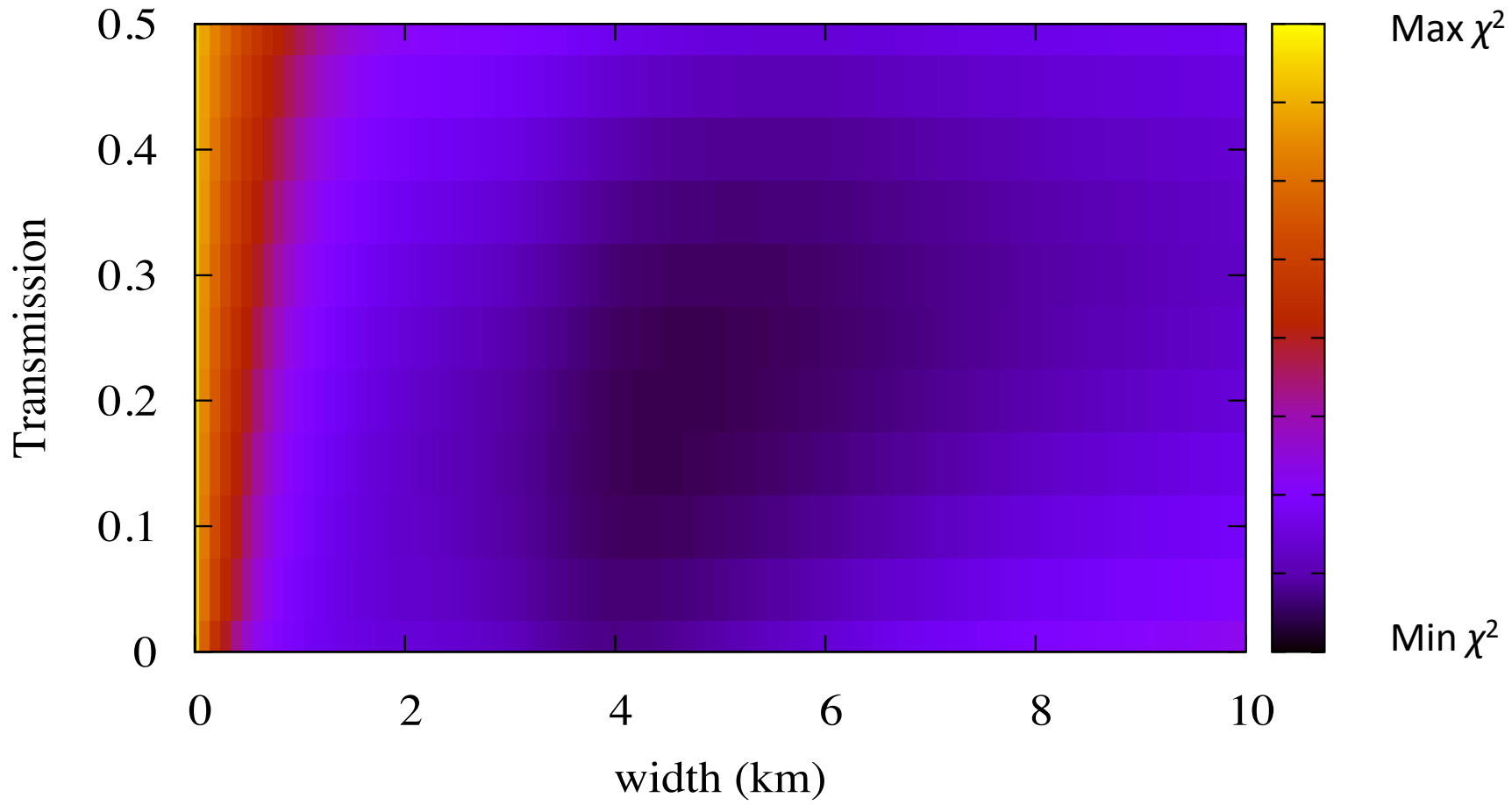
Diffraction model



Data



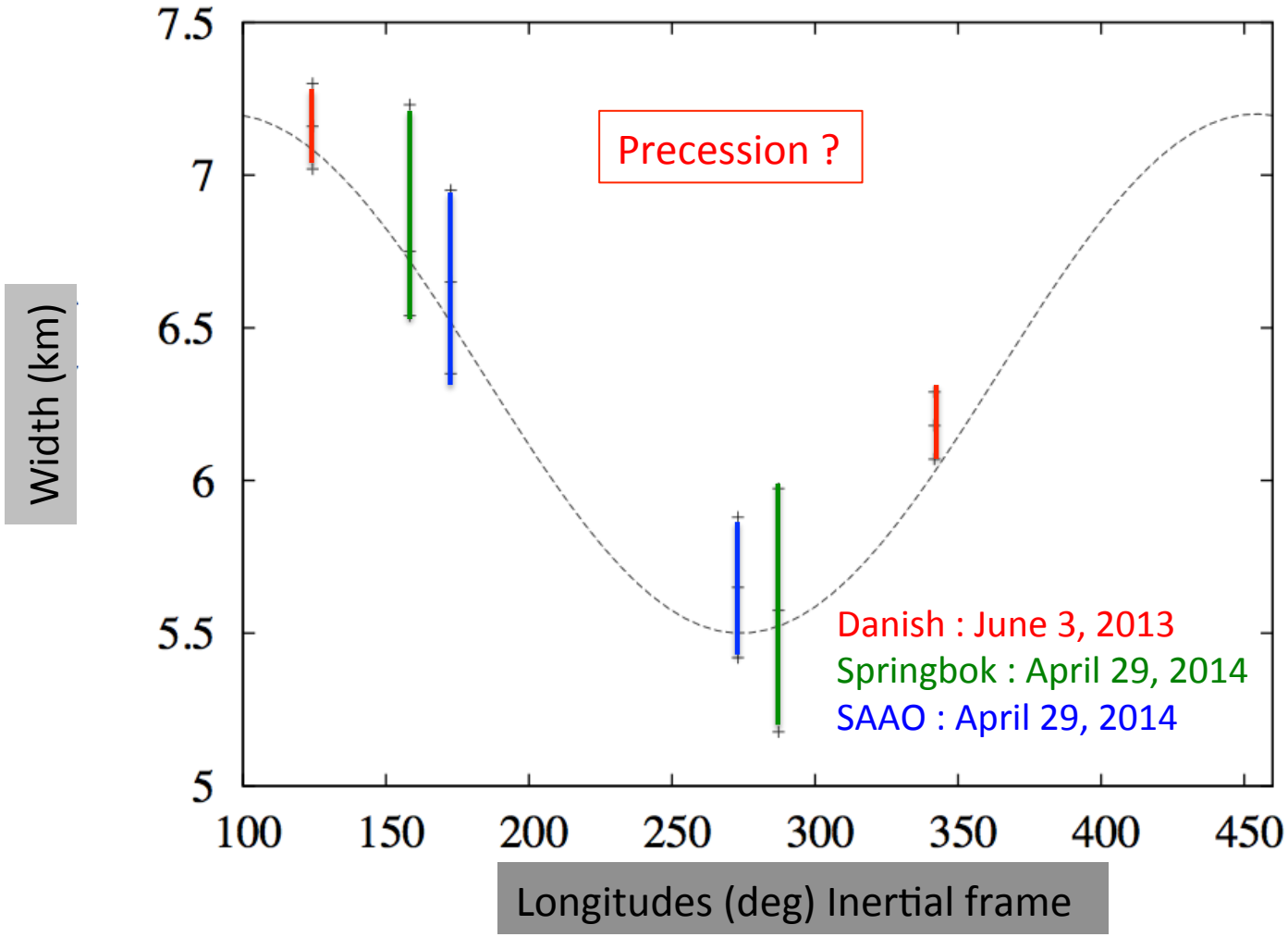

Chariklo 29 April 2014, Springbok C1R imm.
1.5
1
0.5
0
664.5
665
665.5
666
666.5
667
667.5
UT (sec after 83,000=23:03:00)



