The age of the meteoroid complex of comet 96P/Machholz

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Introduction

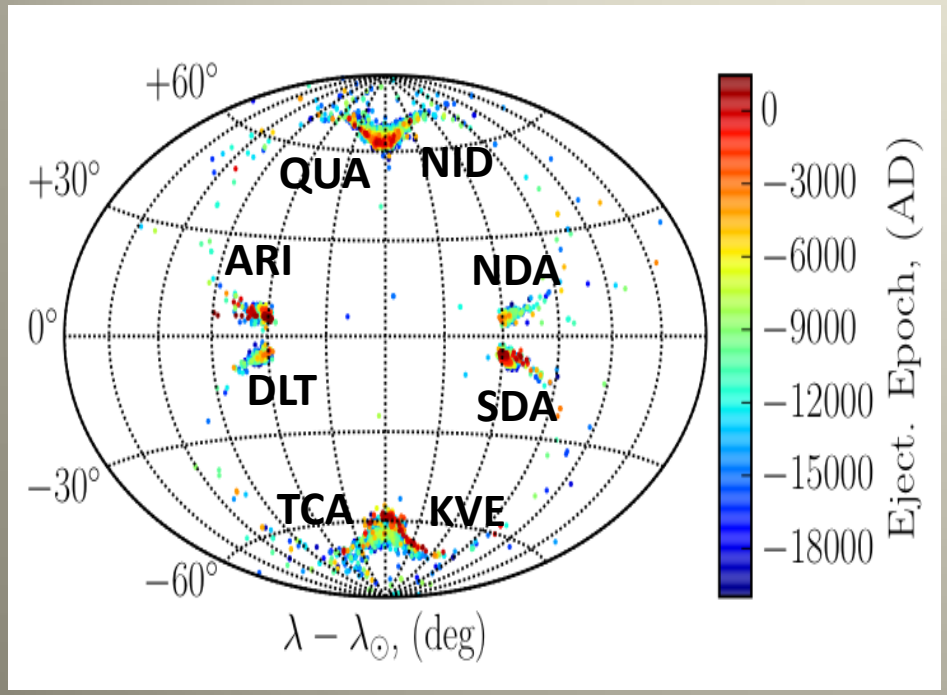
- **Associated with 8 meteor showers - QUA, ARI, SDA, NDA, KVE, Carinids, α-Cetids, Ursids.**
  (Babadzhanov & Obrubov, 1992)
- **Previous age estimates**
  - **QUA, ARI, SDA, NDA =>** 2200 - 7000 years Jones & Jones (1993), Wu & Williams (1993), Neslusan et al. (2013)
- **Recently ARI, SDA, NDA associated with the Marsden group of comets** – Ohtsuka et al. (2003), Sekanina & Chodas (2005), Jenniskens (2012)
  - ARI, SDA, NDA, along with Marsden group of comets, formed between 100 AD – 900 AD

Our work

- Simulations of stream formation.
  - **96P/Machholz => 20000 BC**
  - **Marsden group (P/1999 J6) => 100 AD**
- We find by **simultaneously fitting** shower profiles, radiant and orbital elements that:
  1. We find that 96P contributes to all 8 showers, whereas P/1999 J6 to only 3.
  2. Marsden group of comets alone can not explain the observed duration of the showers.
  3. The complex is much older that previously suggested

