Mid-IR observation of the collision between Deep Impact spacecraft and comet 9P/Tempel 1

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SUBARU Users' Mtg at Mitaka, Tokyo

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Deep Impact Mission

Scope of the mission

- To shoot a projectile into an inactive comet.
- To explore the interior of a comet.

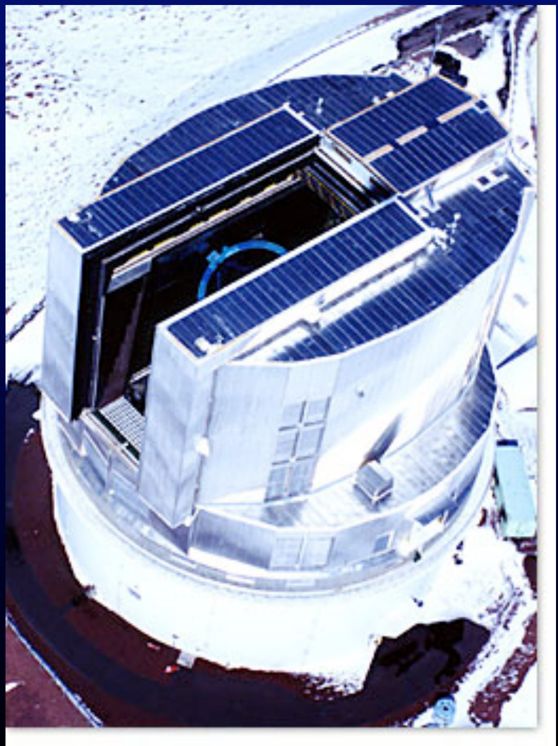
Key questions

- How deep can Deep Impact excavate?
- Comparison with Oort-Cloud comets

Scope of the Observation

- A part of SUBARU/GEMINI collaboration
- Aimed to obtain data complementary to the DI spacecraft observation.

➡ Mid-infrared (8 - 25μm) observation

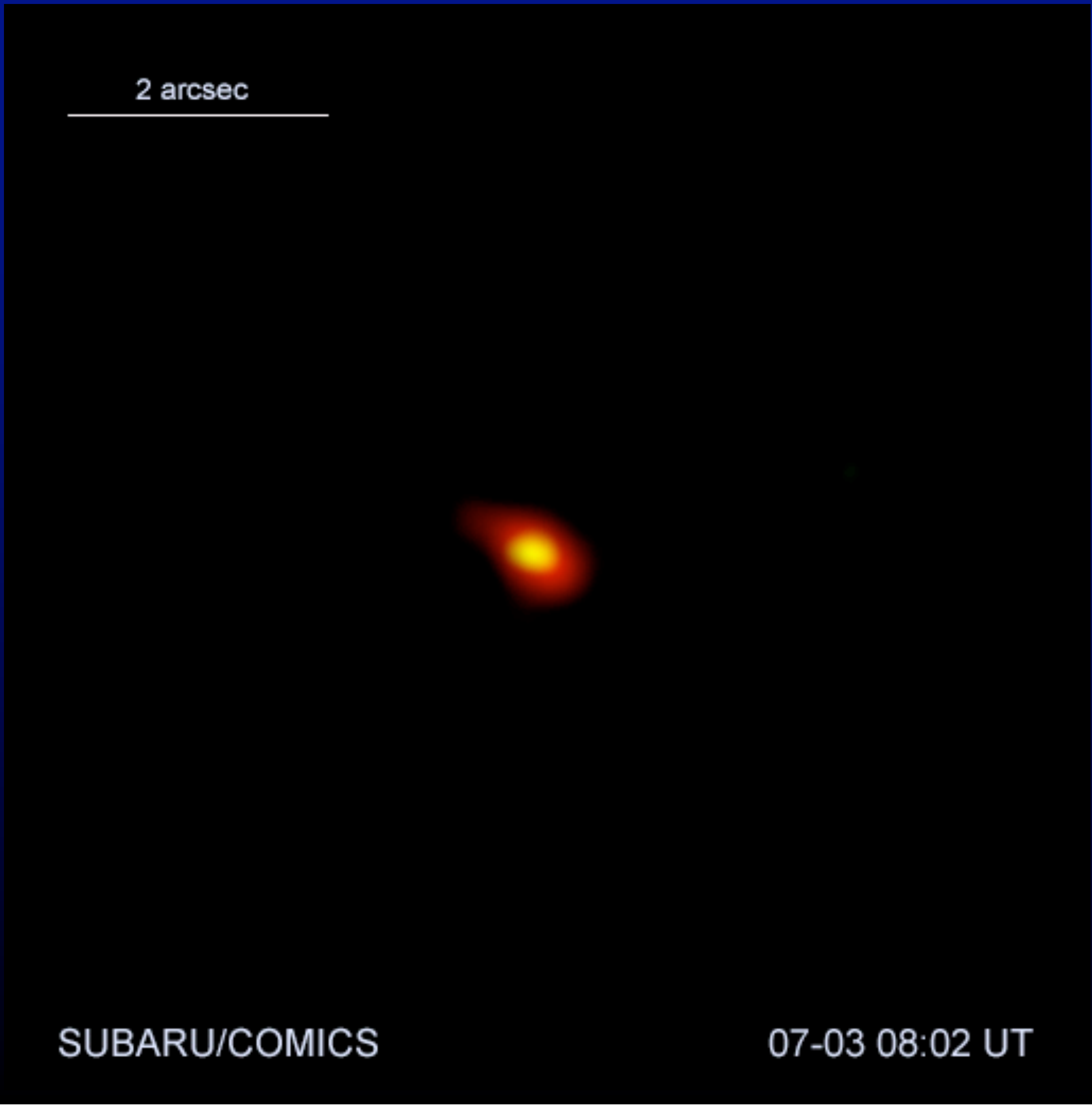


Mission Results

- ✦ Deep Impact successfully collided with the comet.
- ✦ Deep Impact could measured a number of valuable data, such as gravity, size, surface morphology, …
- ✦ But it couldn't observe the crater size or the total mass of ejecta.

➡ Total ejecta mass was a major missing factor.

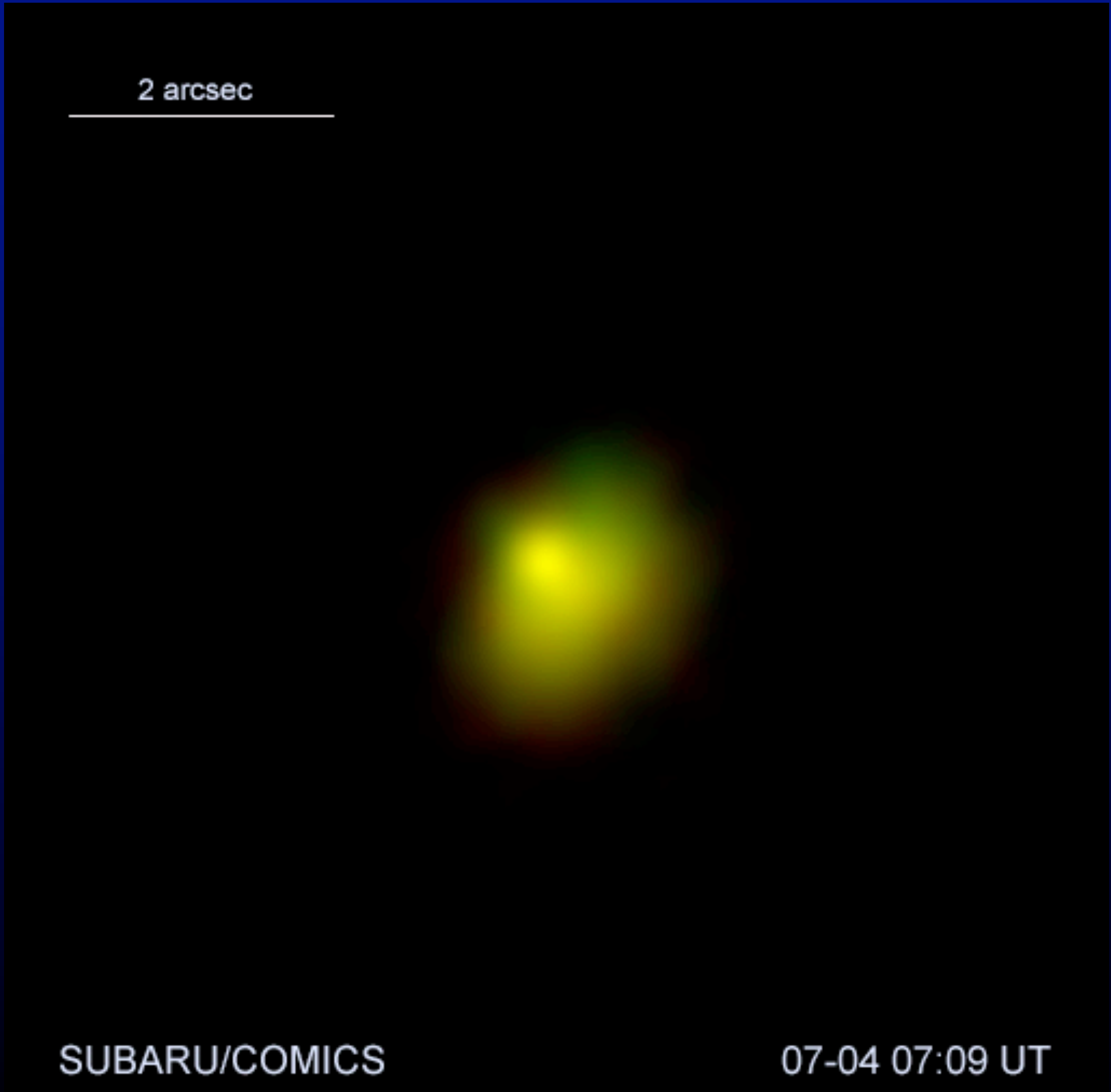
Multi-band false color images



Red = Continuum
= (8.8μm +12.8μm)/2

Green = 10μm peak
=10.5μm - Continuum
= small silicate dust

Multi-band false color images



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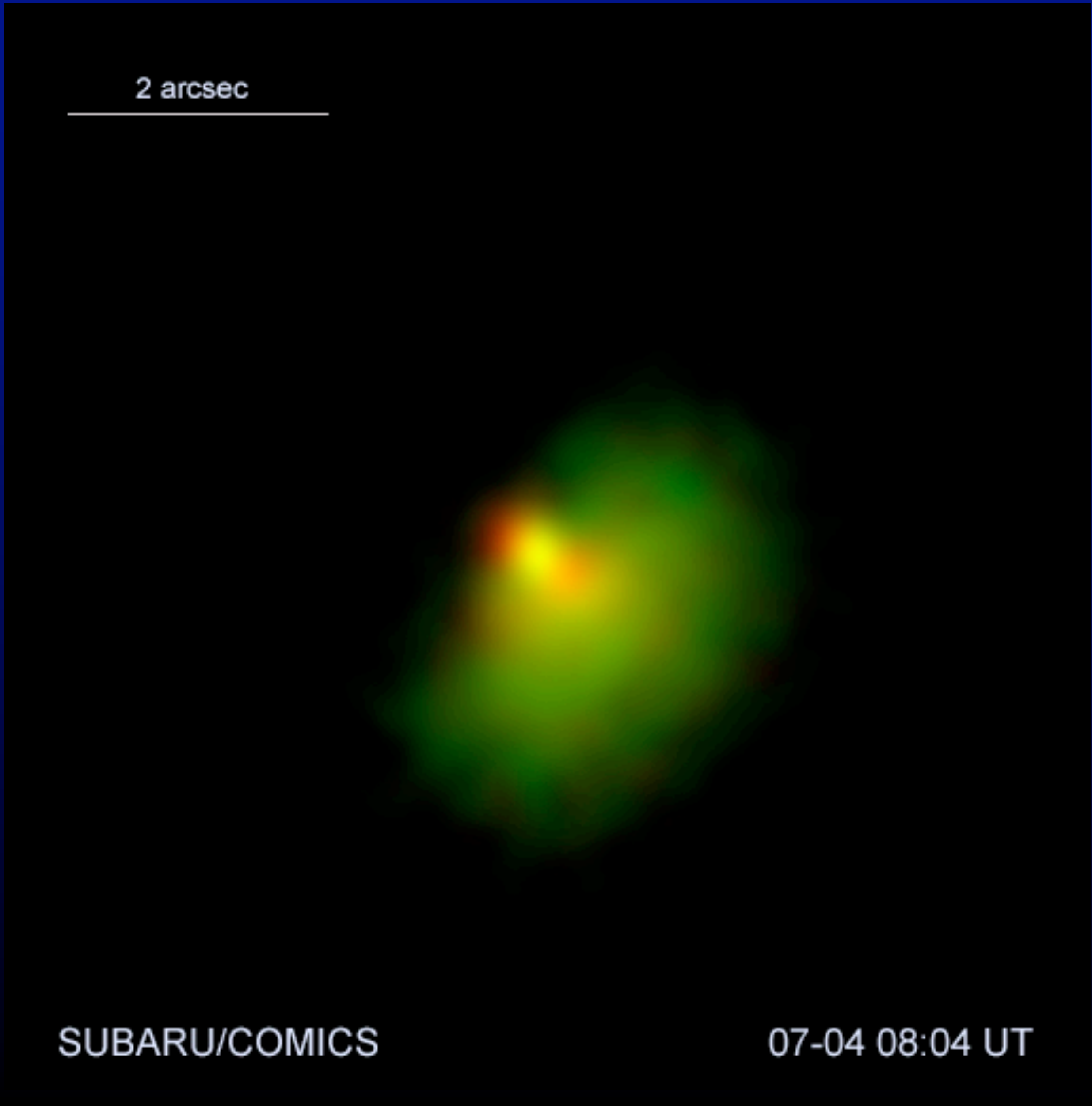