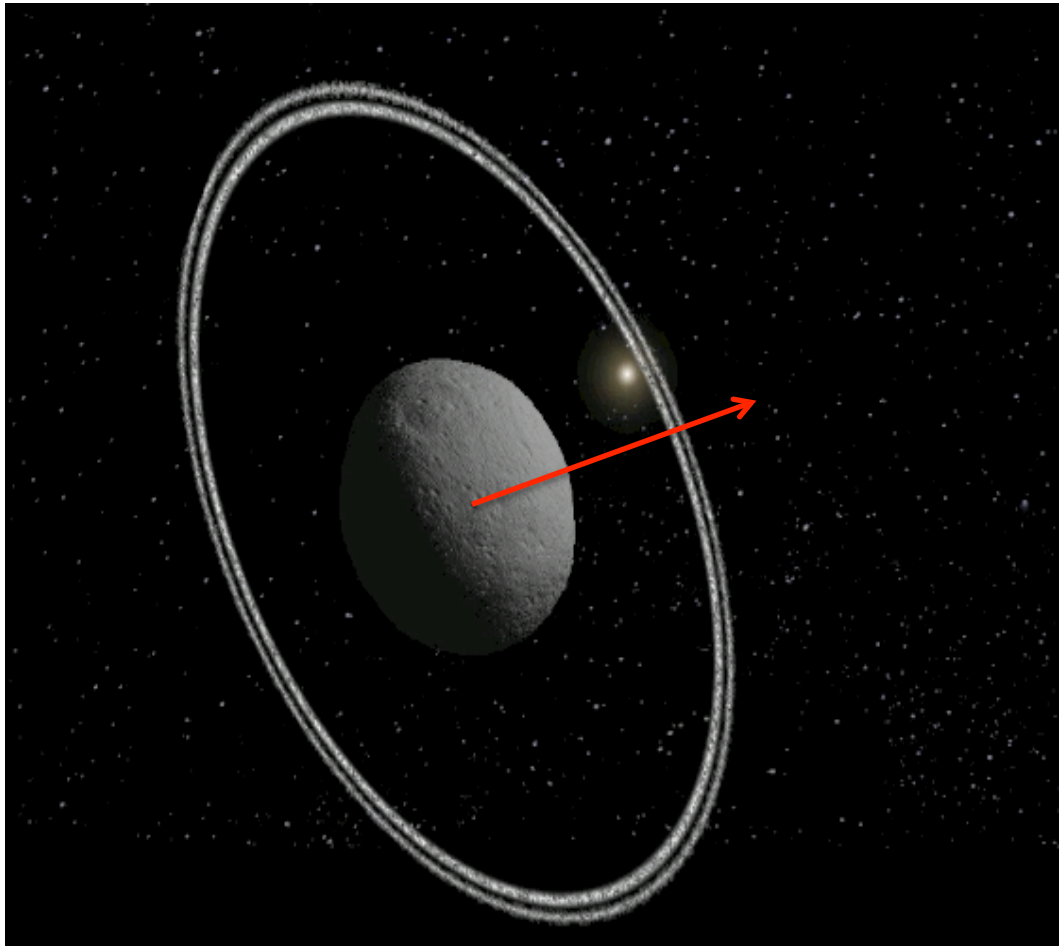
---> The width and the transmission

- The discovery
- Geometry and data processing
- Rings photometry and spectrometry
- Model
    - Photometry
    - Dynamics
- Results
- Origin
- Conclusion

