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, $\alpha$-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 $\Rightarrow$ 20000 BC
  – Marsden group (P/1999 J6) $\Rightarrow$ 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

Showers of $P/1999$ J6
Meteoroid ejection onset 100 AD
Southern Delta Aquariids (SDA)

Age: 100 AD
SDA – Continued

Meteoroid Ejection onset time: **20000 BC**
Assumed parent body: **96P/Machholz**

![Graph showing meteoroid ejection epoch and residuals. Grey bars represent observations, red bars represent simulations.](image)

- 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
Daytime Lambda Taurids

Origin from comet 96P/Machholz => 20000 BC

Grey – observations
Red - Simulations

Ejection epoch
Residuals
Radiant drift

Daytime Lambda Taurids

Radiant position
DLT Cont.
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

1000BC

$r = 3.347$
Radiant drift

Radiant position

NDA – Cont.
NDA – distribution of orbital elements