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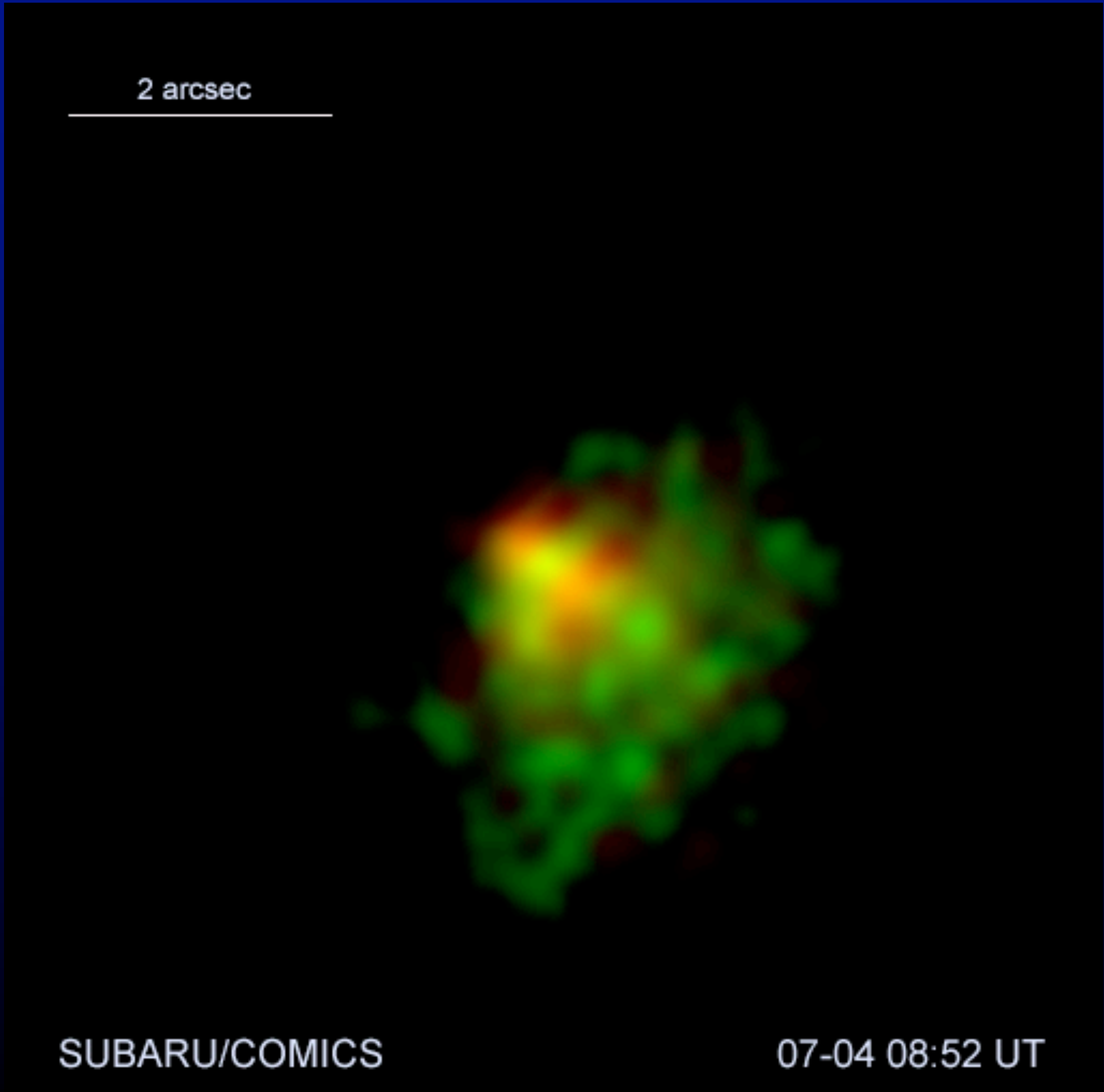

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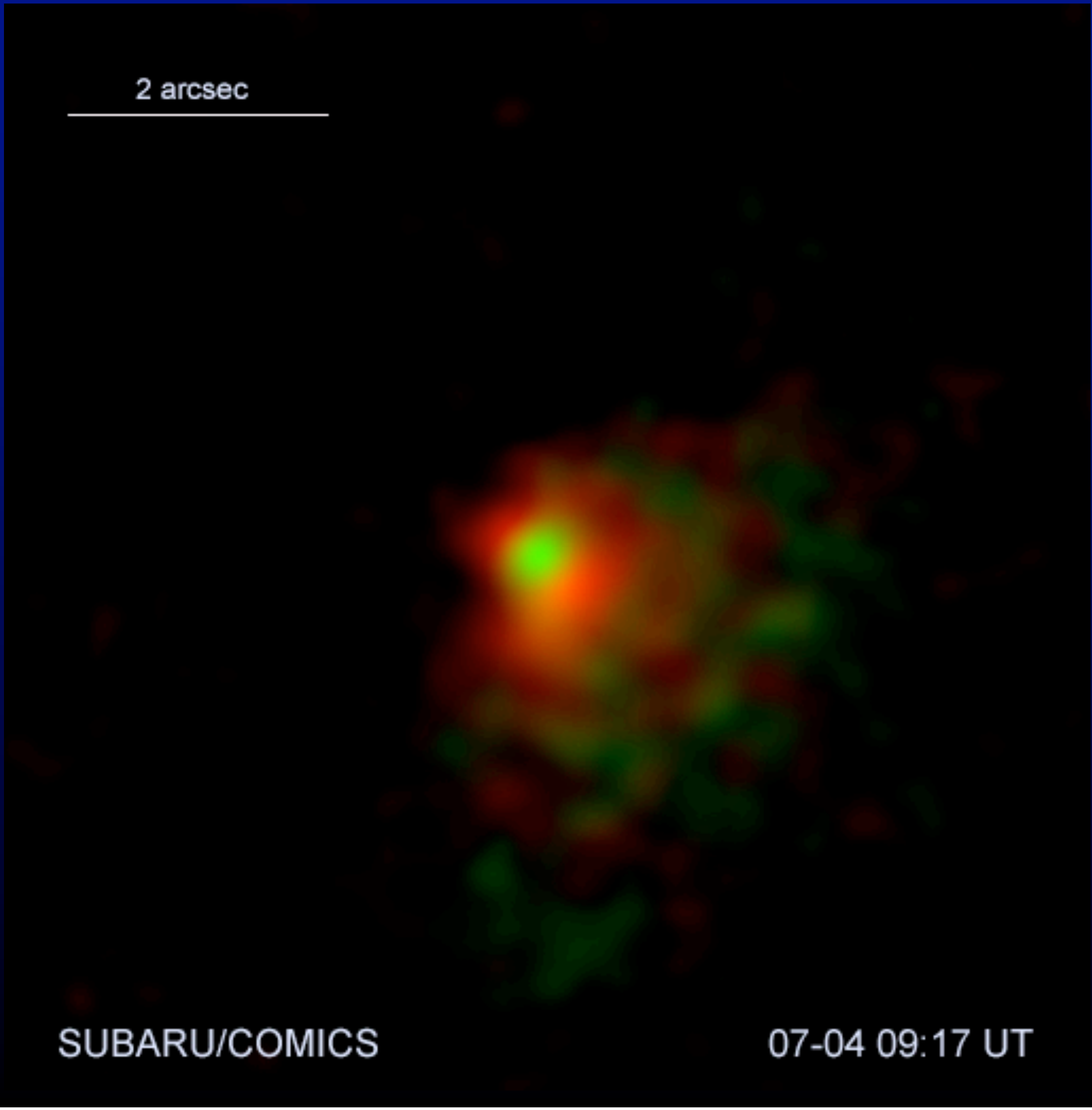

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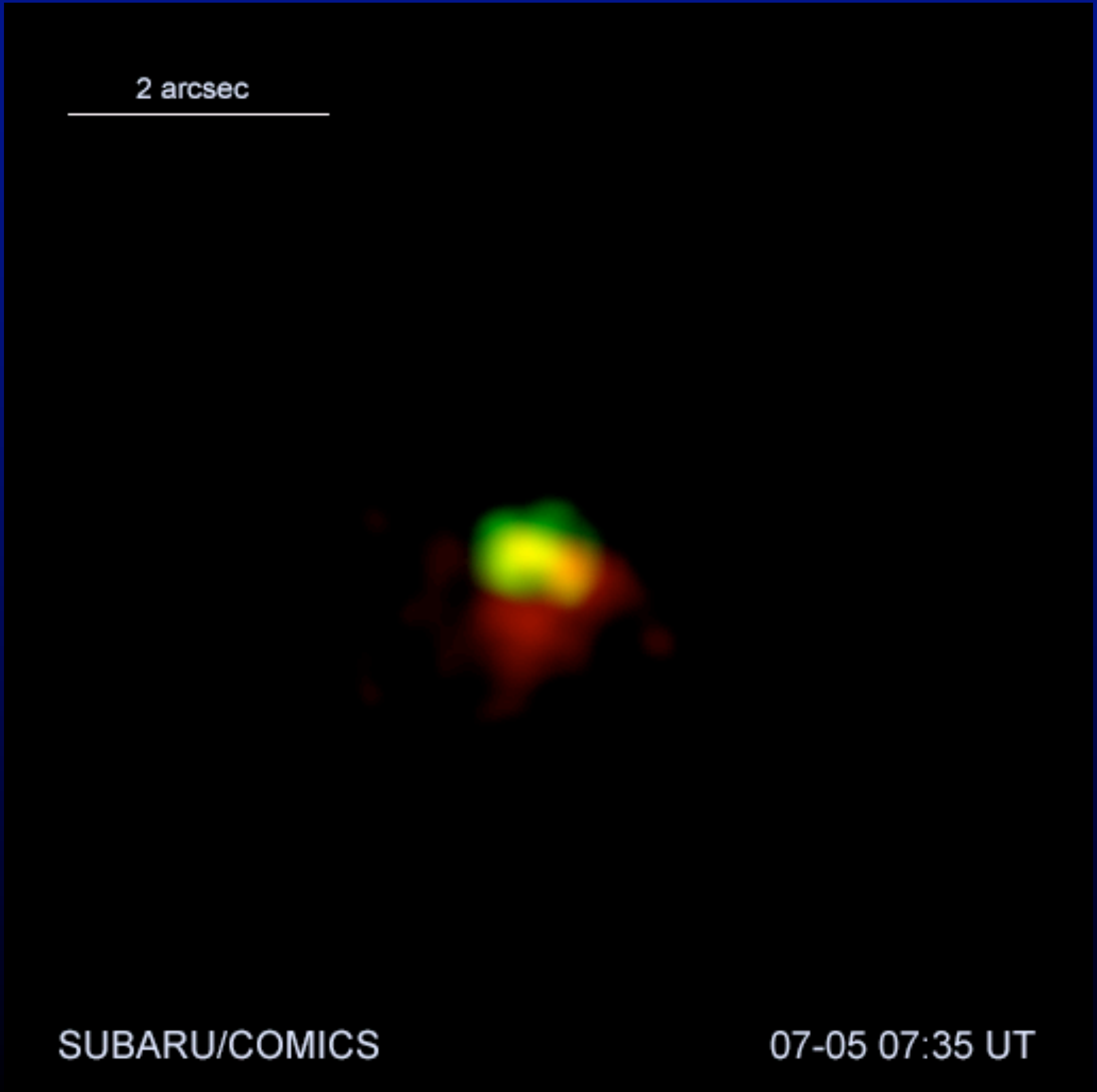