Variation of width versus longitude



Shape and rotation of Chariklo



Fornasier et al 2014, A&A
Ω = 7.004 ± 0.002 hours

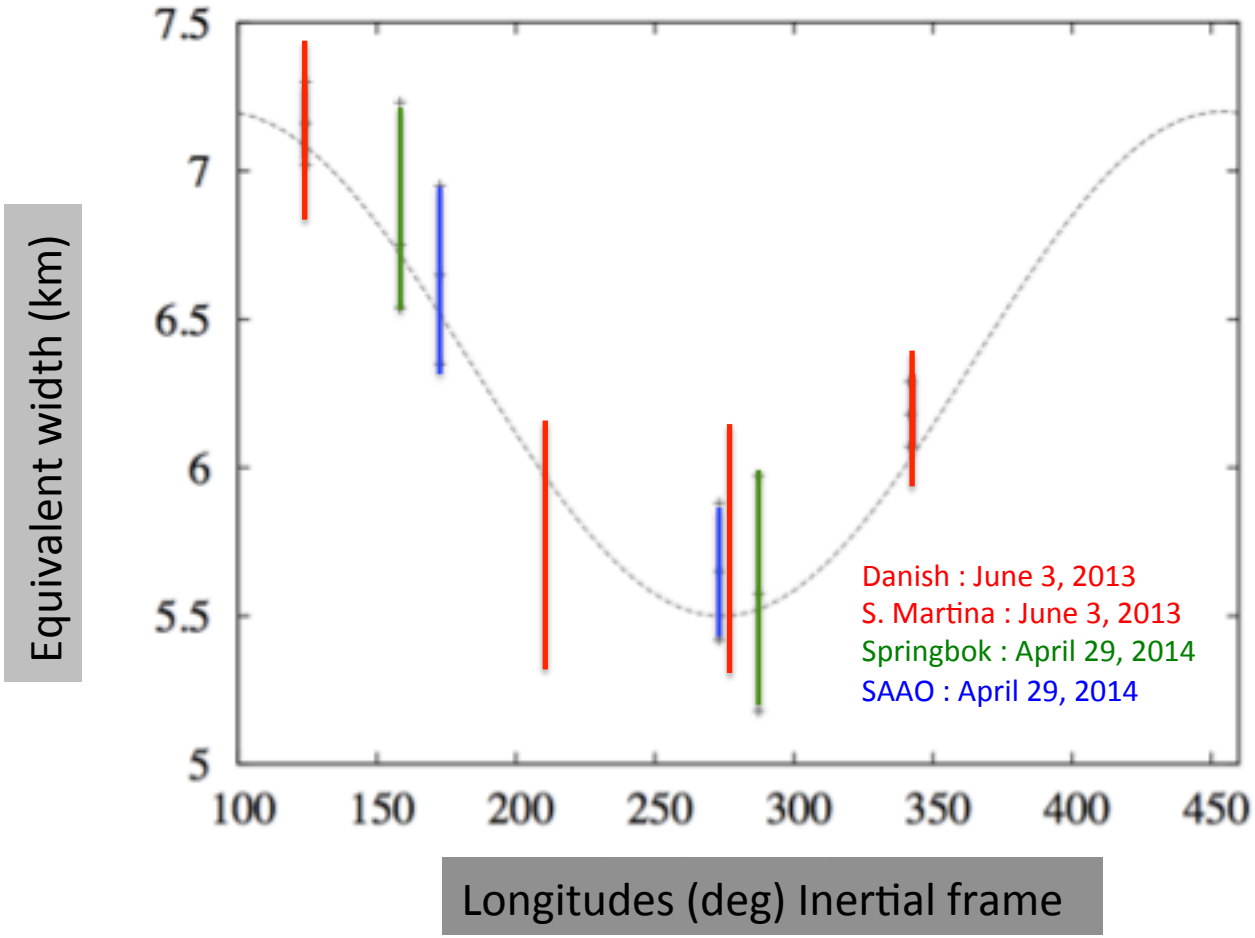
Braga-Ribas et al 2014, Nature
e = 0.213 ±0.002

