Challenges in tracking stock productivity and relaying to ground control

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1 Marmalade review of dynamic productivity

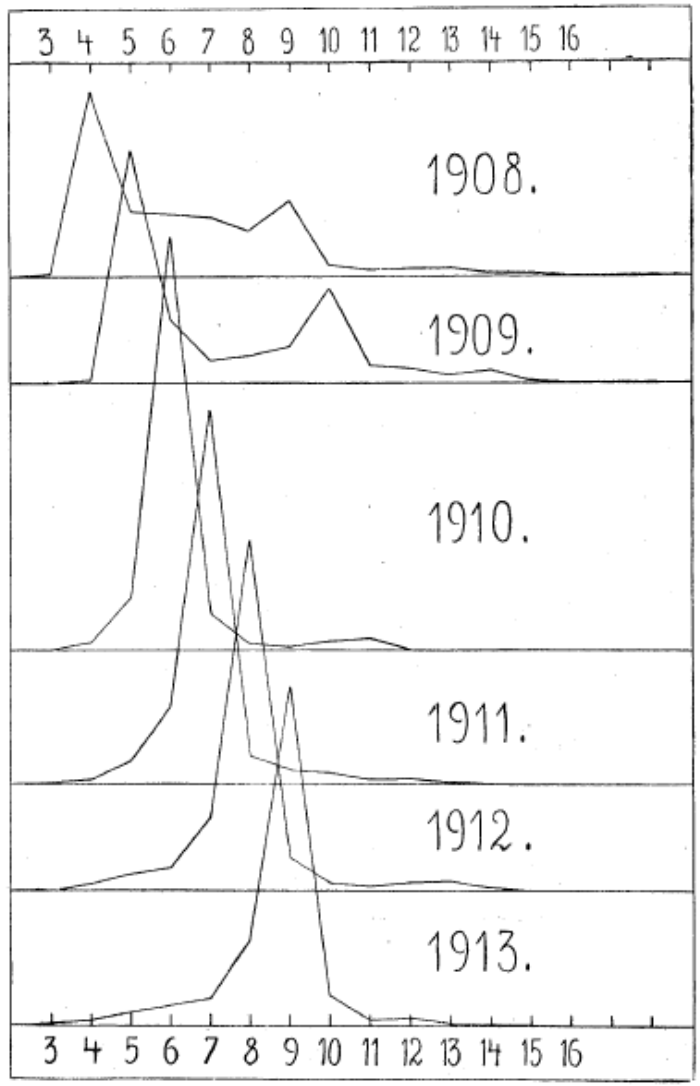
2 Status quo(ta)

3 Spacing out

4 Peterman's productivity method

5 Future forecasts

Hjort 1914



"It will therefore appear most probable that the renewal of the fish stock, as in the case of any stock on land, is dependent upon many factors, all necessary, and all more or less variable."

Beverton and Holt 1957

6.2 Year-to-year Variations in the Total Number of Recruits

In the expressions developed in §6.1.1 to relate the number of recruits to the number of eggs of which they are the progeny, the derived larval mortality coefficients [e.g. α and β of (6.10)] are treated as constants. Hence the models are deterministic in that they require that in a given population a certain number of eggs will always give rise to the same number of recruits. Now, it is characteristic of fish populations that the number of recruits varies greatly from year to year, even though egg-production may remain at a roughly constant level, and an important cause is variation in the pre-recruit mortality rate, especially during the early larval stages. This could be represented in a theoretical model by appropriate changes in coefficients such as $\mu_1(t)$ and $\mu_2(t)$ of (6.8). At the present time, however, it is scarcely possible to deduce the magnitudes of such parameters that would apply to a given set of environmental conditions (see §15.2.3), and discussion here will be restricted to establishing the effect of a varying recruitment on certain kinds of assessments needed for fishery regulation, without attempting to analyse the causes of that variation.

Ricker 1958

2C. Non-uniform recruitment. Use of catch per unit effort for estimating survival 46
Random variation in recruitment 46
Sustained change in level of recruitment 47
Extreme variation in recruitment 47
Trends in recruitment 47

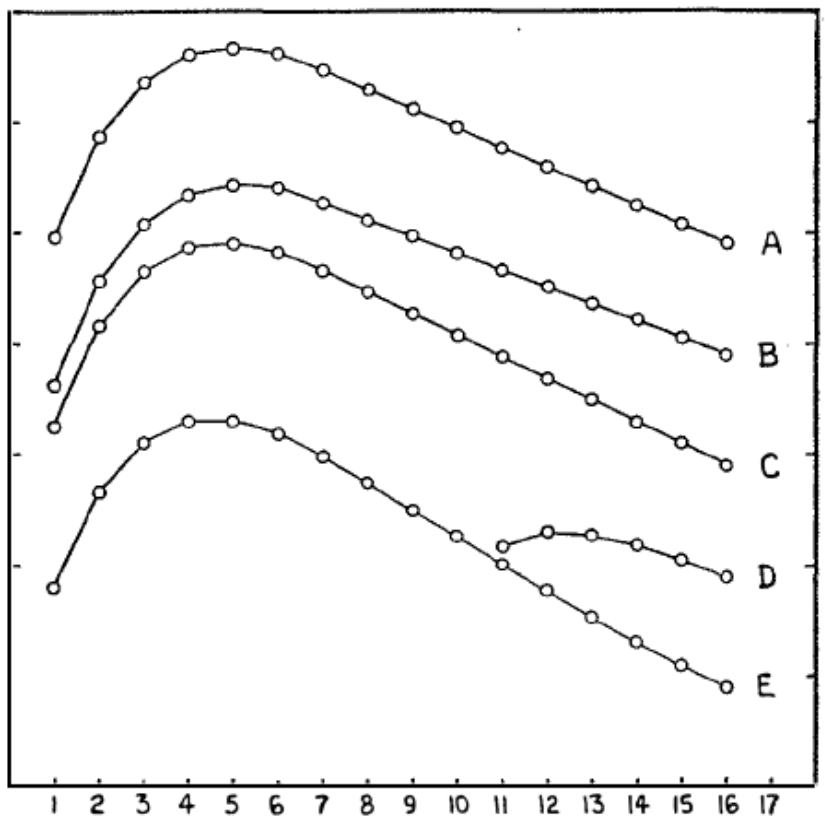
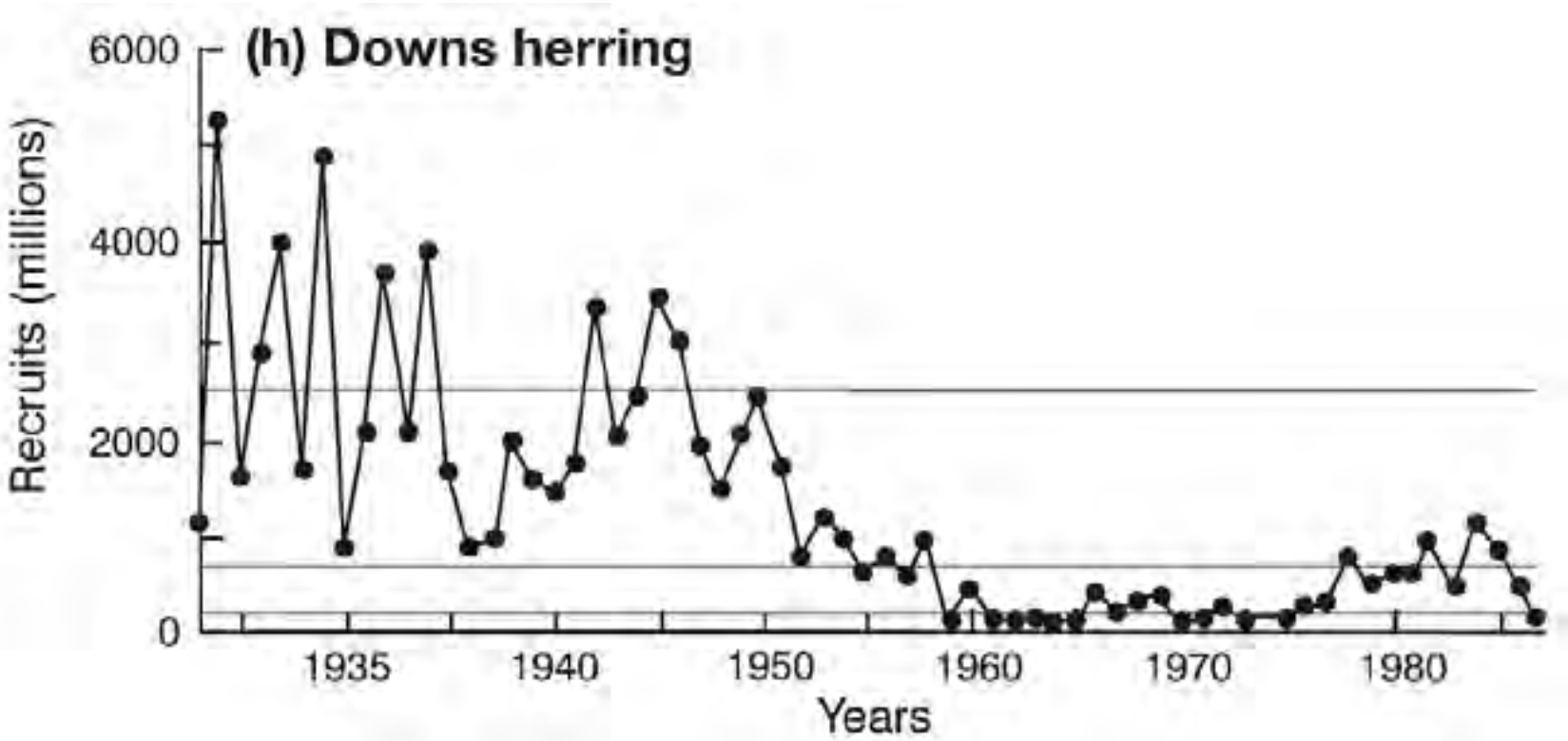


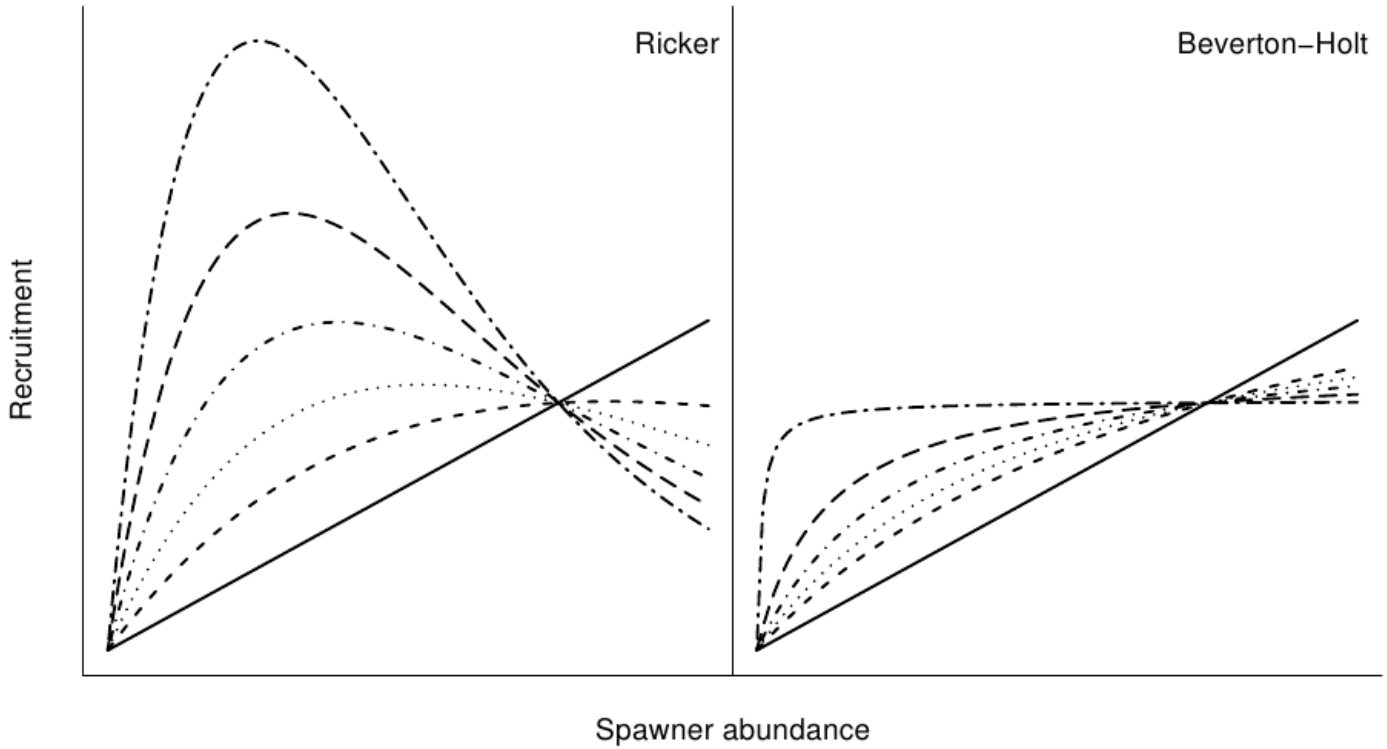
FIGURE 2.2. Effect of variation in recruitment on a catch curve when there is a constant survival rate of 0.67 from age VII onward. A. Steady recruitment.

Cushing 1968 *



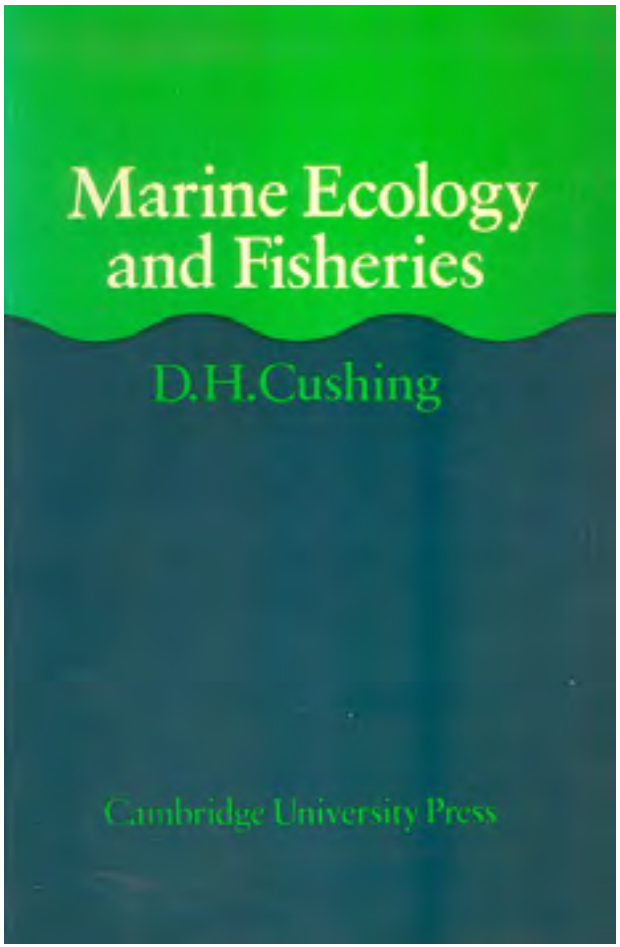
*Journal du Conseil International pour l'Exploration de la Mer, 32: 262-269

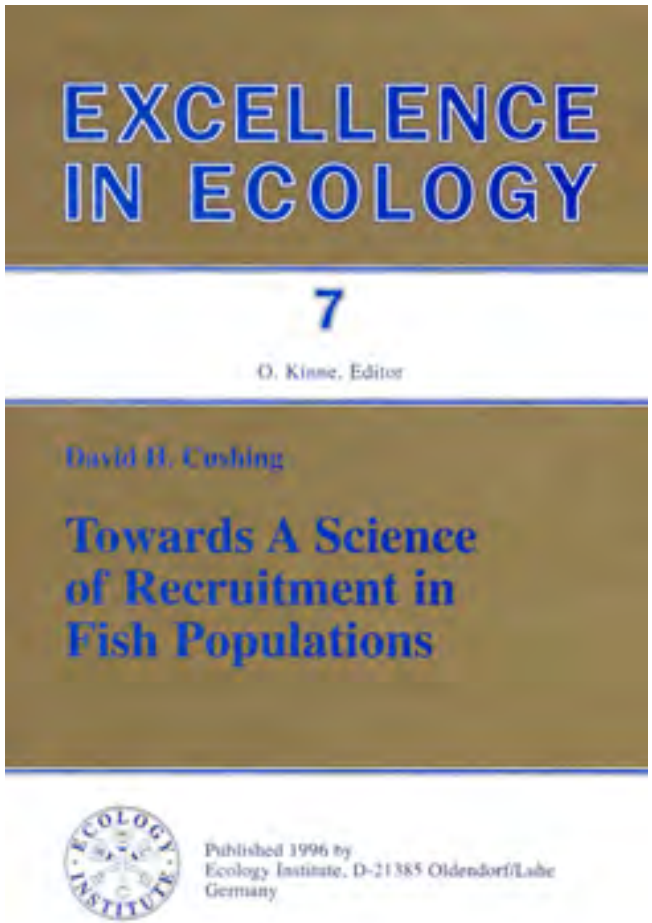
Recruitment uptake from earlier period



- Recruitment dynamically related to spawners
- Form considered static, save measurement errors

Further dynamics: Cushing, 1975, 1996





Focus on a mechanistic understanding of productivity variation in space and time

Myers 1998

Reviews in Fish Biology and Fisheries **8**, 285–305 (1998)

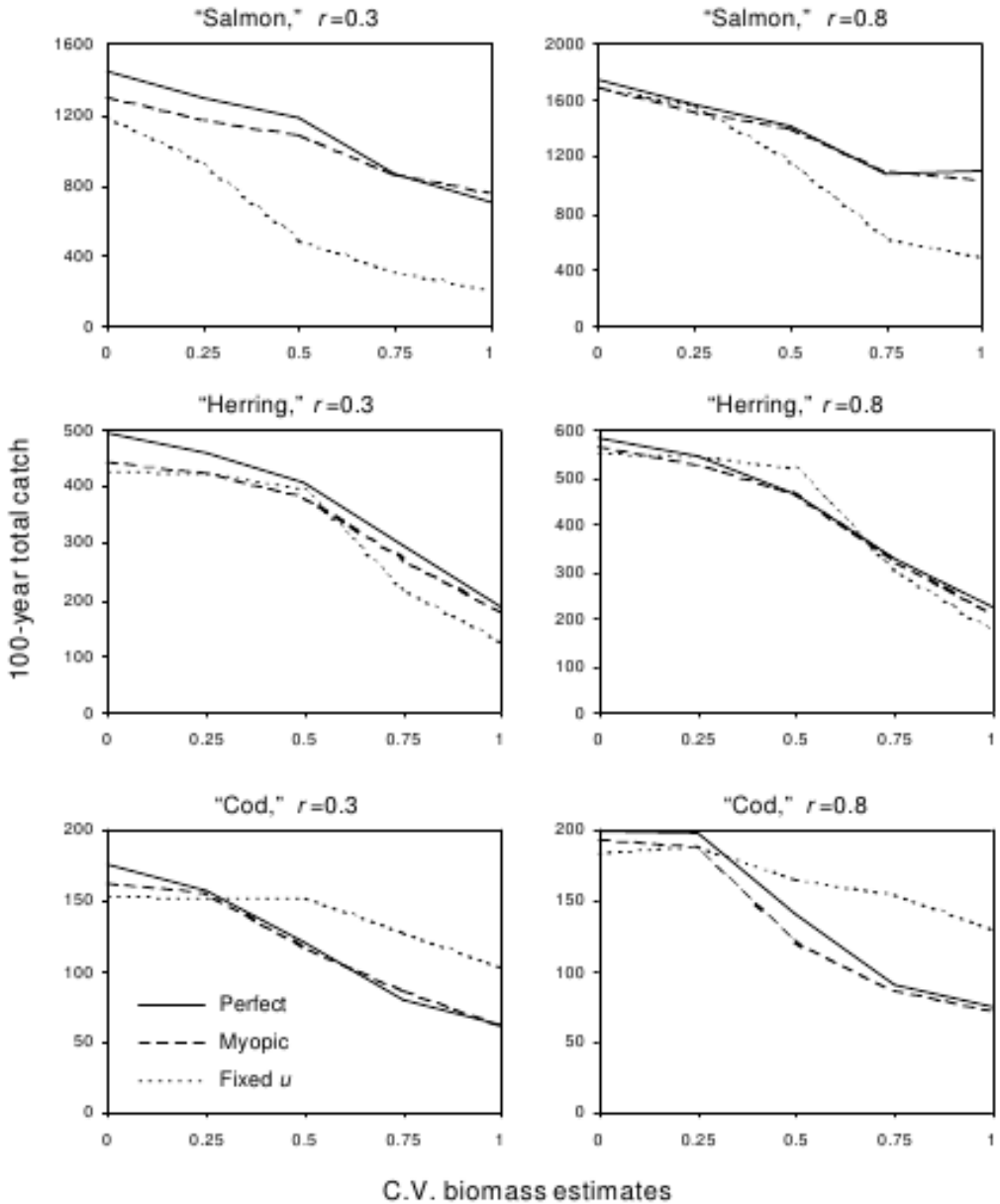
When do environment–recruitment correlations work?

RANSOM A. MYERS

Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1. E-mail: Ransom.Myers@Dal.Ca

- Re-analysis highlighted ephemeral relationships
- Rare use in management advice

Mitigating harvest strategies †



† Walters and Parma (1996). CJFAS, 53: 148–158.