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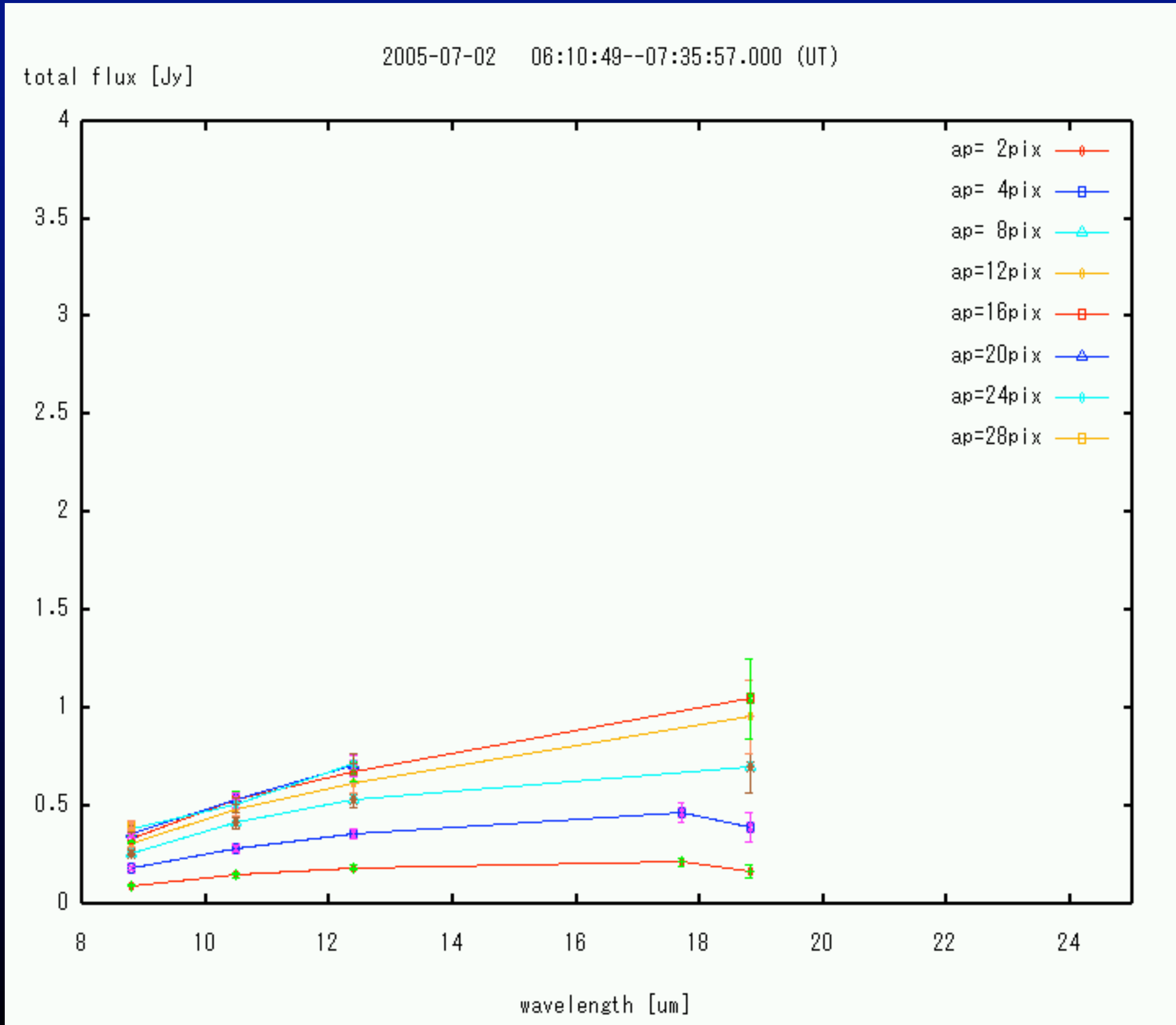
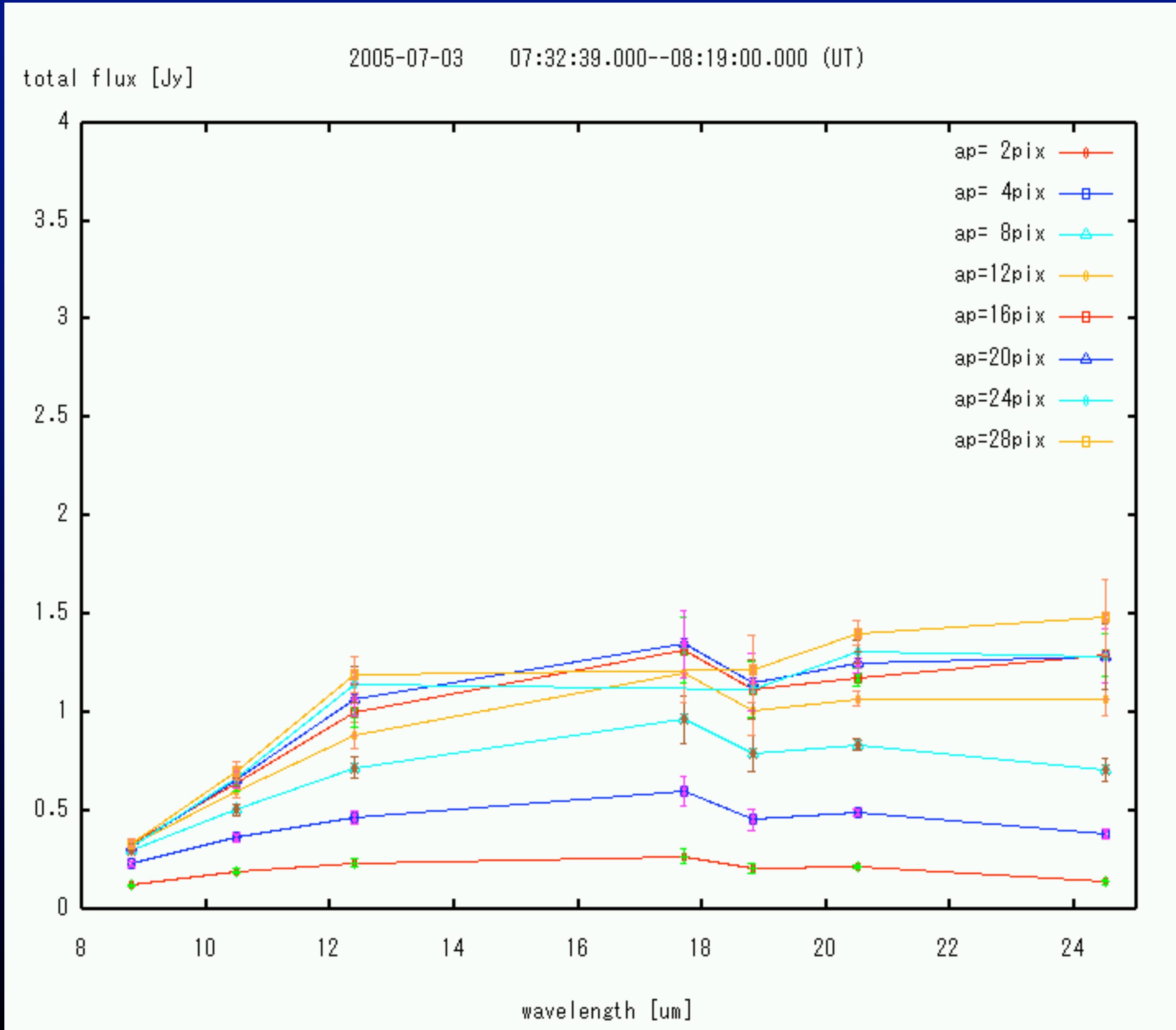
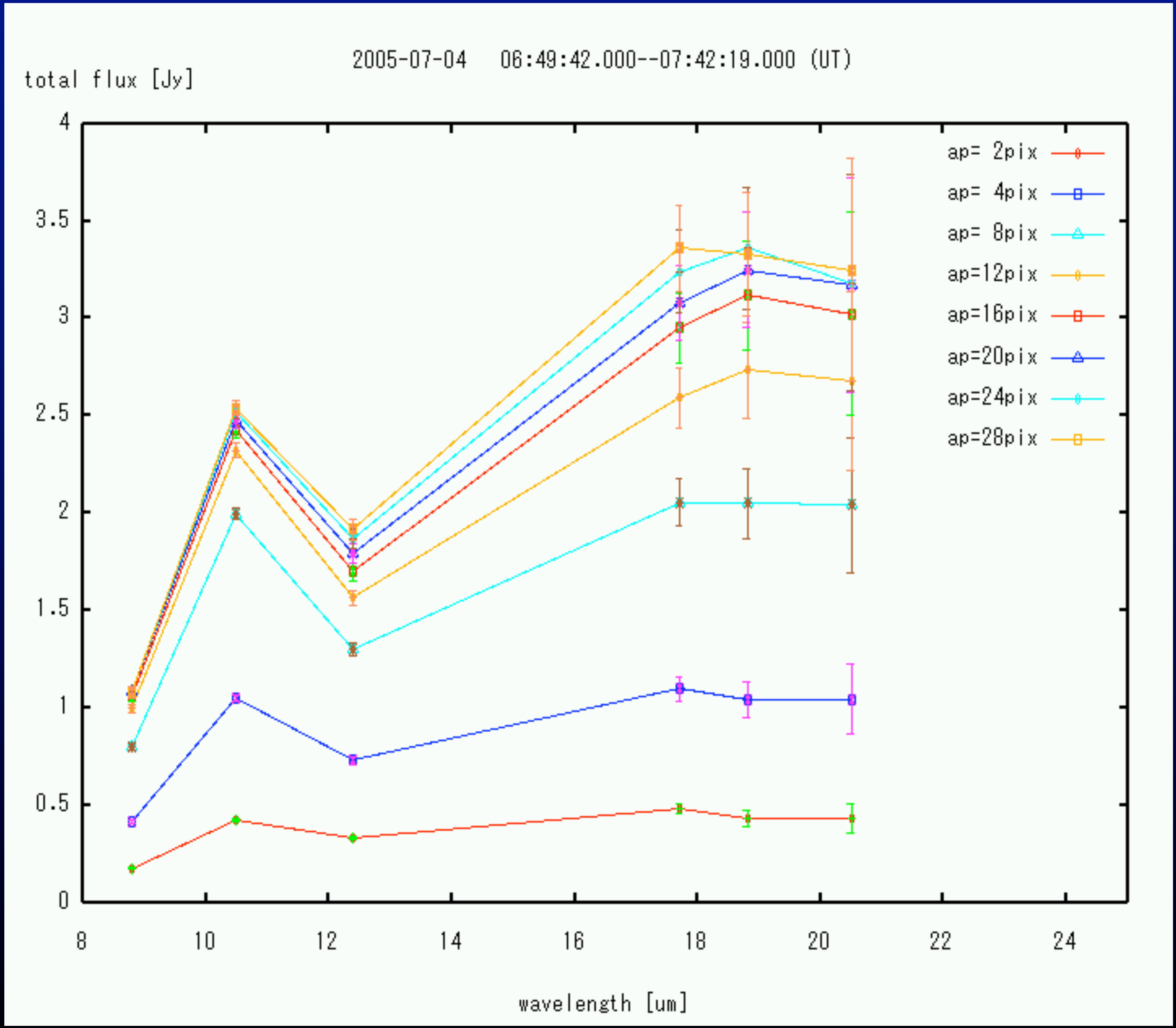
Spectral Energy Distribution: Pre-impact 1



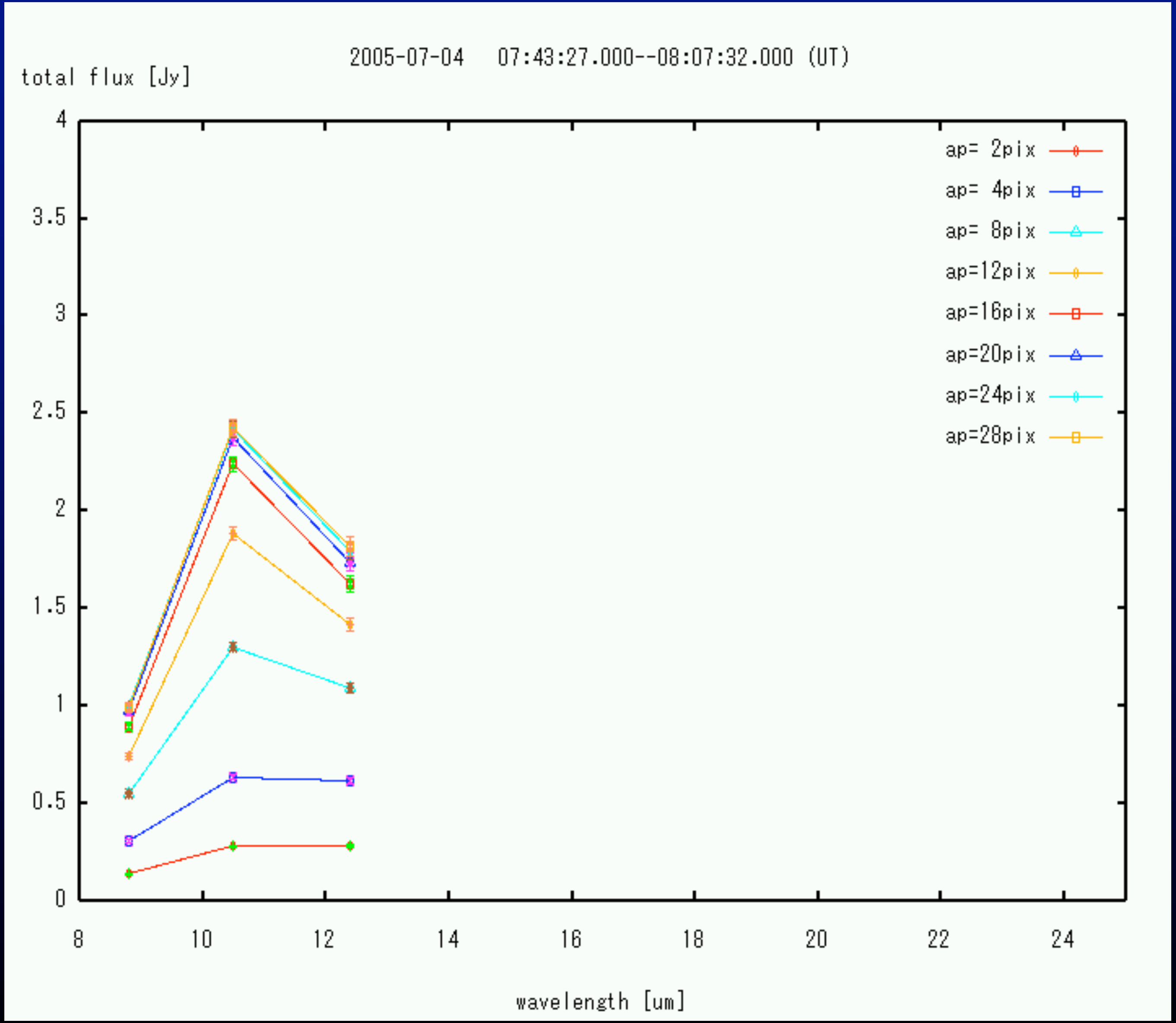
Spectral Energy Distribution: Pre-impact 2