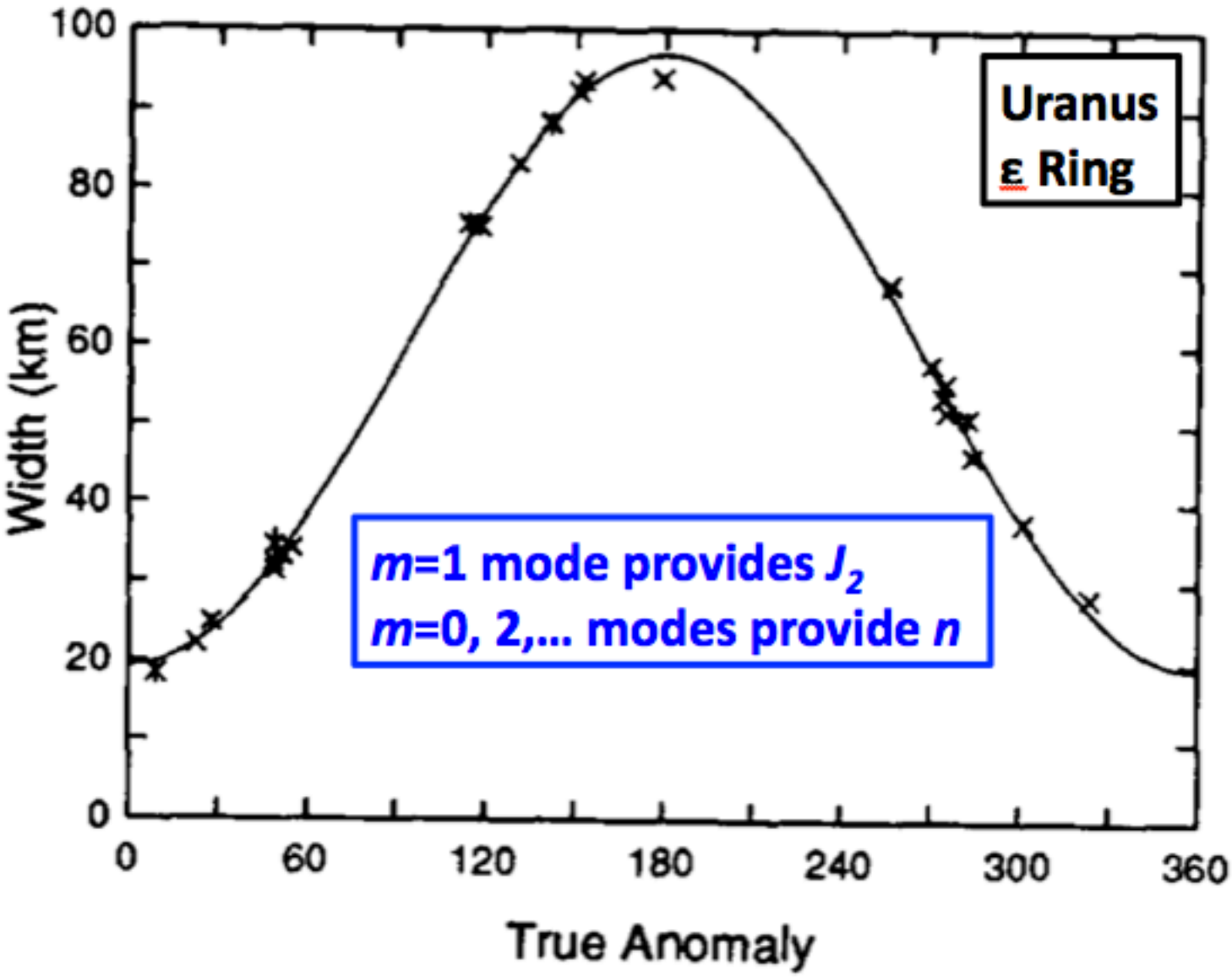
Chariklo:
- Hydrostatic equilibrium
- Homogeneous

