Single machine scheduling of low-frequency radio-astronomical observations

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May 12, 2026

Outline

Outline

SKA Observatory

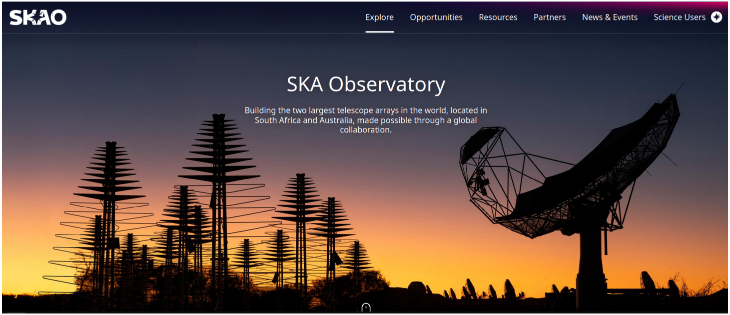

Figure: SKAO project home page

Observing from the Earth

Figure: Time lapse photography (Animalia Life)

Altitude over time

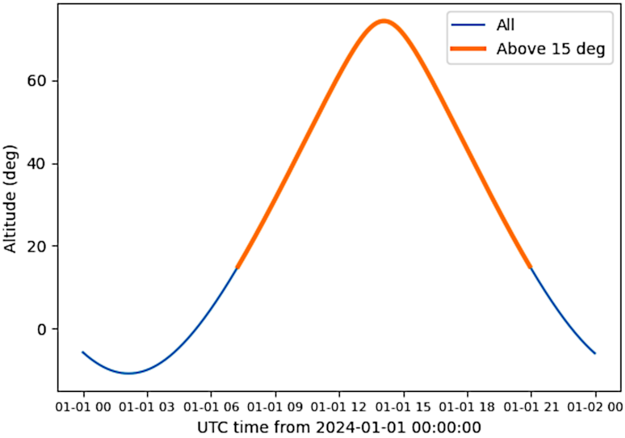

Figure: Altitude of star KELT 16 from the NenuFAR radio-telescope on 1 January 2024.

Altitude over time

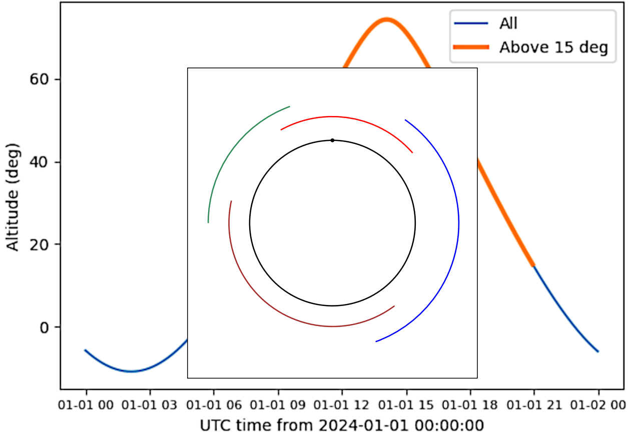

Figure: Altitude of star KELT 16 from the NenuFAR radio-telescope on 1 January 2024.

Postdoc: "Observation Scheduling"

ROMA team, LIP, ENS de Lyon Nov. 2024 - Now

- *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.

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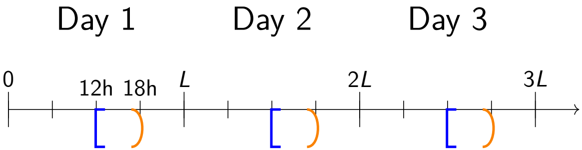
- *Model:* **"Observation Scheduling"**
  - Day length $L \in \mathbb{R}_{>0}$.
  - Processing time $p_j \in \mathbb{R}_{>0}$, daily release time $r_j \in [0, L)$ and daily deadline $d_j \in [0, L)$.



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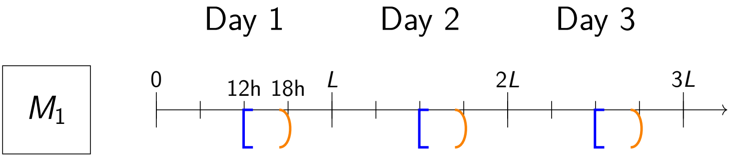
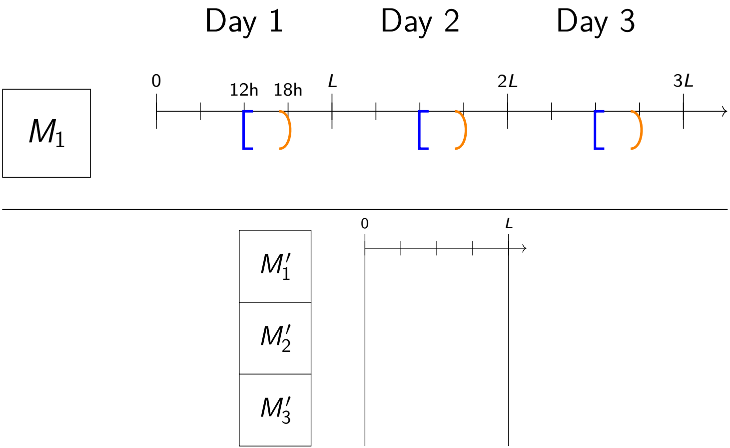
- *Model:* **"Observation Scheduling"**: $1|\text{periodic}_L(r_j, d_j)|C_{\max}$.
  - Day length $L \in \mathbb{R}_{>0}$.
  - Processing time $p_j \in \mathbb{R}_{>0}$, daily release time $r_j \in [0, L)$ and daily deadline $d_j \in [0, L)$.
  - Single machine, non-preemptive, minimizing idle time (i.e., makespan).