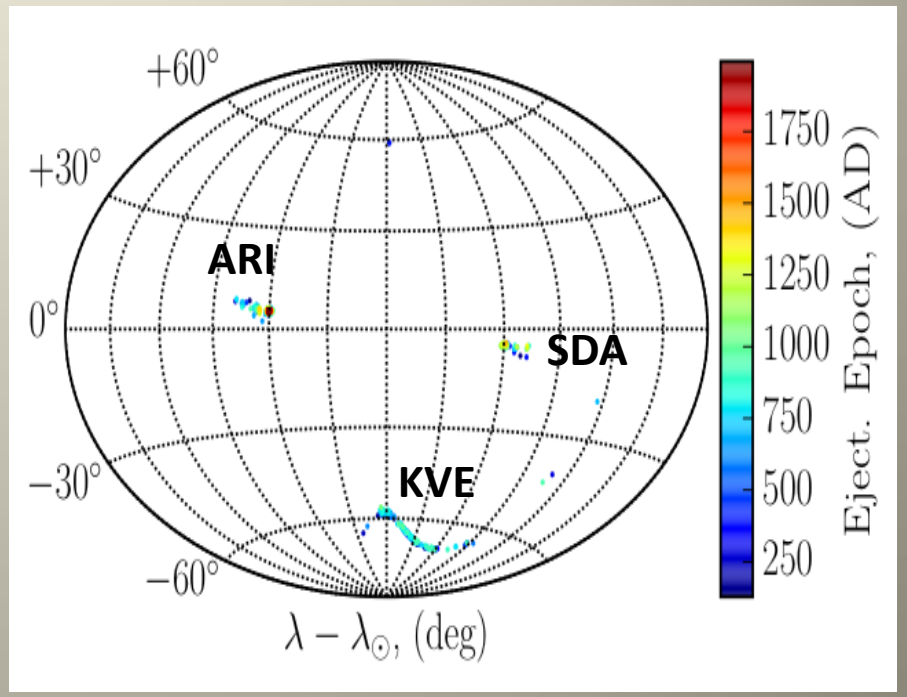
Results from simulations

Showers of 96P/Machholz
Meteoroid ejection 20000 BC



90 <-- 0 <-- 270 <--180 <-- 90

Showers of P/1999 J6
Meteoroid ejection onset 100 AD

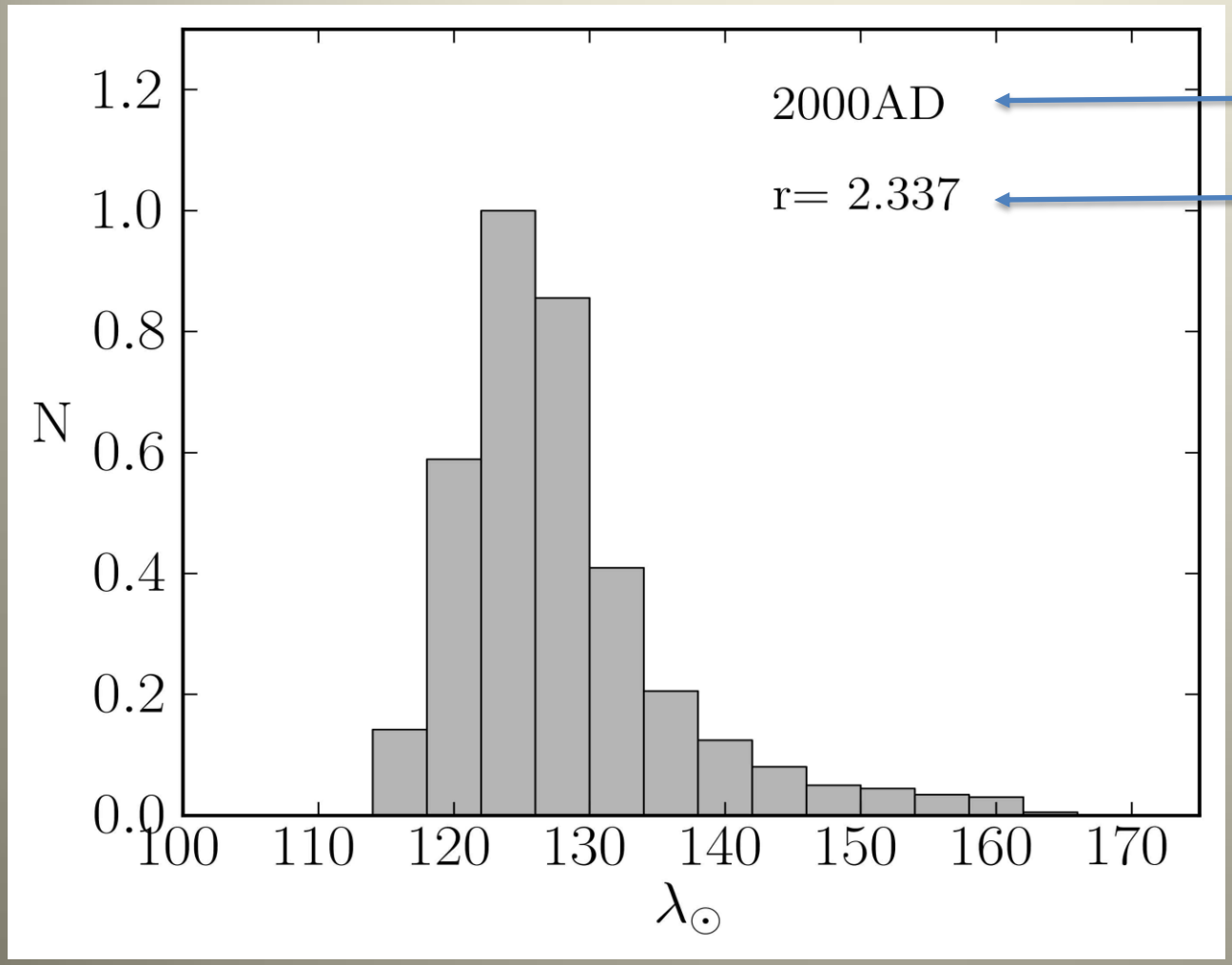


90 <-- 0 <-- 270 <--180 <-- 90

Southern Delta Aquariids (SDA)

Age: 100 AD

Parent body: Marsden group of comets (P/1999 J6) Sekanina & Chodas (2005)