2.13×10^{19} kg < M < 2.17×10^{19} kg

$J_2 = 0.044$ **???? very large !!**

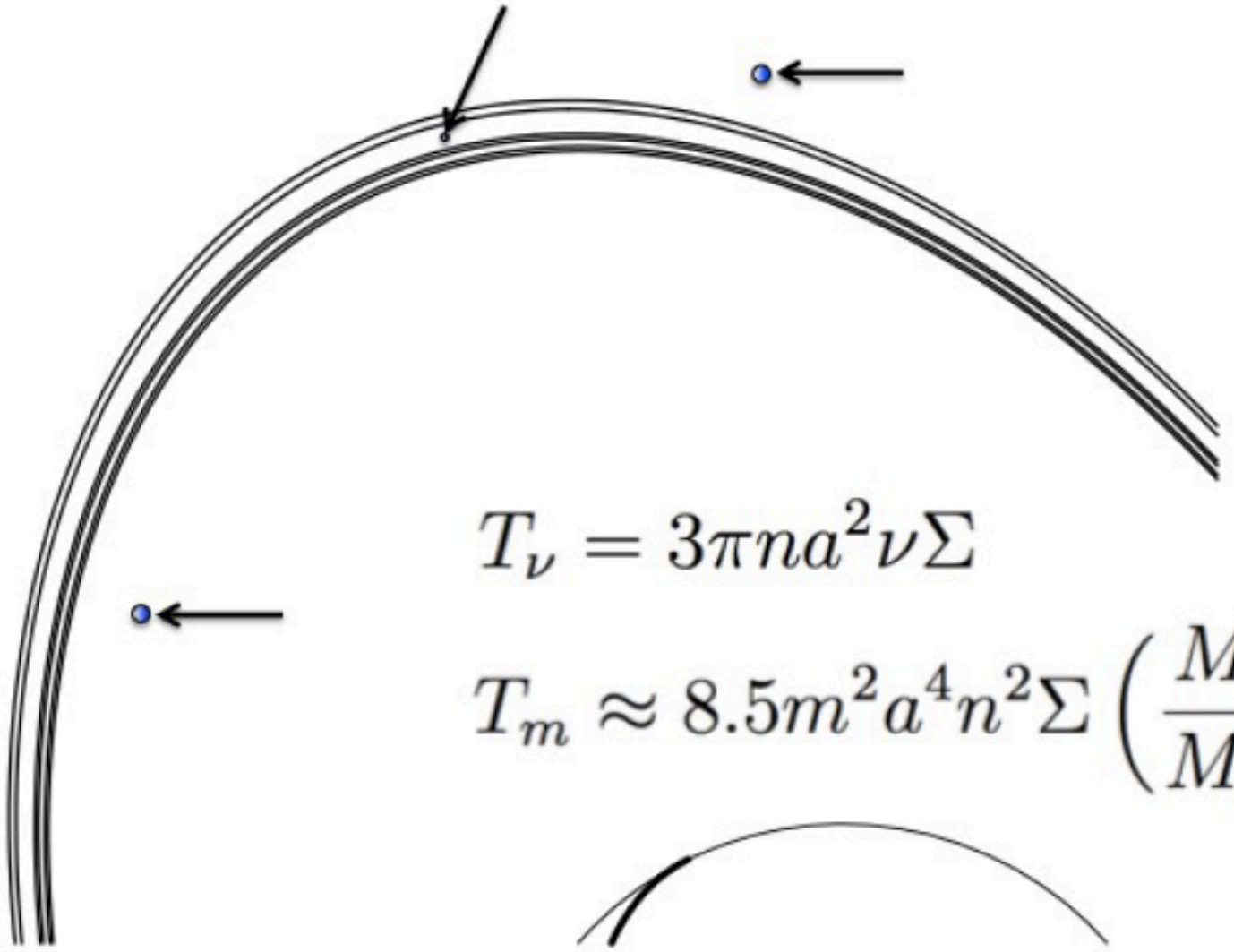
Variation of equivalent width versus longitude





French, Elliot & Levine
Icarus 67, 134 (1986)

shepherds ~ few-km-across moonlet
« gap opener » ~ sub-km moonlet



$$T_\nu = 3\pi n a^2 \nu \Sigma$$

$$T_m \approx 8.5 m^2 a^4 n^2 \Sigma \left(\frac{M_s}{M_C}\right)^2$$

- The discovery
- Geometry and data processing
- Rings photometry and spectrometry
- Model
    - Photometry
    - Dynamics
- Results
- Origin
- Conclusion

Origin ?