Postdoc: "Observation Scheduling" (cont.)



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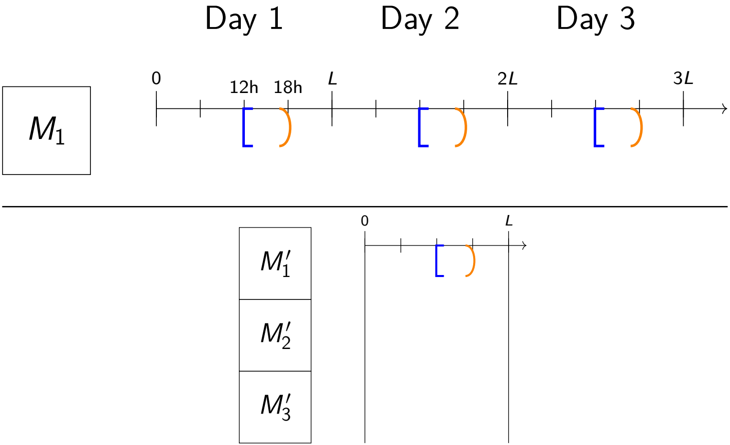

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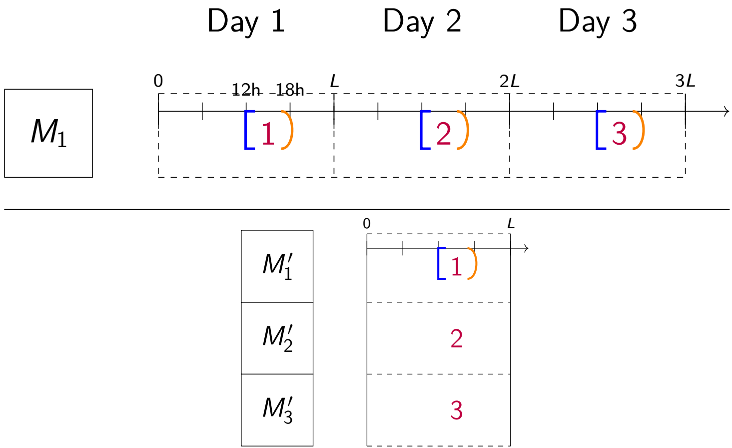

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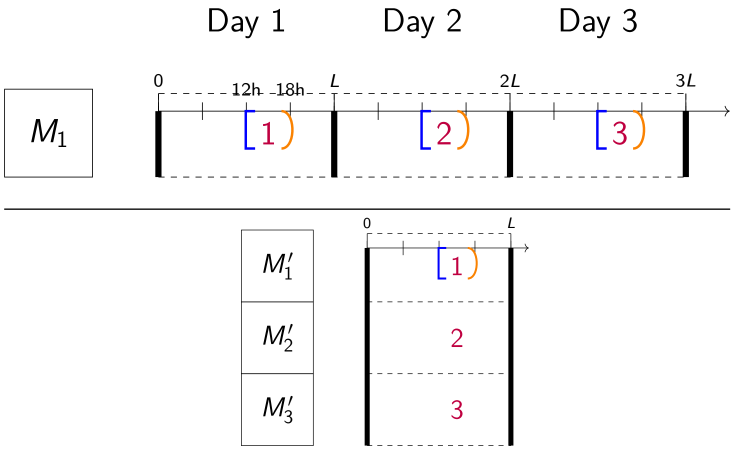

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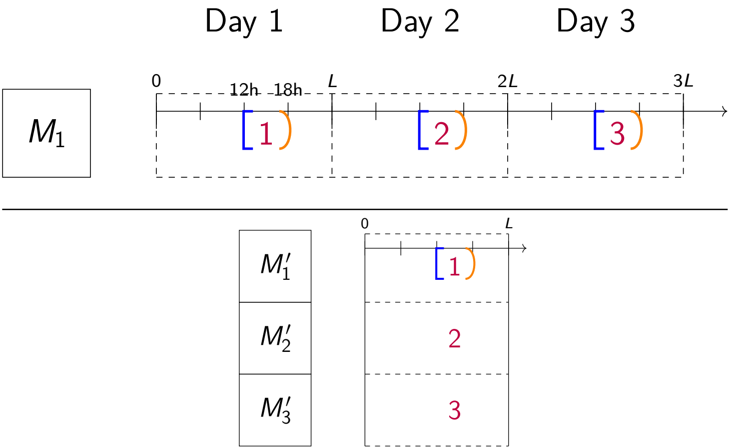
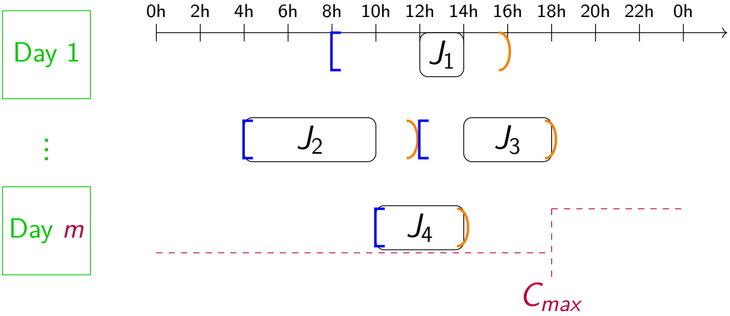