Where we're at

Management advice based on:

- Static stock-recruit relationships fit to entire series or a window
- Static reference points
- To deal with variability:
  - Short-term forecast using average recruitment for interim
  - Where interim year recruitment differs greatly from the assumed level, the forecast may undergo an *in-year adjustment* (often $F \uparrow$)
  - Management procedures/plans to mitigate for the variability

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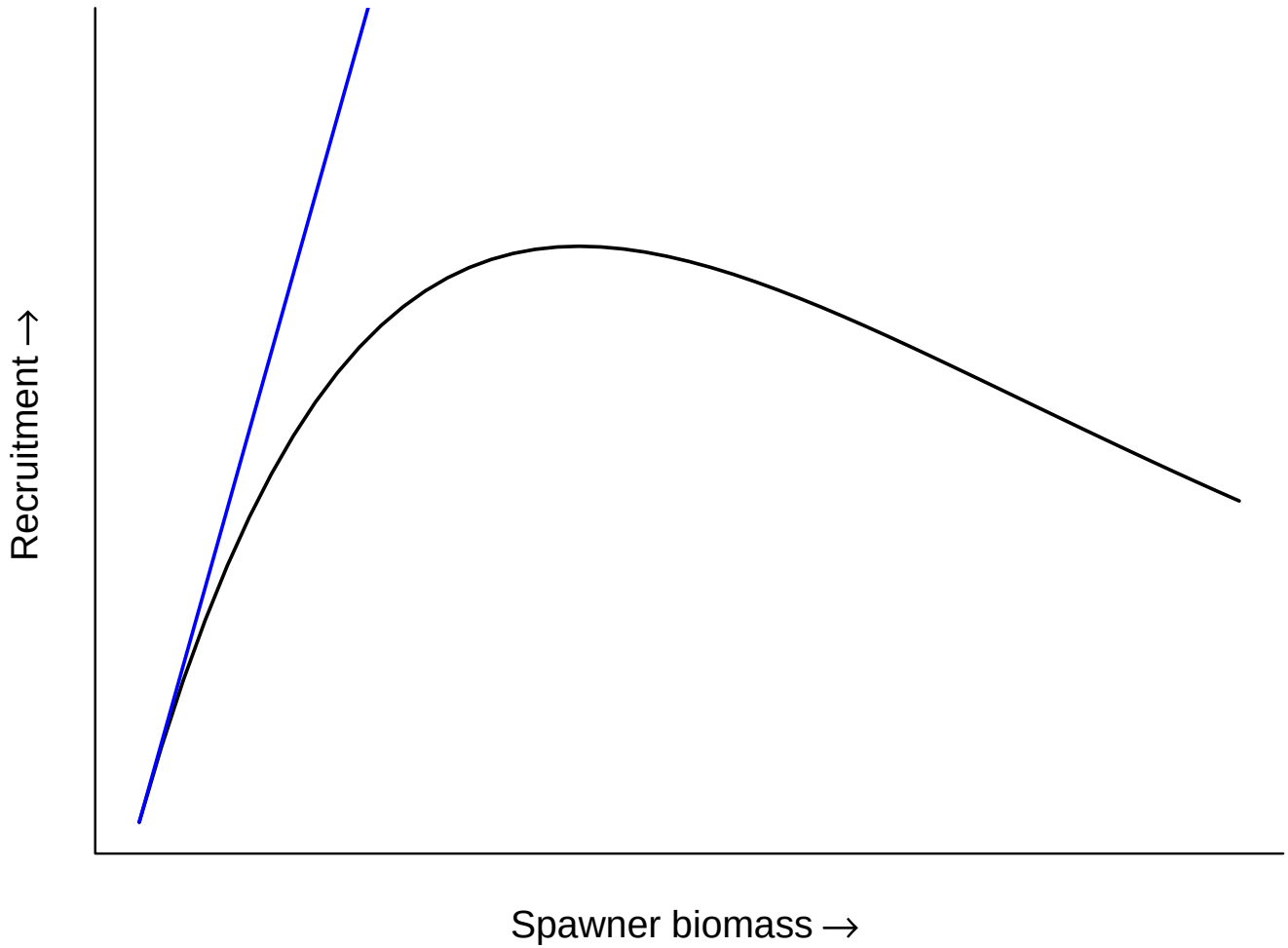
Tradition



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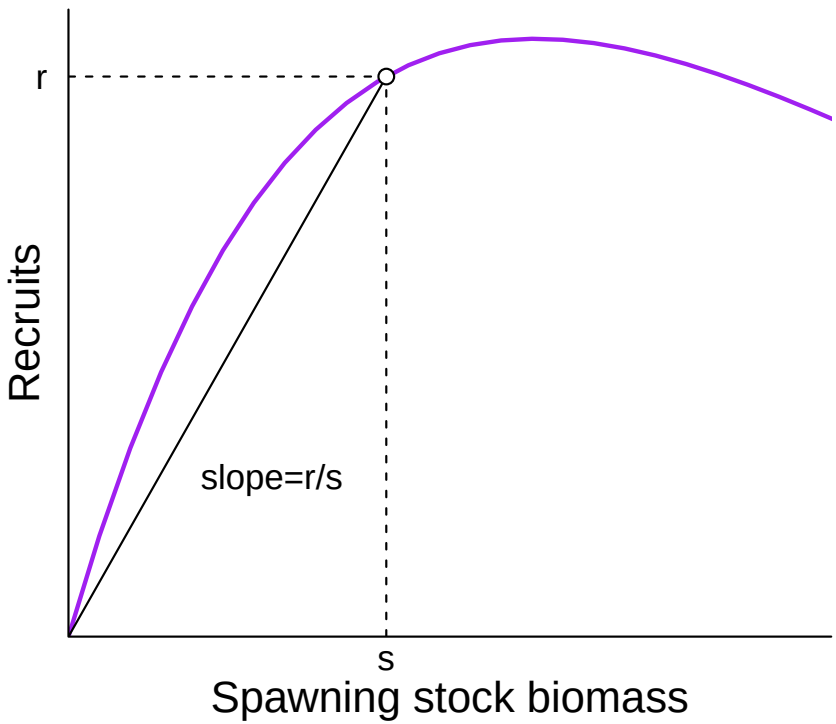
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Recruits
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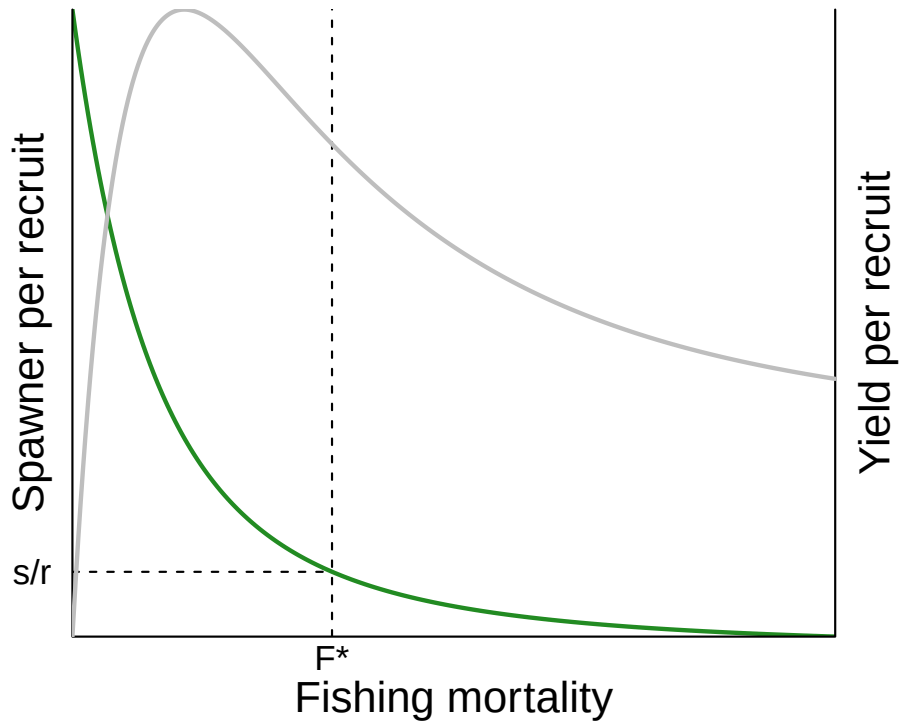
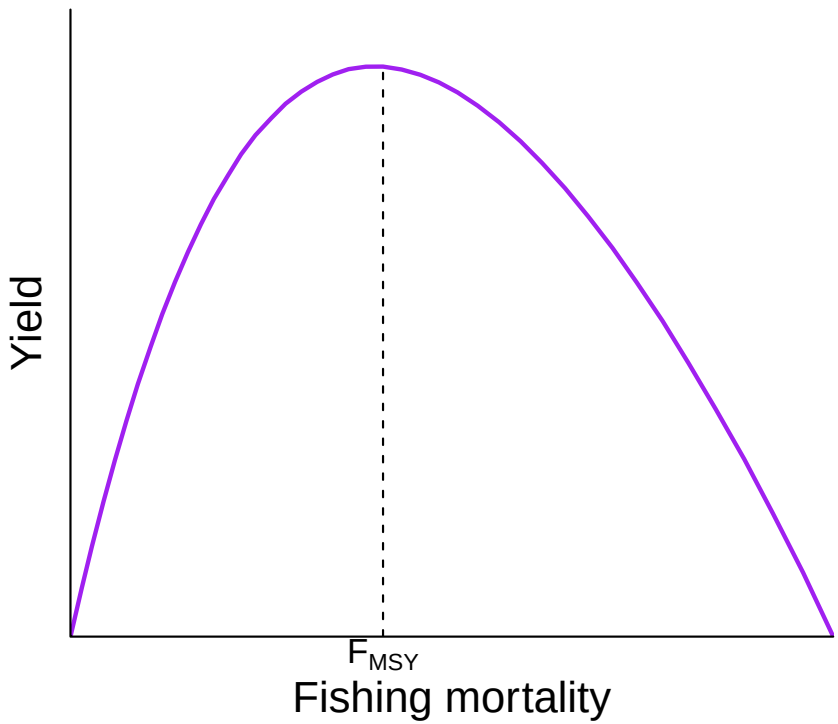
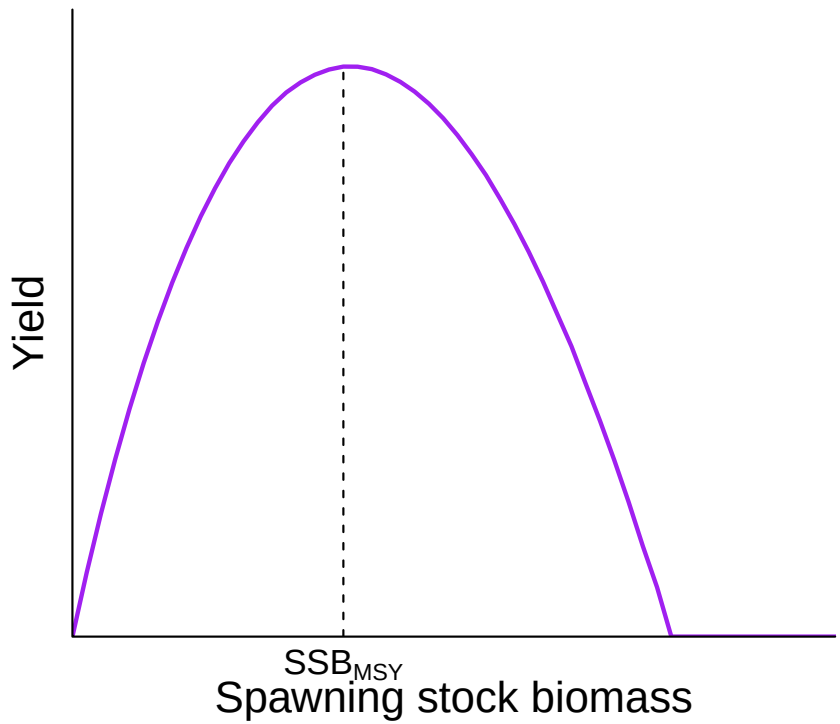
s
Spawning stock biomass


Spawner per recruit
s/r
Yield per recruit
F*
Fishing mortality

Tradition


Yield
F_{MSY}
Fishing mortality


Yield
SSB_{MSY}
Spawning stock biomass

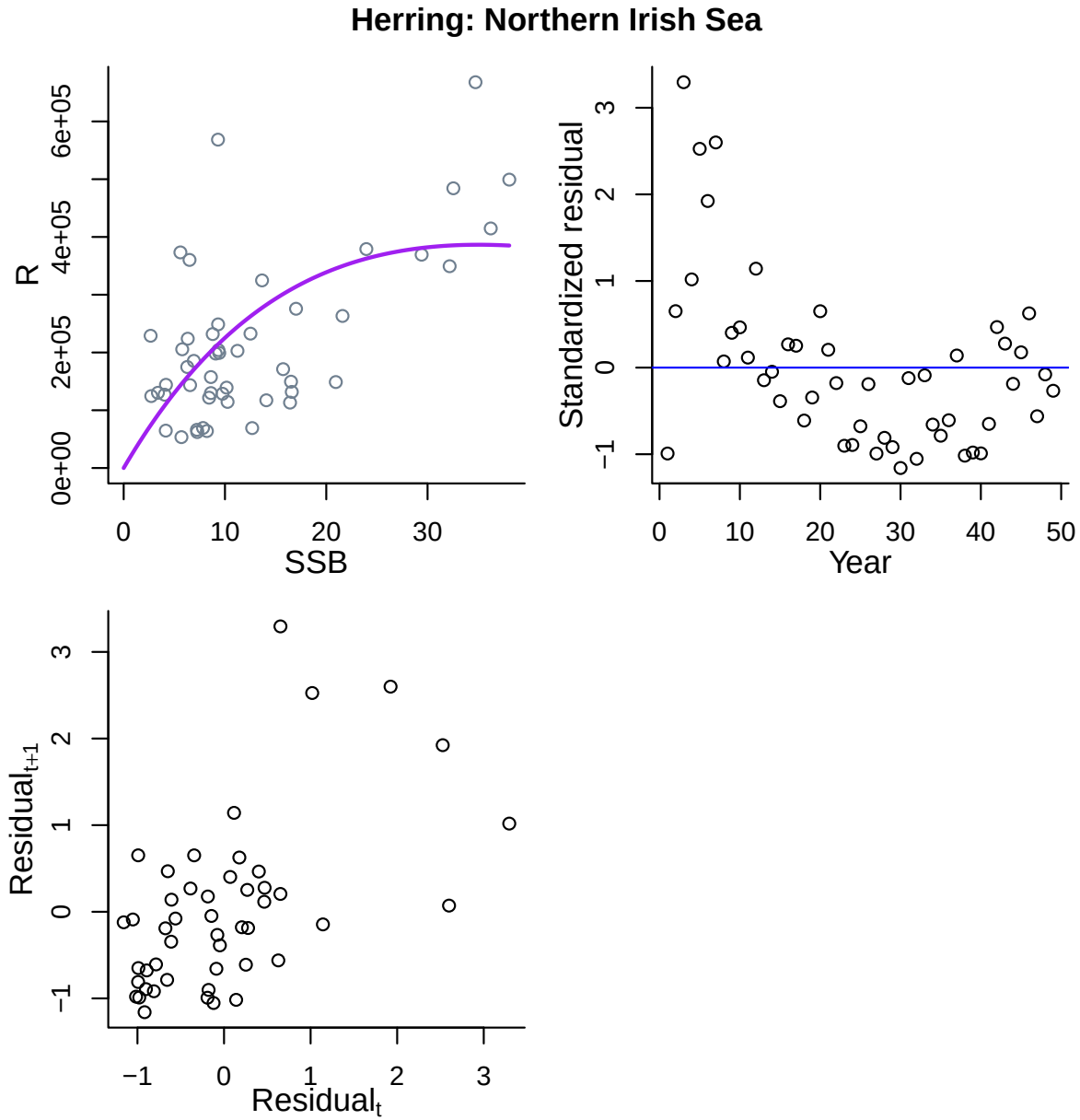
Traditional woes

All components for estimating *MSY*-based reference points can vary in time:

- Weights-at-age, maturity-at-age
  - Relatively easy to measure
- Selectivity
  - Can be modelled (e.g., a4a additive approach to separable model)
- Natural mortality
  - Difficult but in terms of research focus *M* has dominated the applied focus of EBFM thus far
- Year-class variability
  - Somewhat of a stagnation of recruitment research (ephemeral correlations). Yet, it may be here that we have the greatest opportunity to empirically deliver on some of the requirements of EBFM

Traditional woes

Typical fit



Traditional woes

Traditional approach is to account for autocorrelation on the residuals (GLS-type) correcting the degrees of freedom for inference on the constant parameters
However:

- Autocorrelation is often the dominant feature of SR data
- Residual corrections are shoe-horning exercises
- Autocorrelation/non-constant variance are often the most interesting
  - They mean there's more to the story than our present model of the system!
- Need to keep track of the changes somehow

[...]the dynamics of fish stocks are subject to changes in time, particularly due to fishing pressure but perhaps also pollution and other environmental effects, it may be the case that a particular stock will exhibit different stock-recruitment relationships over different periods of time.

Iles (1994)

Pacific salmon (Oncorhynchus spp.) populations can experience persistent changes in productivity[...] Management agencies need to rapidly and reliably detect such changes to avoid costly suboptimal harvests or depletion of stocks.

Peterman et al. (2000)

The methodologies used to estimate weights-at-age and recruitment have in common their reliance on an average over some past period as an indicator of a future condition. Clearly, this assumption has been inappropriate for both parameters, owing to prolonged trends during specific periods.

Reeves and Pastoors (2007)