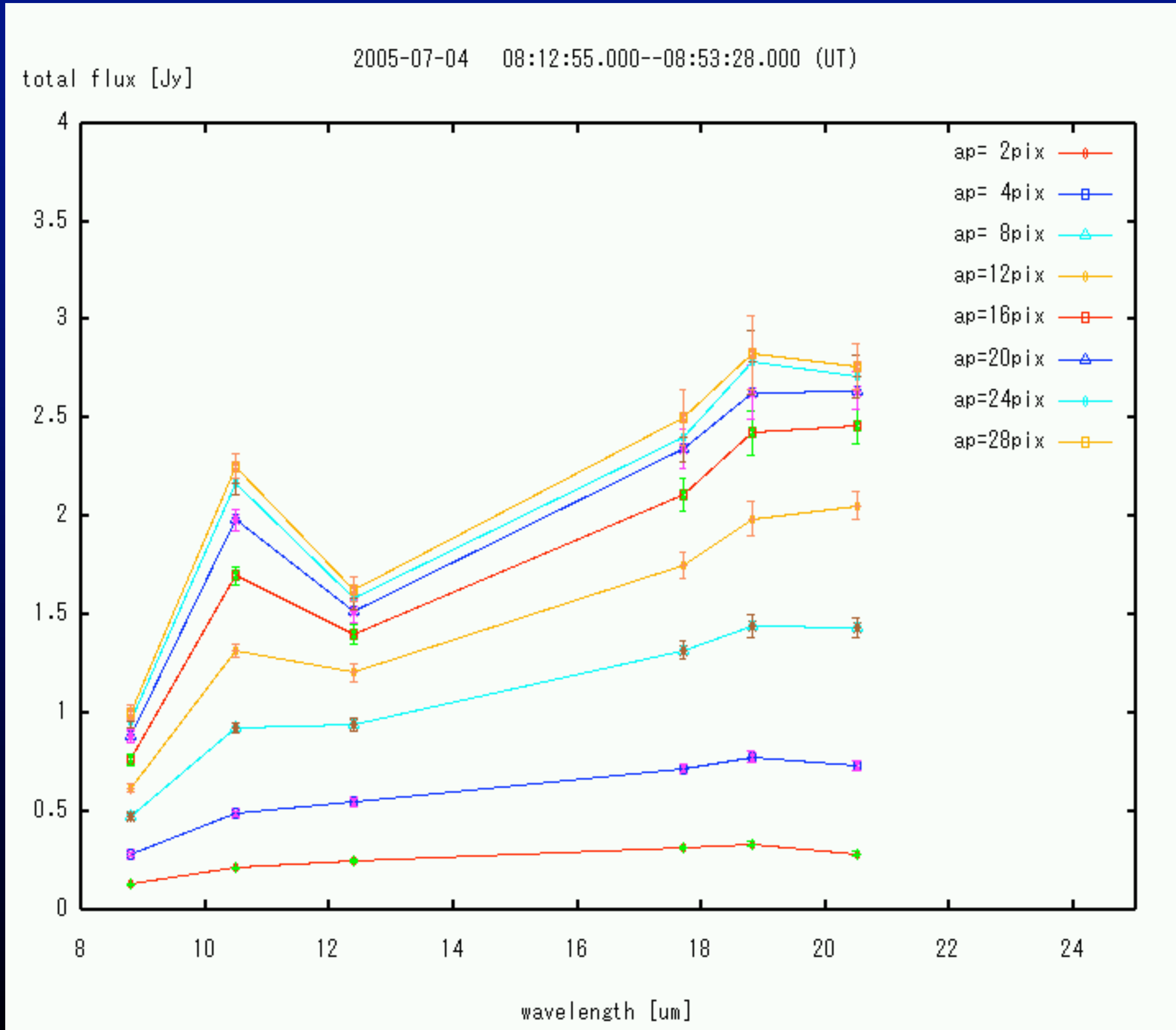
Spectral Energy Distribution: D.I. +1 hour



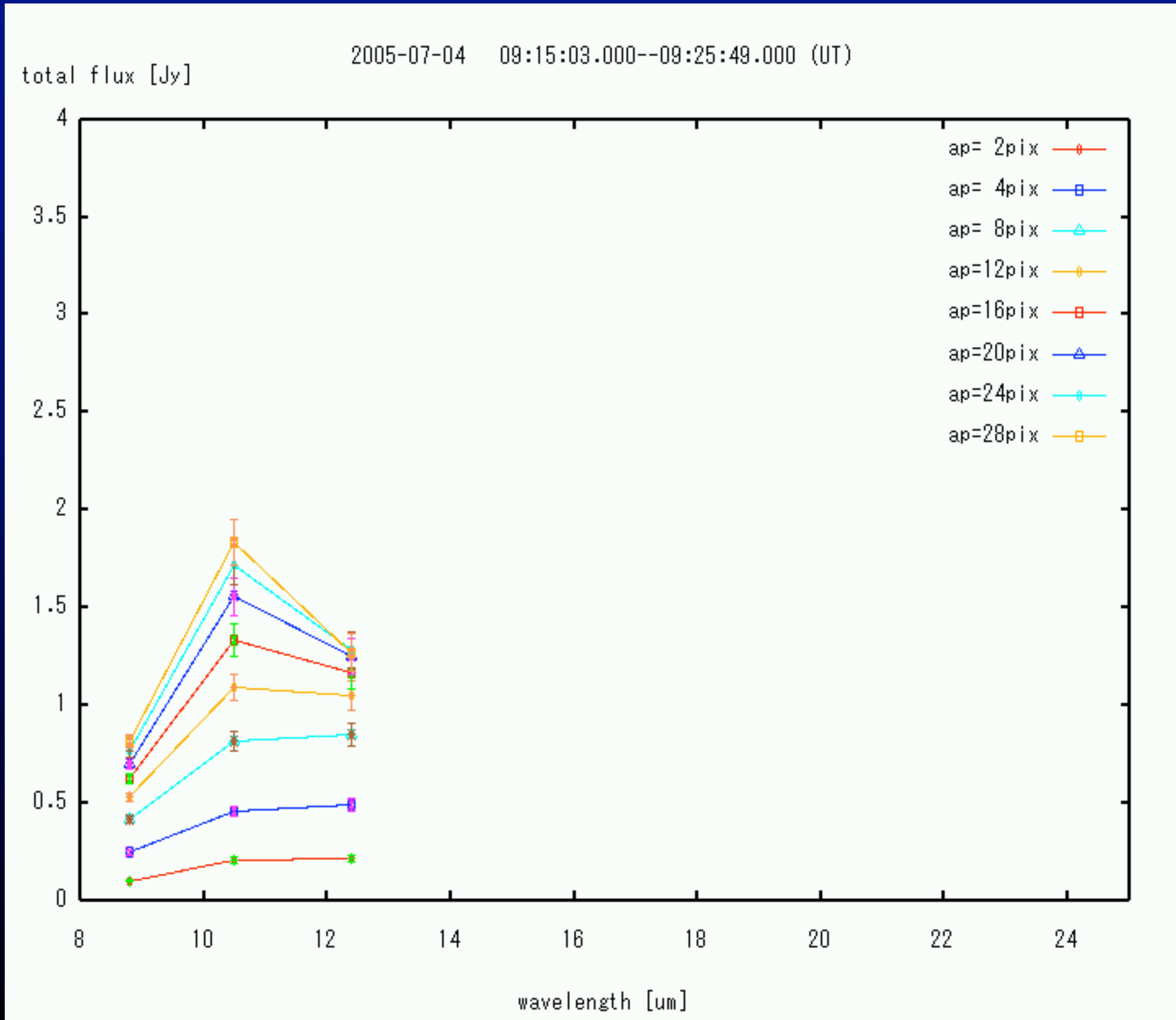
Spectral Energy Distribution: D.I. +2 hours



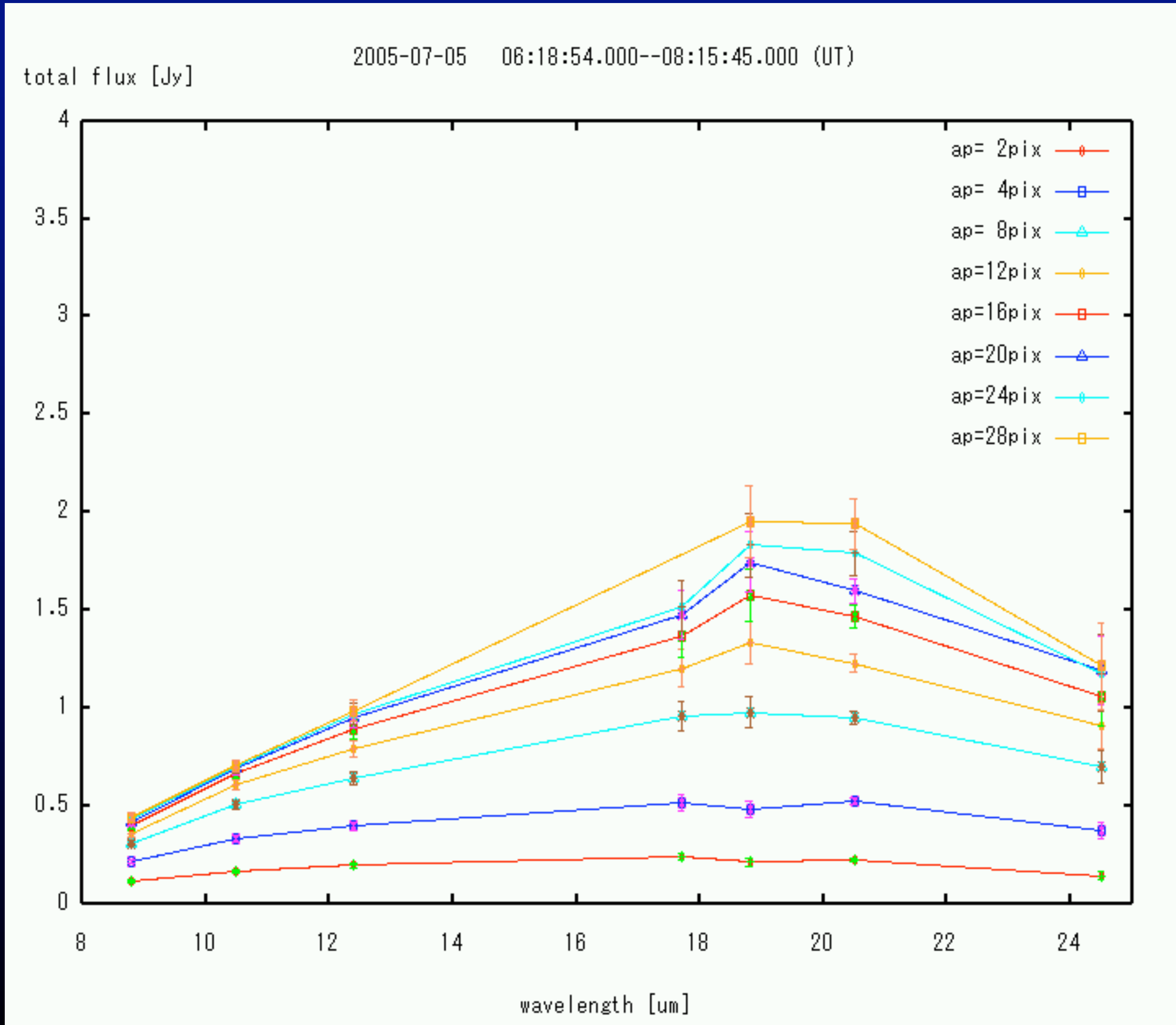
Spectral Energy Distribution: D.I. +3 hours



Spectral Energy Distribution: D.I. +3.5 hrs



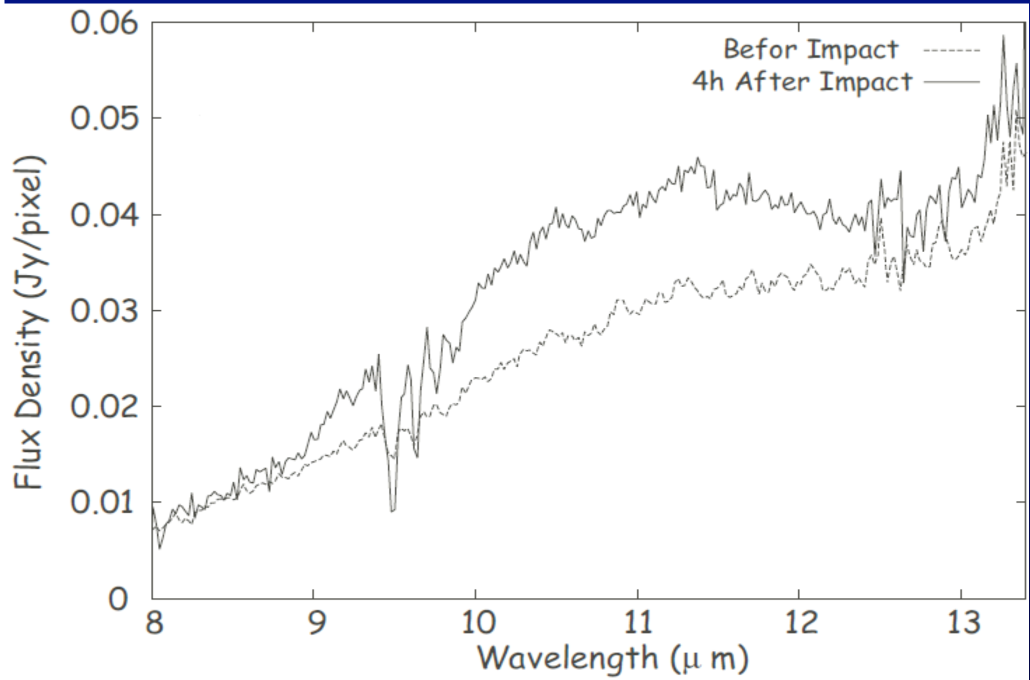
Spectral Energy Distribution: D.I. +28 hrs