Day-overlapping job $\Longrightarrow$ time window over consecutive days.

Scheduling observations



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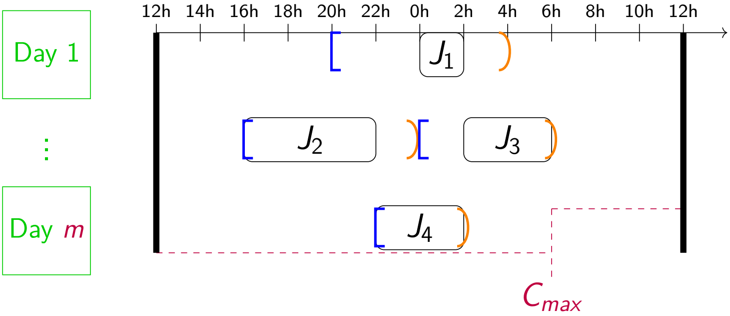
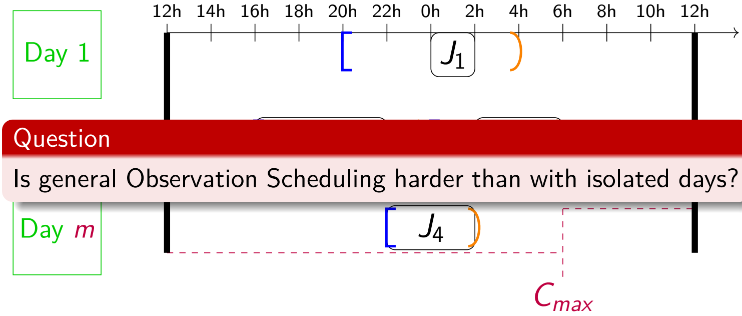


With isolated days: $P|r_j, d_j|\min(m)$.

Scheduling observations



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Is general Observation Scheduling harder than with isolated days?

With isolated days: $P|r_j, d_j|\min(m)$.

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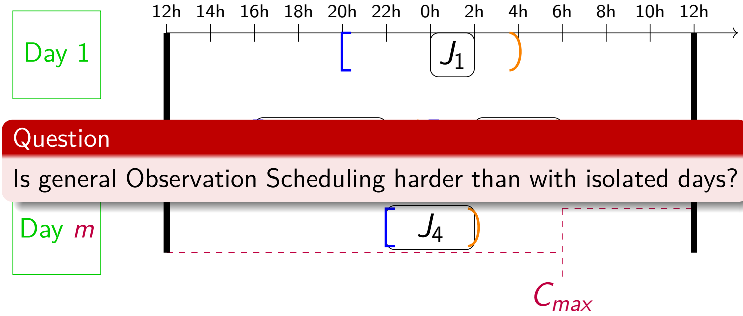

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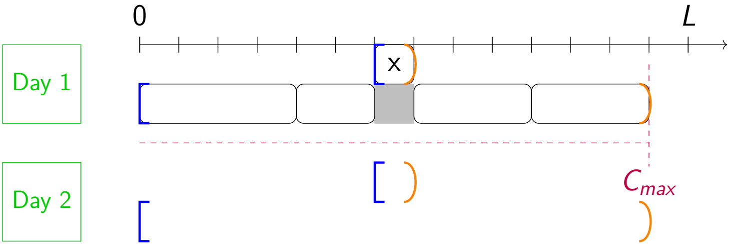
One day: strongly NP-complete [Lenstra et al., 1977].