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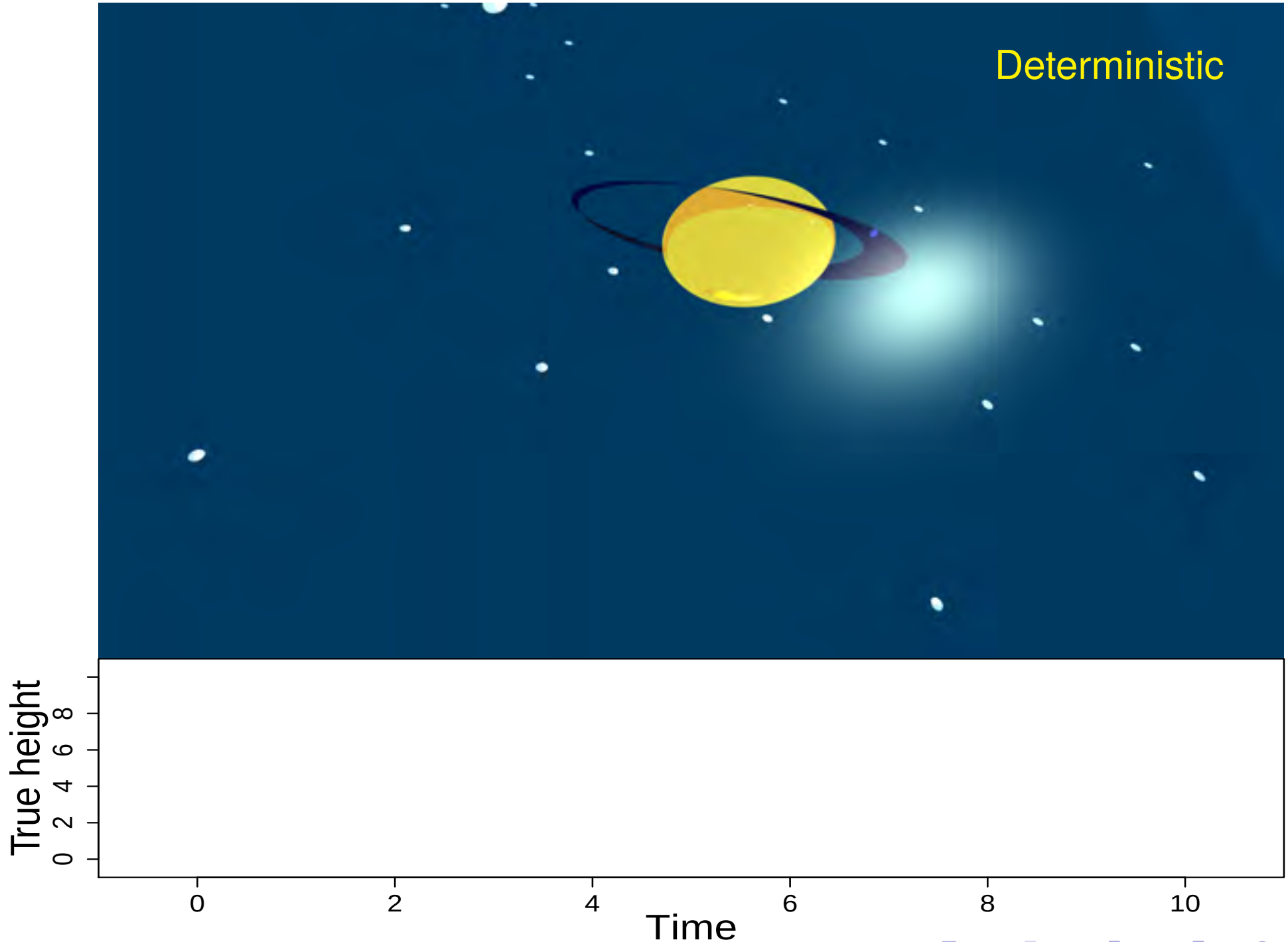
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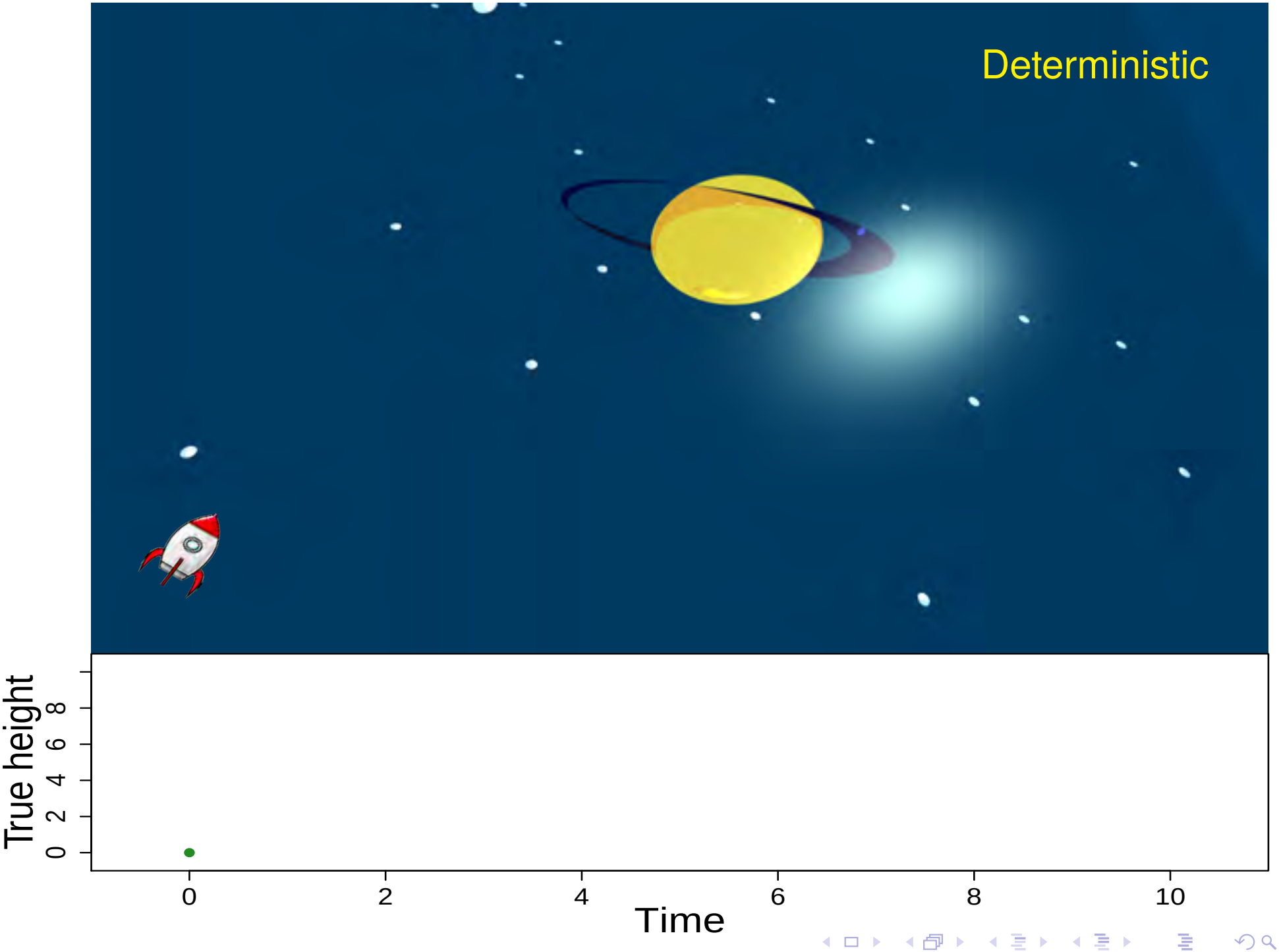
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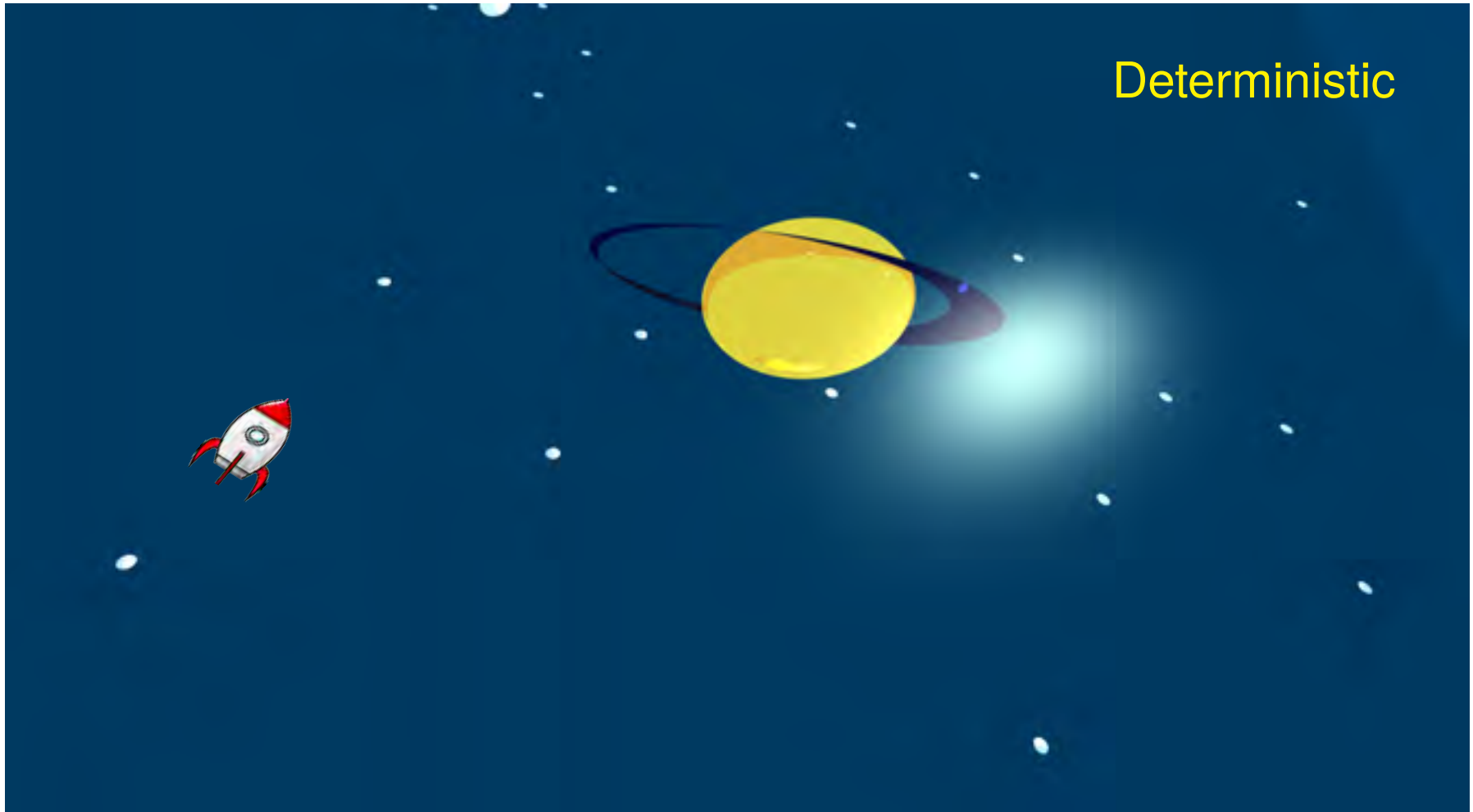
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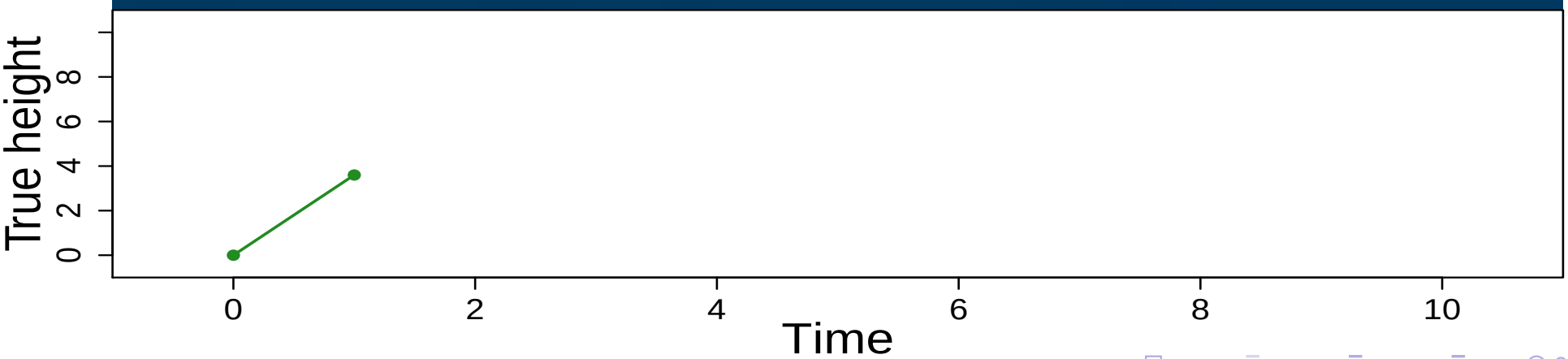
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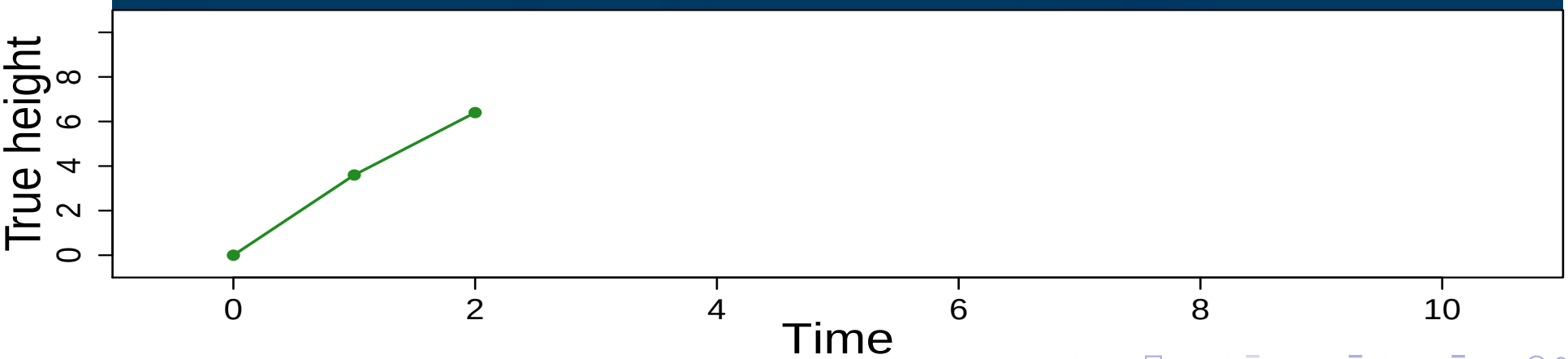
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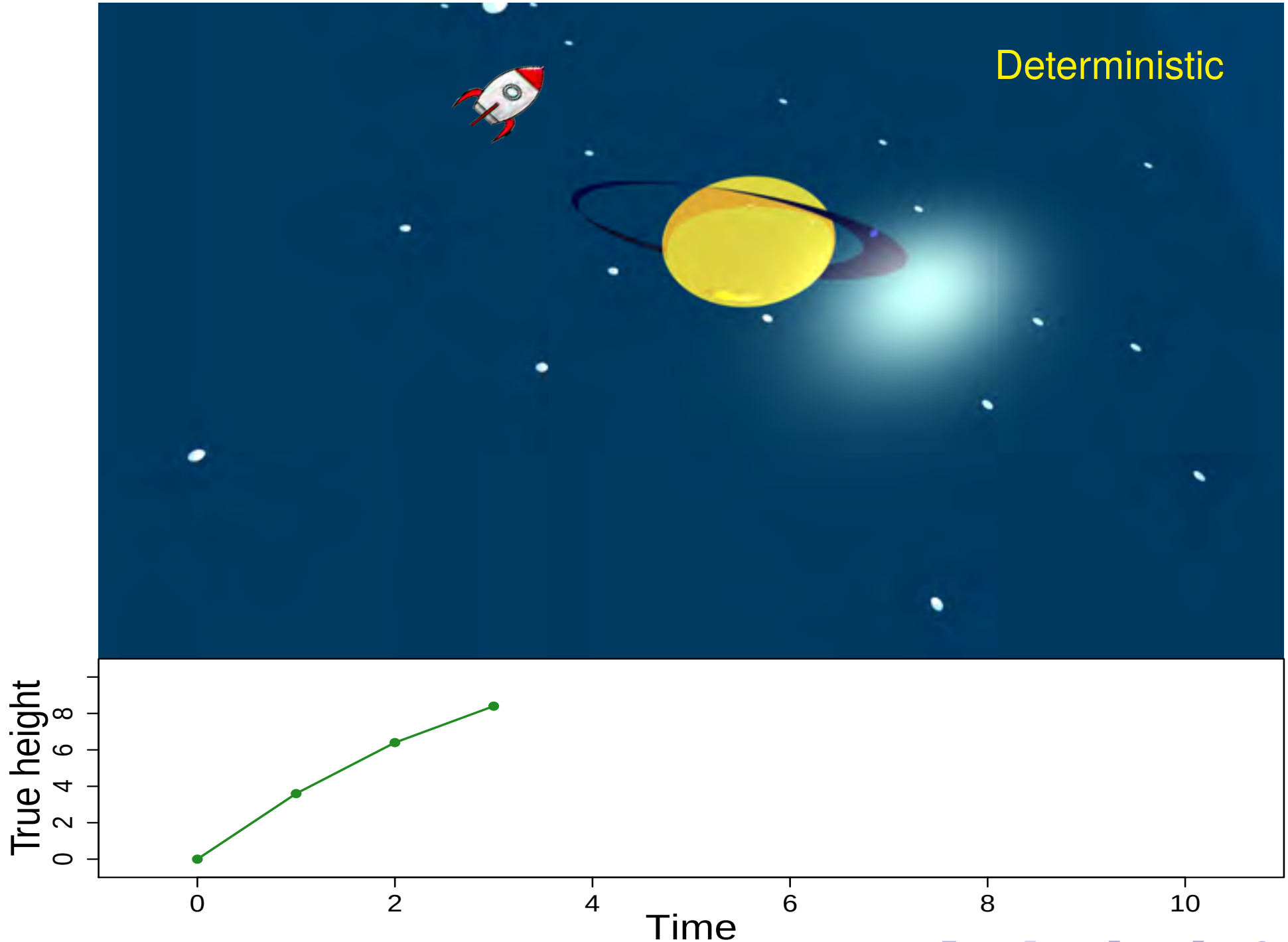
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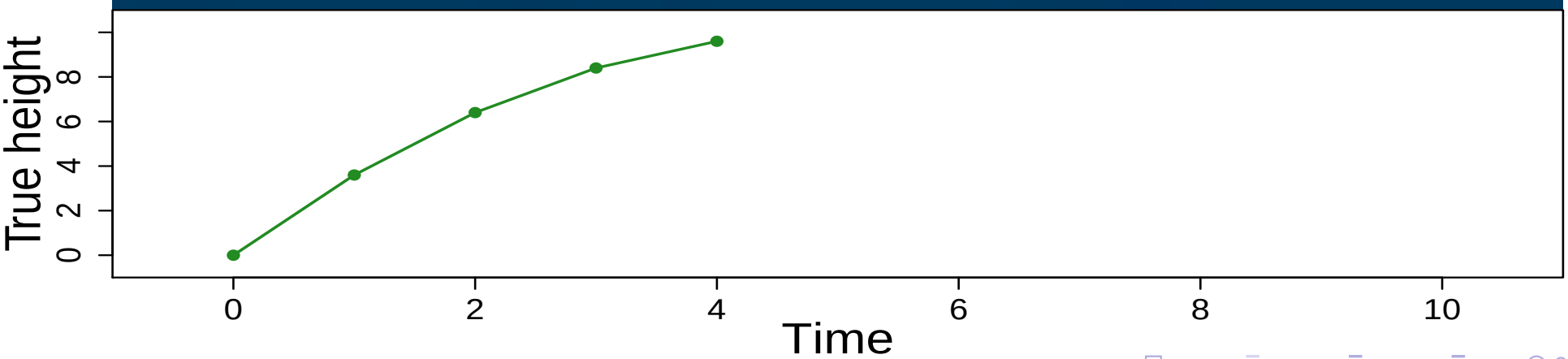
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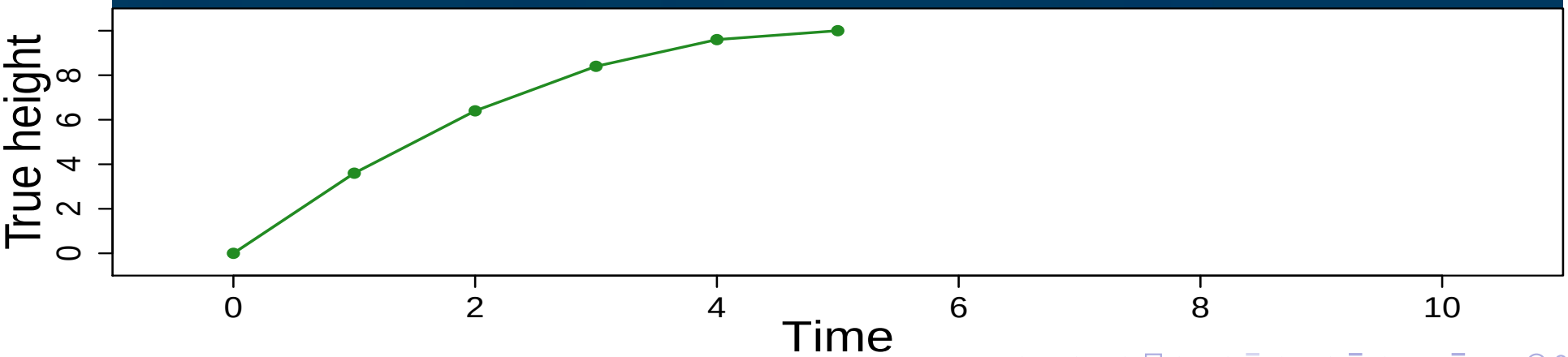