Ejection epoch

Residuals

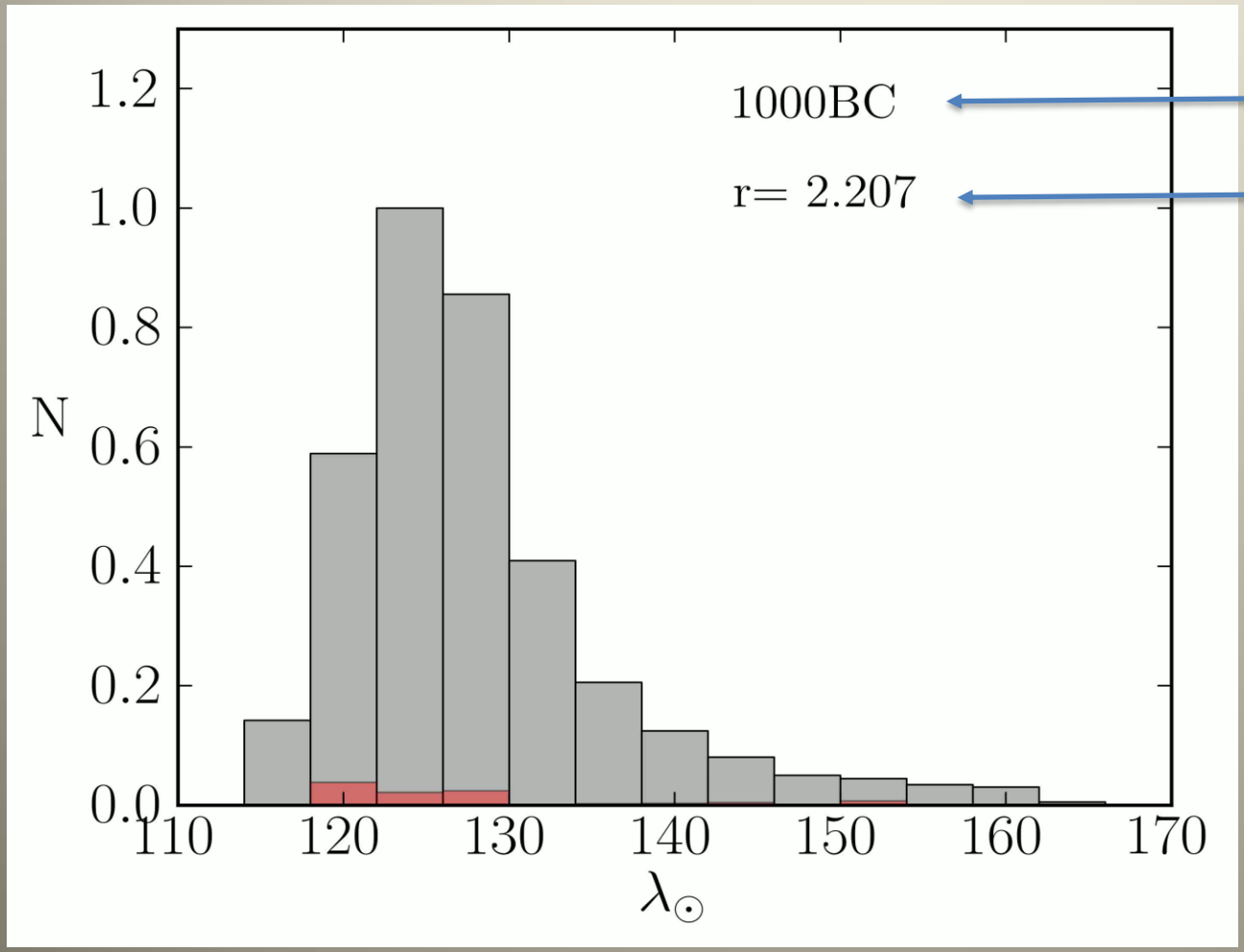
Grey – observations

Red - Simulations

SDA – Continued

Meteoroid Ejection onset time: 20000 BC

Assumed parent body: 96P/Machholz



Ejection epoch

Residuals

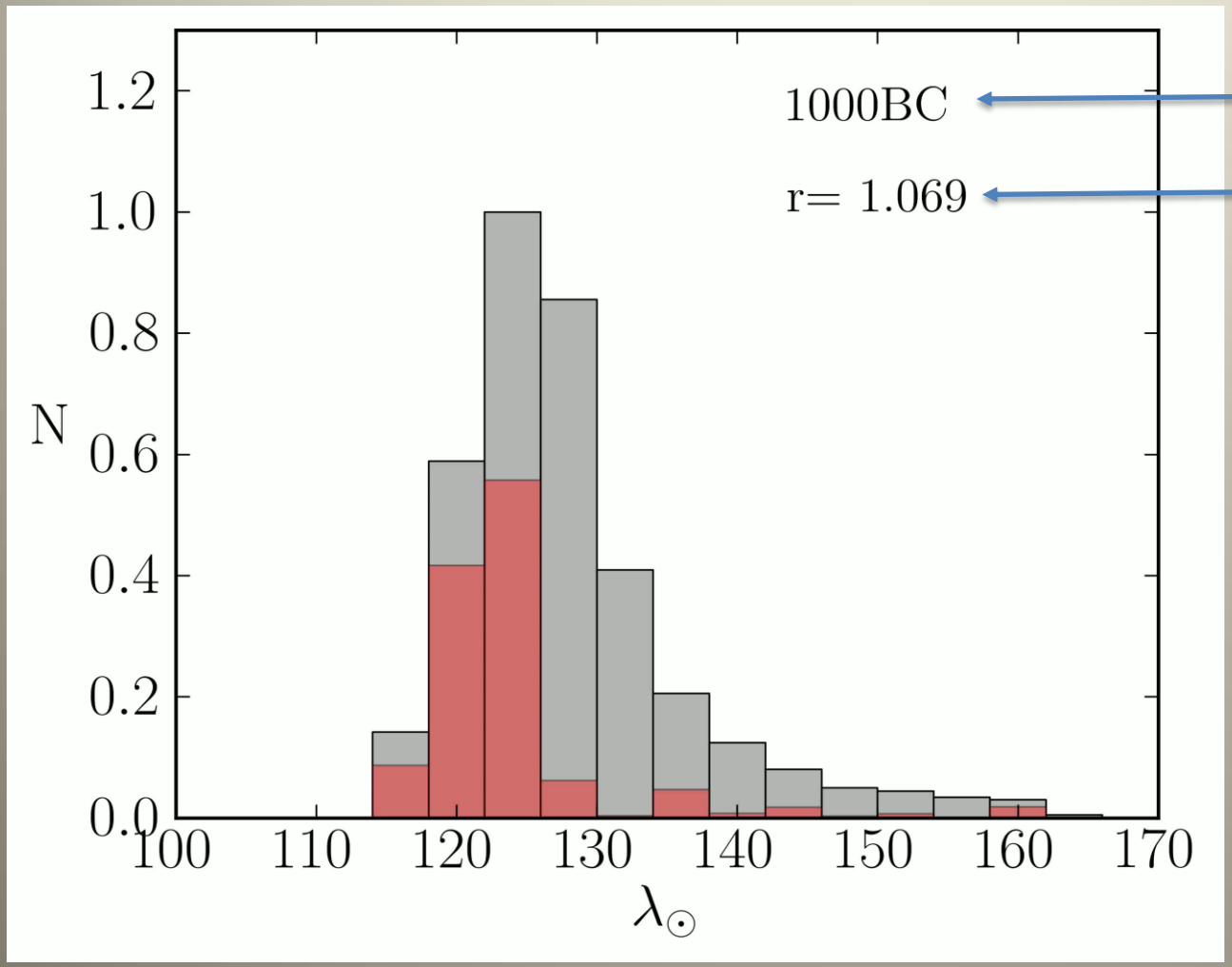
Grey – observations

Red - Simulations

SDA – Combined profile

Marsden group (P/1999 J6) => 100 AD

96P/Machholz => 20000 BC



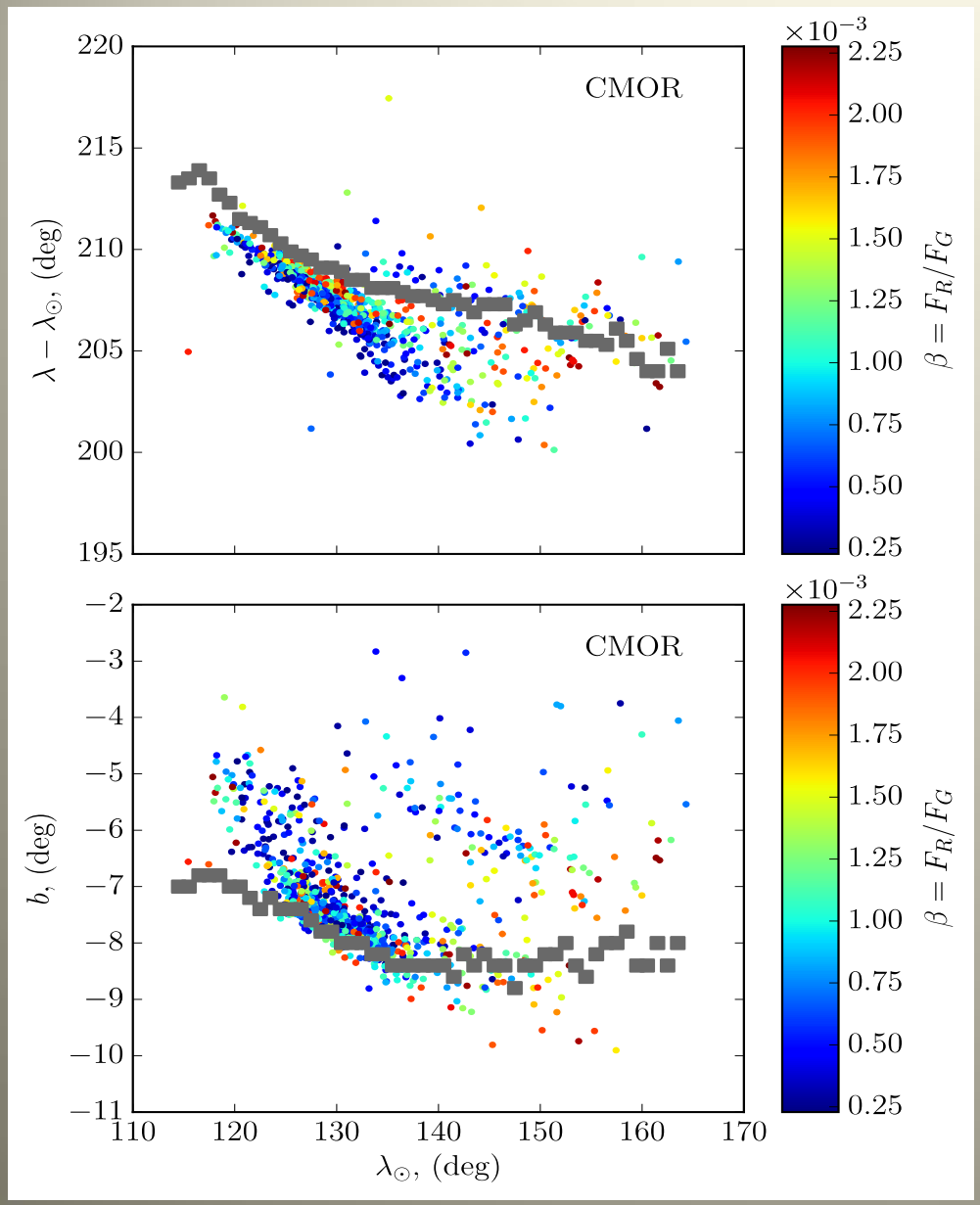
Ejection epoch