Outline

$(2-\varepsilon)$-inapproximability



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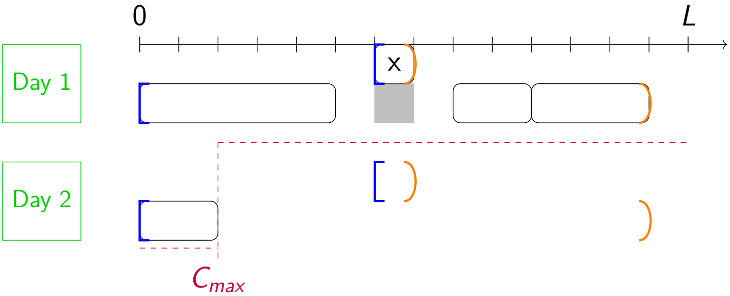

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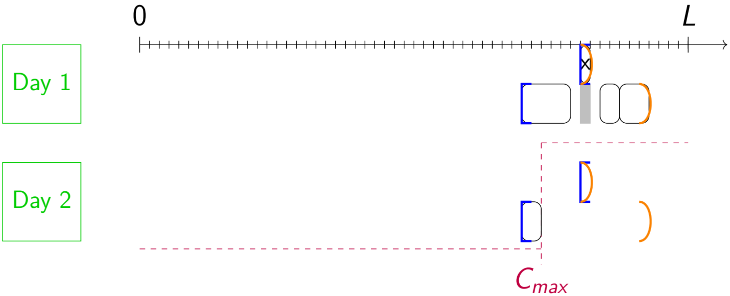

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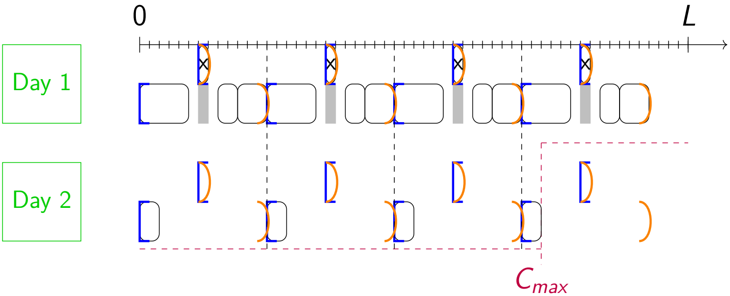

Observation Scheduling with isolated days.

- Goal: minimize the number of days.
  - $P|r_j, d_j|\min(m)$.

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Job Interval Selection problem.

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Job Interval Selection problem.

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- 1/2-approximation: "Earliest Completion Time". [Spieksma, 1999]

$\mathcal{O}(\log(n))$-approximation (cont.)

Remark

W.l.o.g: $\forall j, p_j \leq L$.

Proposition

If $L \leq OPT$, then any f-approximation algorithm with isolated days is a $[(2 + L/OPT) \cdot f]$-approximation algorithm for Observation Scheduling.

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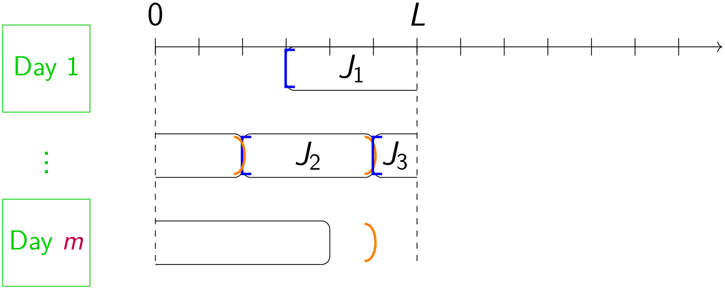

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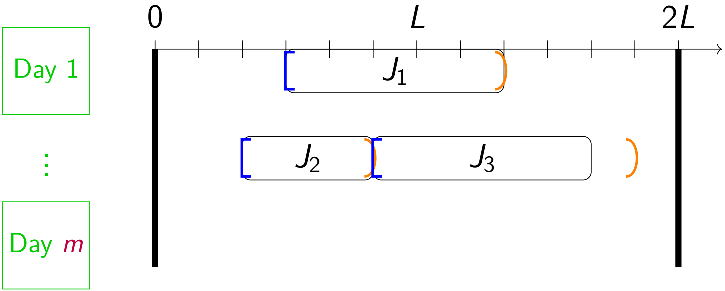

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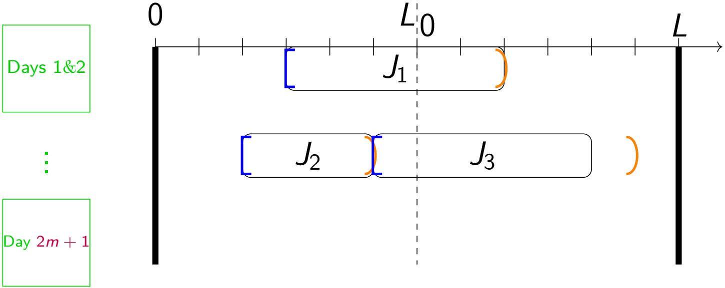

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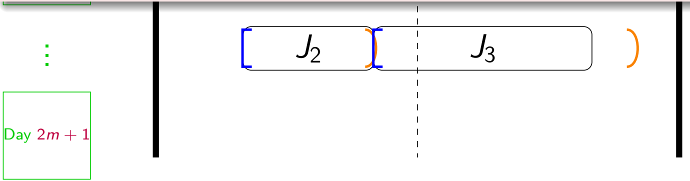
0 L 0

Question

Constant approximation algorithm?



Outline

Going beyond NP-hardness

- Problem $\mathcal{P}$, instance $\mathcal{I}$.
- P: deterministic time $\mathit{poly}(|\mathcal{I}|)$.
- NP: nondeterministic time $\mathit{poly}(|\mathcal{I}|)$.