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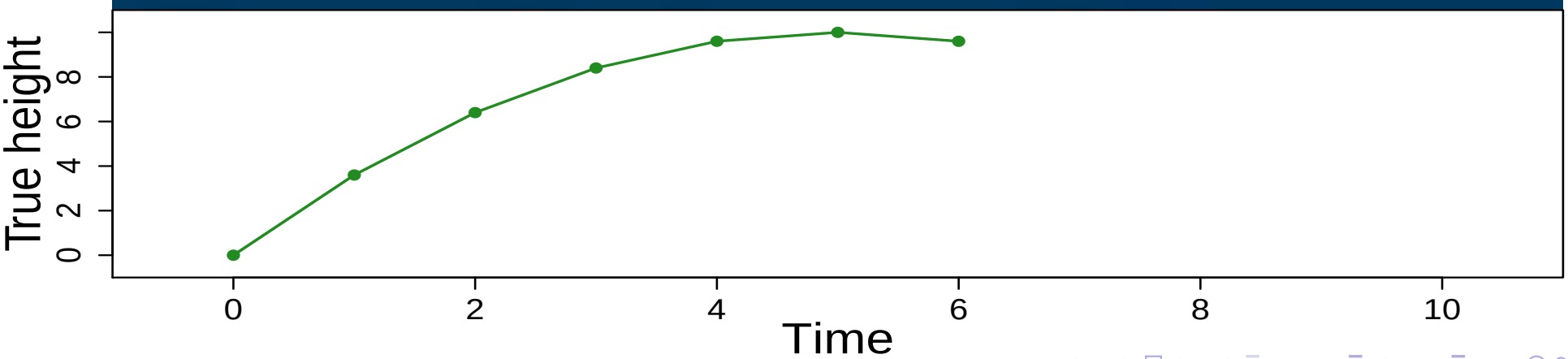
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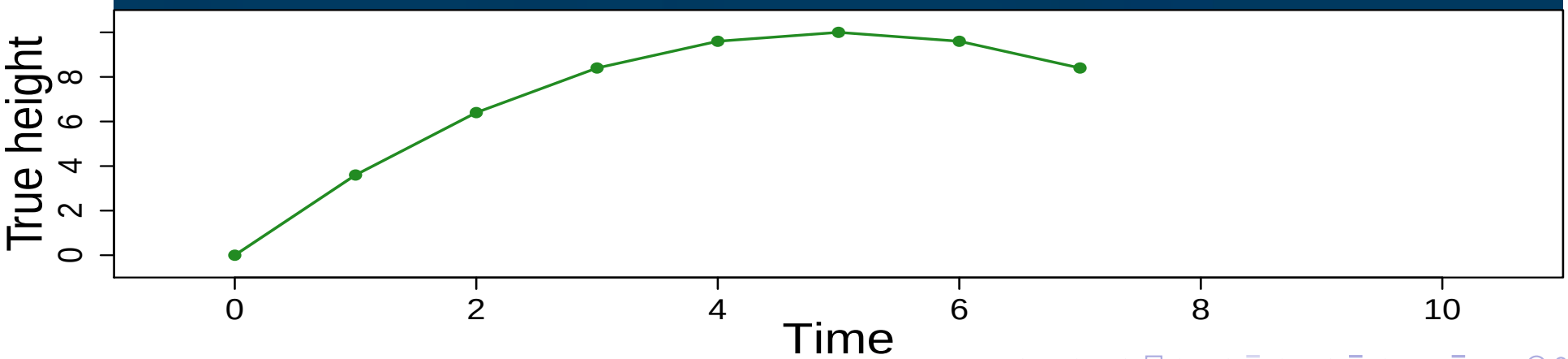
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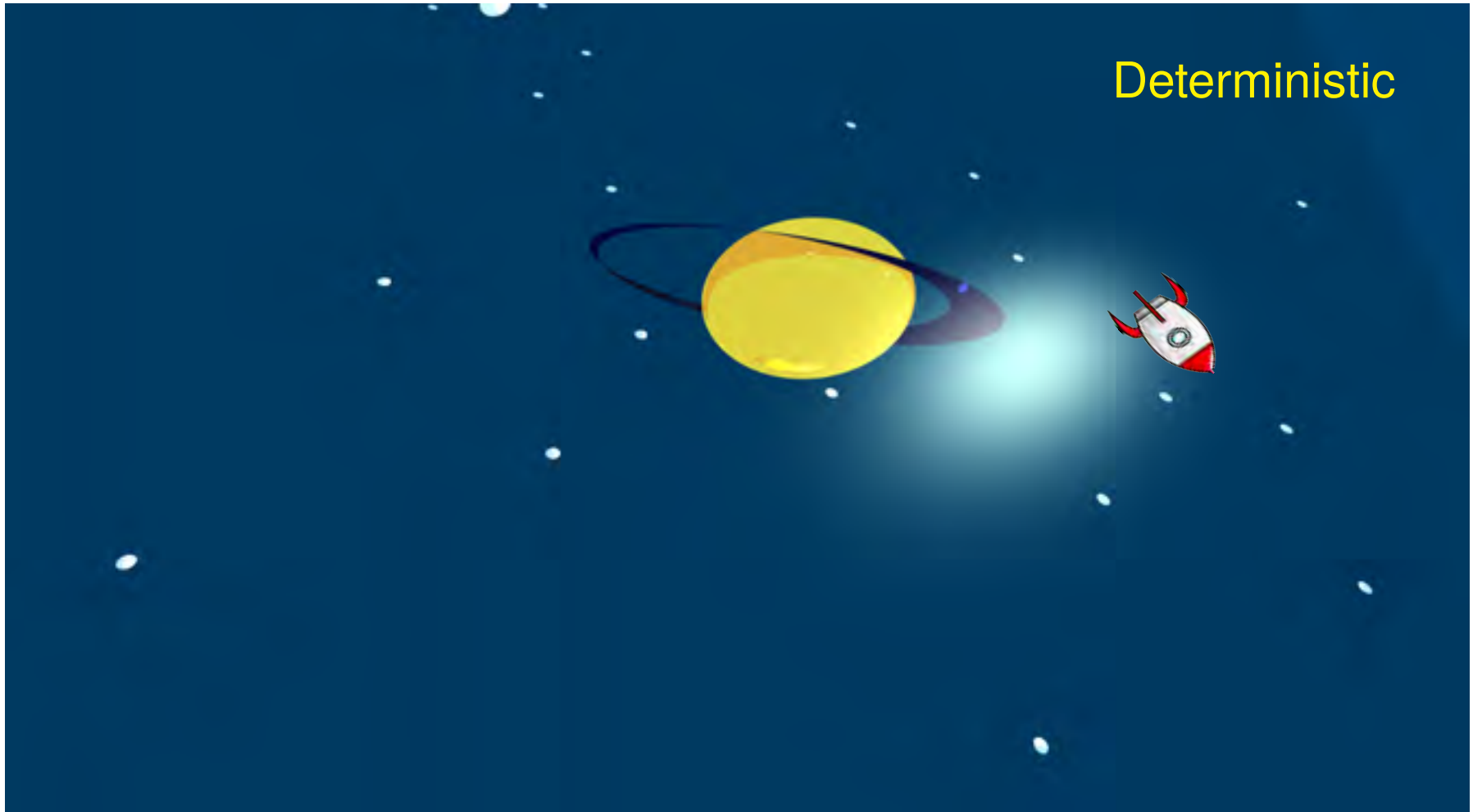
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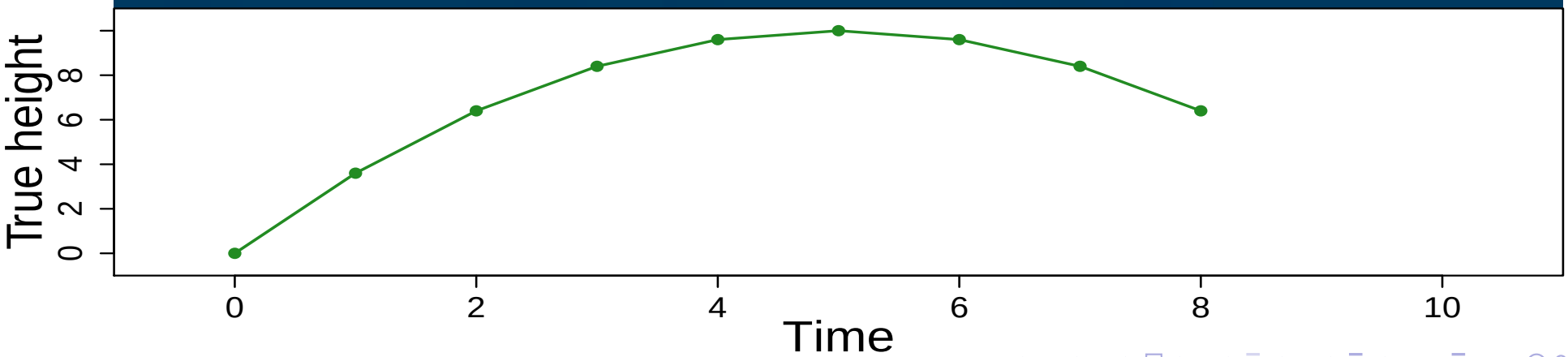
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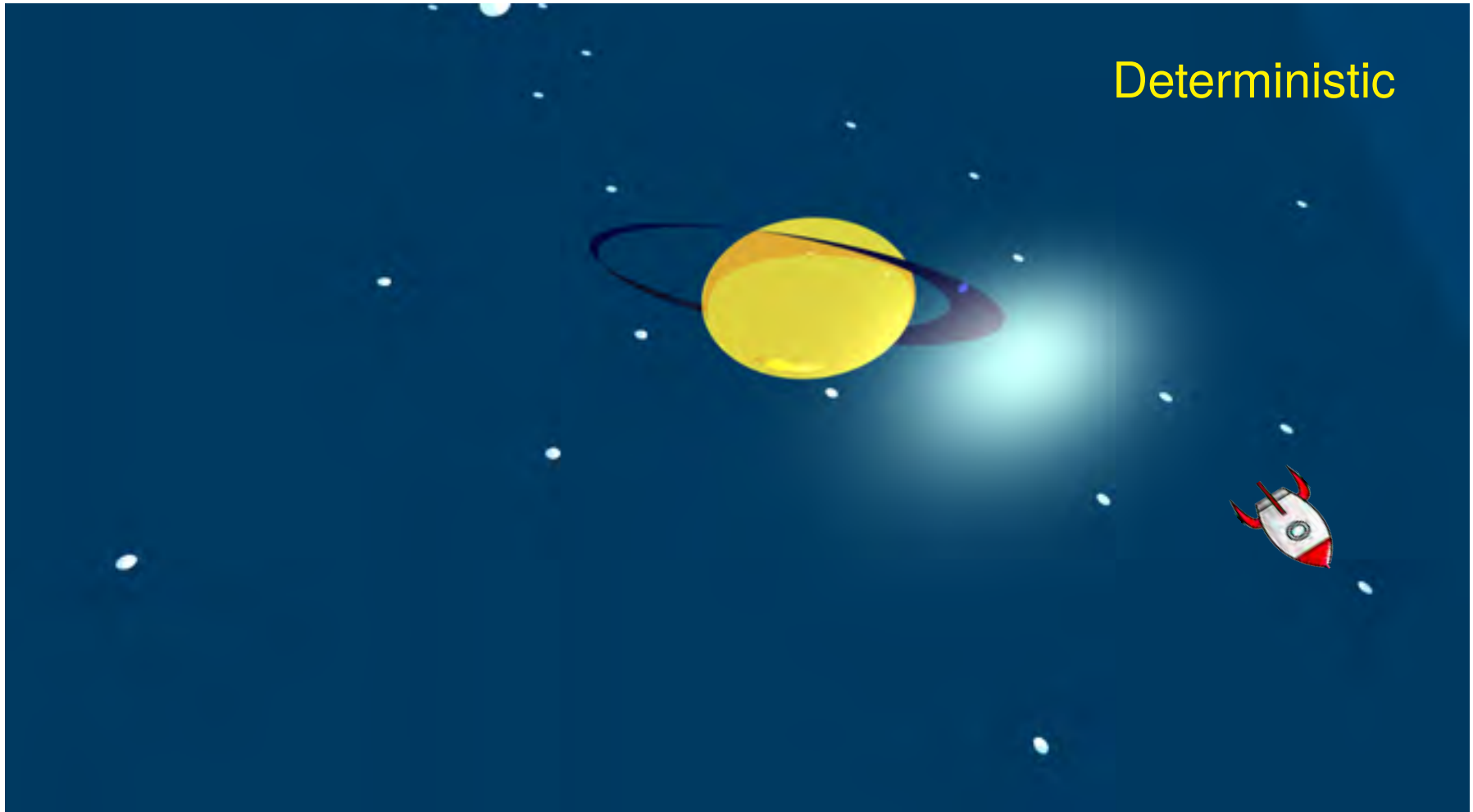
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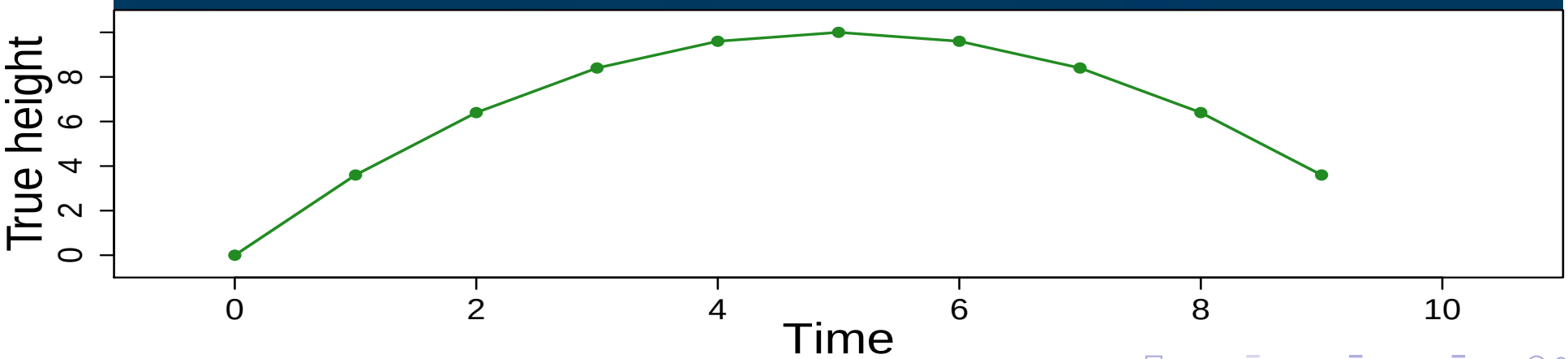
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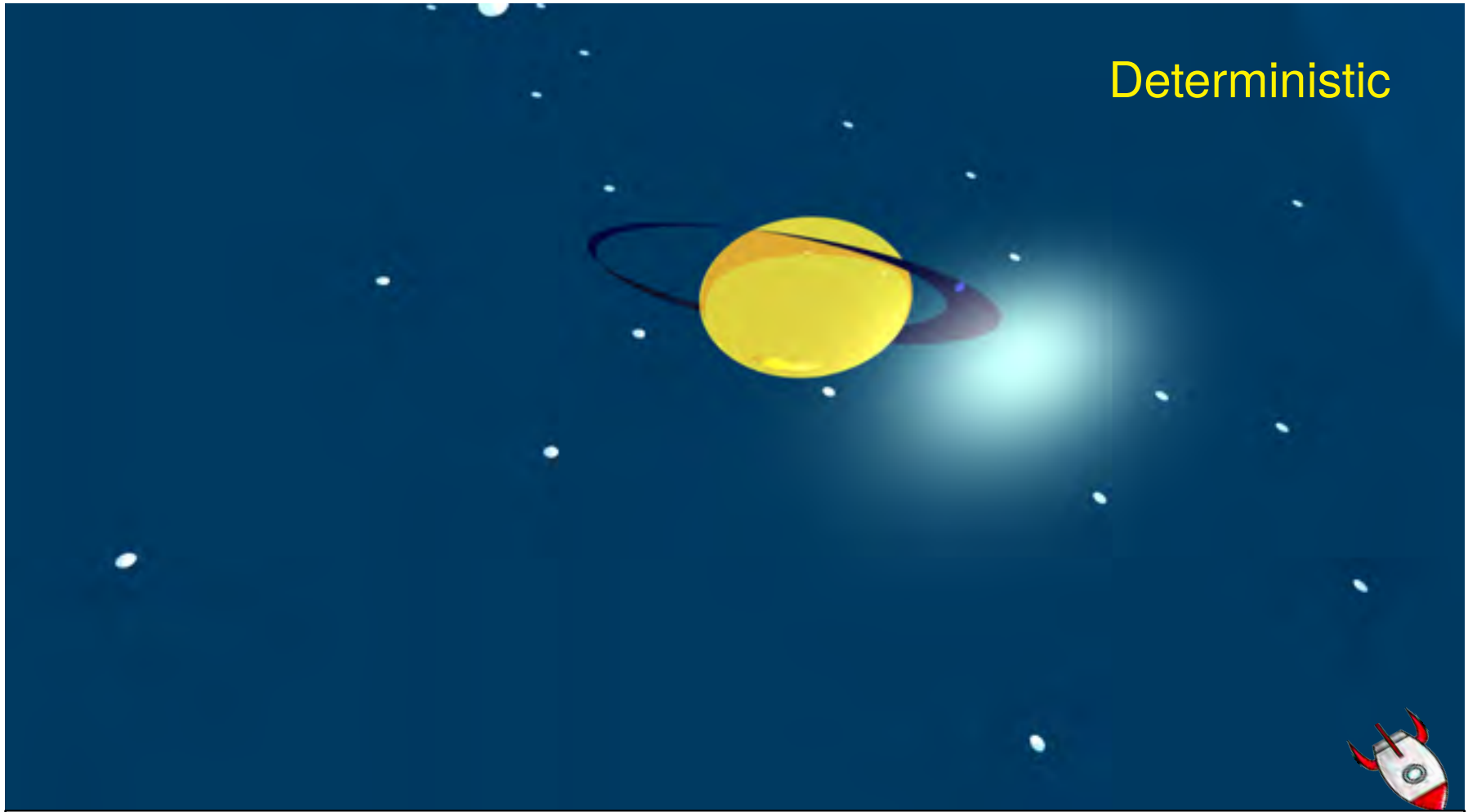