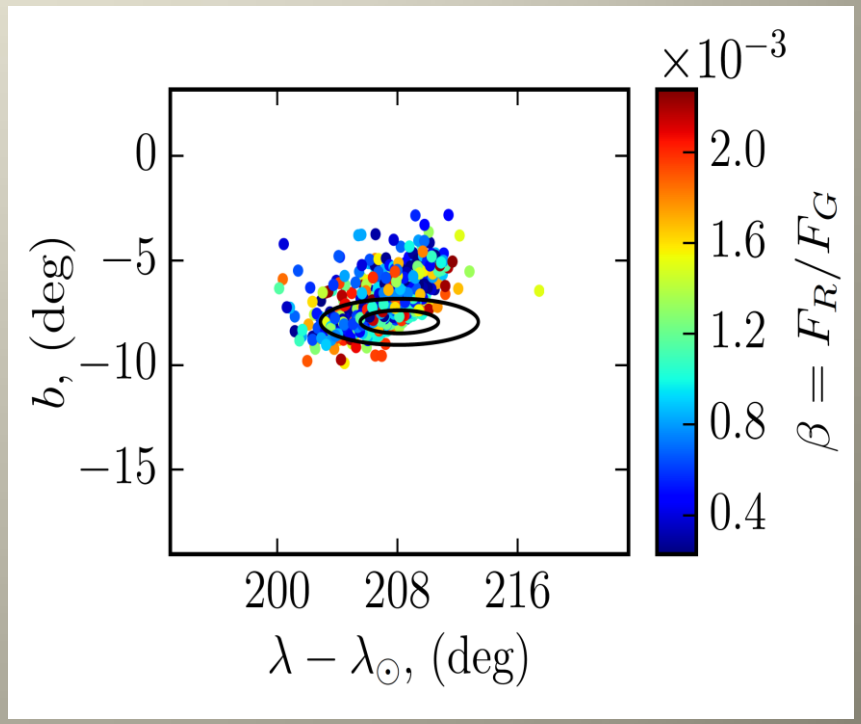
Residuals

Grey – observations

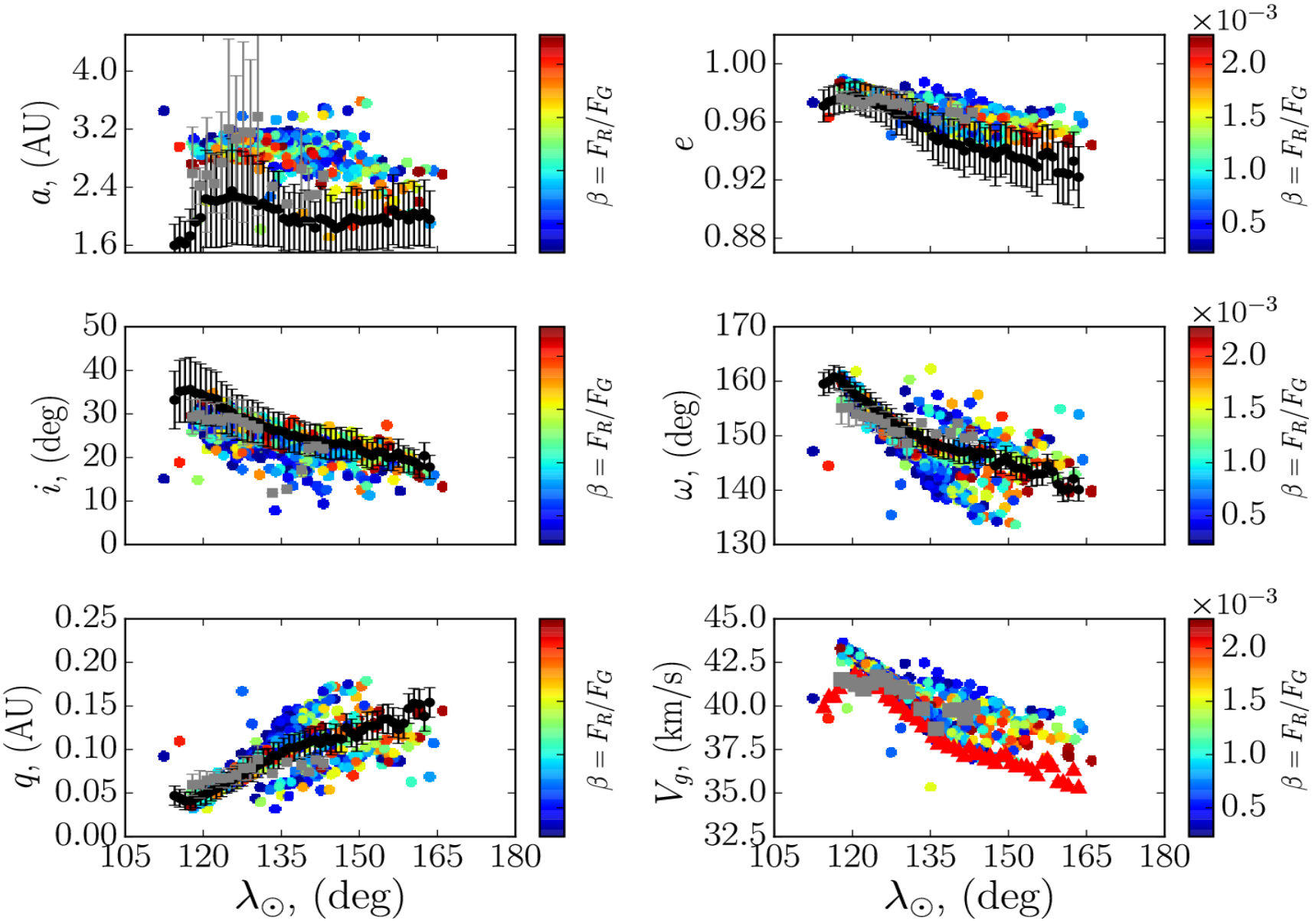
Red - Simulations

SDA – radiant drift and position



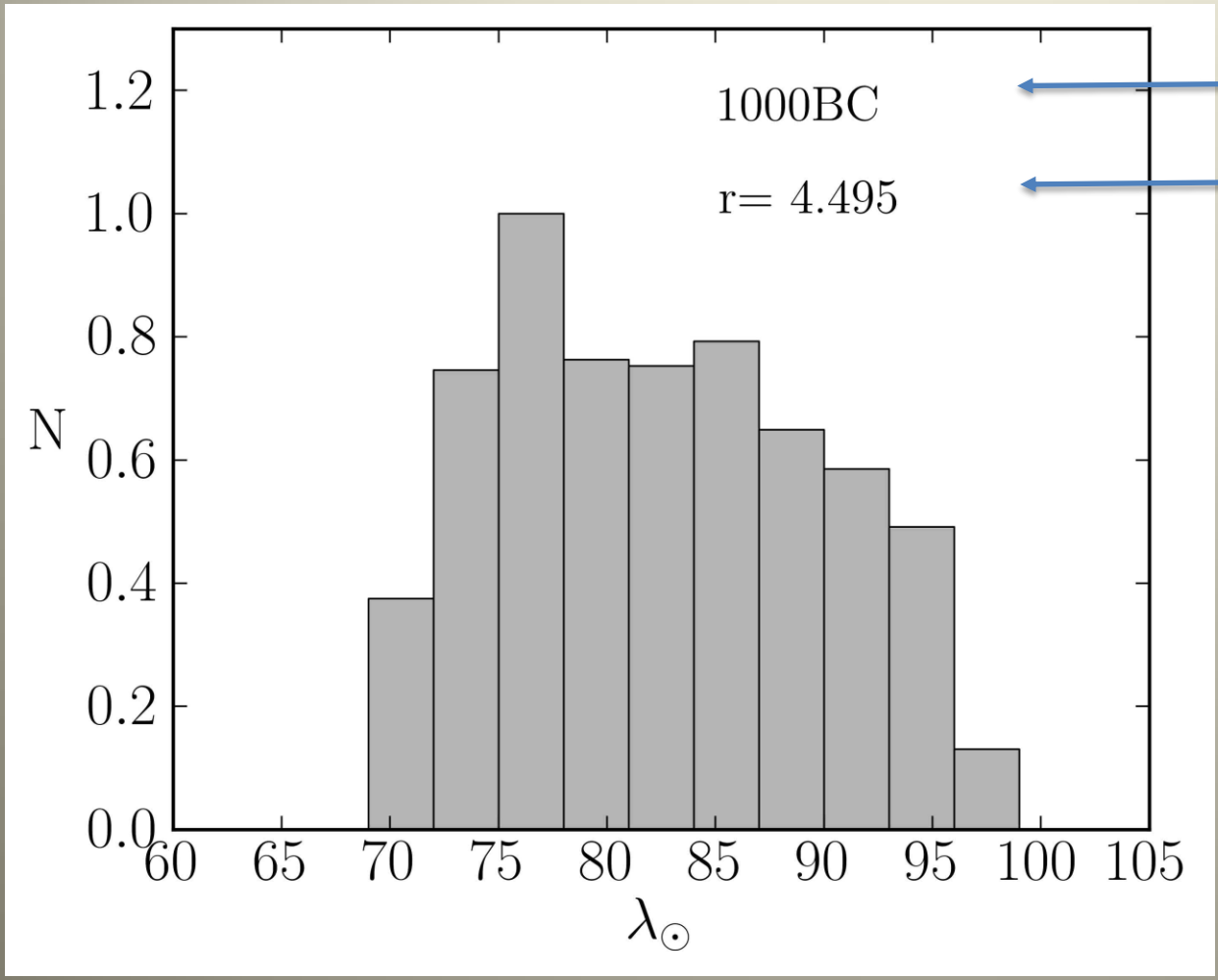


SDA


a, (AU)
4.0
3.2
2.4
1.6
e
1.00
0.96
0.92
0.88
×10⁻³
2.0
1.5
1.0
0.5
β = F_R/F_G
i, (deg)
50
40
30
20
10
0
ω, (deg)
170
160
150
140
130
q, (AU)
0.25
0.20
0.15
0.10
0.05
0.00
V_g, (km/s)
45.0
42.5
40.0
37.5
35.0
32.5
105
120
135
150
165
180
λ⊙, (deg)