Going beyond NP-hardness

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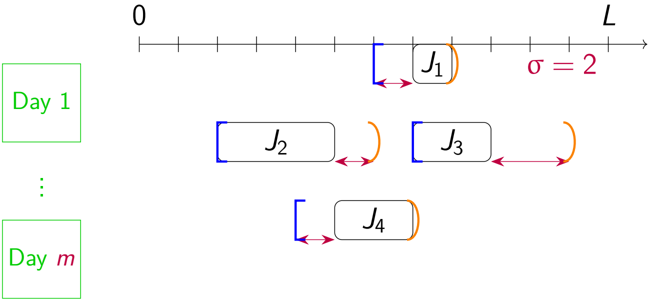
  - para-NP-complete: NP-complete for some fixed k.

Scheduling with tight windows



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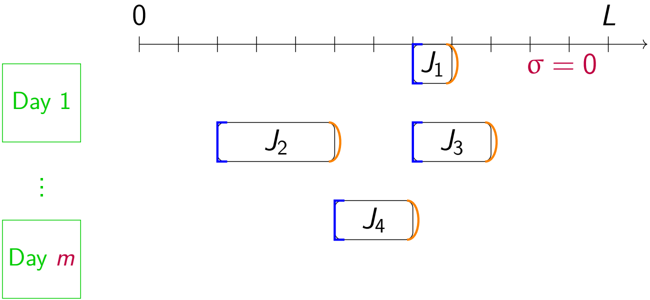

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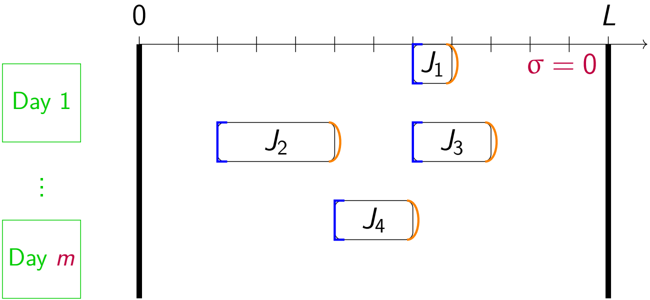

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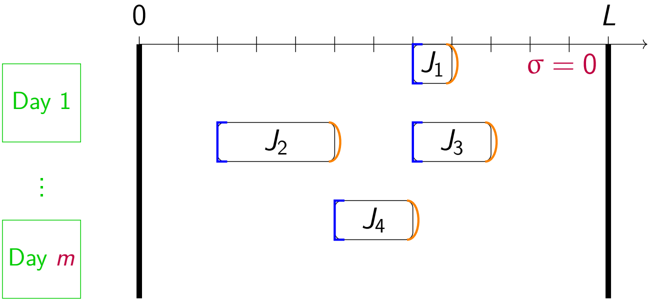

Interval graph coloring: $\mathcal{O}(n \cdot \log(n))$ time.

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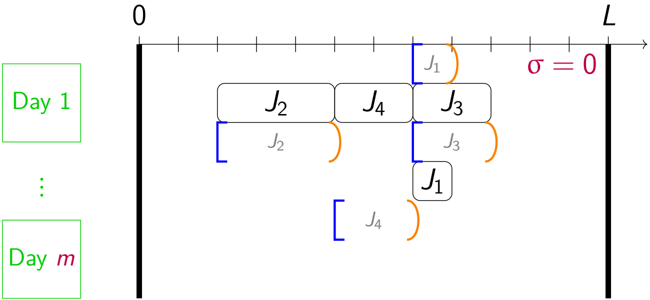

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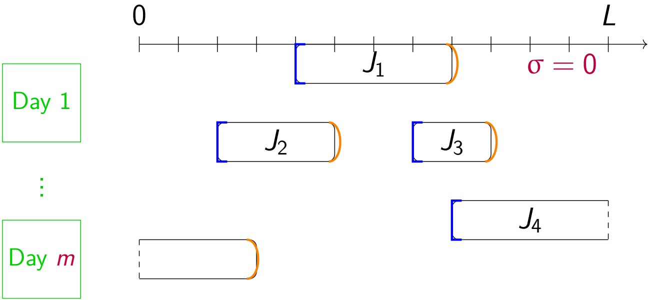

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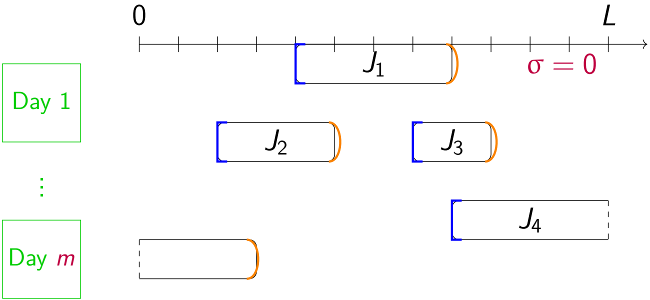

Circular-arc graph coloring: NP-complete [Garey et al., 1980].