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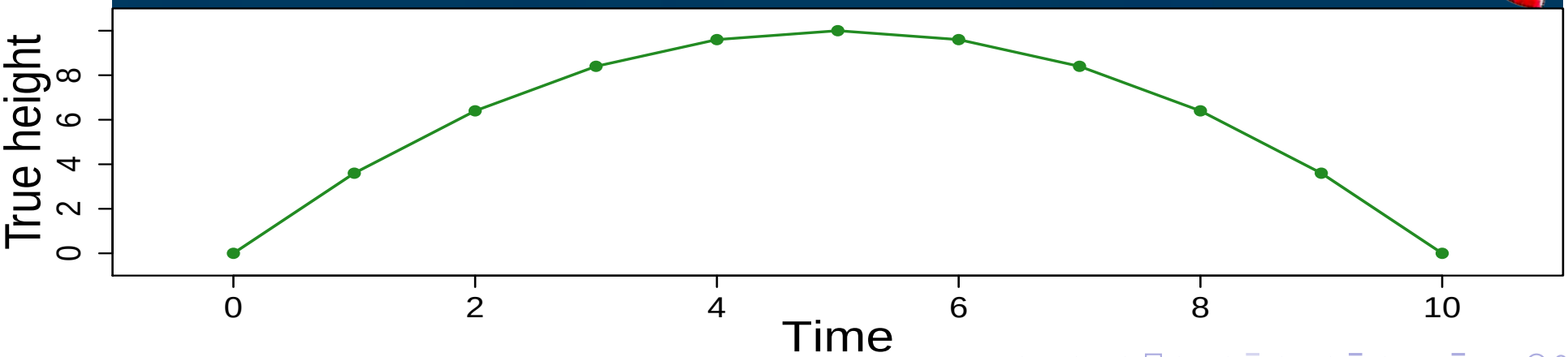
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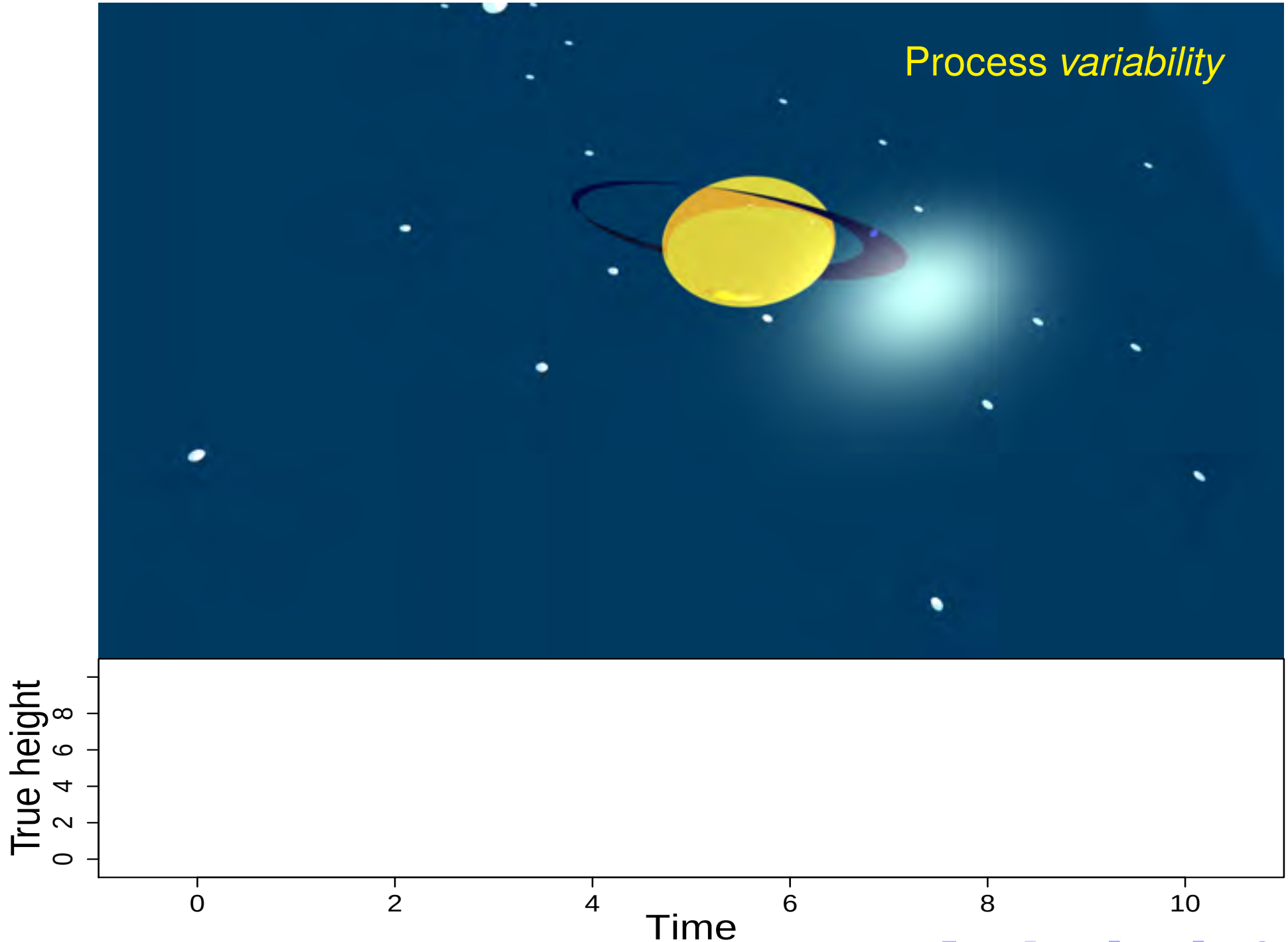
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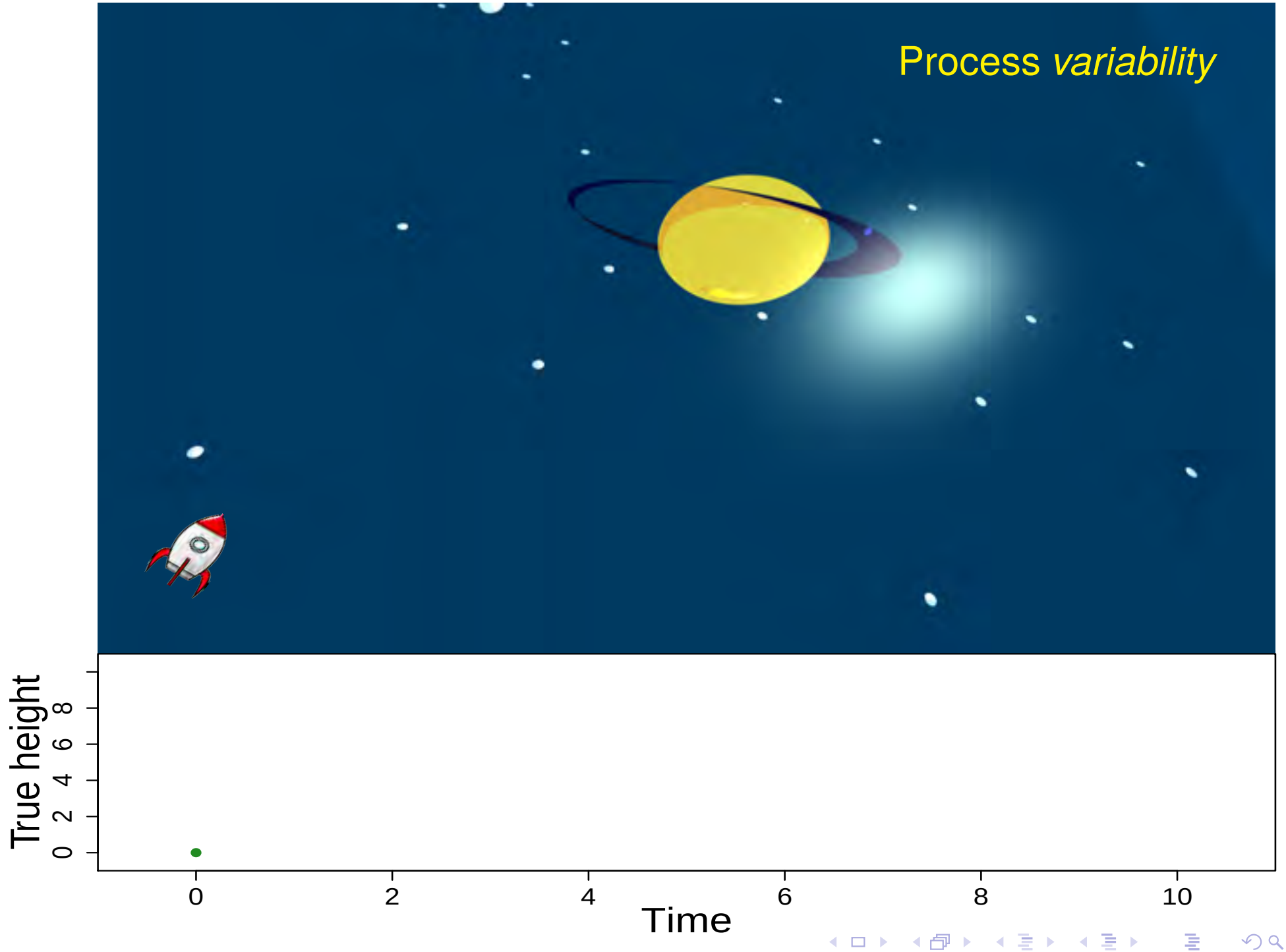
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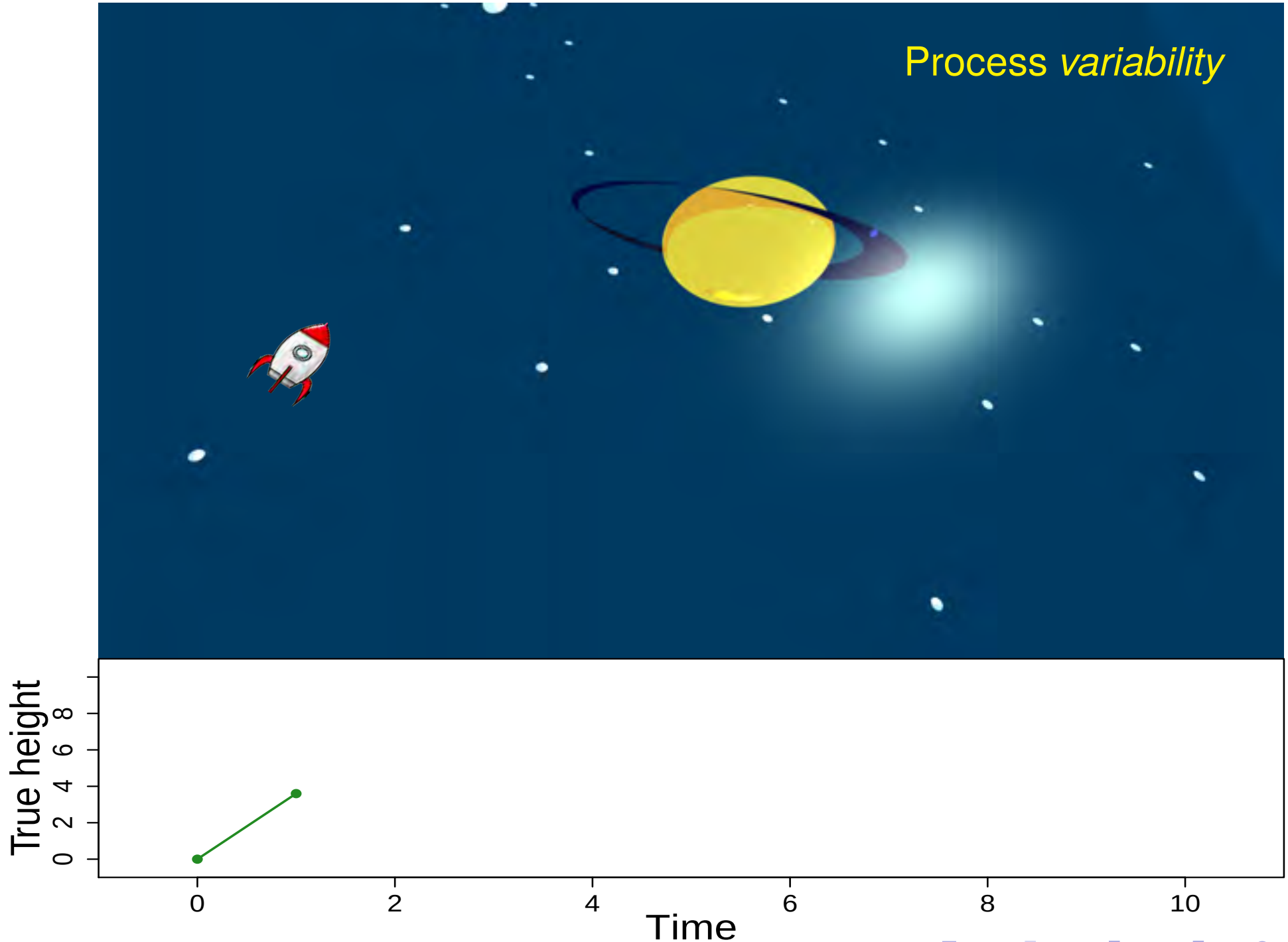
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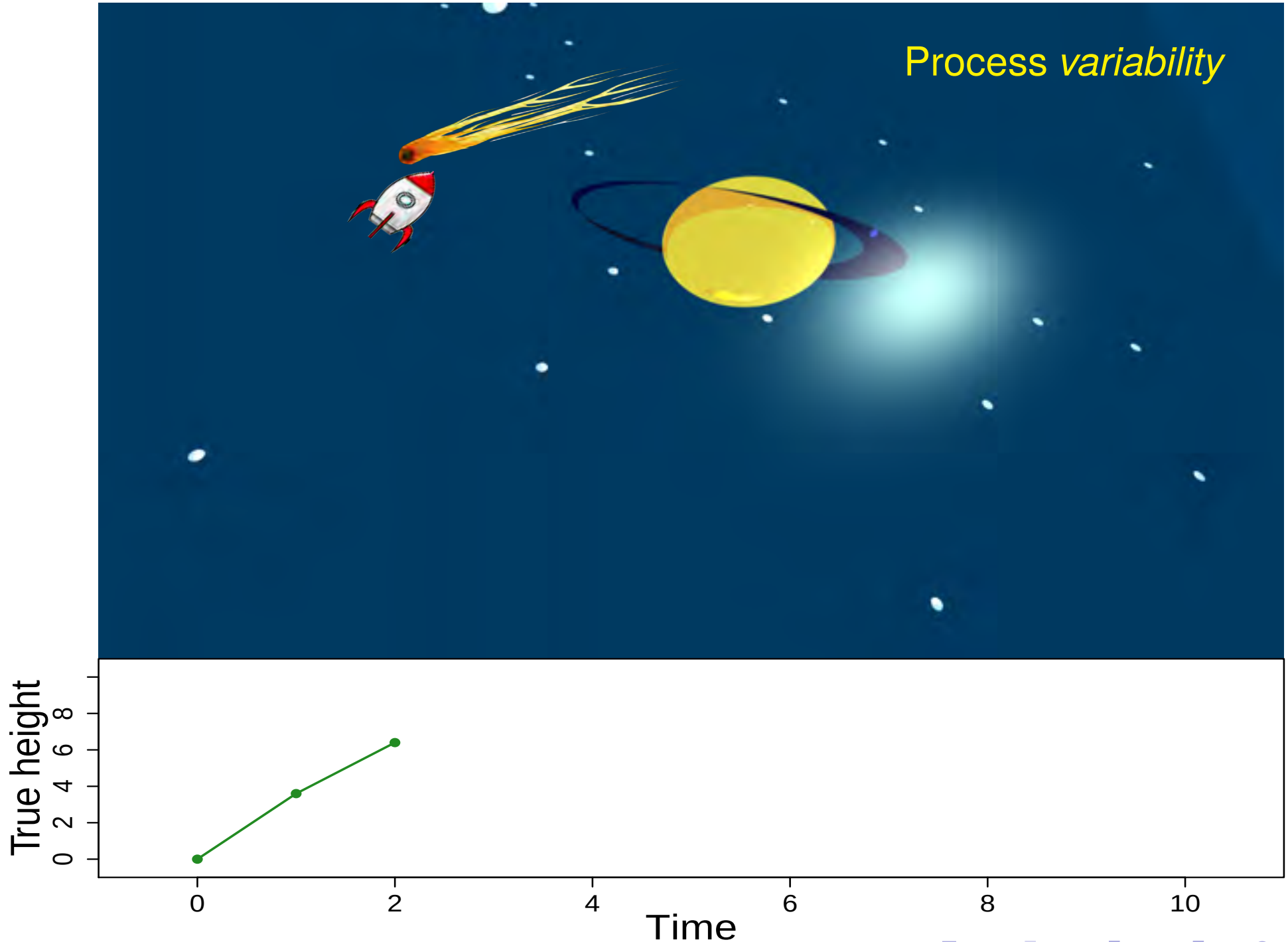
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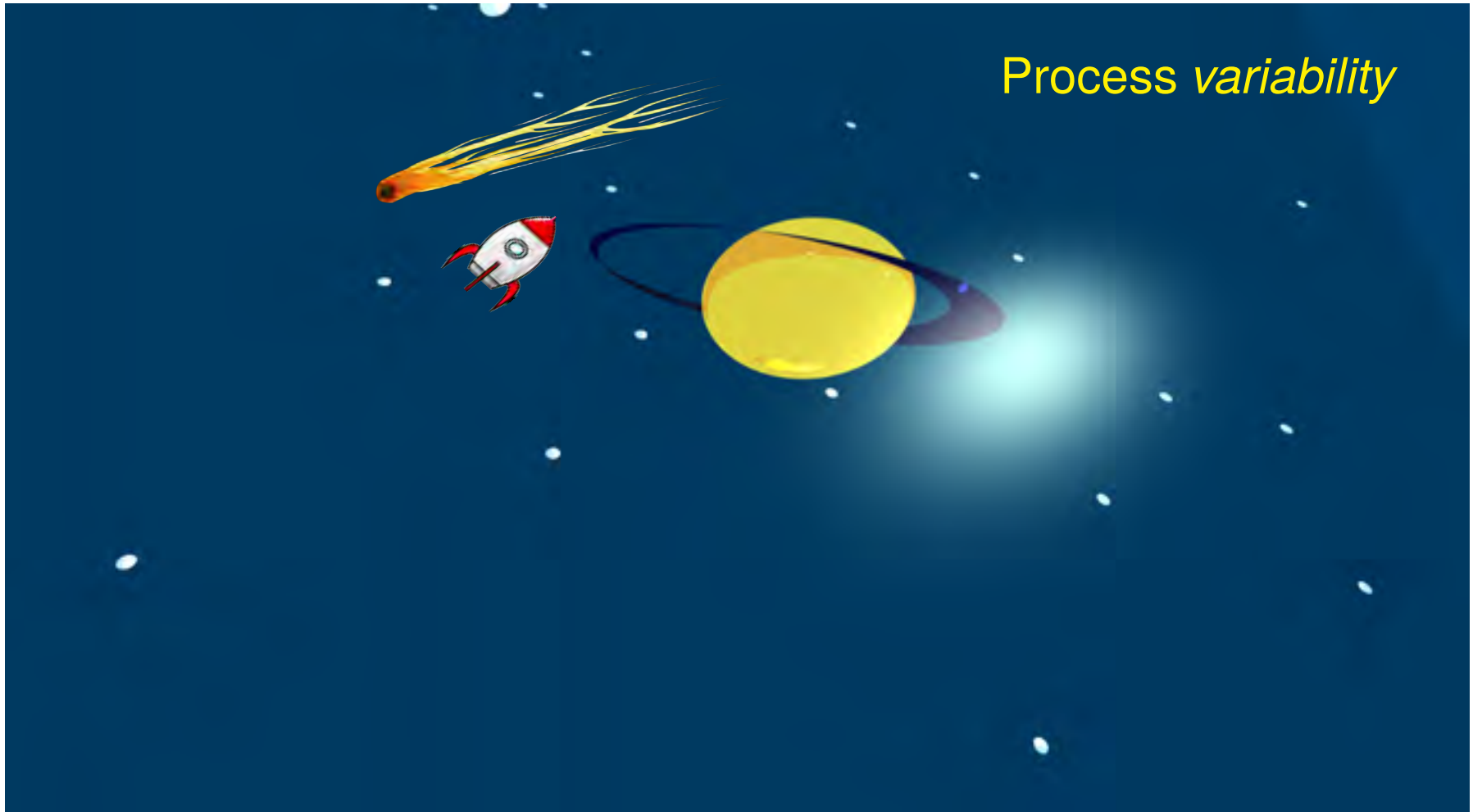
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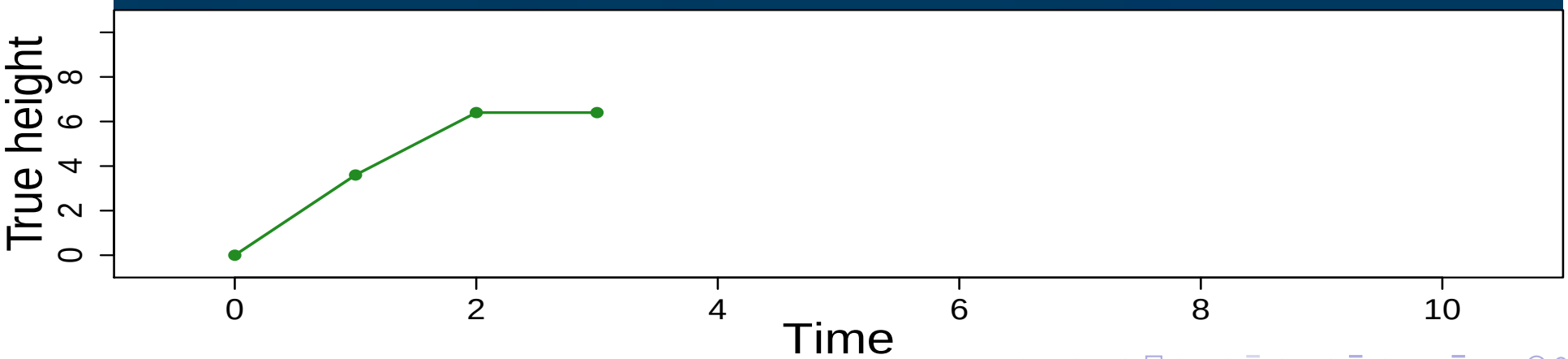
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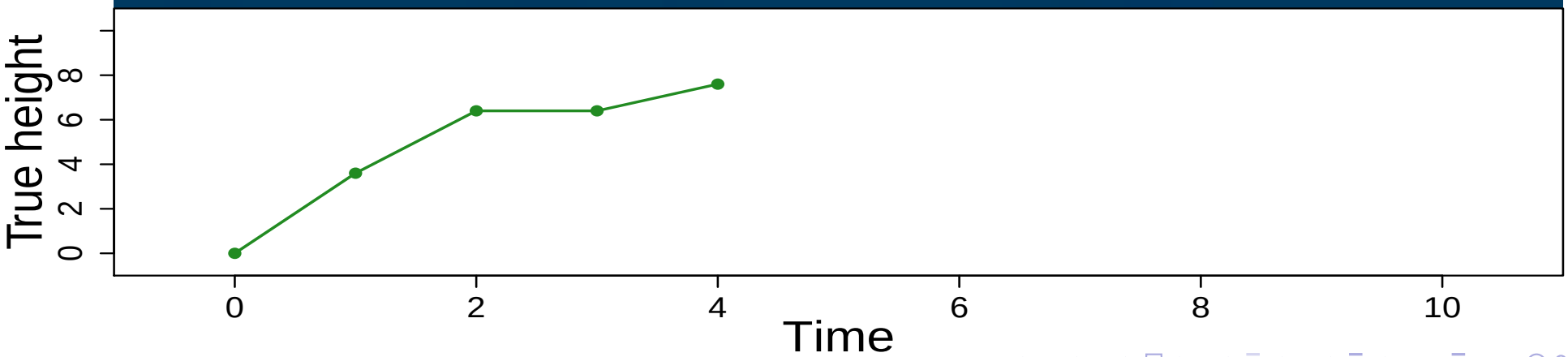