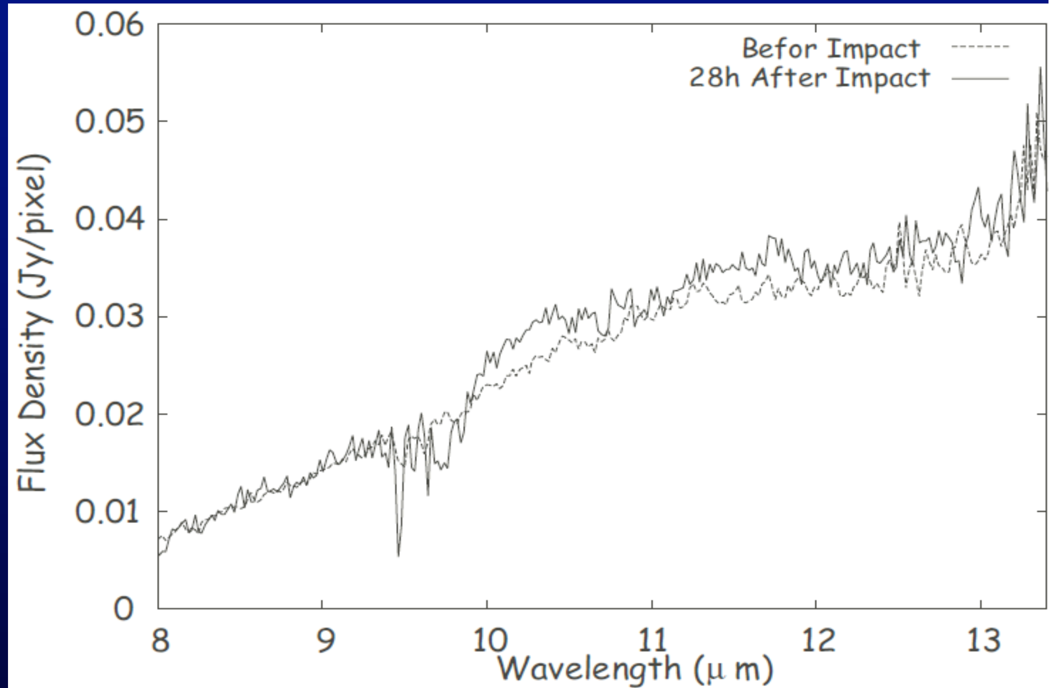


Observation Results 1

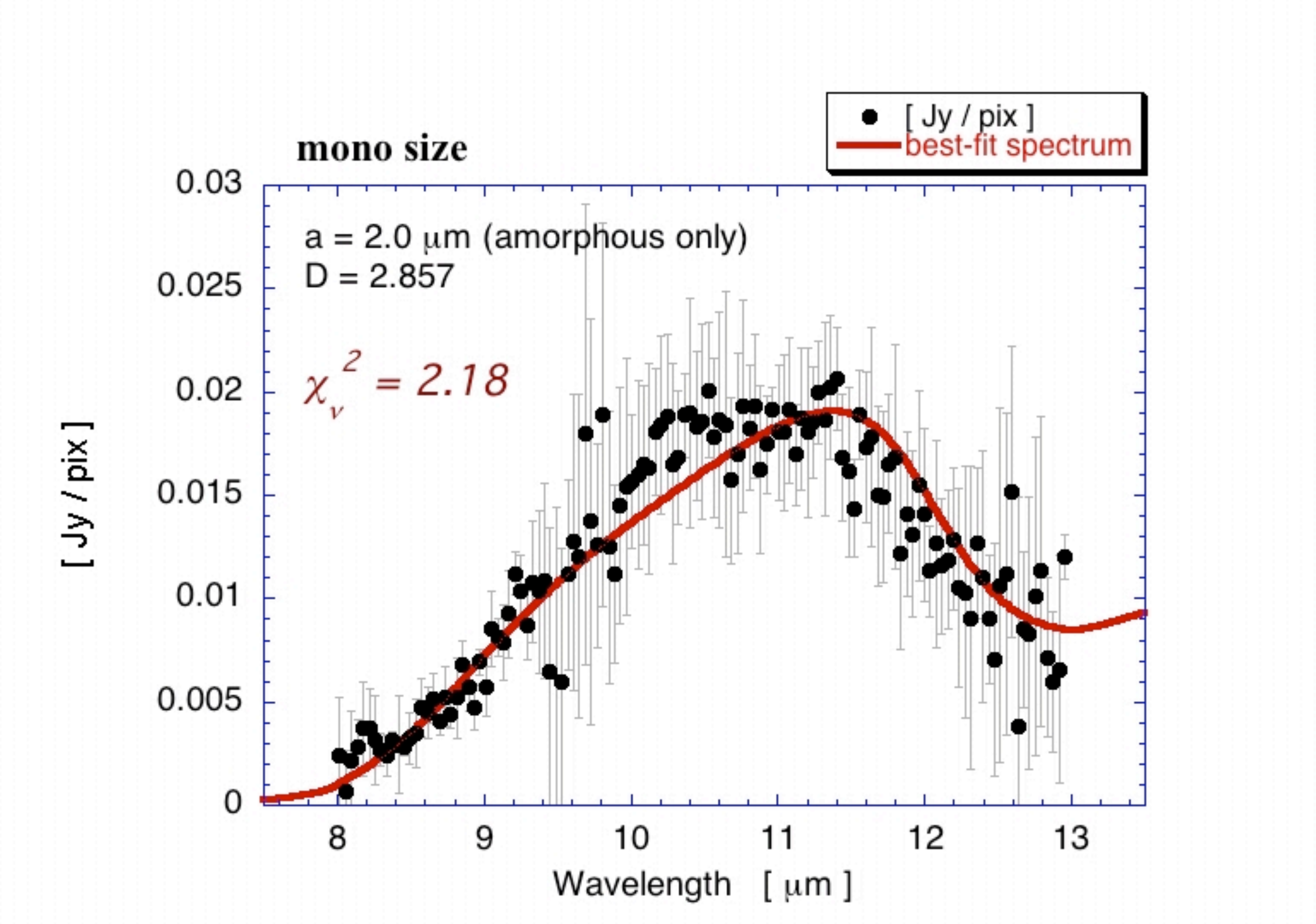
- Rapid development of a large fan-shaped dust plume in ~225°PA, over ~2500 km range.
- Rapid increase in 10μm silicate feature (< 1 hour).
- SED returned to the pre-impact condition ~ 1 day.
- The decrease in light flux is probably due to the plume expansion.

Low Resolution Spectra in N-band



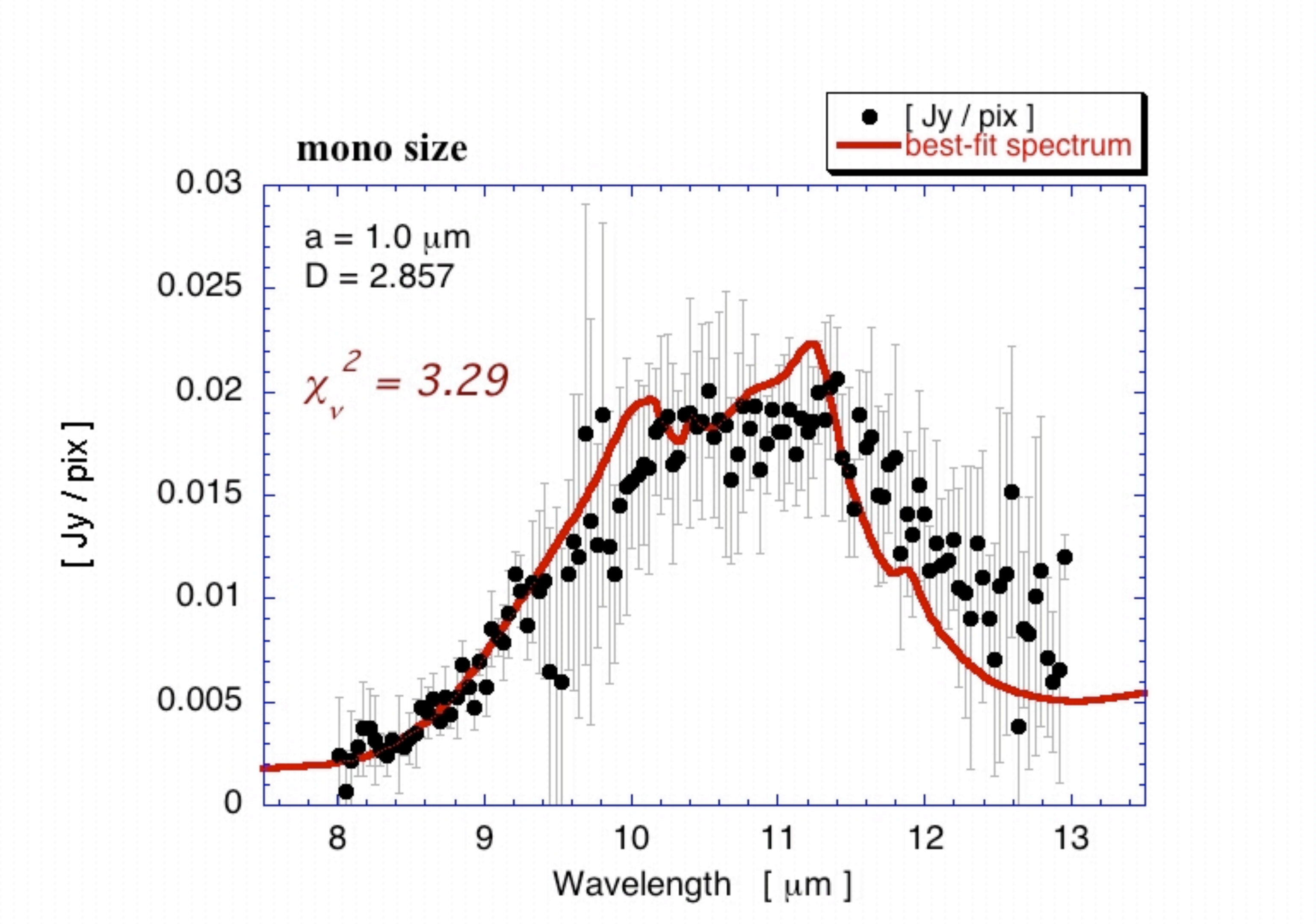


N-band spectrum (July 4 – July 3)



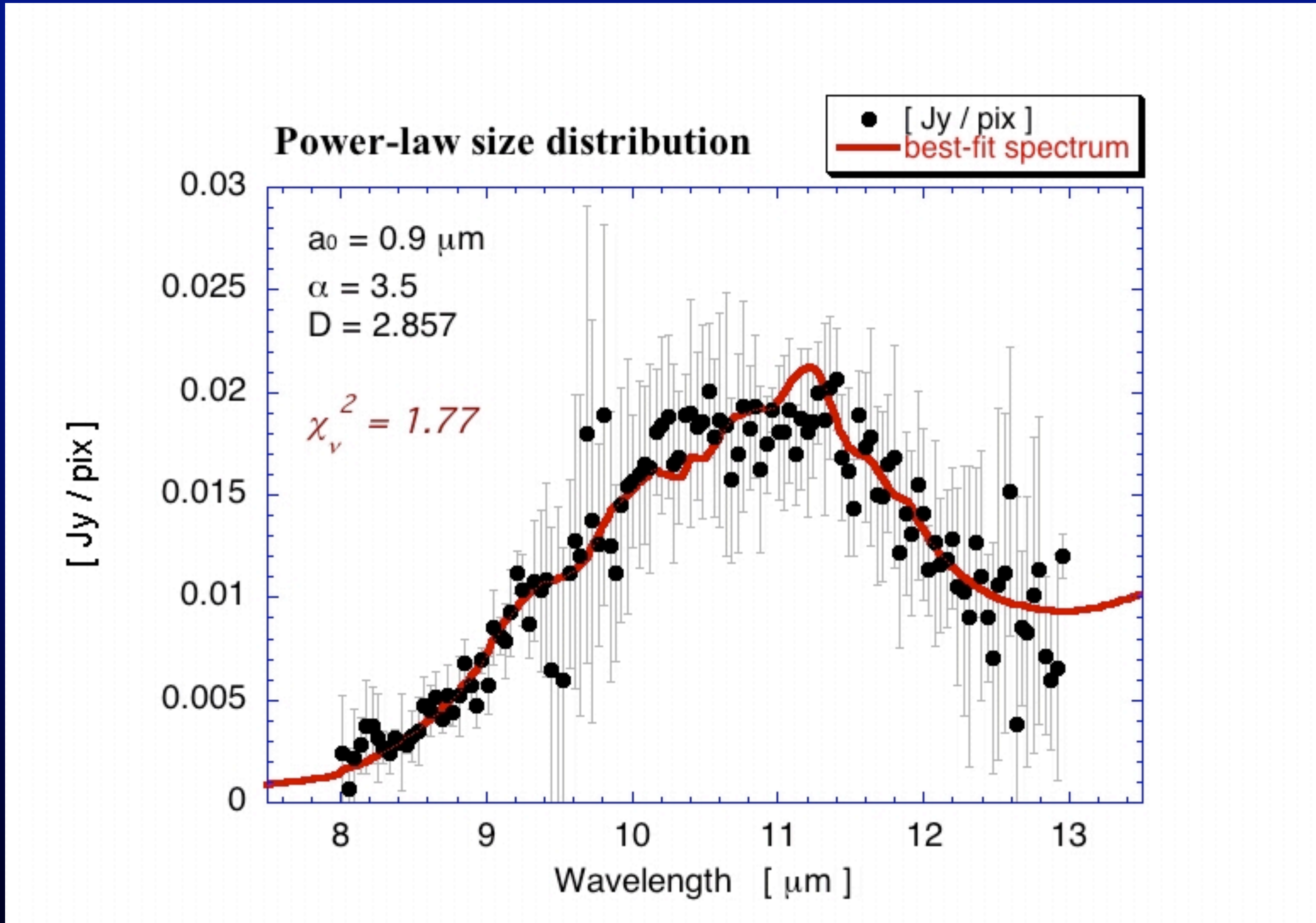
Best Fit Mono Size Distribution (2)

N-band spectrum (July 4 – July 3)



