An introduction to scheduling: The case of astronomical observations

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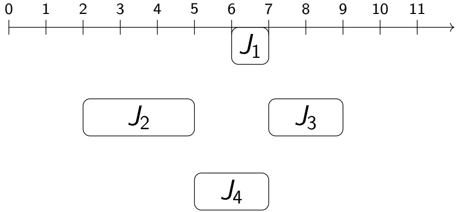
20 November 2025

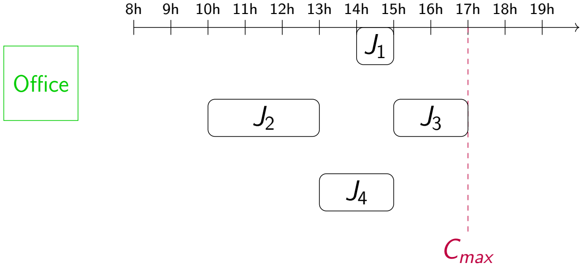
Outline

Outline

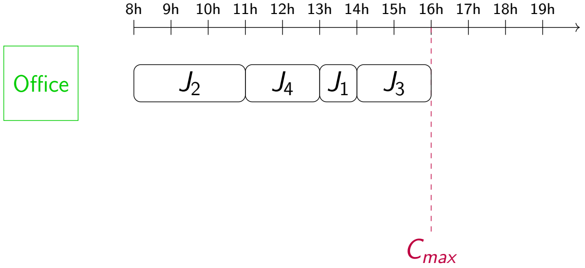


$\mathcal{J} = \{J_1, \ldots, J_n\}$ set of n jobs of processing time $p_1, \ldots, p_n$

Introduction to scheduling



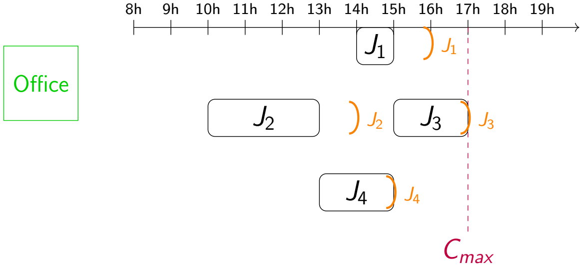
$1||C_{max}$



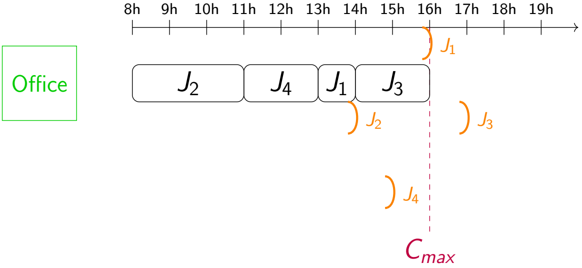
$1||C_{max}$

Any job order. $\mathcal{O}(n)$ time.

Introduction to scheduling



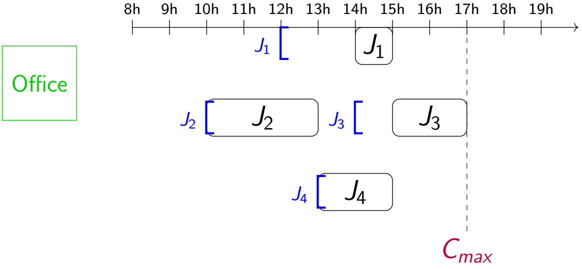
$1|d_j|C_{max}$



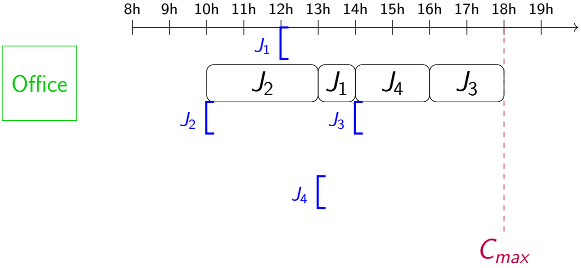
$1|d_j|C_{max}$

"Earliest Deadline First" (EDF) job order. $\mathcal{O}(n \cdot \log(n))$ time.

Introduction to scheduling

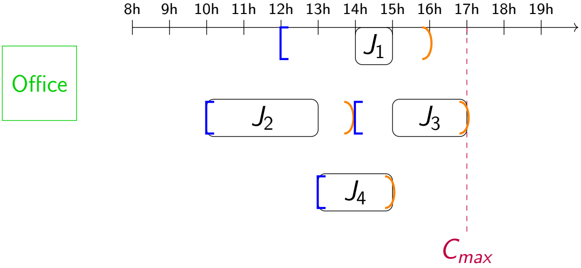


$$1|r_j|C_{max}$$



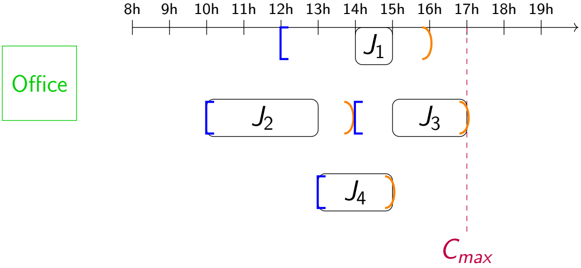
$1|r_j|C_{max}$

"Earliest Start Time" (EST) job order. $\mathcal{O}(n \cdot \log(n))$ time.