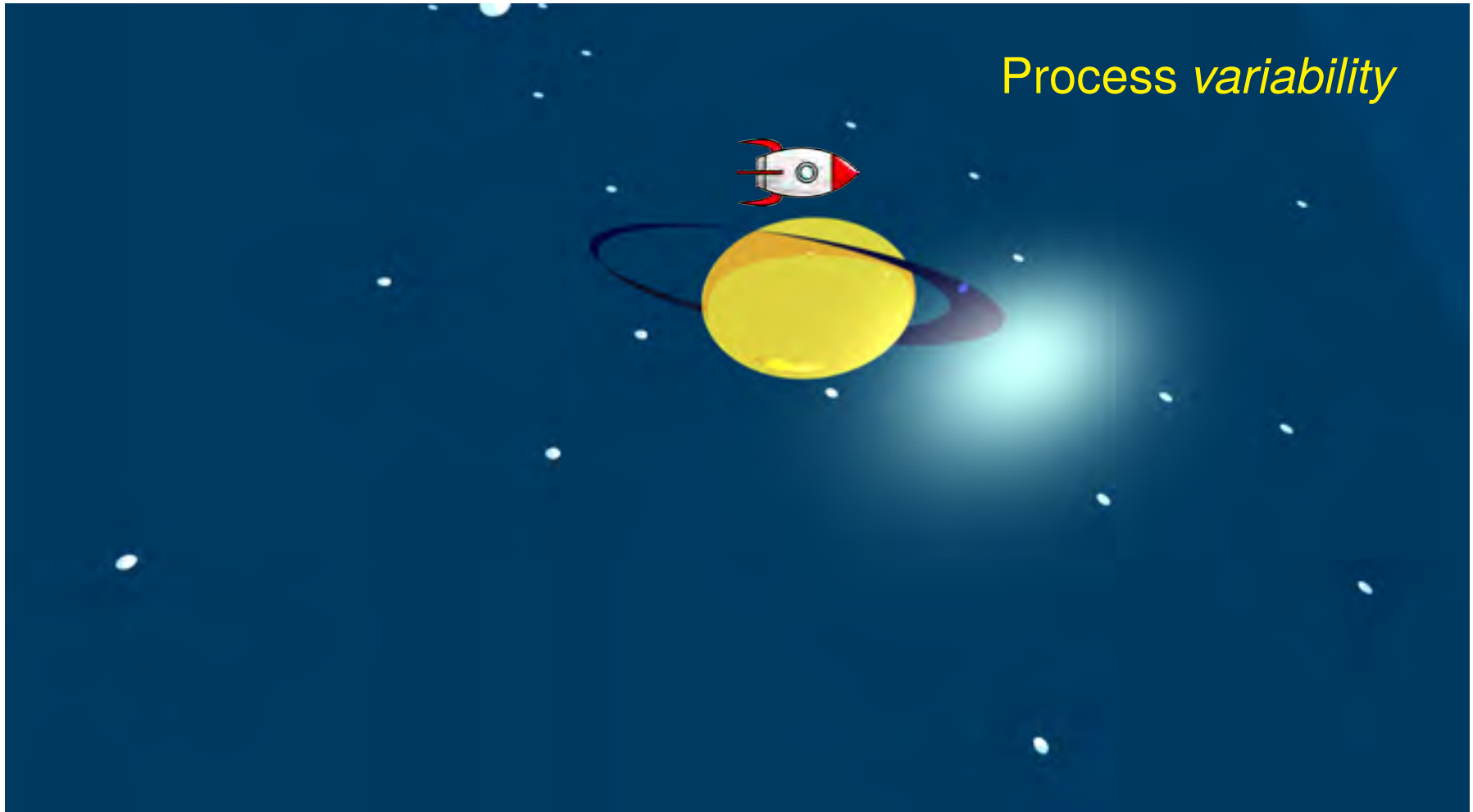
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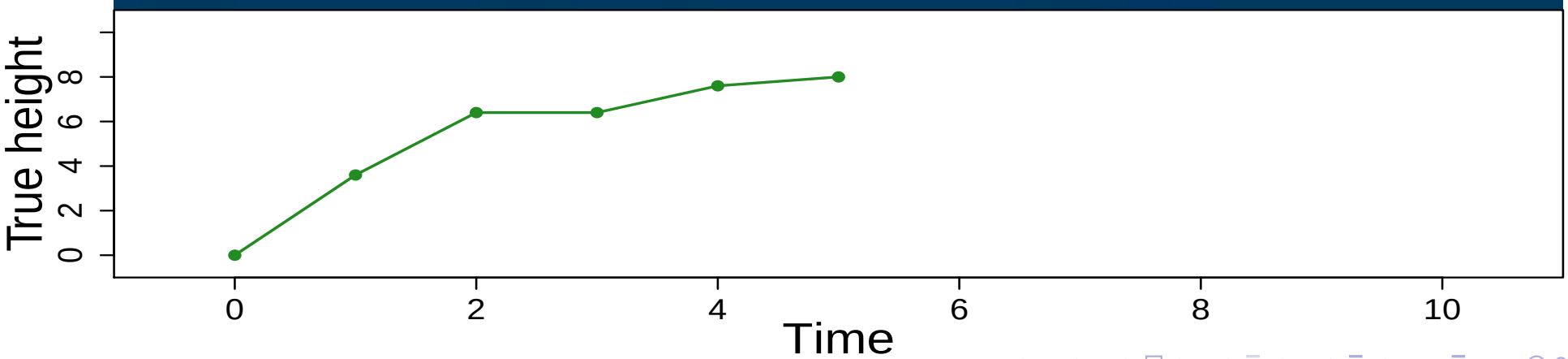
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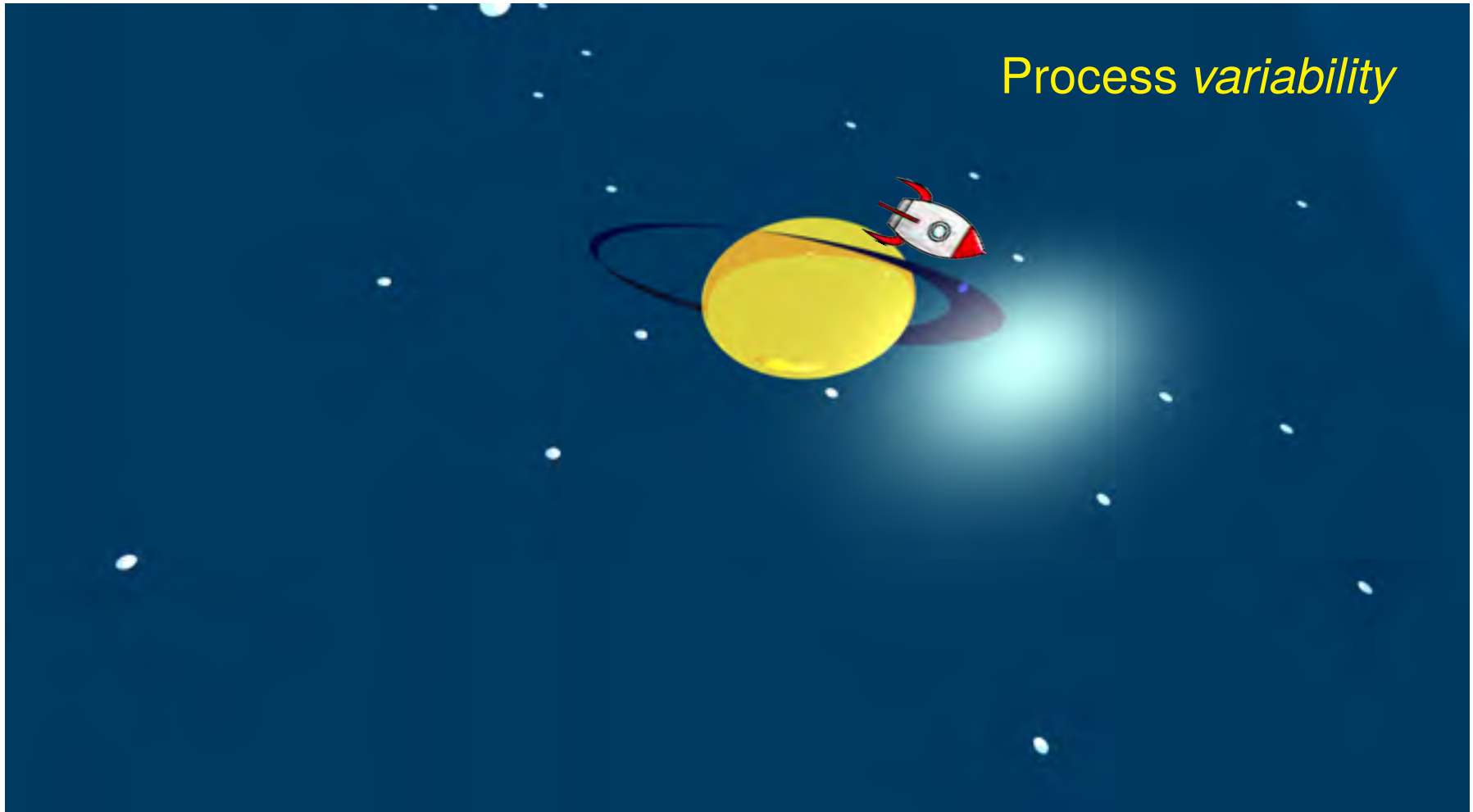
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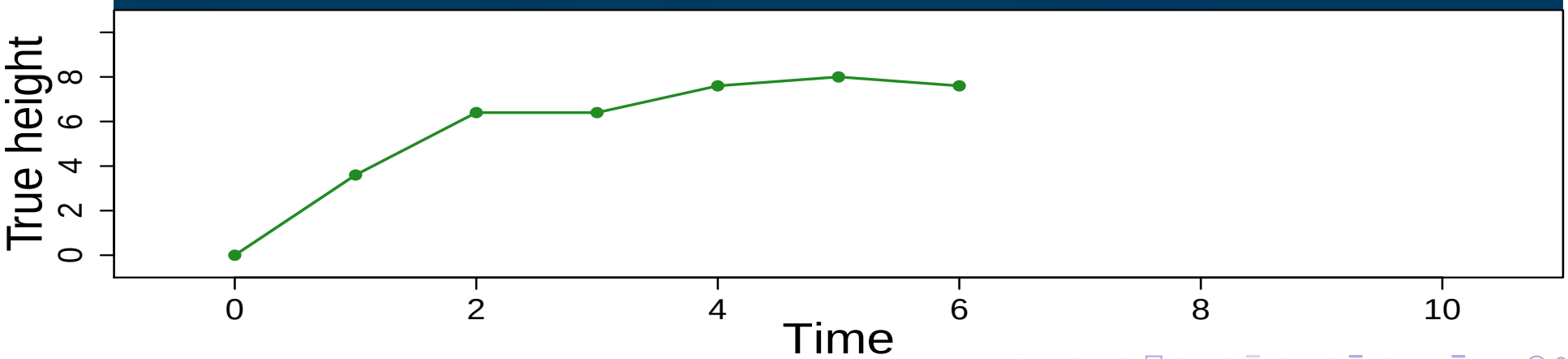
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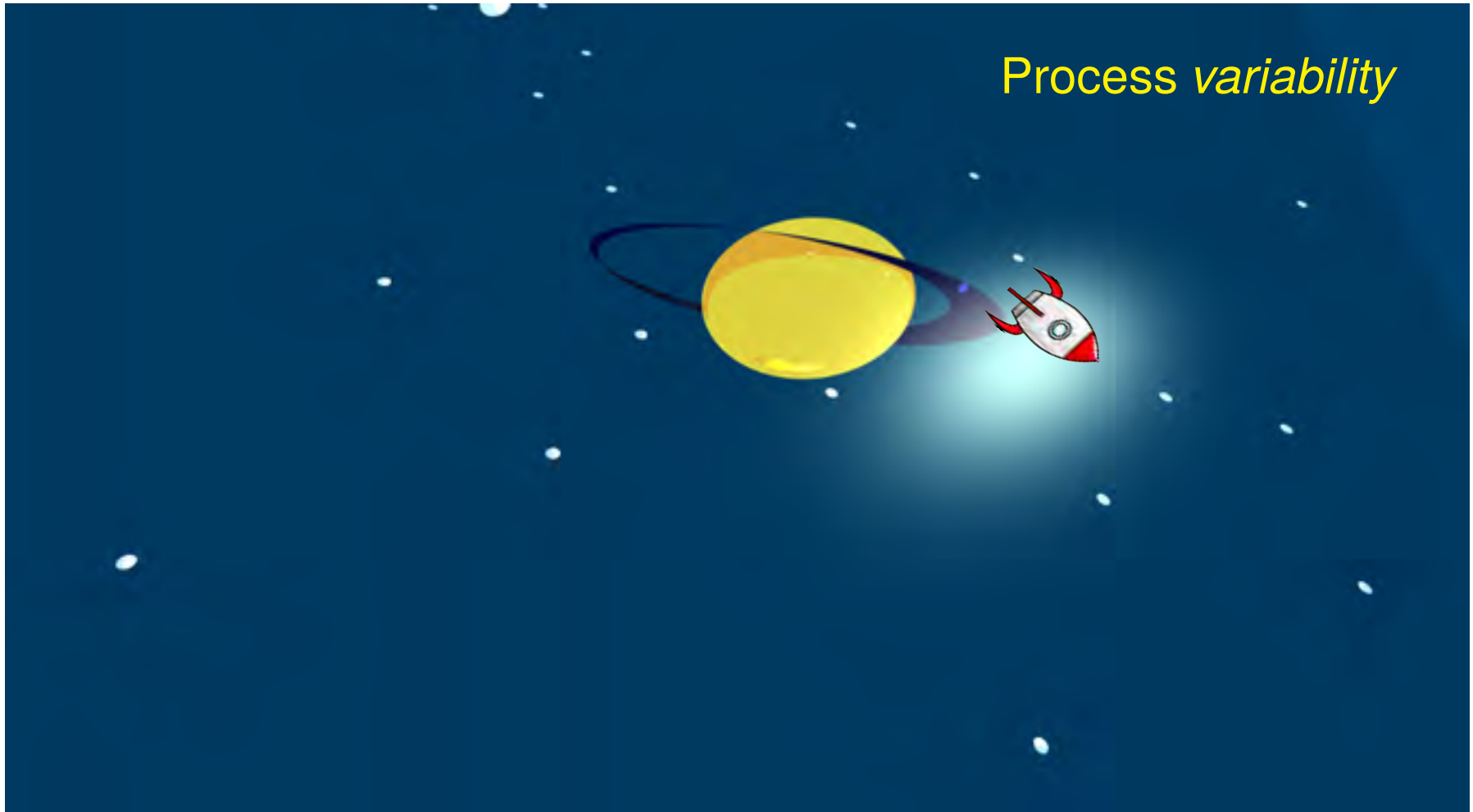
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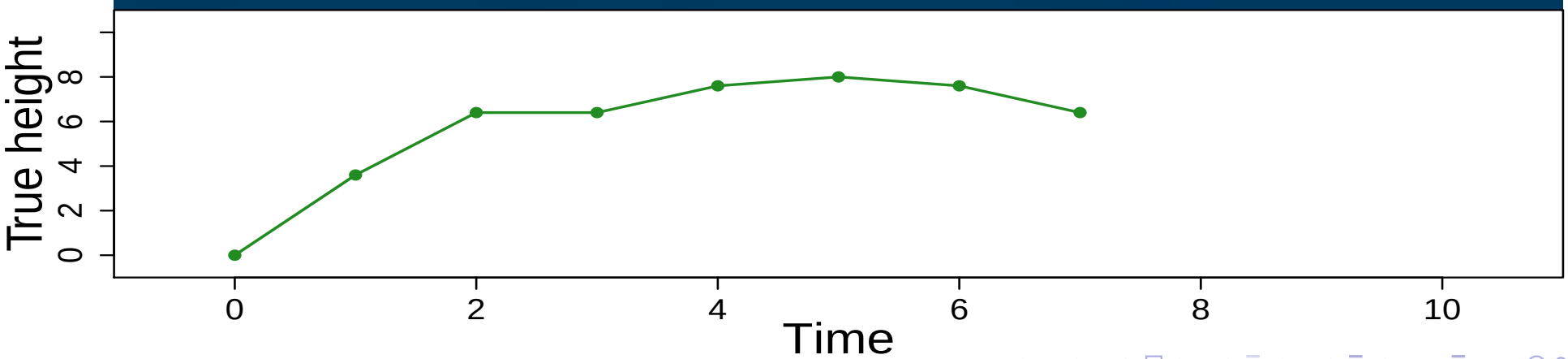
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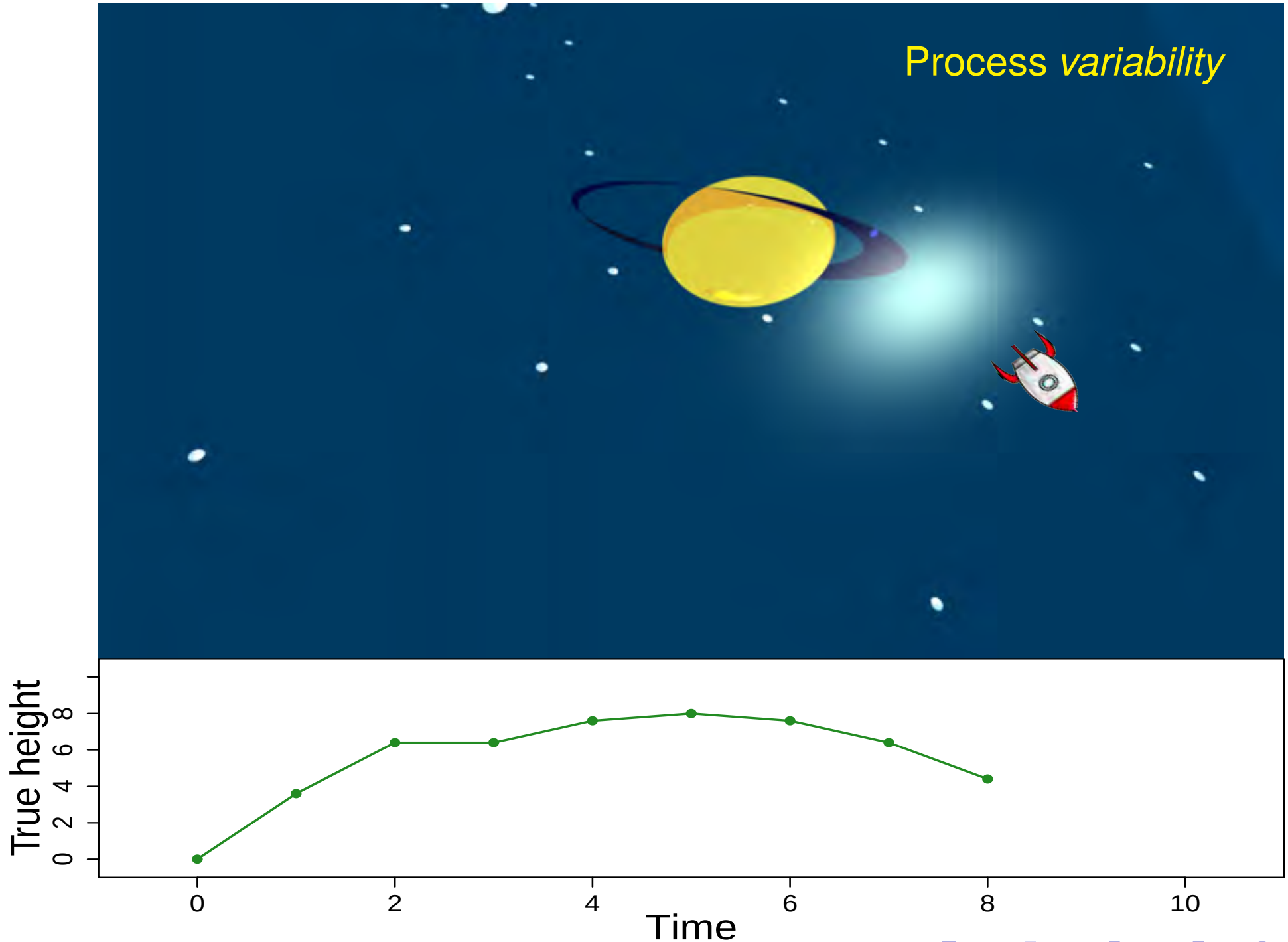
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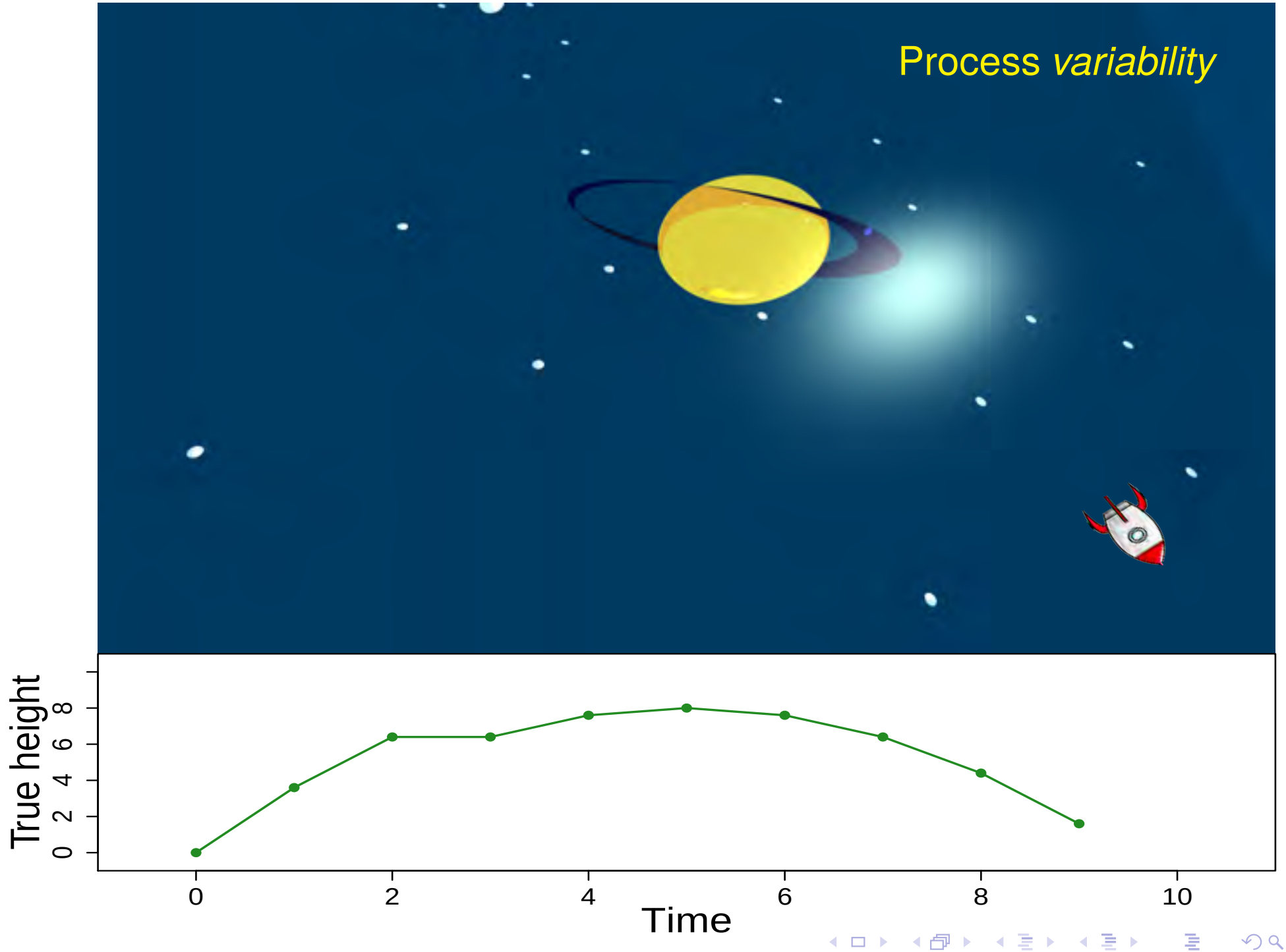
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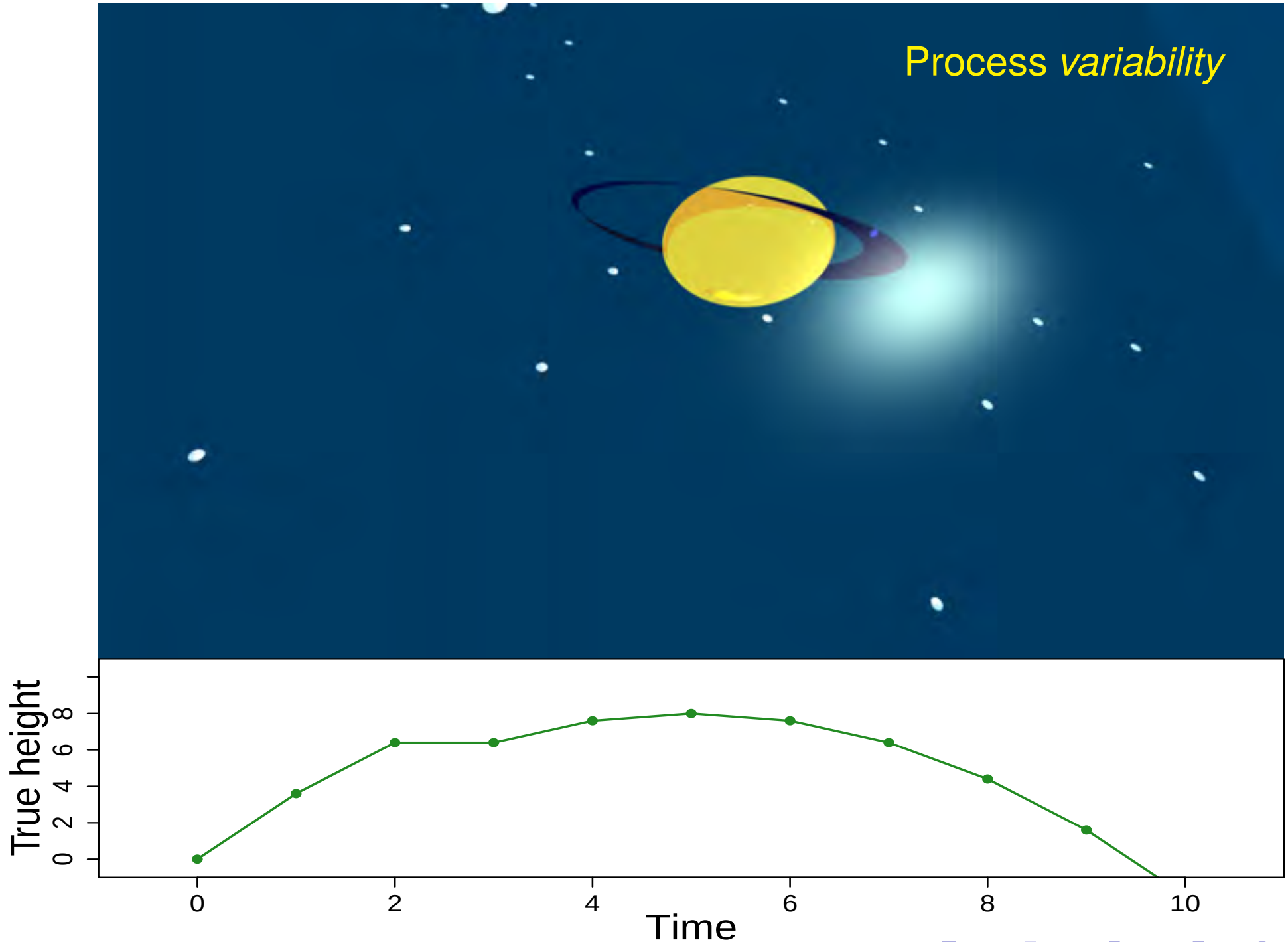