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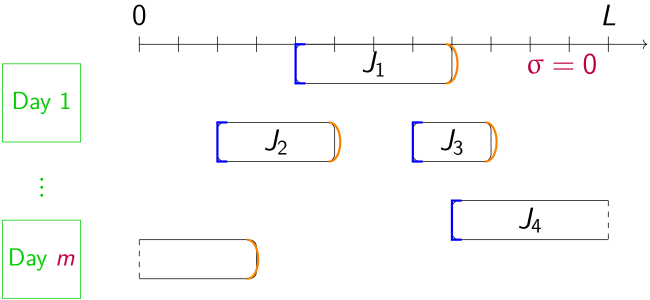

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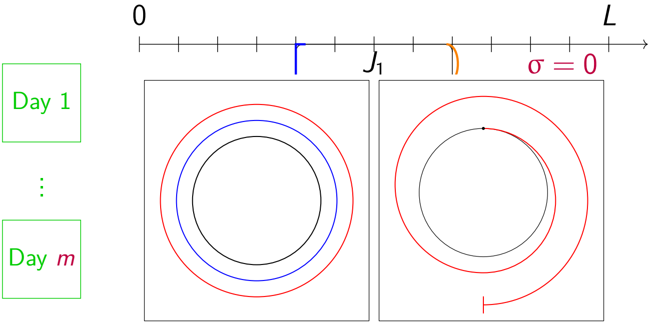

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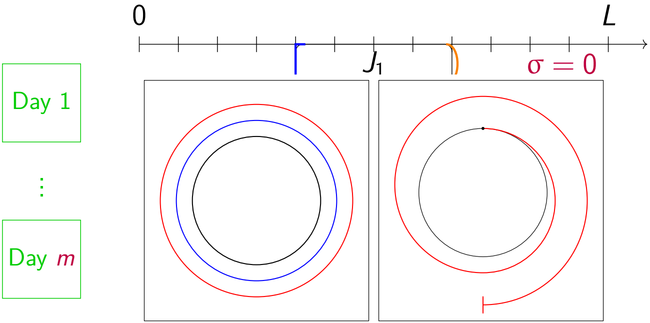

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Multi-slot Just-in-time: $\mathcal{O}(n \log(n)^2)$ time [Dereniowski and Kubiak, 2010].

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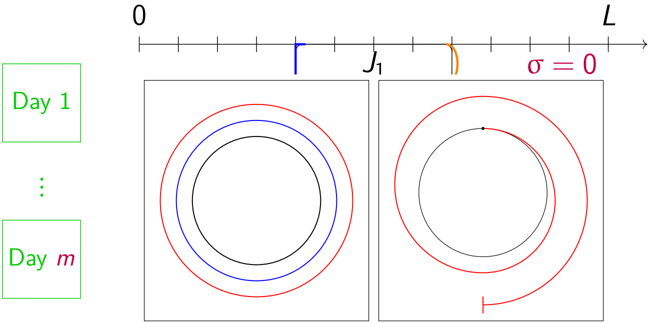

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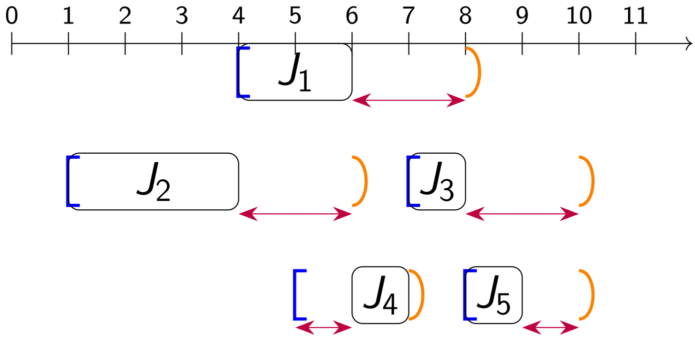
$\rightarrow$ TSP with a Gilmore-Gomory distance matrix.

[Gilmore and Gomory, 1964, Vairaktarakis, 2003]

Width μ



$\sigma = 2$: NP-complete [Cieliebak et al., 2004].

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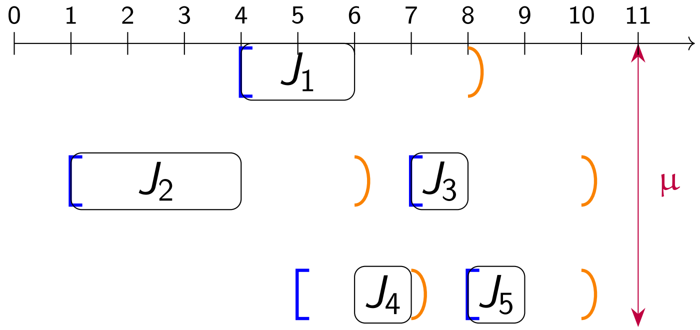