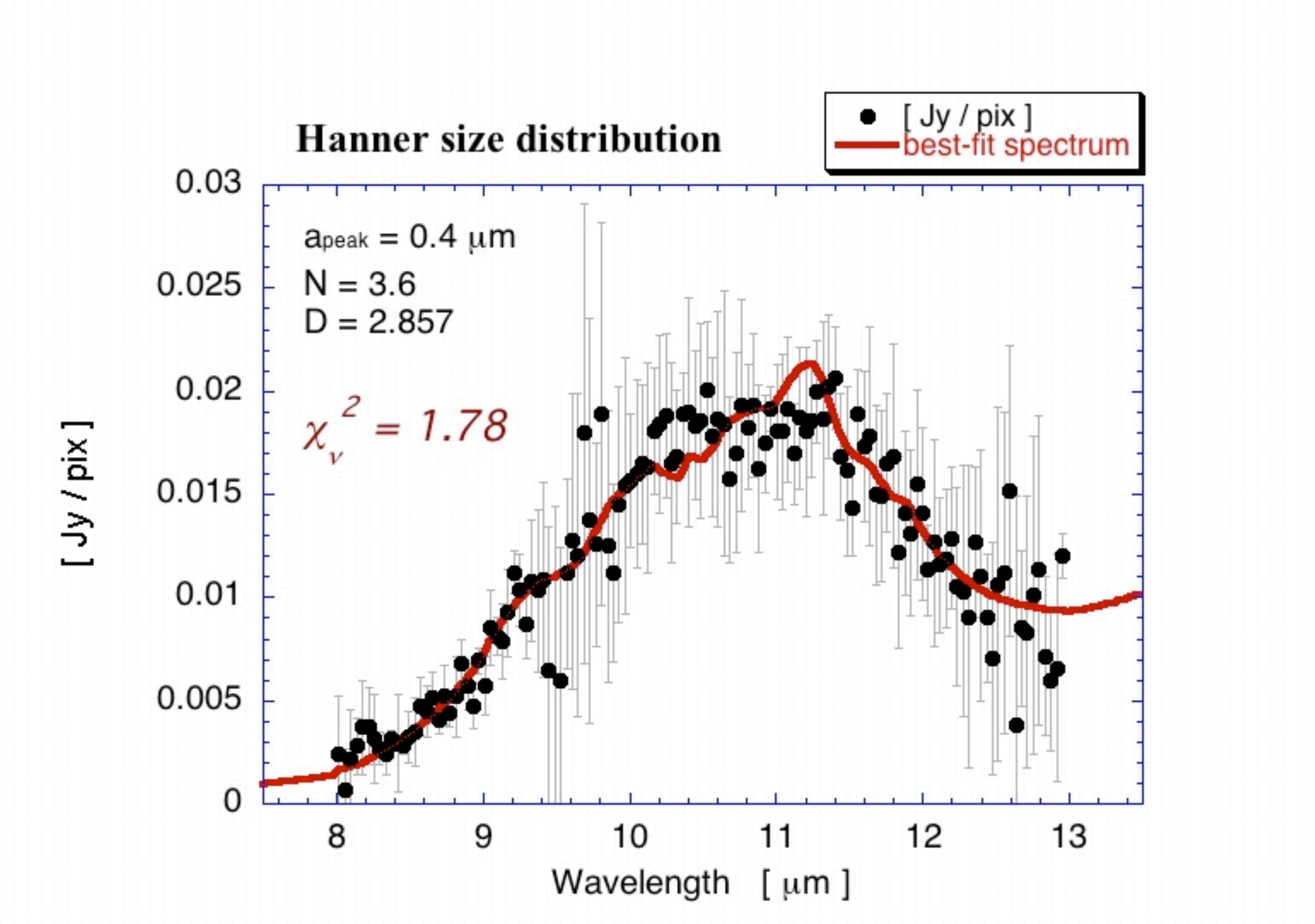
Best Fit Mono Size Distribution (1)

N-band spectrum (July 4 – July 3)



Best Fit Power-Law Size Distribution

N-band spectrum (July 4 – July 3)



Best Fit Hanner's Size Distribution

Observation Results 2

- **Dust size distribution:**
  - **Peaked around sub-micron to micron size.**

    --> Greenburg particles?
  - **Best-fit power law: $N(>a) \sim a^{-3.6}$**

    --> Similar to the size distribution of Oort-Cloud comets

- **A large mass fraction of crystalline silicate:**
  - **Crystalline/amorphous olivine = 4 - 5**
  - **Silicate/carbon = 40**

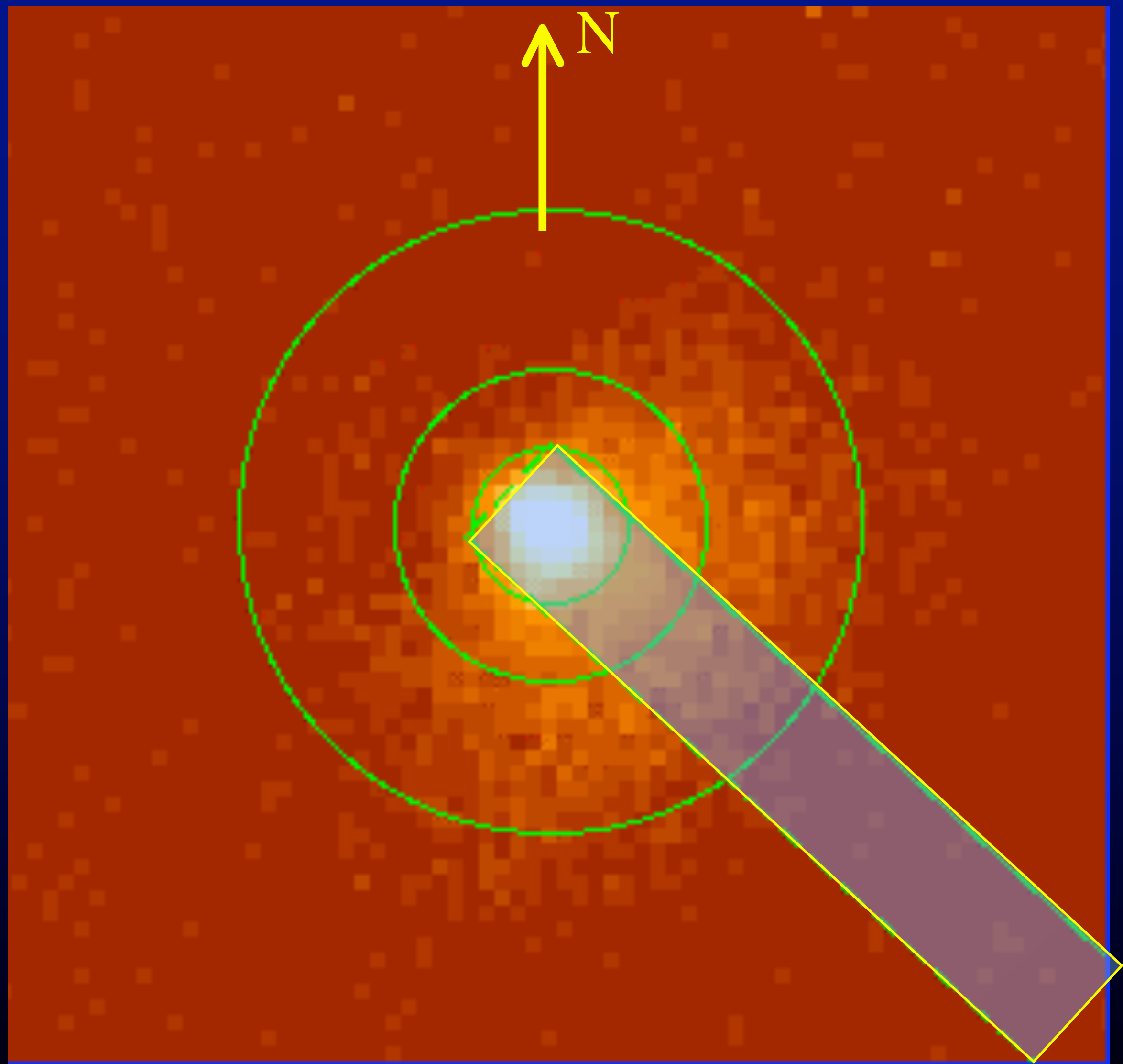
    --> Similar to the size distribution of Oort-Cloud comets

Observation Results 3

- Total dust mass in the plume ~ 10^6 kg
- A large ejecta mass is inconsistent with strength-controlled cratering.
- Equivalent to ejecta from a gravity-controlled crater with ~10^2 m diameter (-> ~10m excavation).
- Impact-induced silicate crystallization < 1 - 10 %

  → The observed crystalline silicate is intrinsic.

Analysis of Radial Profile



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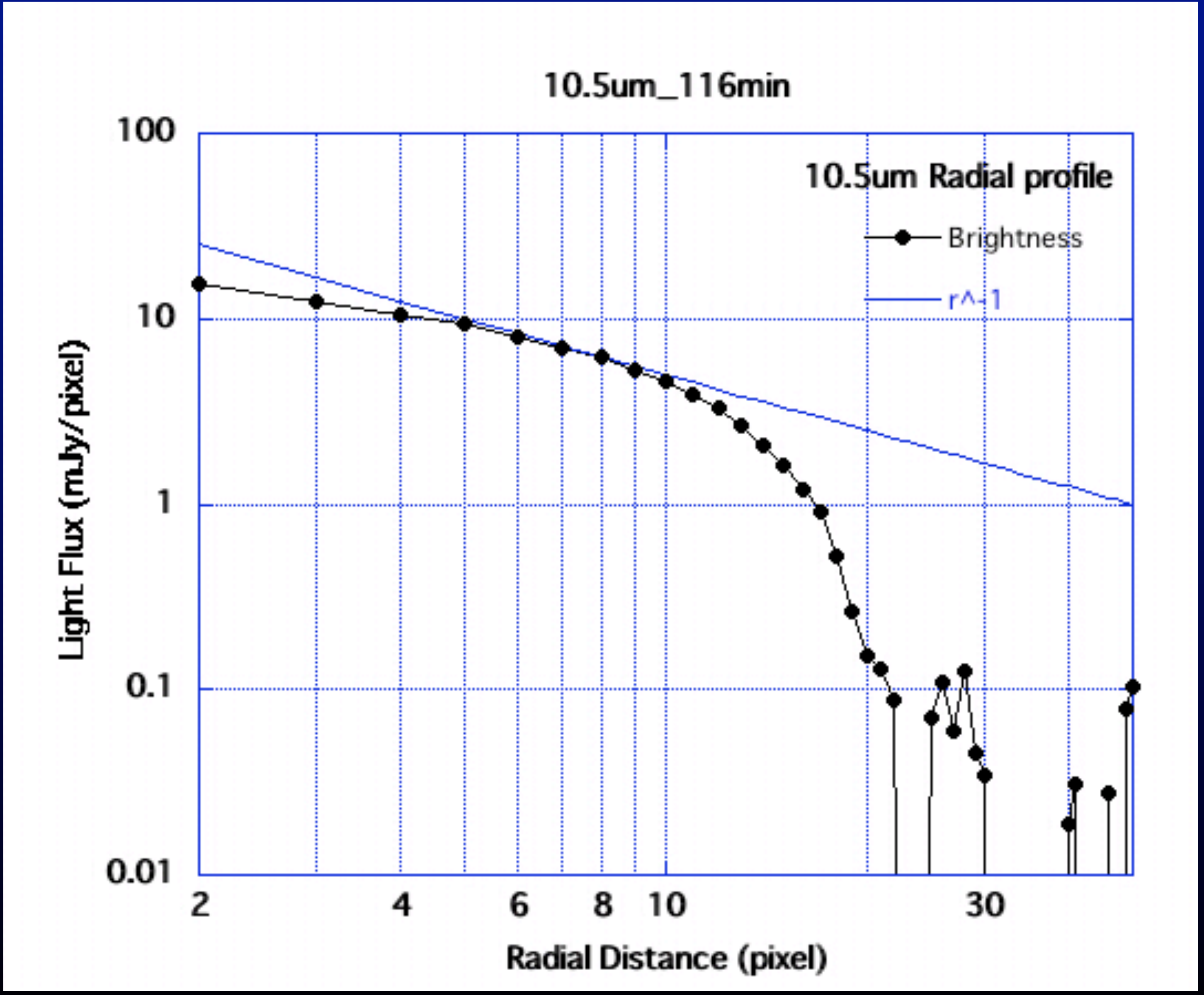

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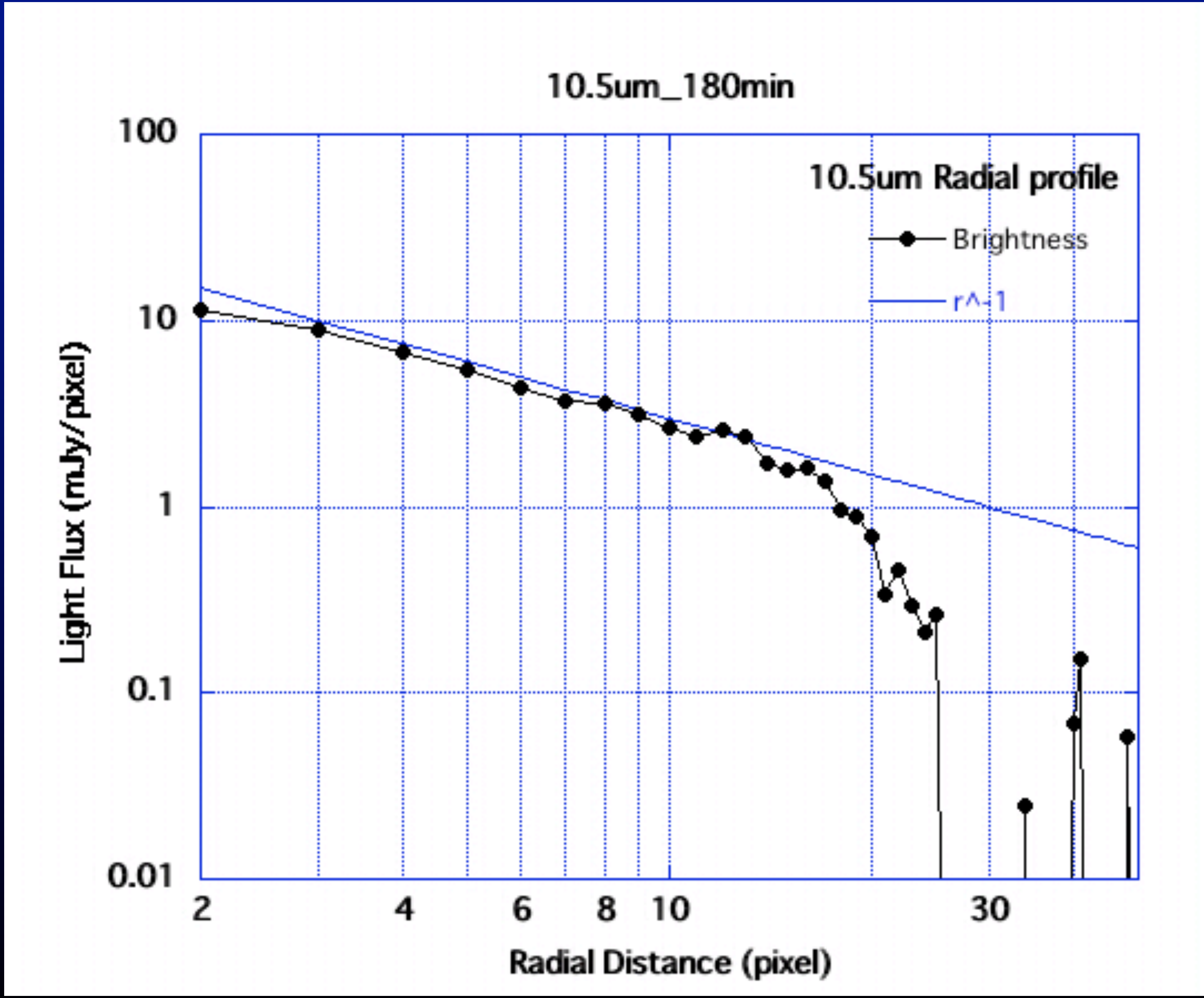