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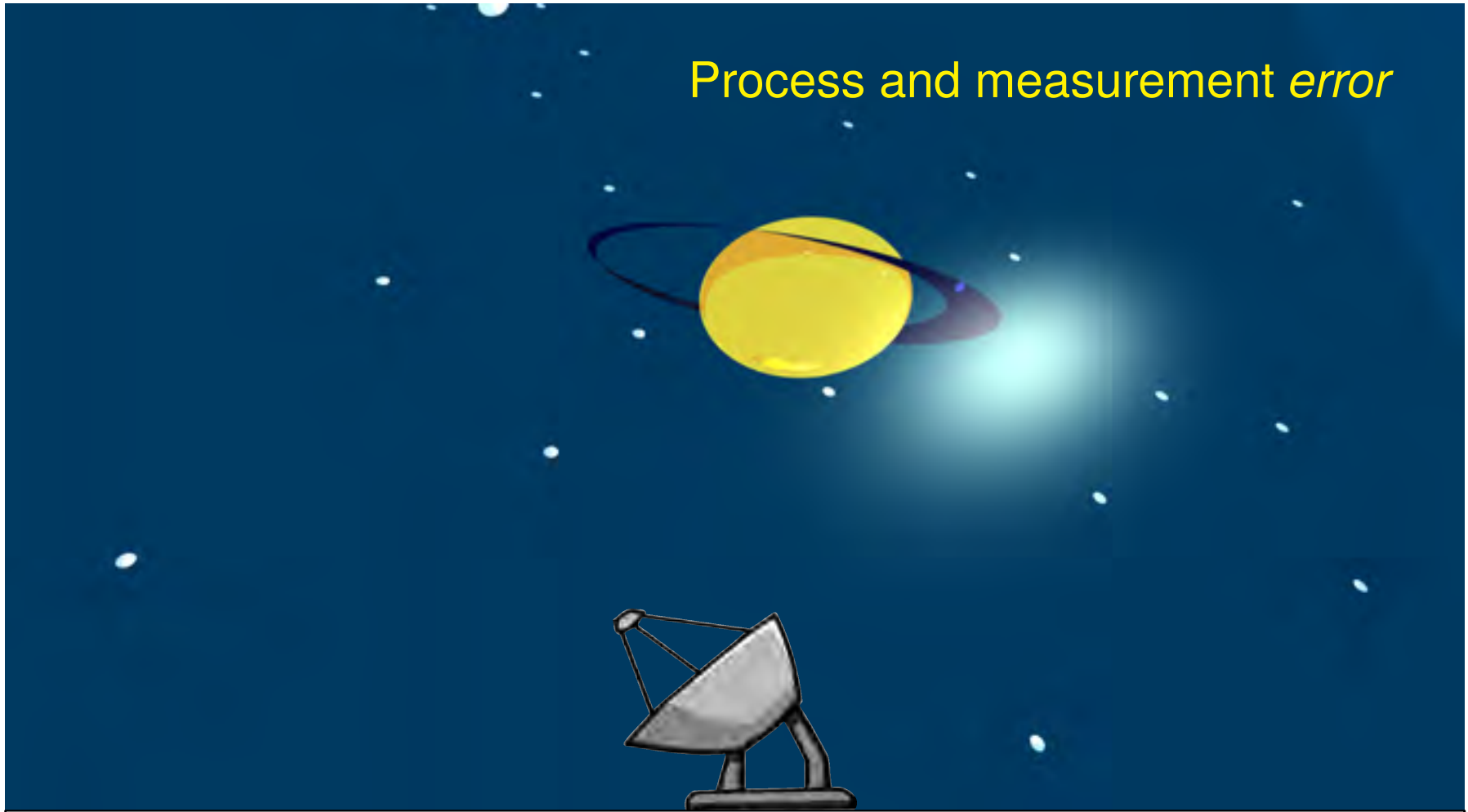
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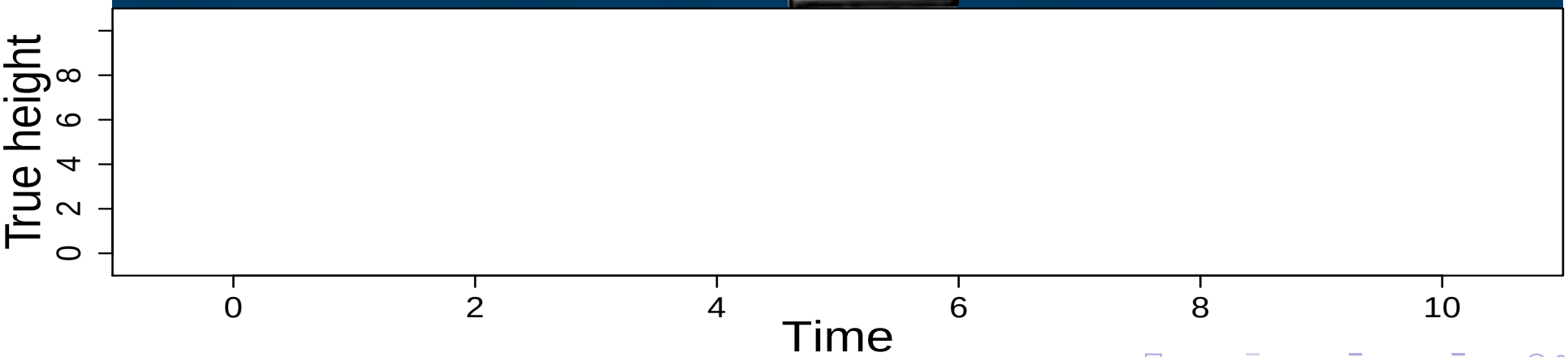
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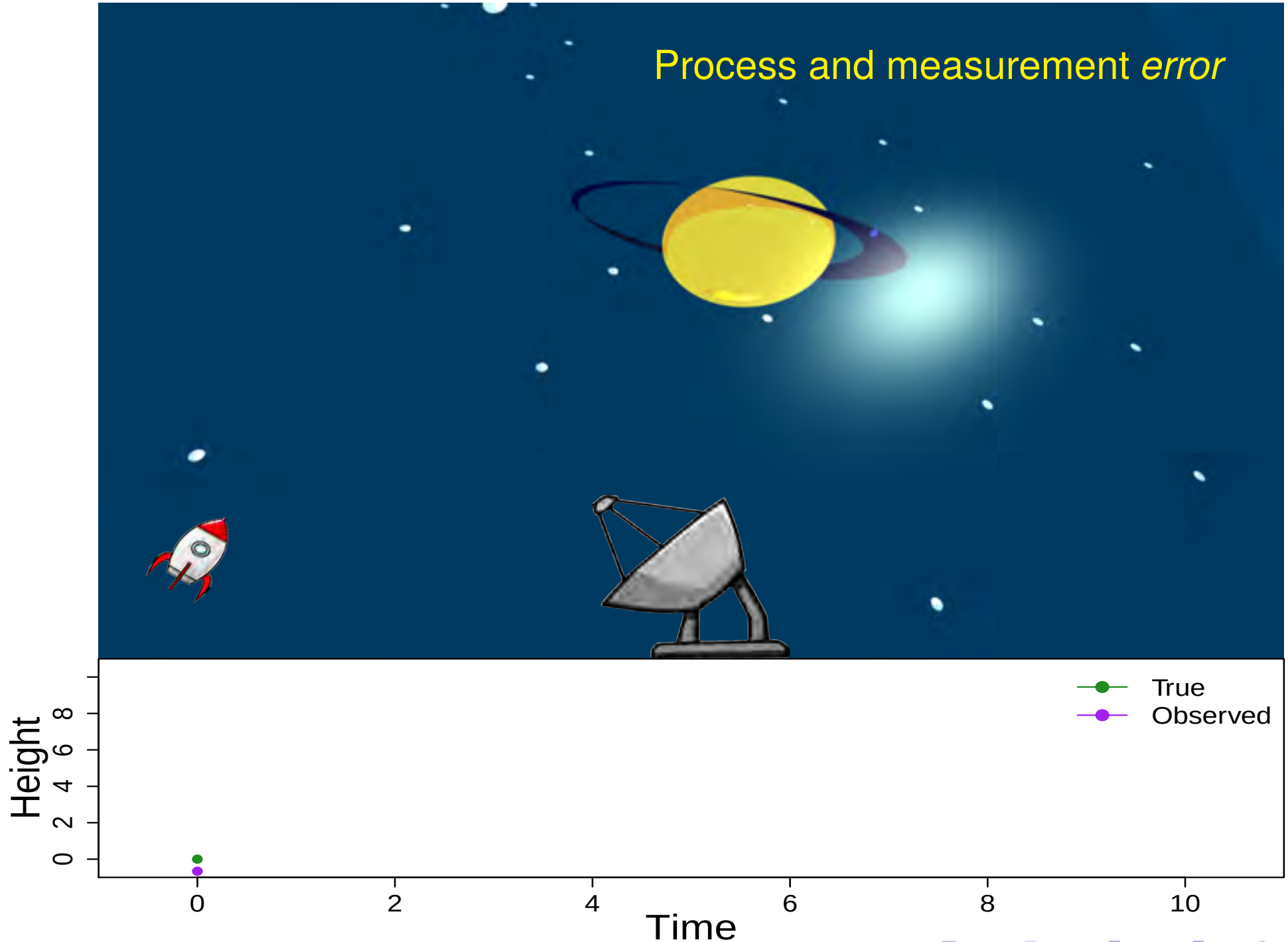
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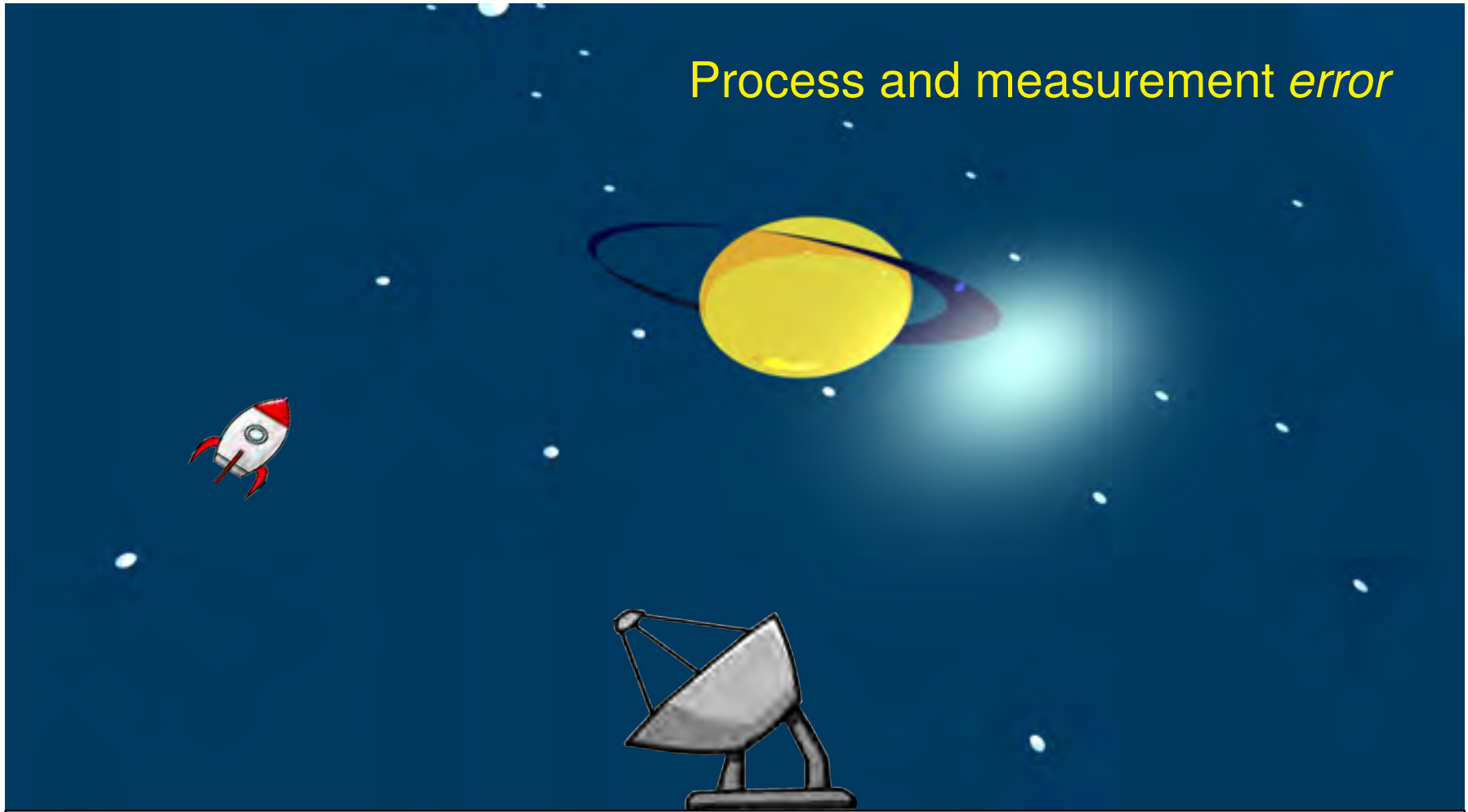
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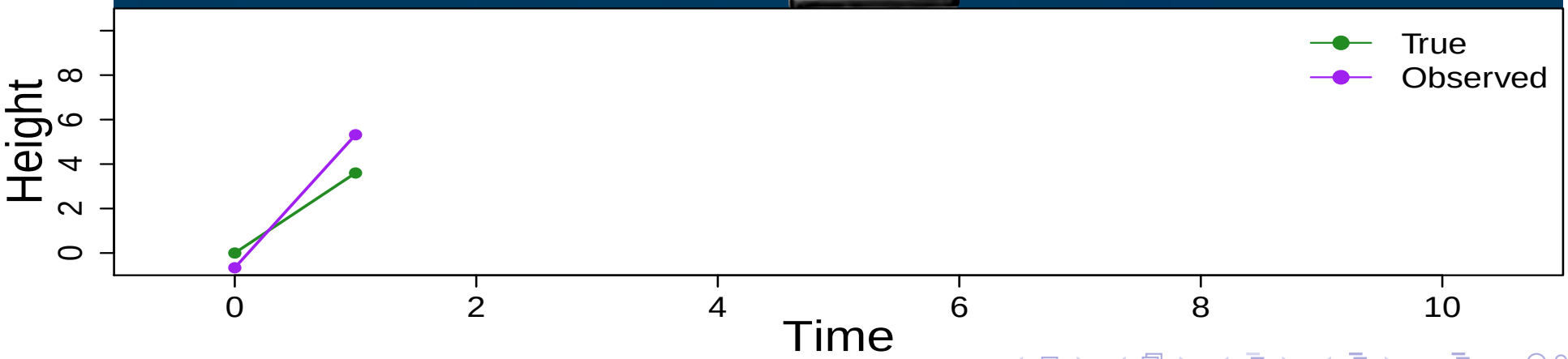
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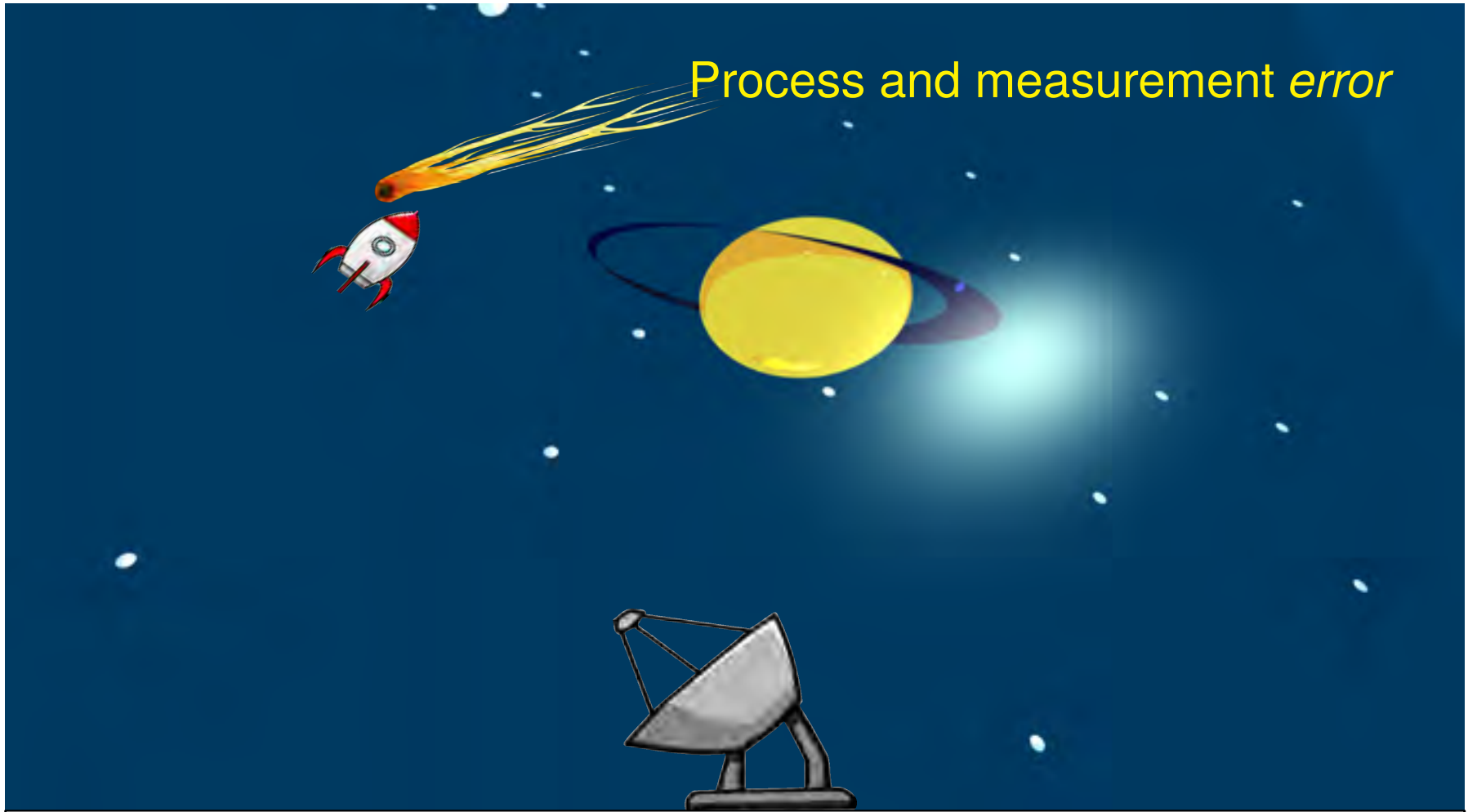
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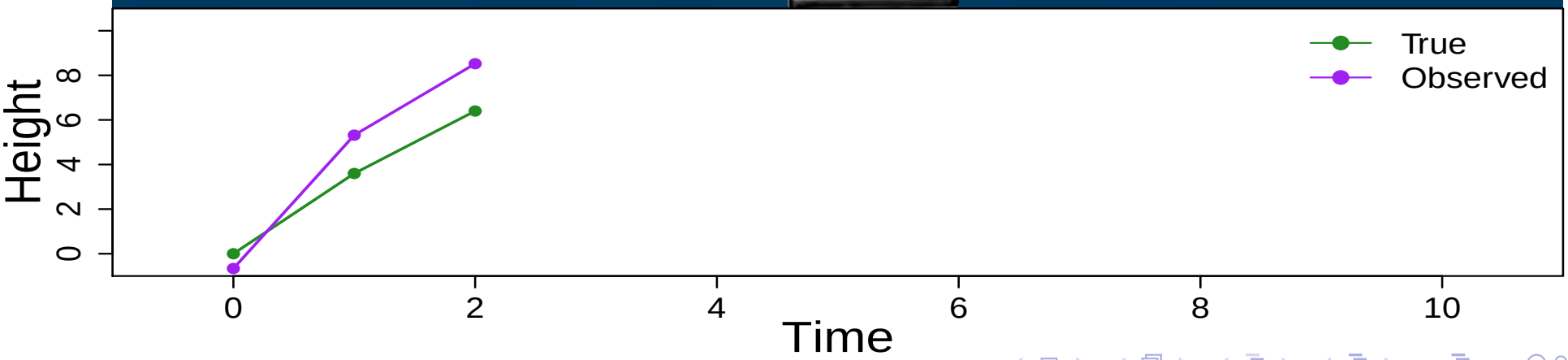
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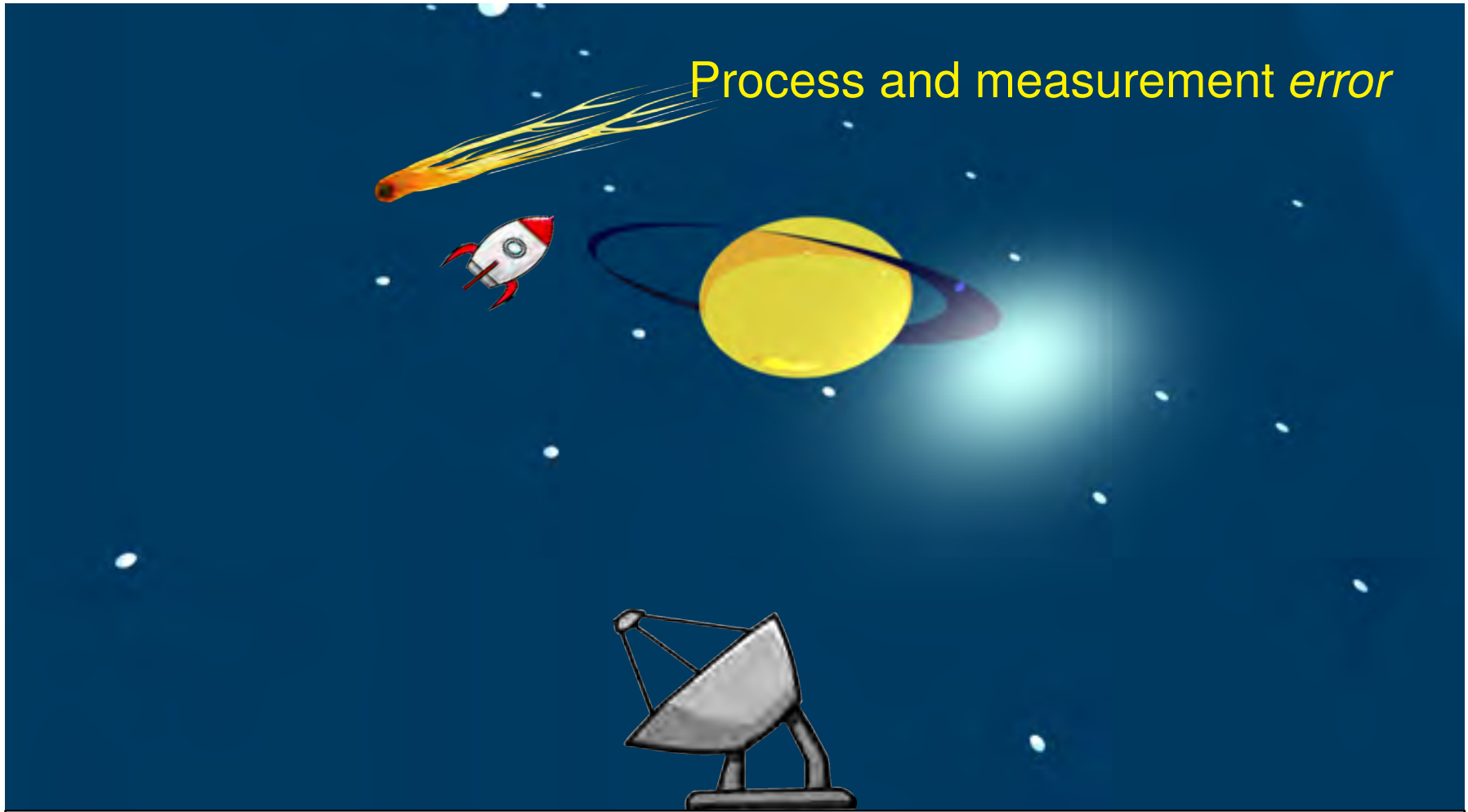