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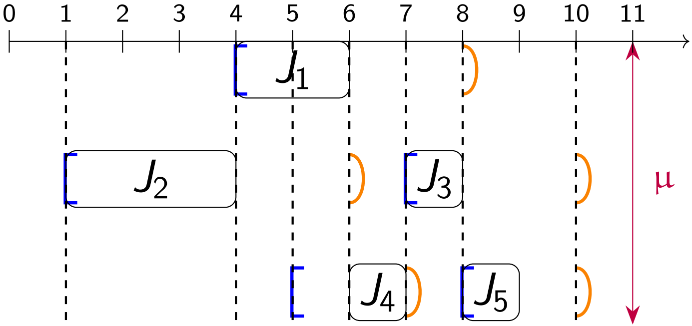

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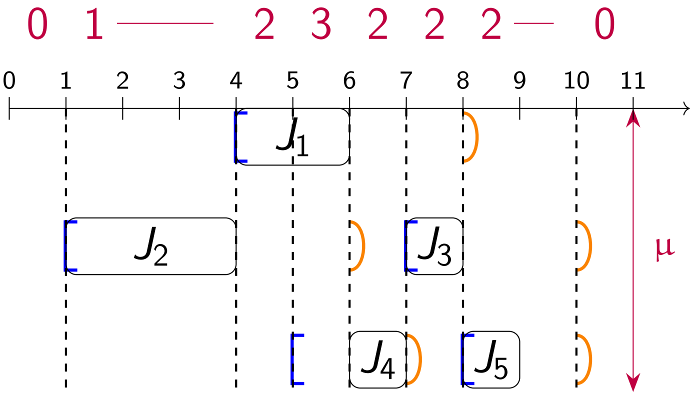

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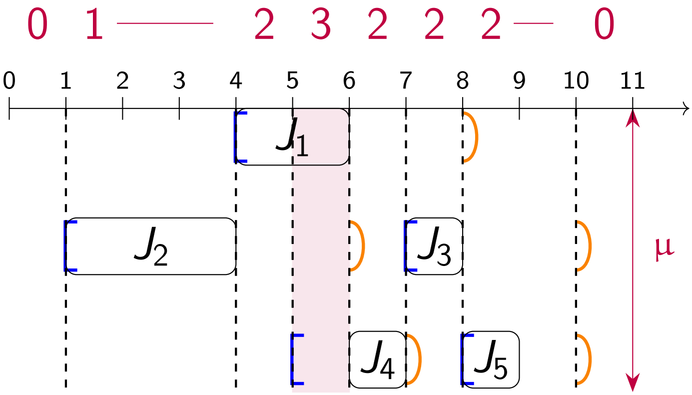

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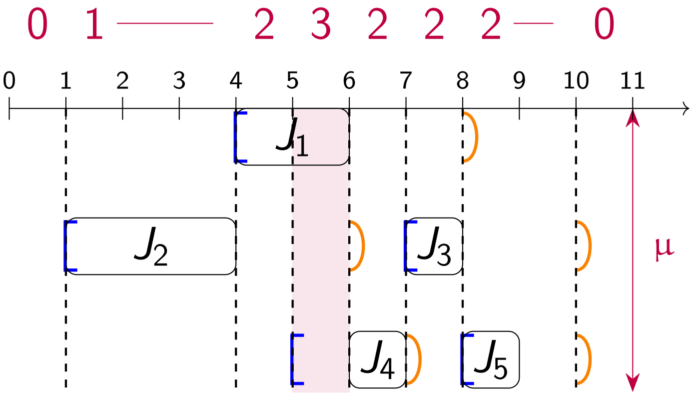

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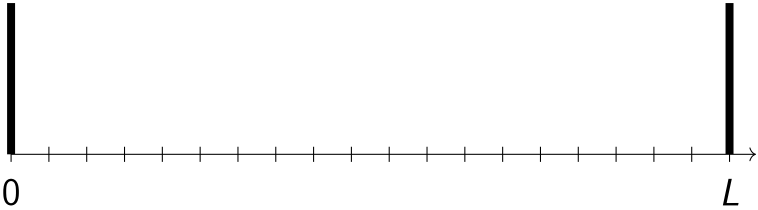
$\mu = 4$: NP-complete [Hanen and Munier Kordon, 2023].

FPT membership with $(\mu + \sigma)$: border schedules



- Isolated days: in $\mathrm{FPT}(\mu + \sigma)$.
  [Cieliebak et al., 2004, Hanen and Munier Kordon, 2023]

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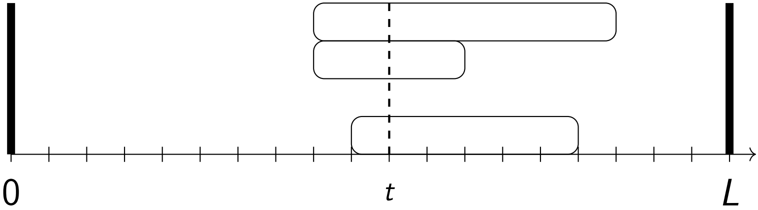

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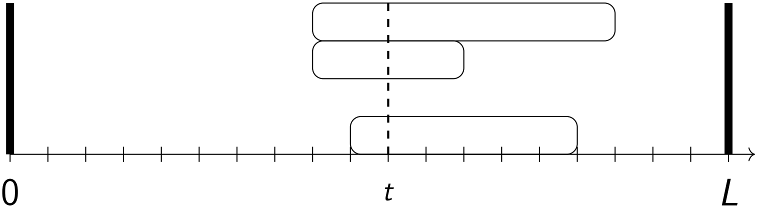

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- $\mathcal{O}([\mu(\sigma + 1) + 1]^m)$ border schedules associated to t mod L.