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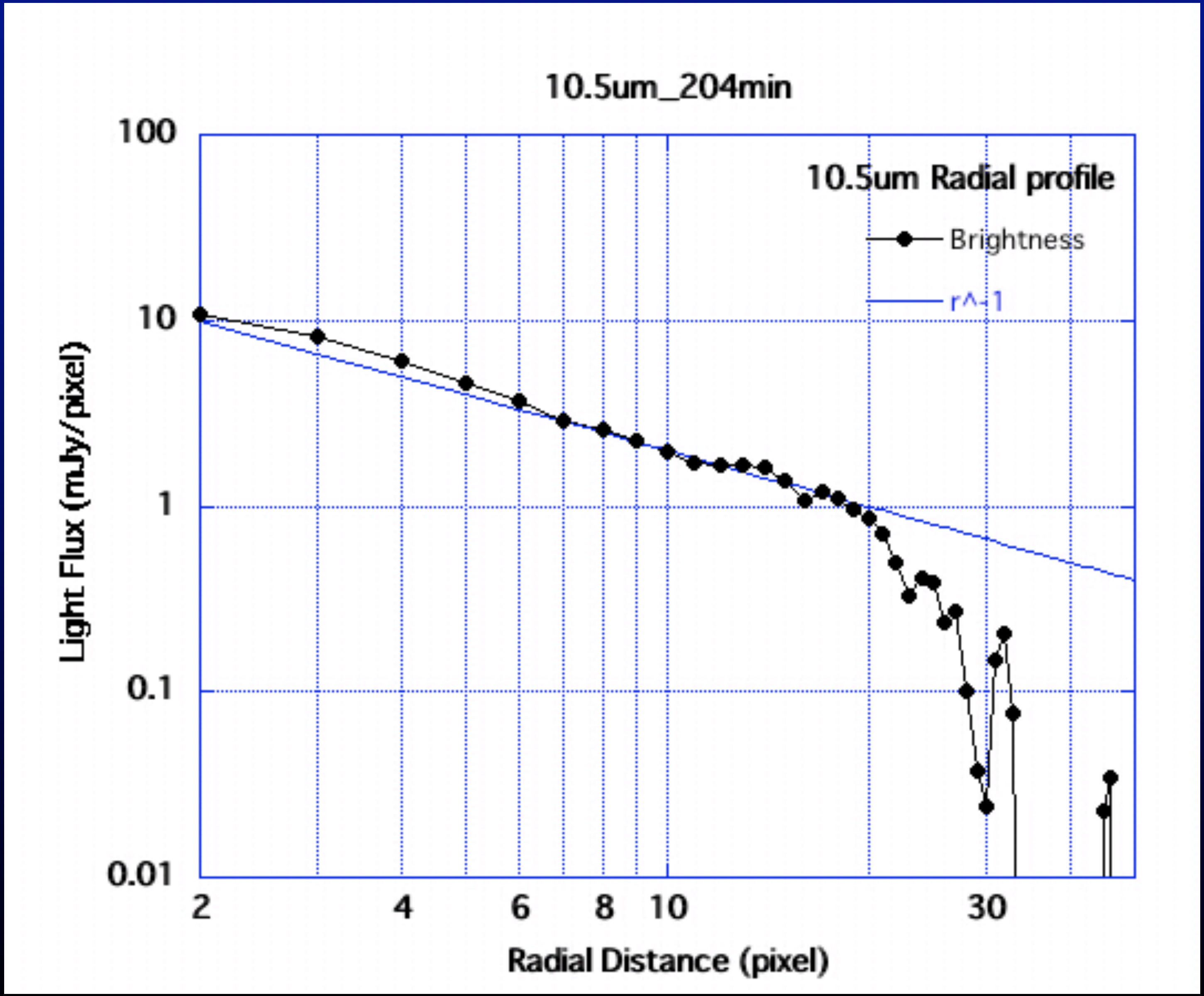

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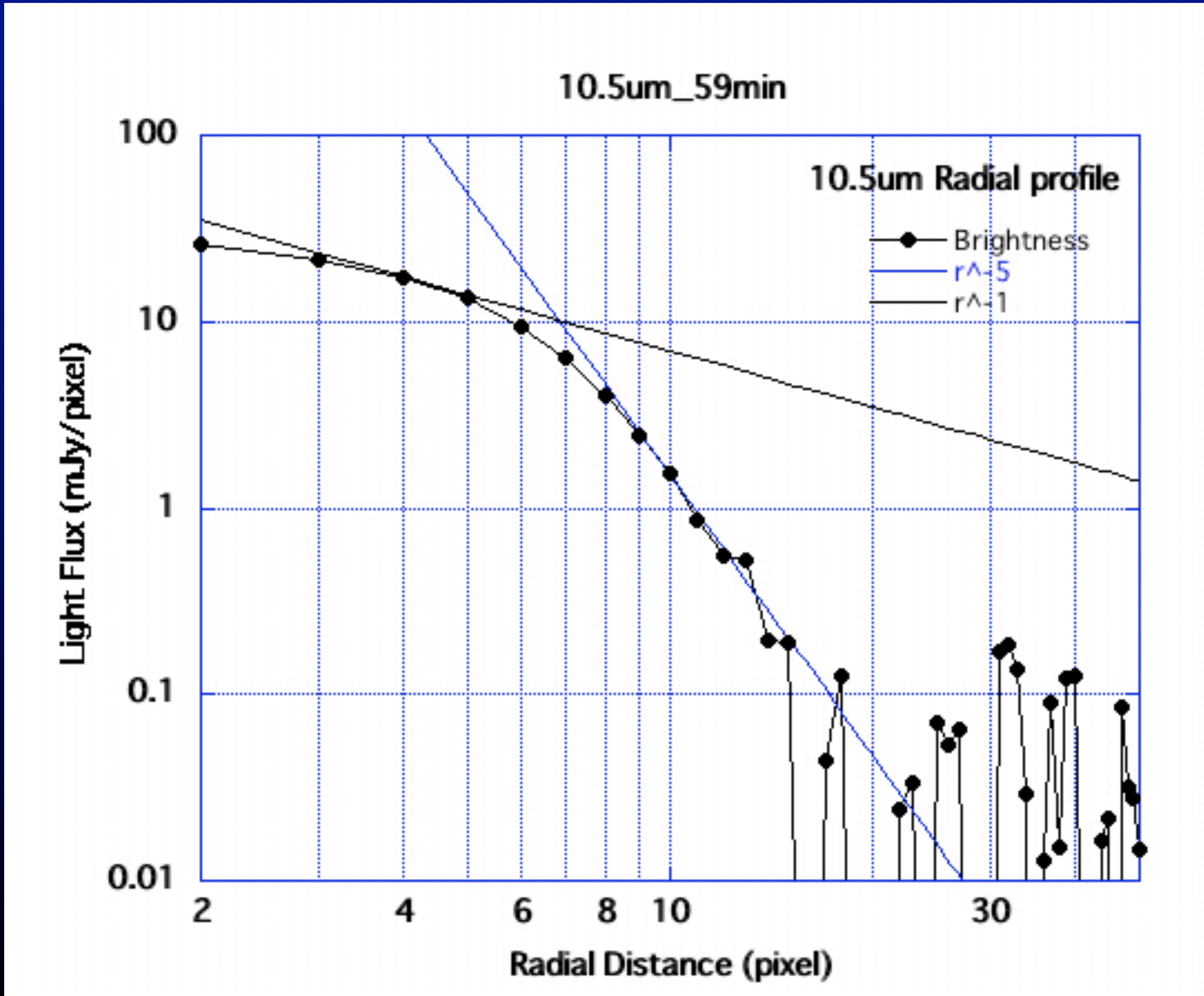

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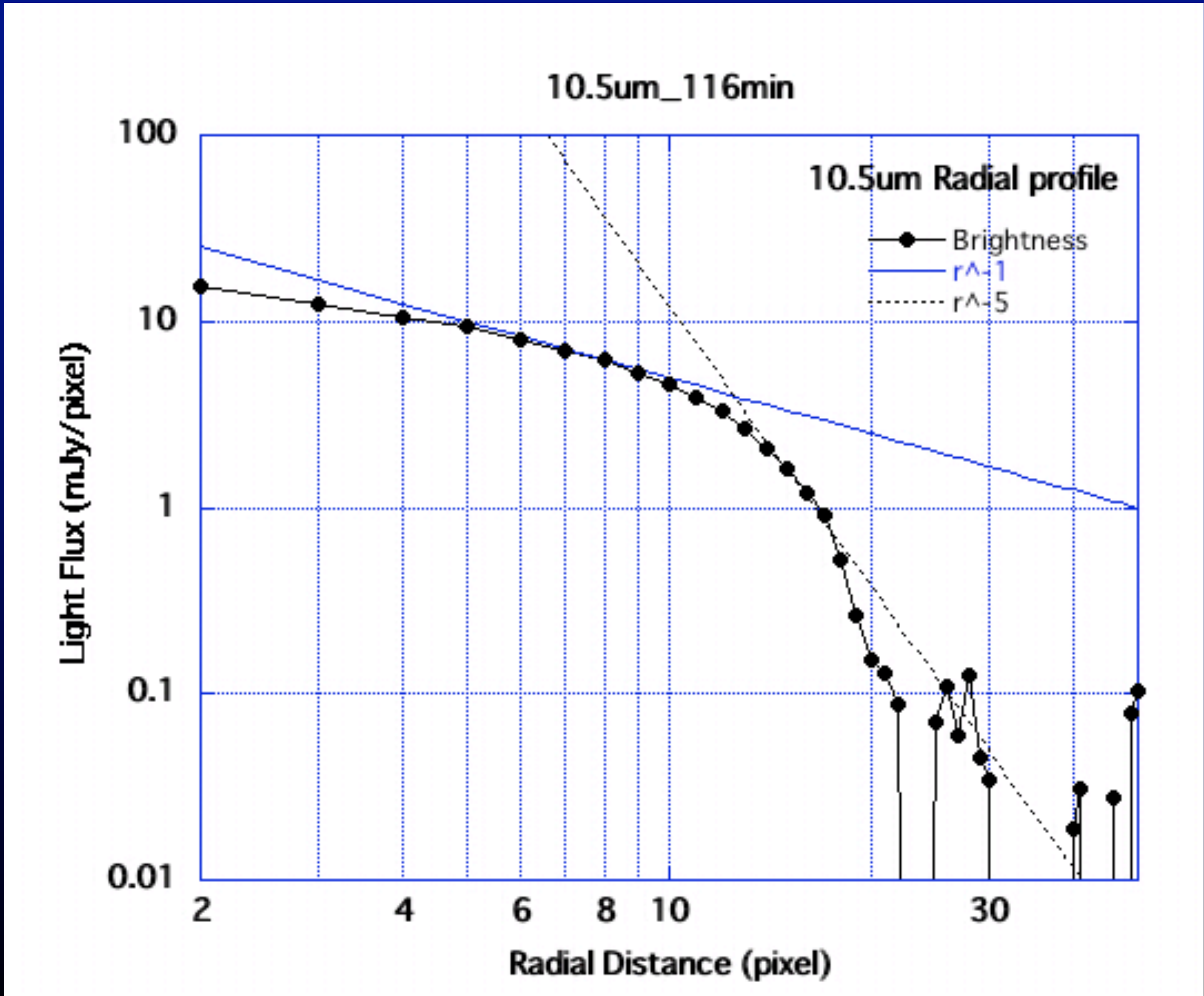

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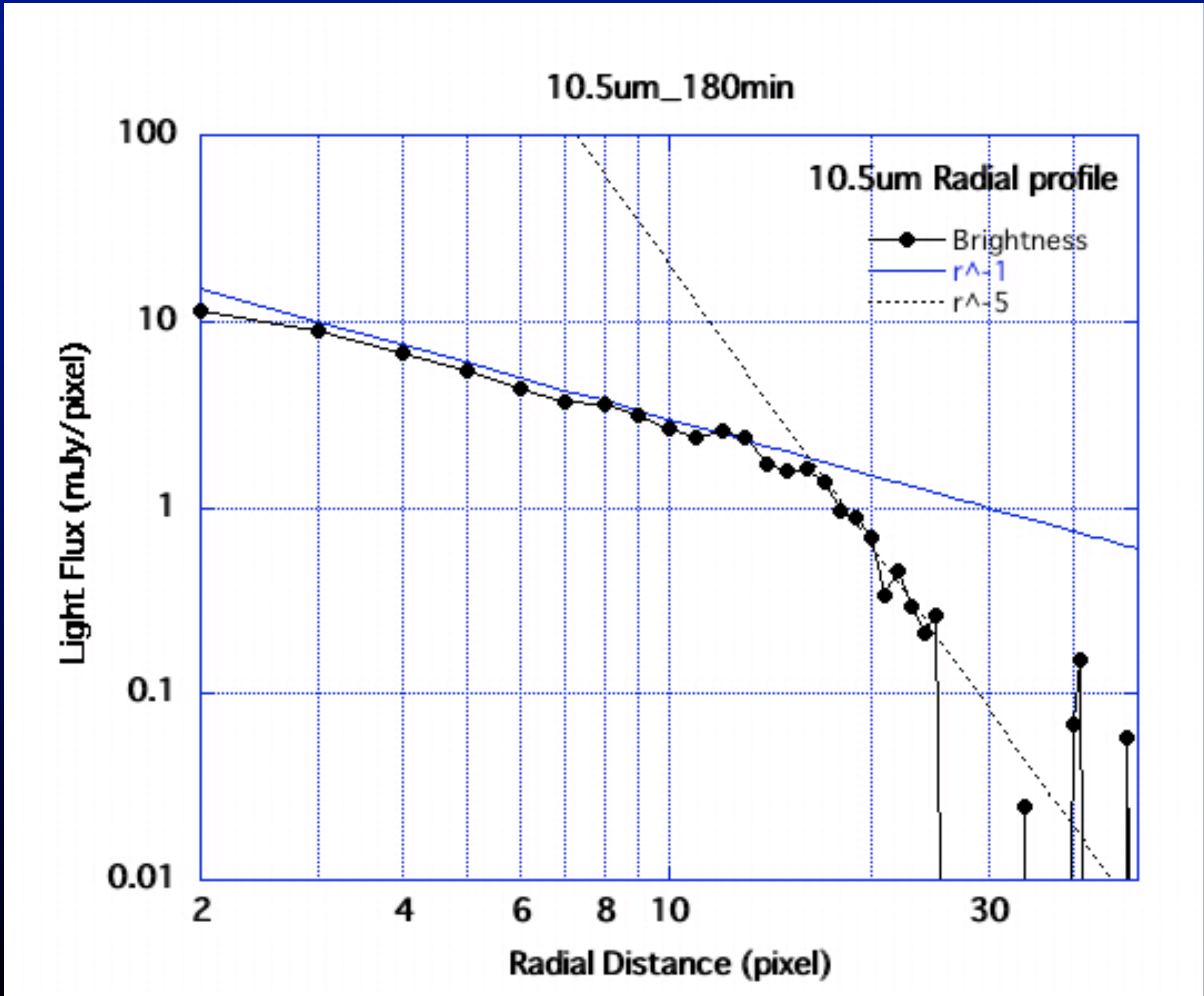