8h
9h
10h
11h
12h
13h
14h
15h
16h
17h
18h
19h
Office
J_1
J_2
J_3
J_4
C_{max}

$$1|r_j, d_j|C_{max}$$

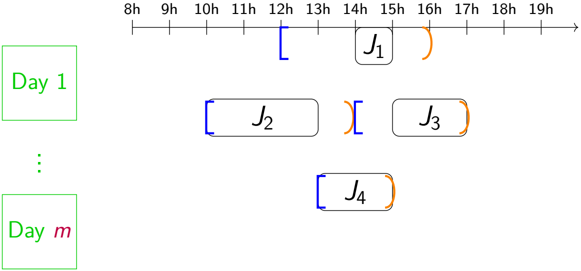
Introduction to scheduling



$1|r_j, d_j|C_{max}$

Strongly NP-complete [Lenstra et al., 1977].

Introduction to scheduling



$$P|r_j, d_j|min(m)$$

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Outline

Why?

Fixed daily start times

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- (Maybe) easier to solve.

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- Upper bound.

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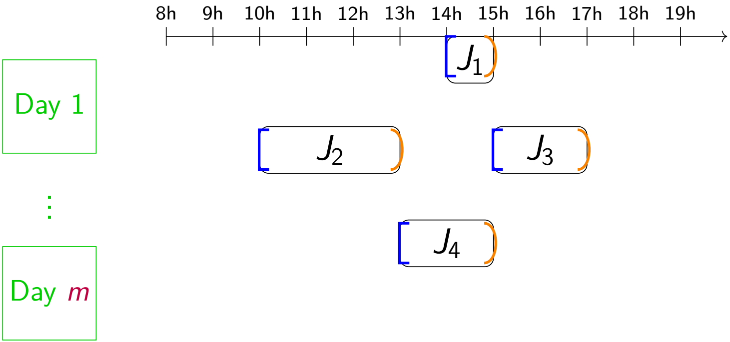
- Upper bound.
- Set around altitude peaks.
  $\longrightarrow$ Best observation quality.

Back to meeting planning



$$P|r_j, d_j, d_j - r_j = p_j|min(m)$$

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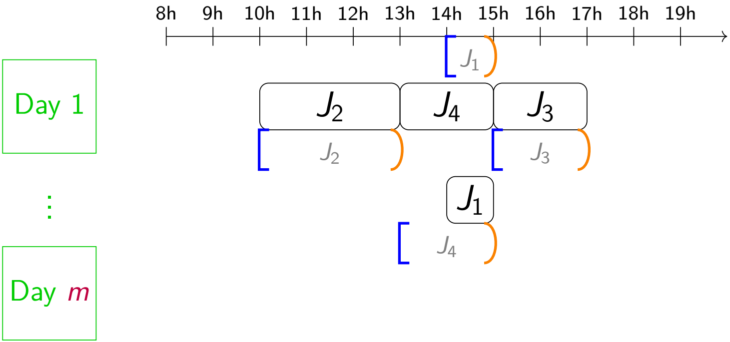

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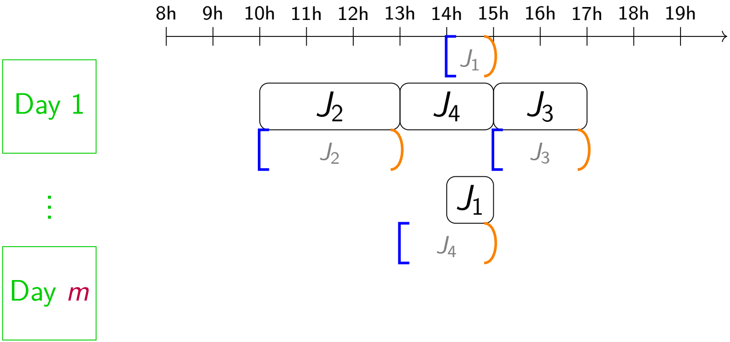

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Interval graph coloring: $\mathcal{O}(n \cdot \log(n))$ time.

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More flexible settings

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  $\rightarrow$ $\mathcal{O}(\log(n))$-approximation algorithm for observation scheduling.

Personalize day choices.

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Open questions

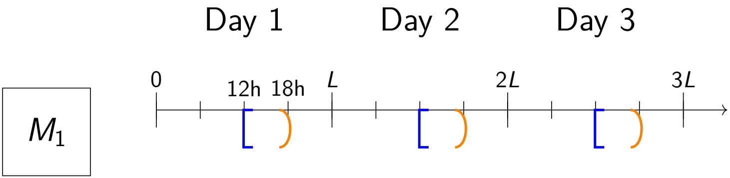
- Constant factor approximation algorithm?
- More efficient fixed-parameter algorithms?

Outline

Postdoc: daily time windows

LIP, ENS de Lyon Nov. 2024 - Apr. 2026

- *Topic:* Scheduling radio-astronomical observations.
  - Joint work with Frédéric Vivien and Anne Benoit.
  - Partnership with the ECLAT laboratory (HPC & AI for astronomy & astrophysics).
  - Access to NenuFAR radio-telescope usage data.



References I

Lenstra, J., Rinnooy Kan, A., and Brucker, P. (1977).
Complexity of machine scheduling problems.
Ann. of Discrete Math., 1:343–362.