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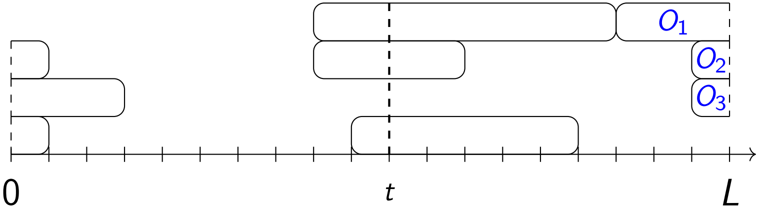

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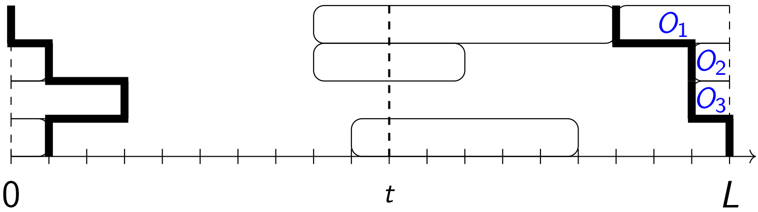

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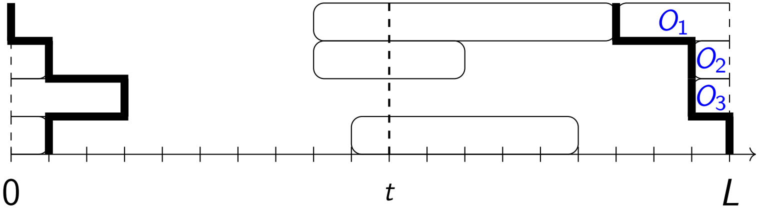

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Idea

For each of the $\mathcal{O}([\mu(\sigma + 1) + 1]^{m-1})$ border schedules associated to 0 mod L, solve an instance of "$P|r_j, d_j|\min(m)$ with machine availabilities".

Outline

Conclusion

Results: same as with isolated days

- $\mathcal{O}(\log(n))$-approximation with “Earliest Completion Time”.
- No $(2-\varepsilon)$-approximation algorithm (unless P $=$ NP).
- Fixed-parameter tractability: slack σ, width μ and $(\mu+\sigma)$.

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Future work

- More in-depth analysis (approx. factor, param. dependency).
- "Earliest Start Time" performance guarantee?
- Include observation data processing to the model.

Projet d'intégration : recherche (équipe DATA-PHM)

- **Approches frugales et robustes aux incertitudes**
  - Algorithmes conviviaux à garantie de performance.
  - Hybridation apprentissage machine / méthodes de décomposition.
  - GT SCALE (Scheduling for Computing Architecture and Low Energy).
    - Lyon (LIP), Grenoble (LIG), Besançon (département DISC).
- **Interdisciplinarité et enjeux sociétaux**
  - Postdoc (LIP, Lyon) : radio-astronomie (projet SKAO, laboratoire ECLAT (Alan Loh), radio-télescope NenuFAR).
  - Postdoc (G-SCOP, Grenoble) : recharge et vieillissement des batteries de bus électriques (Pierre-Xavier Thivel).
  - Projet ANR SOCLOUD (Jean-Marc Nicod).

Expériences d'enseignement

Médiation scientifique — Fév. 2026 - Auj.

- Accueil de collégiens/lycéens (2 à 3, stages d'observation).
- Journée "Sciences, un métier de femmes" (~15 lycéennes par binôme).
- Speed-meeting à la Maison des Mathématiques et de l'Informatique.

Université Claude Bernard Lyon 1 — 2025-2026

- L2 informatique.
- ***Modules :***
  - Algorithmique et programmation C++ (24h TP).
  - Bases de données et programmation web (22.5h TP).

Polytech Sorbonne — 2021-2024

- Diplôme d'ingénieurs, cursus Électronique et Informatique.
  - Étudiants et apprentis de première année (L3).
- ***Modules :***
  - Algorithmique (22h TD, 72h TP).
  - Programmation C (83h TP).
  - Outils pour l'informatique (15h TP).

Projet d'intégration : enseignement (génie industriel)

Thématiques

- Gestion de production
  - Planification, ordonnancement.
  - Maîtrise des flux industriels.
- Performance industrielle
  - Indicateurs de performance.
  - Modélisation et simulation.
- Maintenance et maîtrise des risques industriels
- Lean Manufacturing

Implication dans le service d'enseignement

- Accompagnement des élèves ingénieurs.
- Contenus pédagogiques innovants et transversaux.
  - Médiation scientifique.
- Tâches collectives (e.g., responsabilité d'UE, participation aux jurys/examens).

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Vairaktarakis, G. L. (2003).
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Journal of Scheduling, 6(6):499–520.