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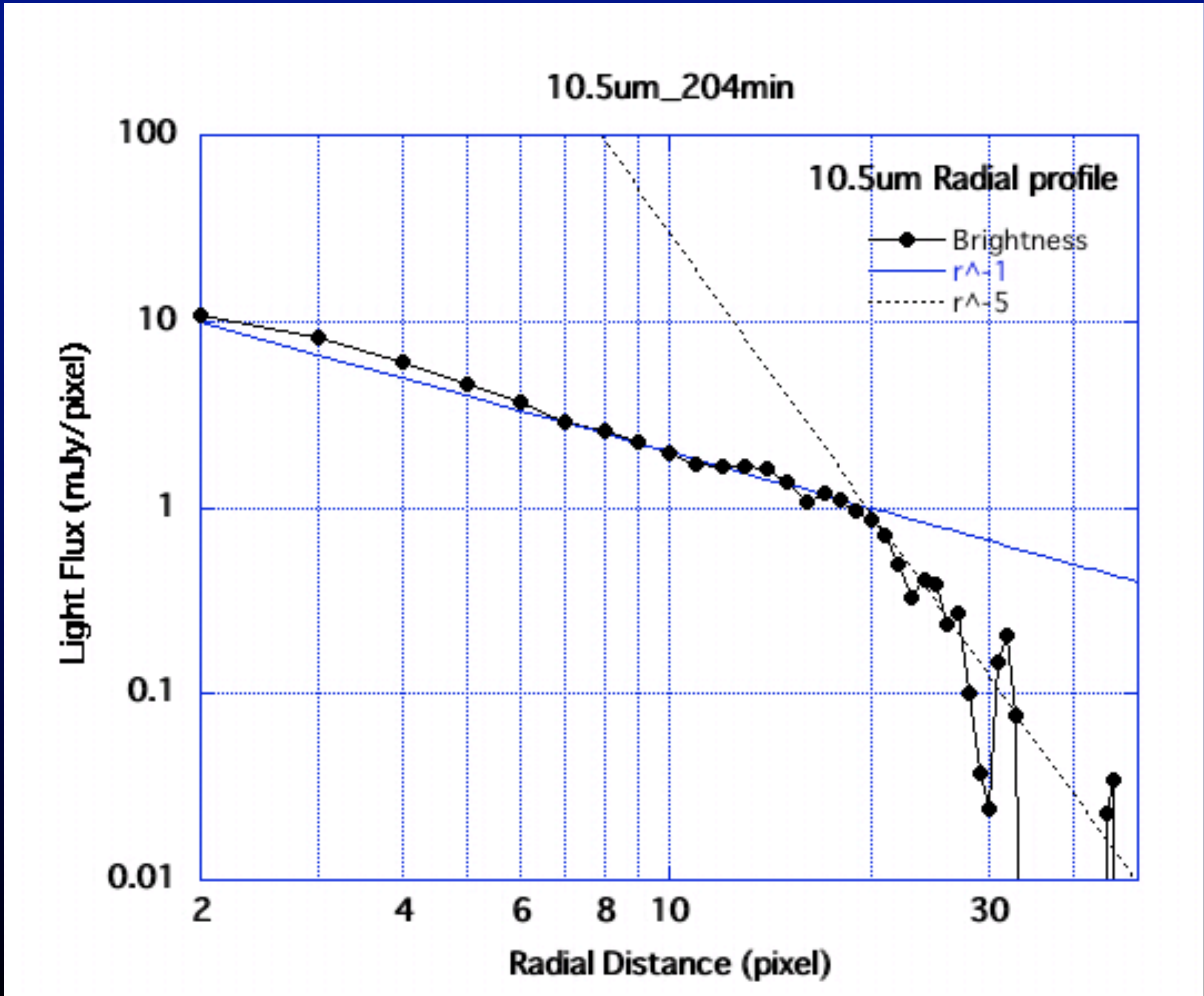


Observation Results 4

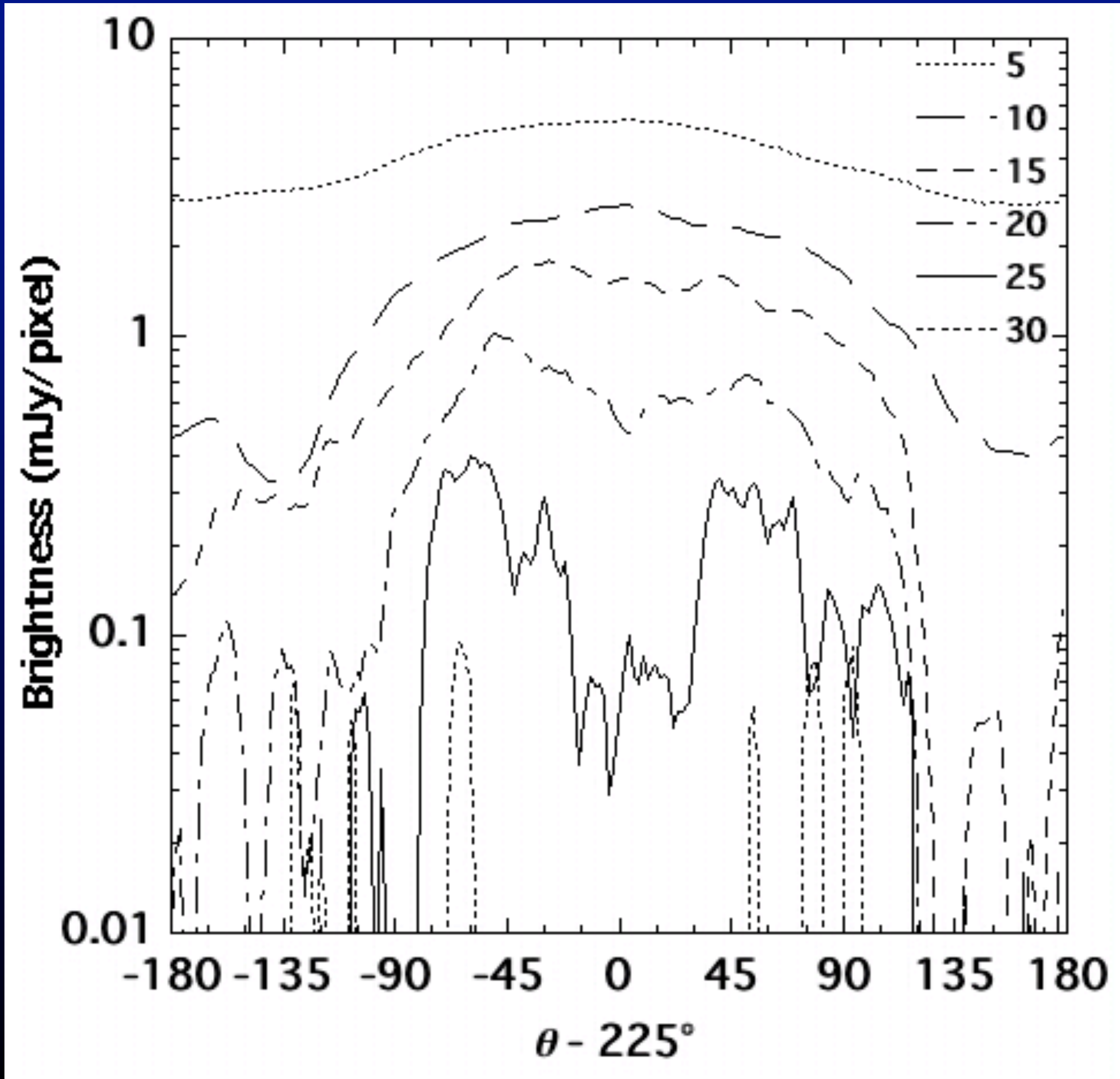
- The brightness distribution of dust plume is <u>not</u> consistent with a simple ejecta model $\sim r^{-3}$.

- Radial profile shows two slopes in the plume.
  - Outer r^{-5} slope (~ PSF profile)
  - Inner r^{-1} slope

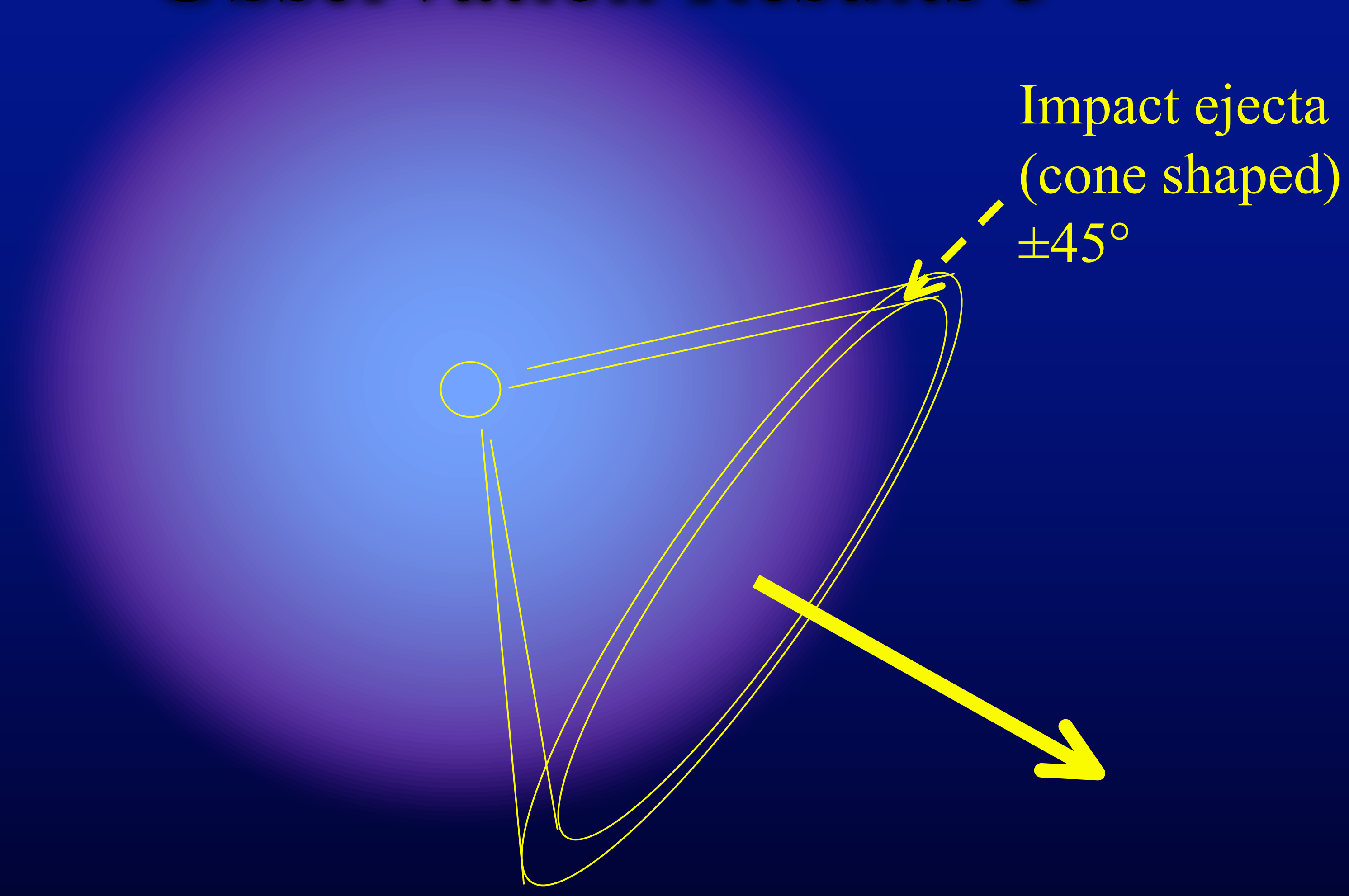
- The r^{-1} profile suggests dust acceleration by gas.

  ➡Sublimation of ejecta ice ?

Analysis of Angular Profile



Observation Results 5



- **Outer plume exhibits ±45° of wings; ejecta curtain?**
- **Consistent with gravity-controlled cratering.**

Summary of the observation

- **DI cratering was probably gravity-controlled.**
- **Deep Impact excavated fresh cometary material containing fine silicate grains with high crystallinty very similar to that of active Oort-cloud comets.**
- **Deep Impact probably reached a volatile-rich layer, and the sublimated gas controlled the dust dynamics within the plume.**

Implications of the observation

- ✦ Similarity in dust properties between Oort-Cloud comets and a Jupiter-family comet (JFC).
- ✦ High crystallinity of JFC dust (i.e., high temperature)
- ➡ JFC may not be from the main Kuiper belt but from the scattered disk, which is originally from the Giant-Planets Region.

Thank you for your attention.

Reprints for our *Science* paper are available.

Sugita et al. *Science*, *310*, 274-278 (2005)