Daytime Lambda Taurids

Origin from comet 96P/Machholz => 20000 BC



Ejection epoch

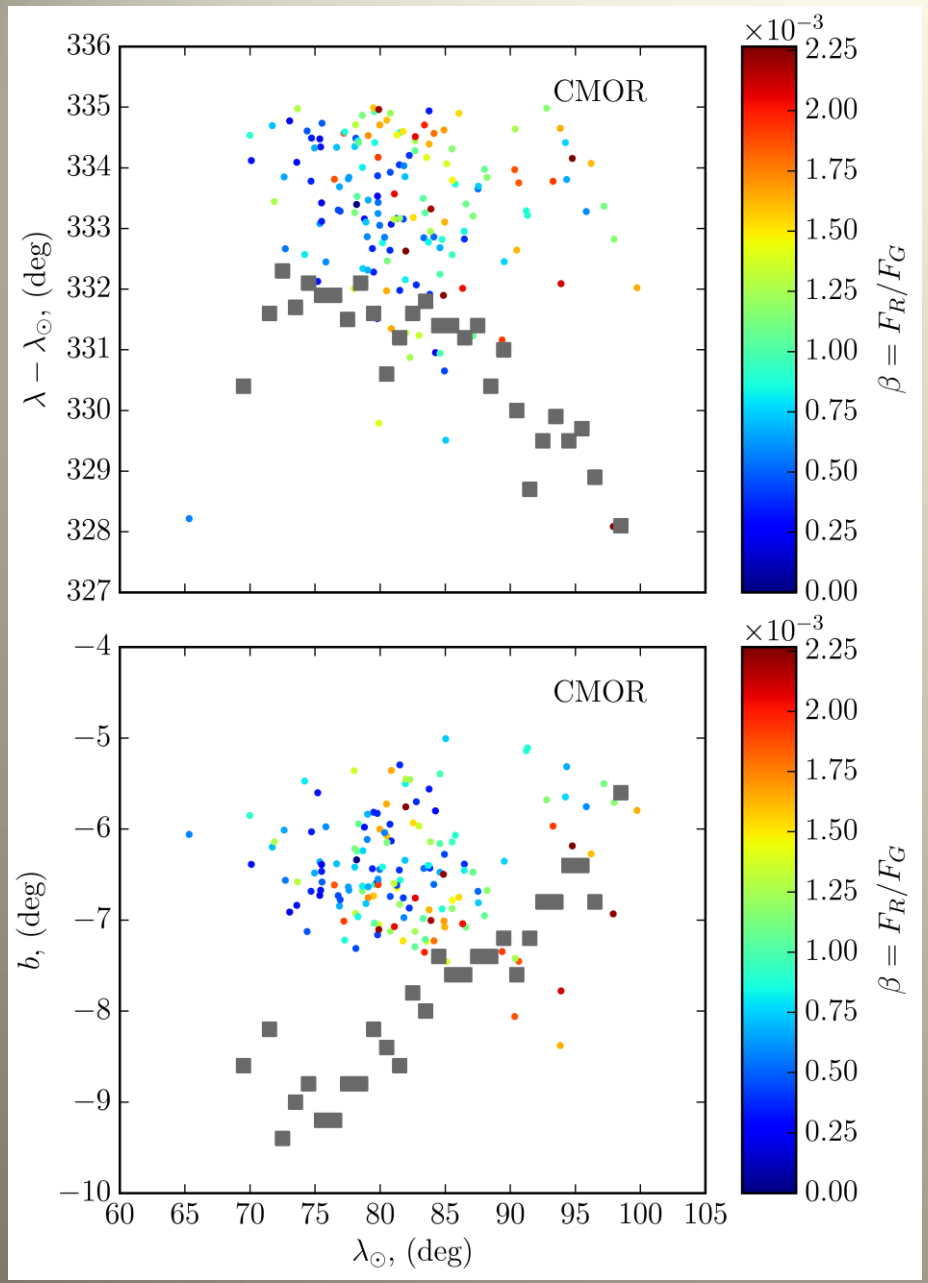
Residuals

Grey – observations

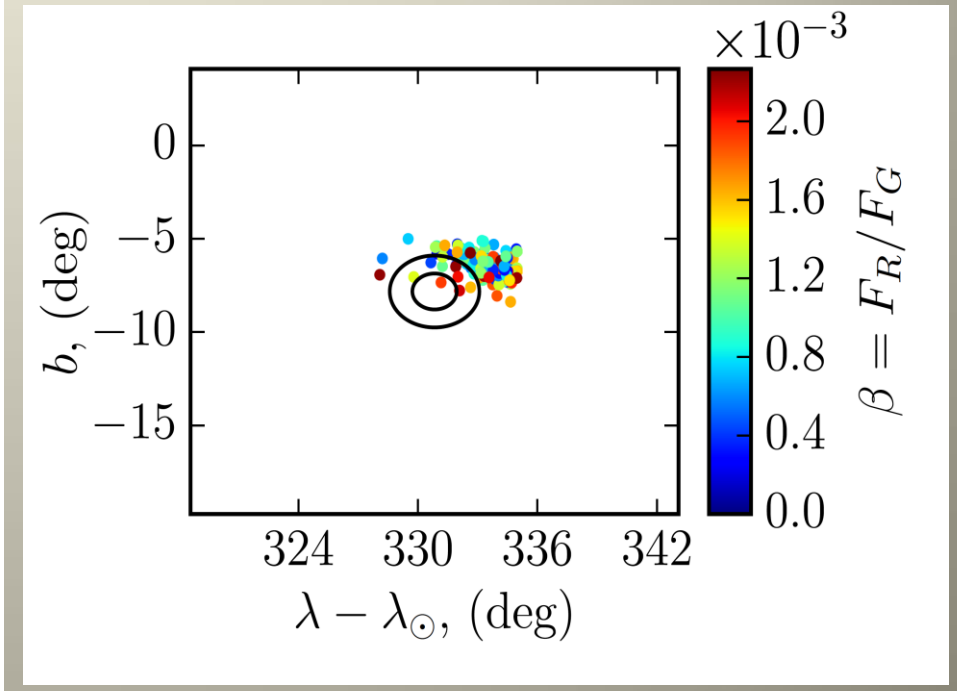
Red - Simulations

Daytime Lambda Taurids

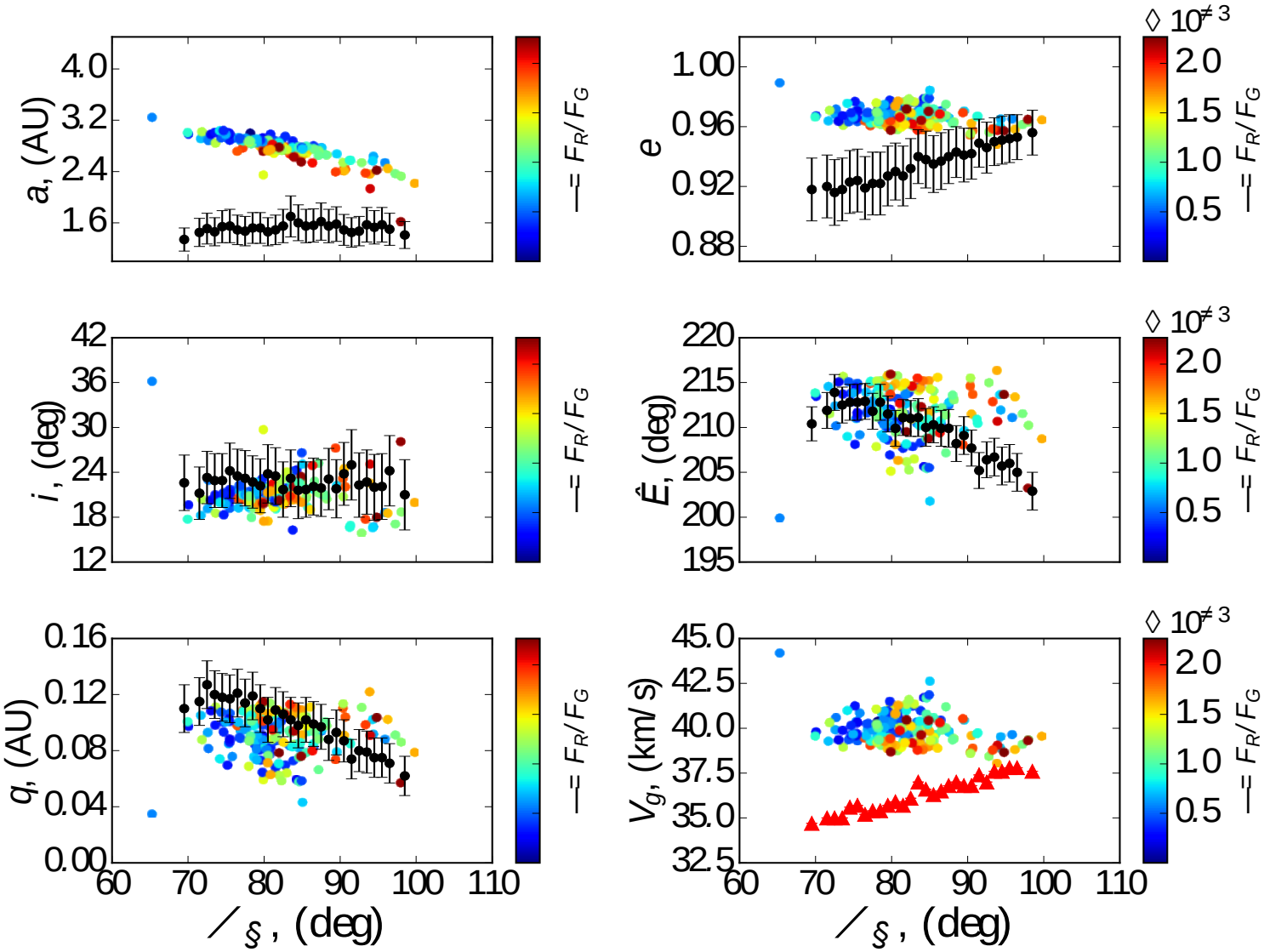
Radiant drift



Radiant position



DLT Cont.

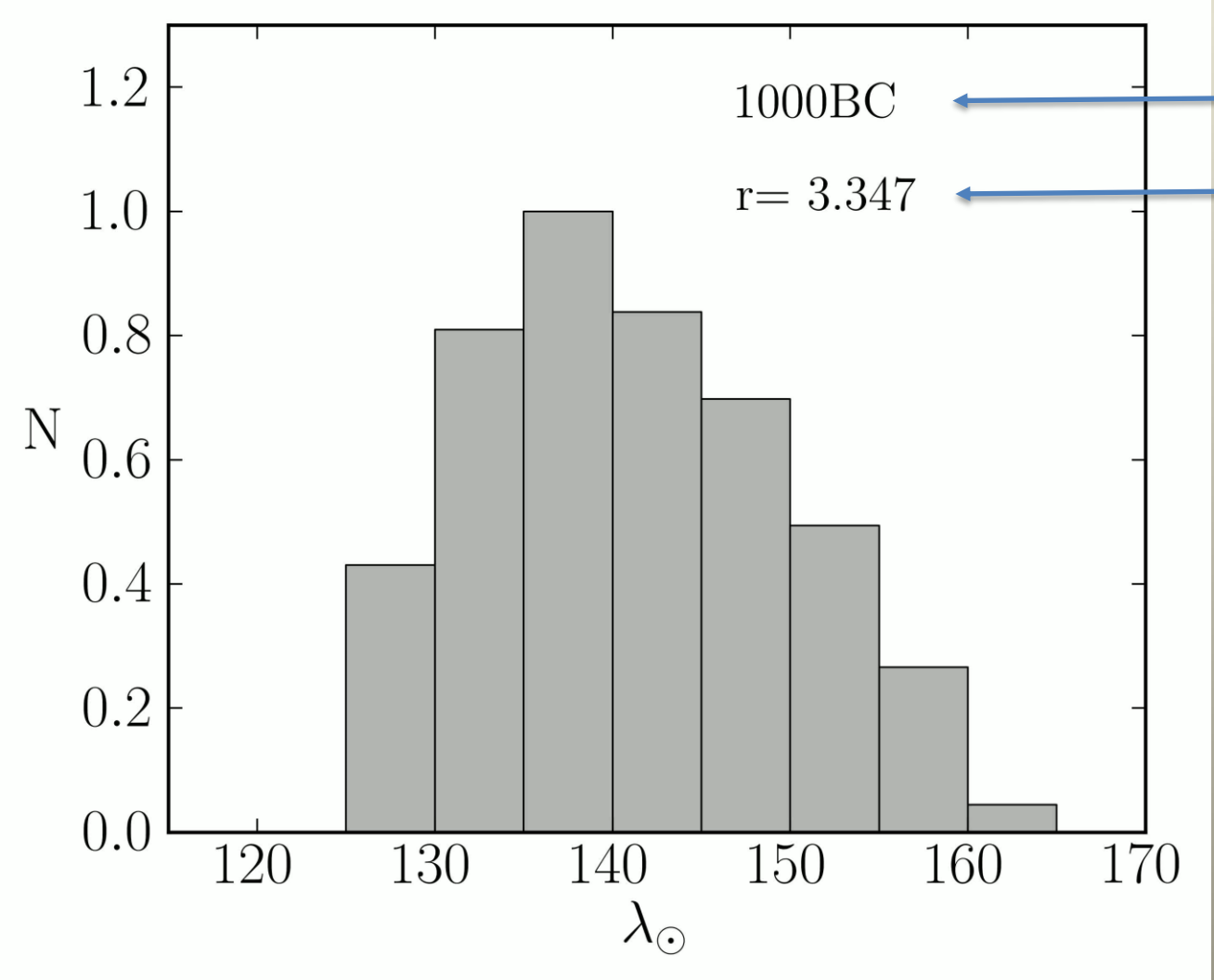

a, (AU)
4.0
3.2
2.4
1.6
e
1.00
0.96
0.92
0.88
i, (deg)
42
36
30
24
18
12
Ê, (deg)
220
215
210
205
200
195
q, (AU)
0.16
0.12
0.08
0.04
0.00
Vg, (km/s)
45.0
42.5
40.0
37.5
35.0
32.5
60
70
80
90
100
110
∕§, (deg)
= FR/FG
◊ 10≠3
2.0
1.5
1.0
0.5

Summary

- There is more than one body contributing to the complex
- Comet P/1999 J6 can not alone explain the observed characteristics of the ARI, SDA, NDA
- The age of the complex is much older than previously suggested (perhaps older than 15000 years).
- We have no explanation yet as to the discrepancy in orbital elements (radar and optical surveys).

Thank you!

Northern Delta Aquariids (NDA)