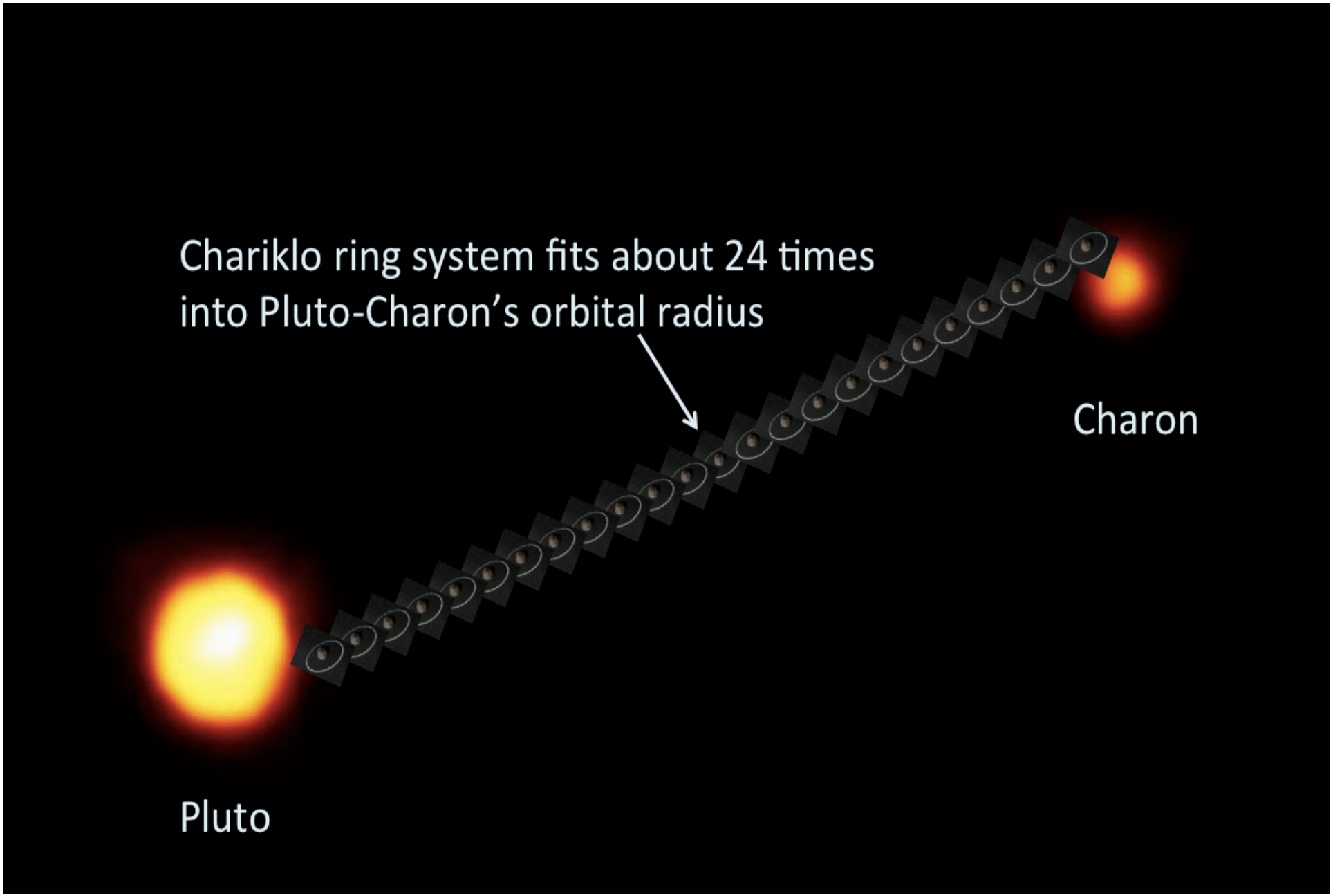
- **Exogenous?**
  - **Collision on Chariklo → debris+moonlets → rings**
  - **Collision onto a pre-existing satellite → rings**
- **Endogenous?**
  - **Inter-satellite collision → rings**
  - **Satellite spiralling inward → tidal breakup**

Conclusion

- First detection of ring system around an asteroid
  - Small primary body (compared to giant planets)
  - Narrow rings (5 - 7 km) with high optical depth (t = 0.4)
- Confirmation by many other stellar occultations in 2014
- Similarities with Saturn rings (composition and optical depth)
- Similarities with Uranus rings (optical depth and width)
- Determination of width and transmission by square and diffraction model
- First determination of J_2 of Chariklo (Hydrostatic equilibrium), we need more data to check this value.
- Determination of size of shepherding satellites


Where did it all come from?


Where did it all come from?
S. Harris



Credit : Bruno Sicardy