Ejection epoch

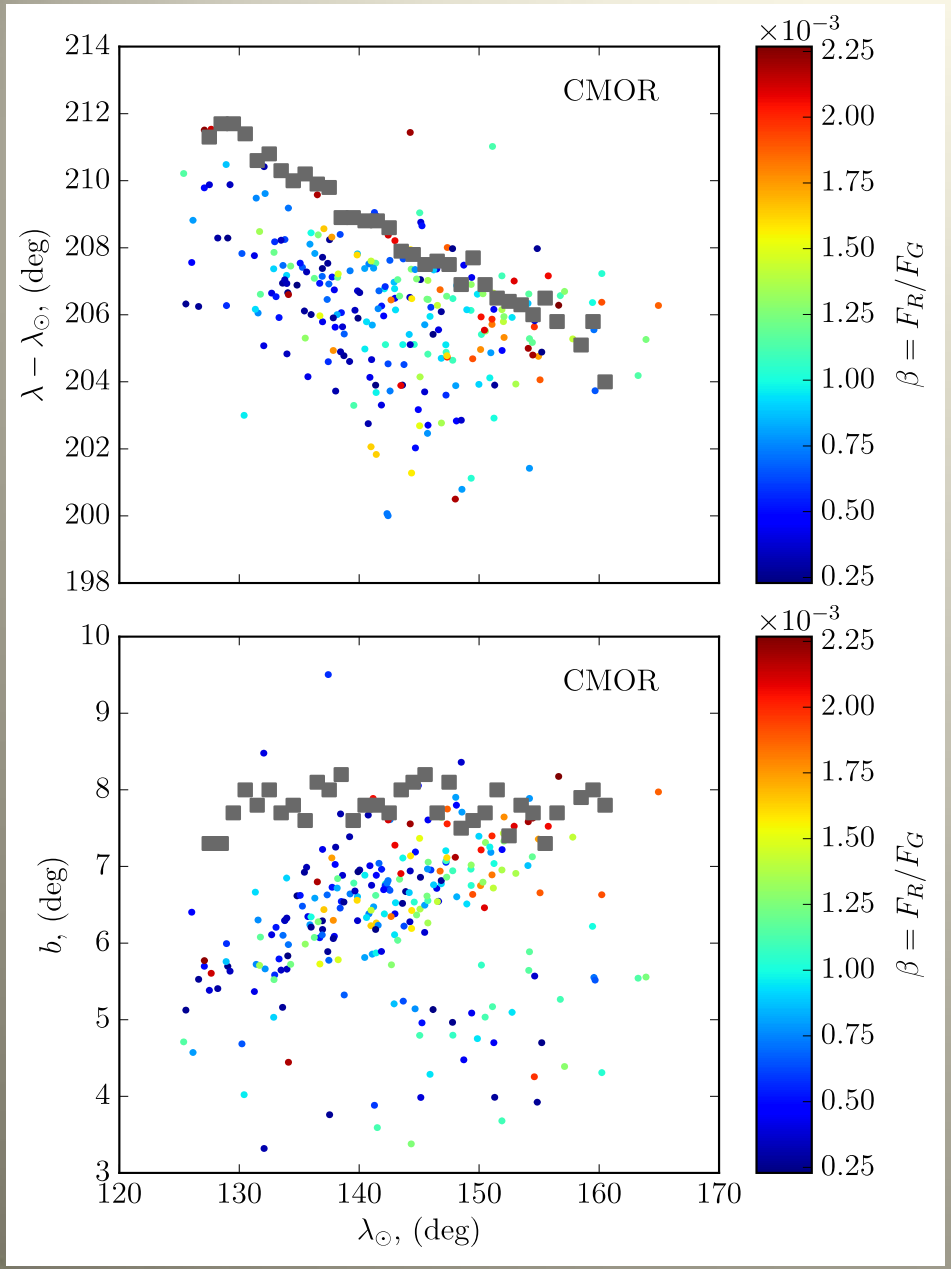
Residuals

Grey – observations

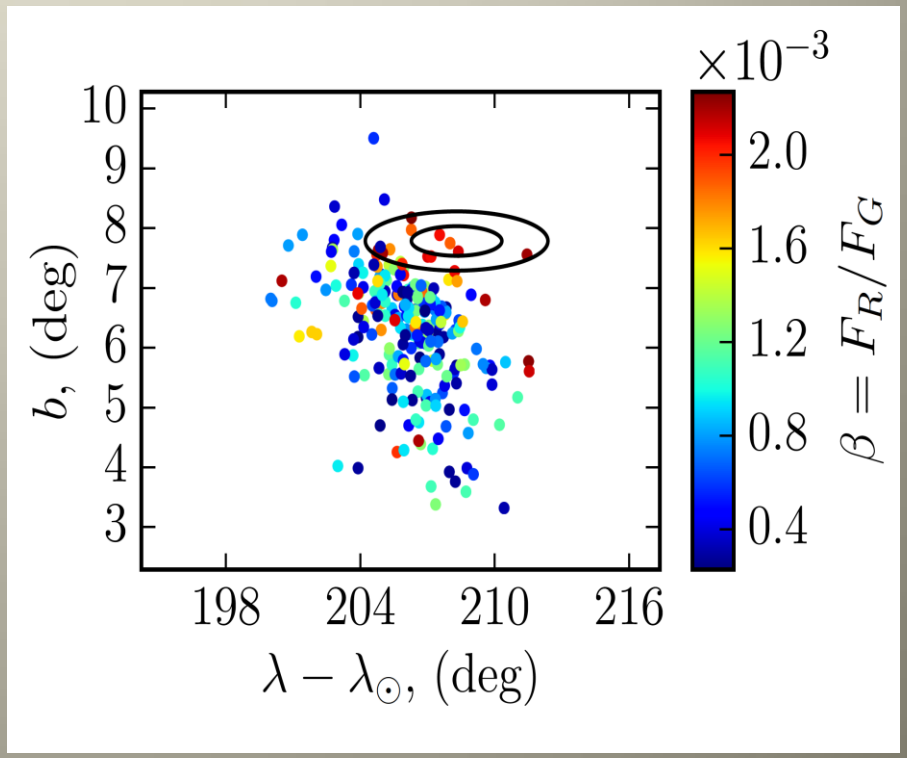
Red - Simulations

NDA – Cont.

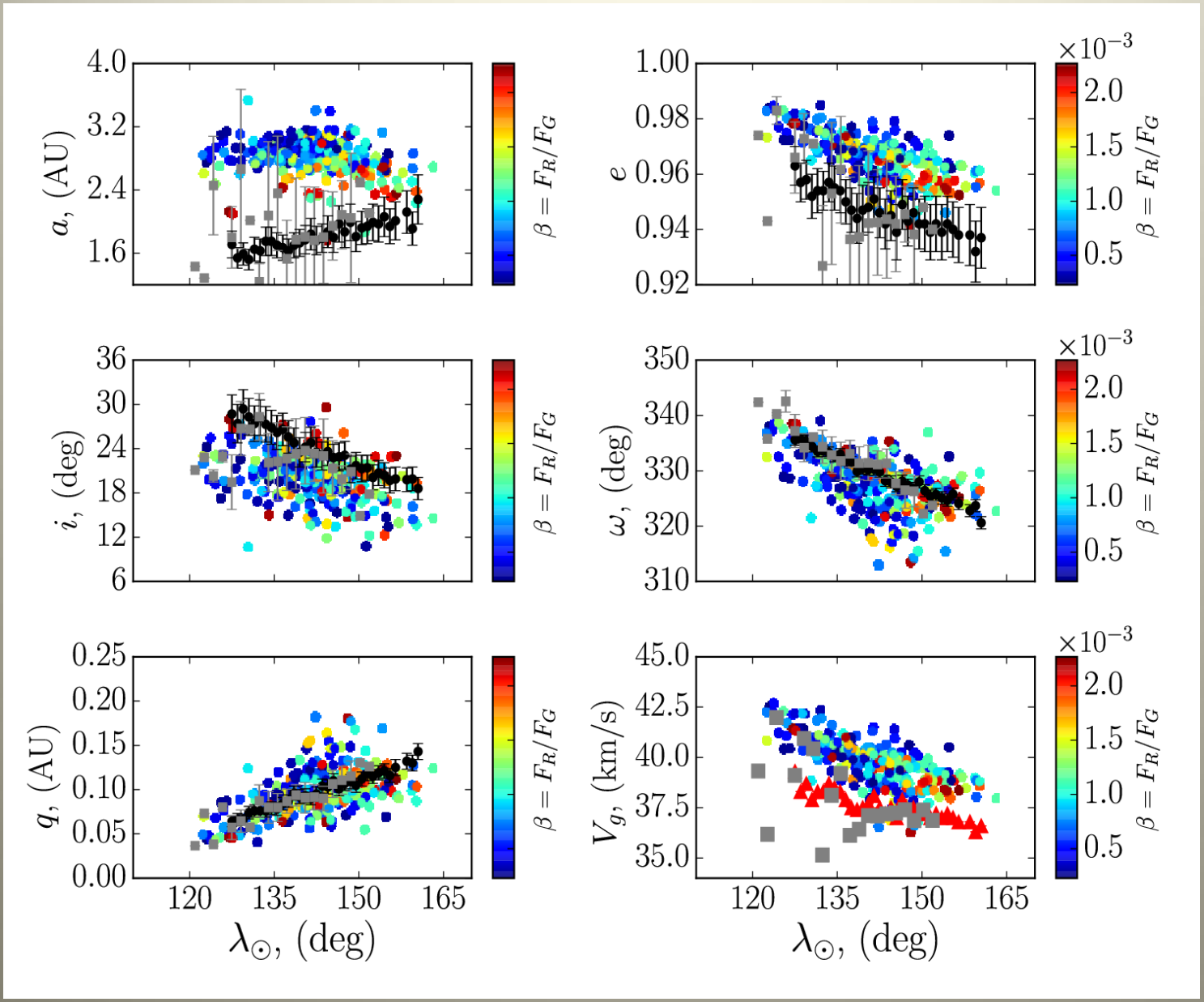
Radiant drift



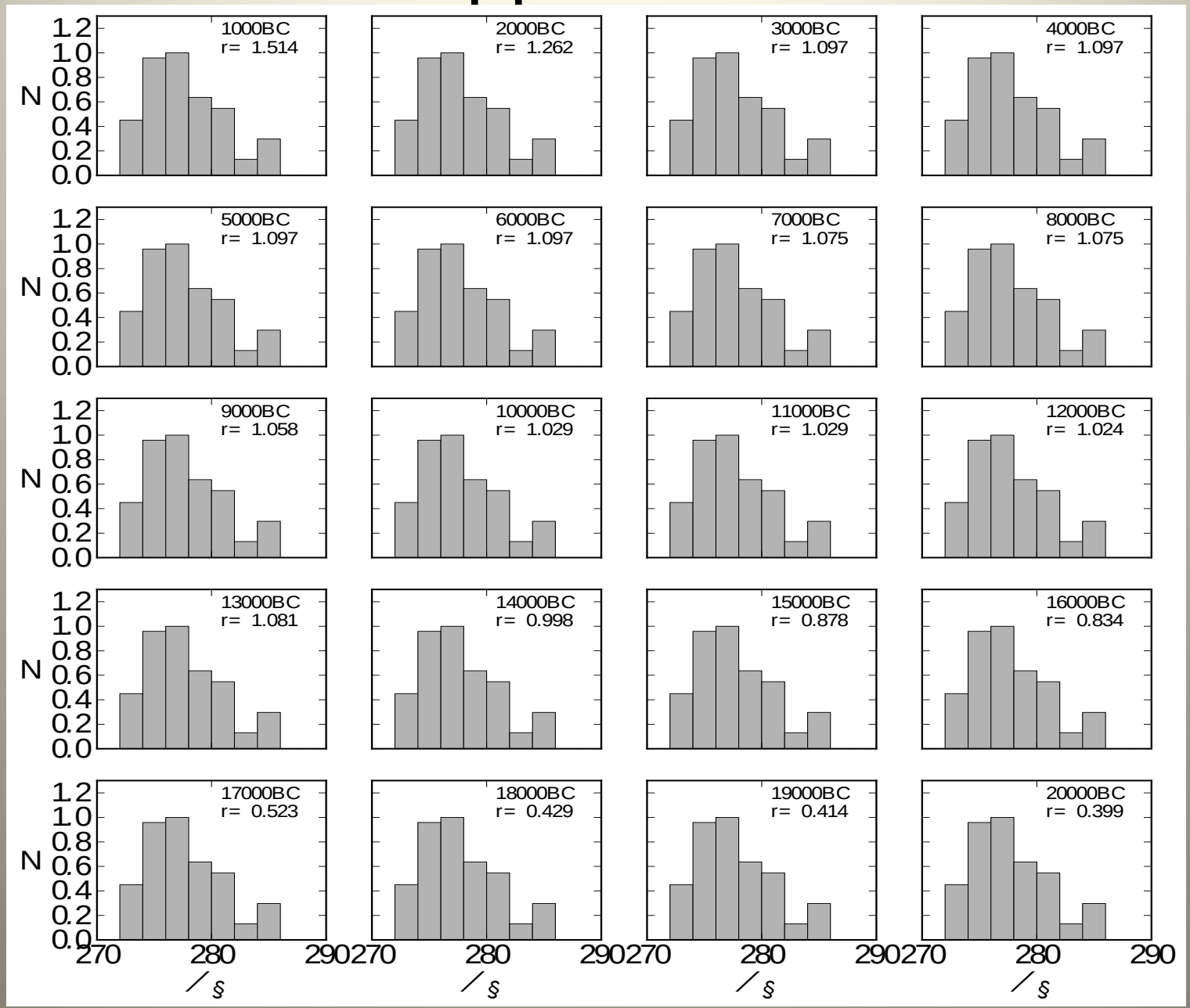
Radiant position

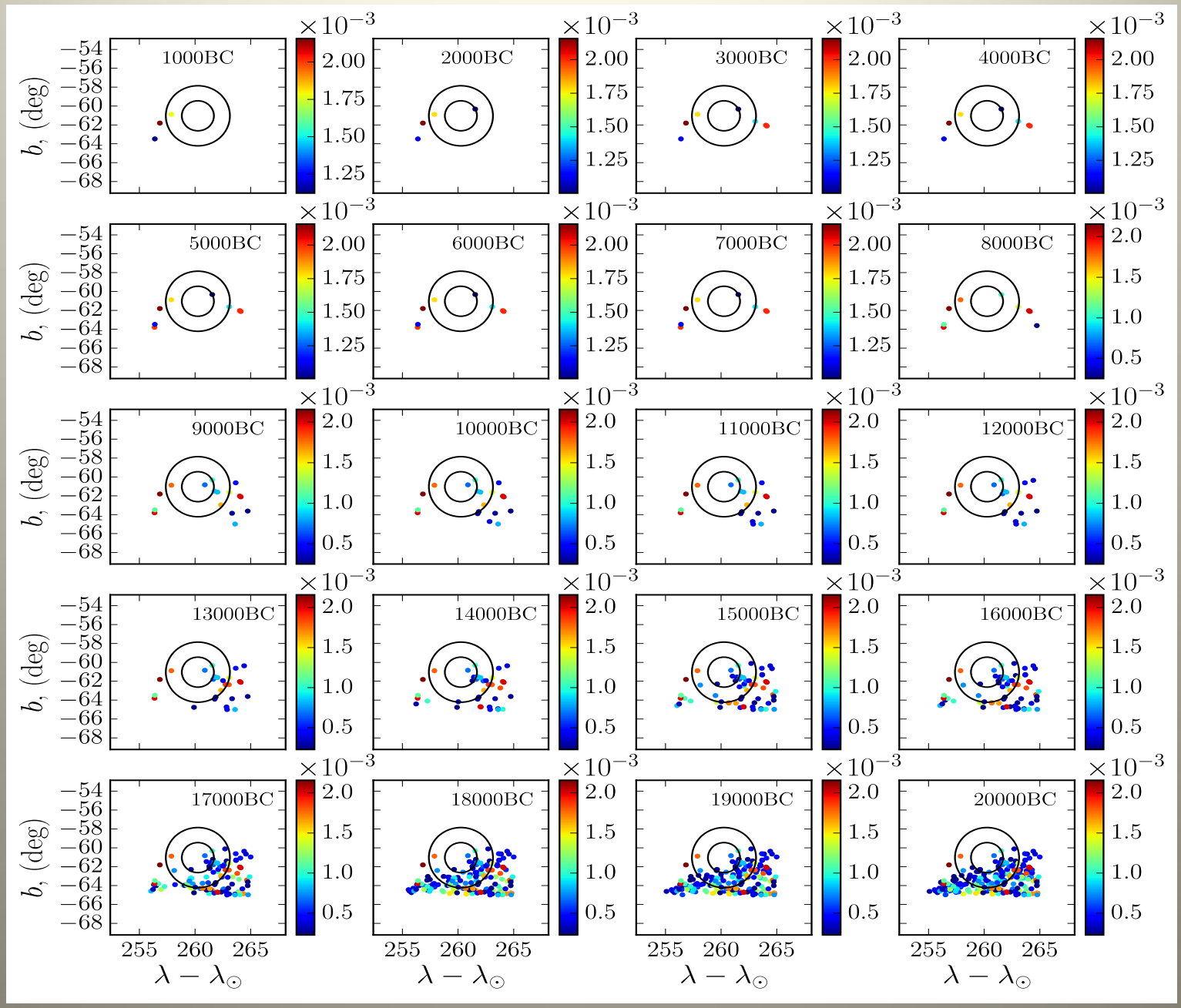


NDA – distribution of orbital elements



Kappa-Velids




1000BC
2000BC
3000BC
4000BC
5000BC
6000BC
7000BC
8000BC
9000BC
10000BC
11000BC
12000BC
13000BC
14000BC
15000BC
16000BC
17000BC
18000BC
19000BC
20000BC
b, (deg)
$\lambda - \lambda_\odot$
$\times 10^{-3}$