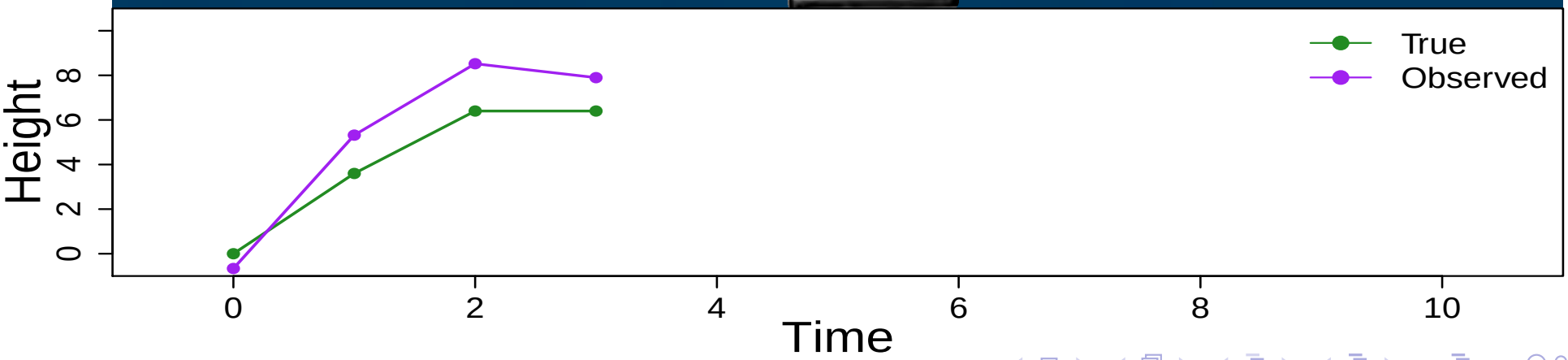

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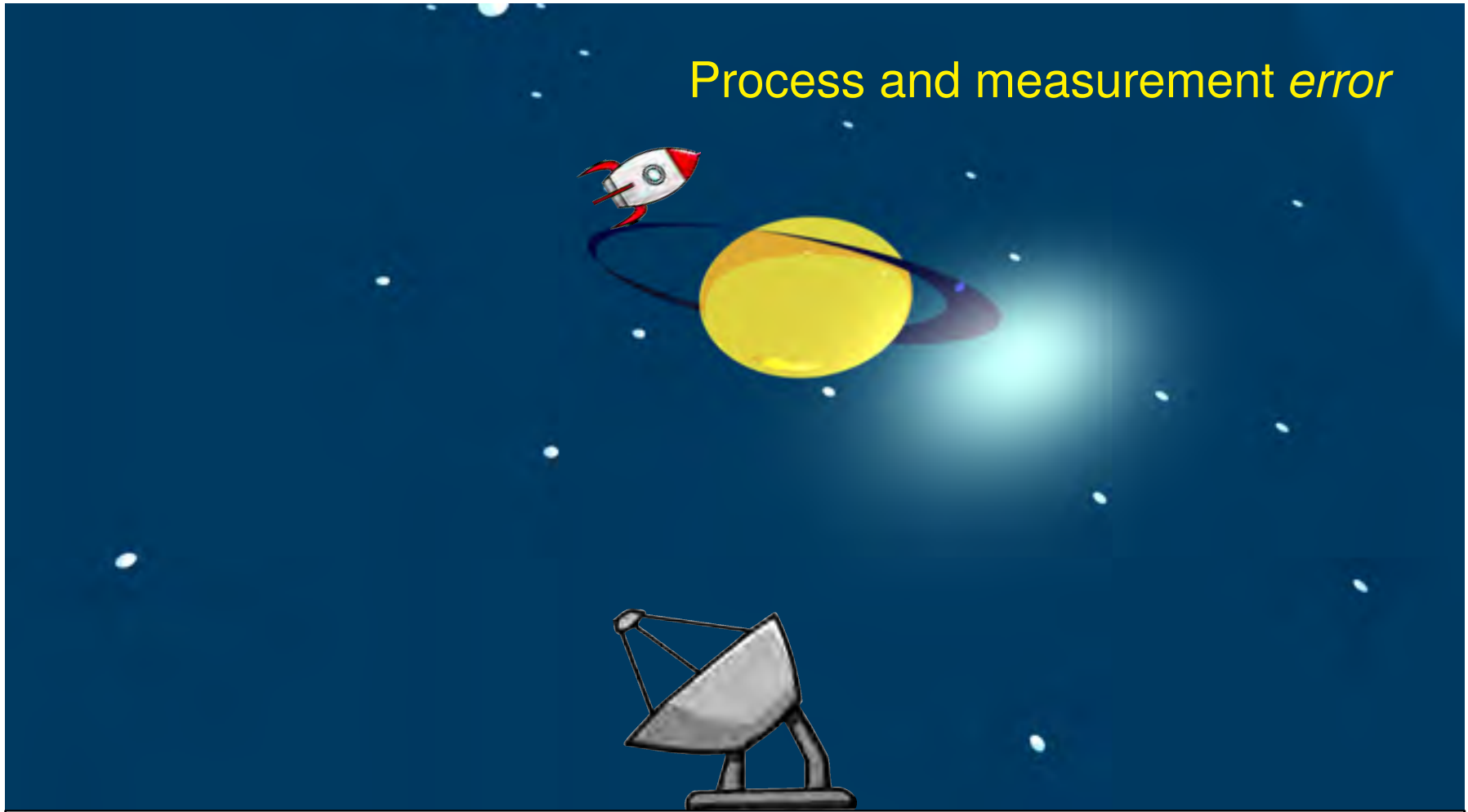

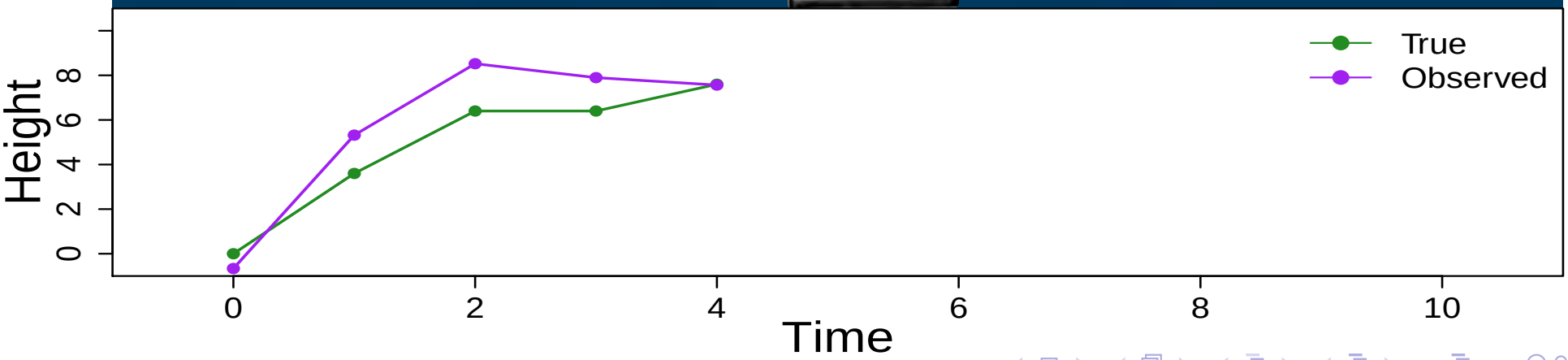

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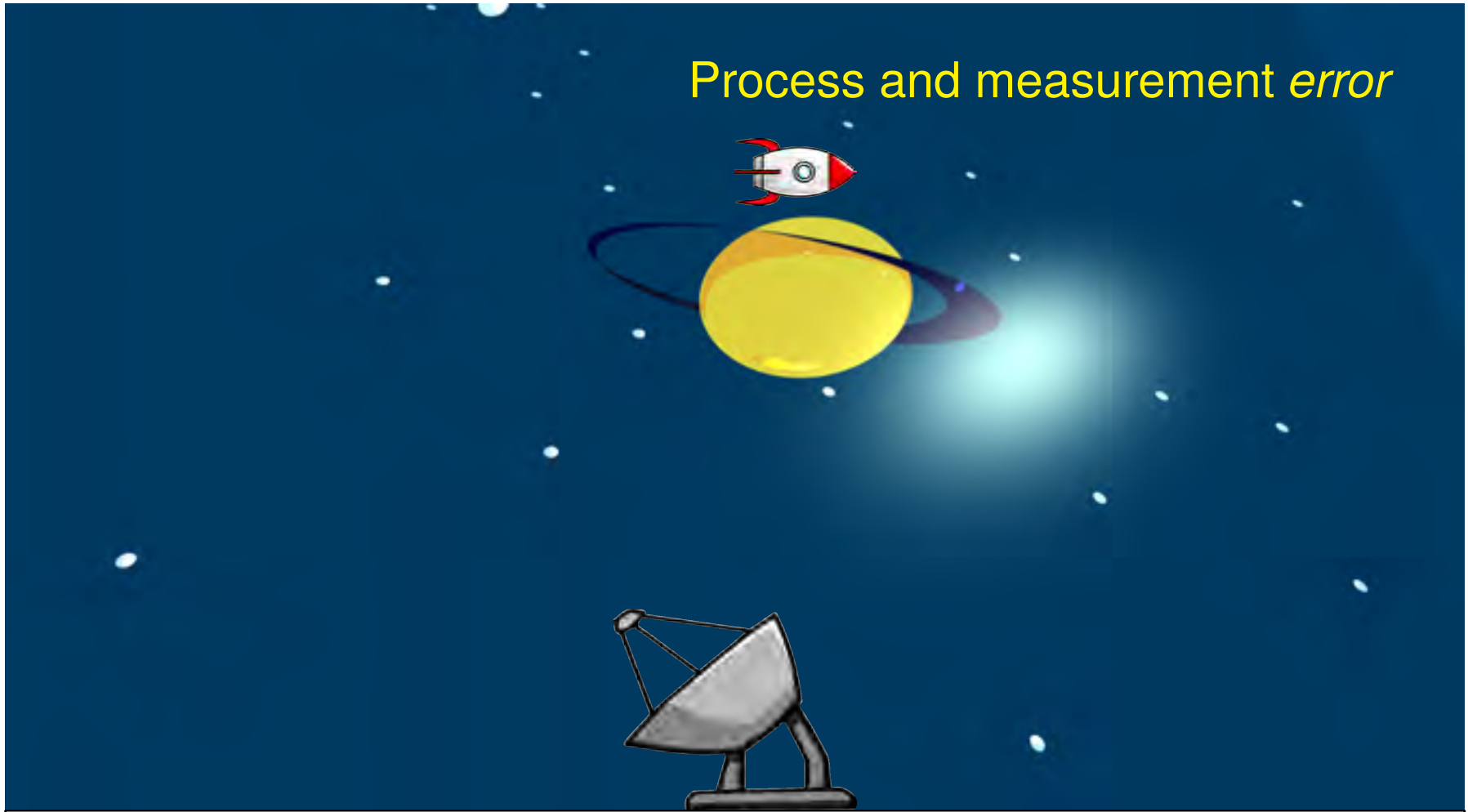

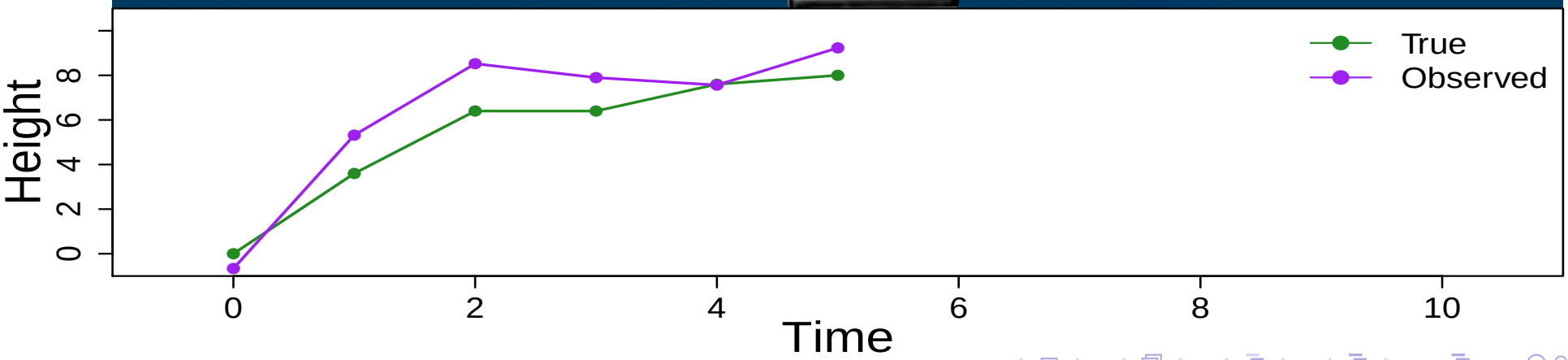

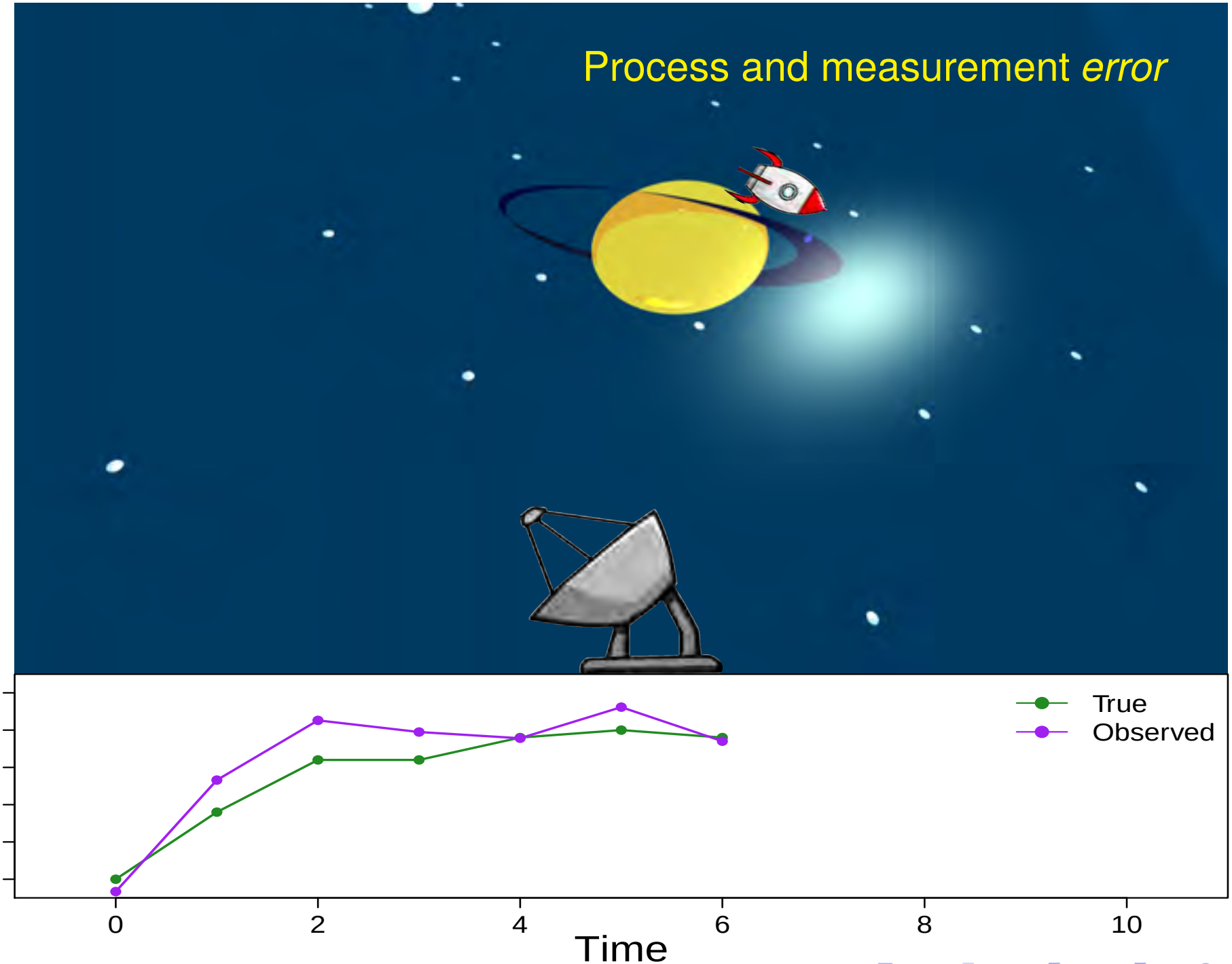
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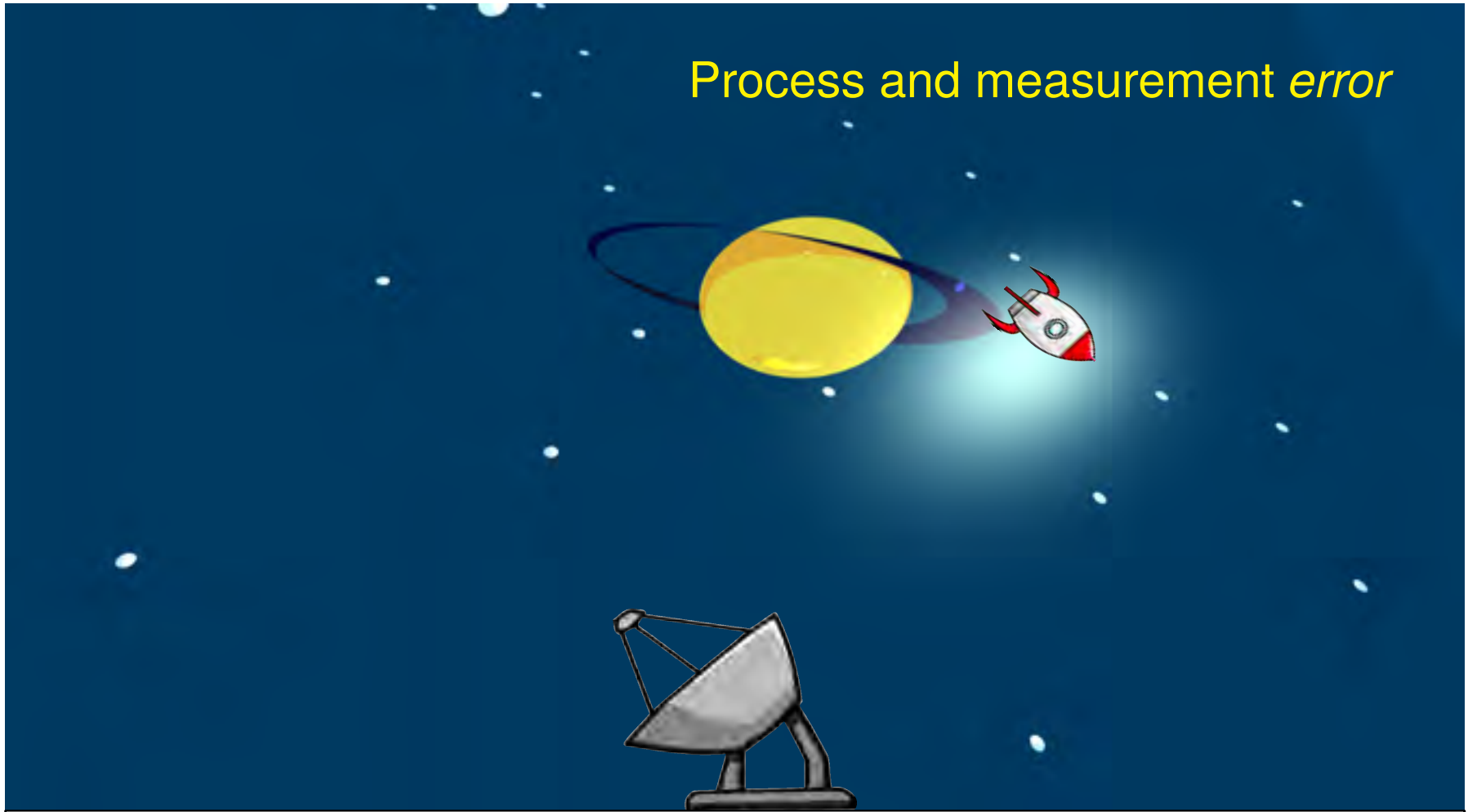
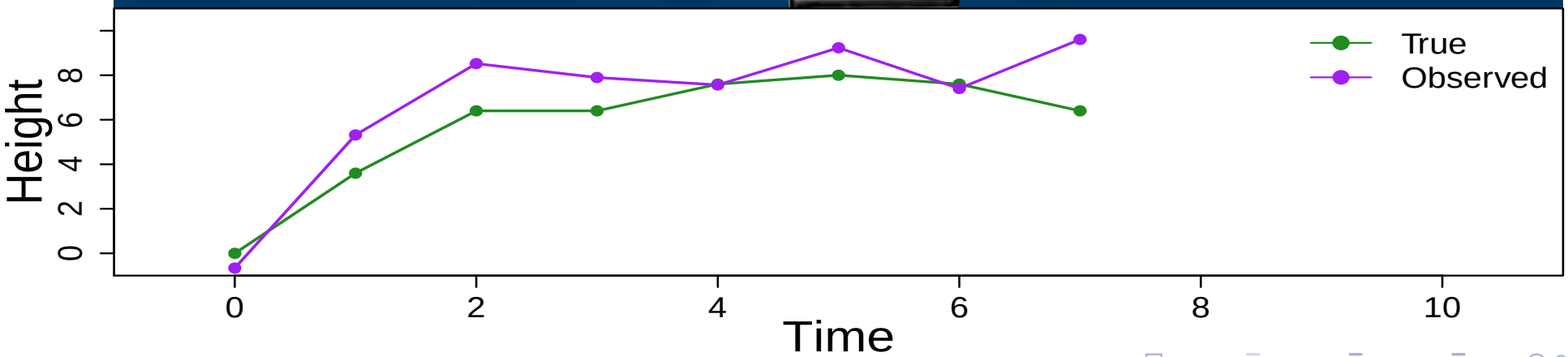
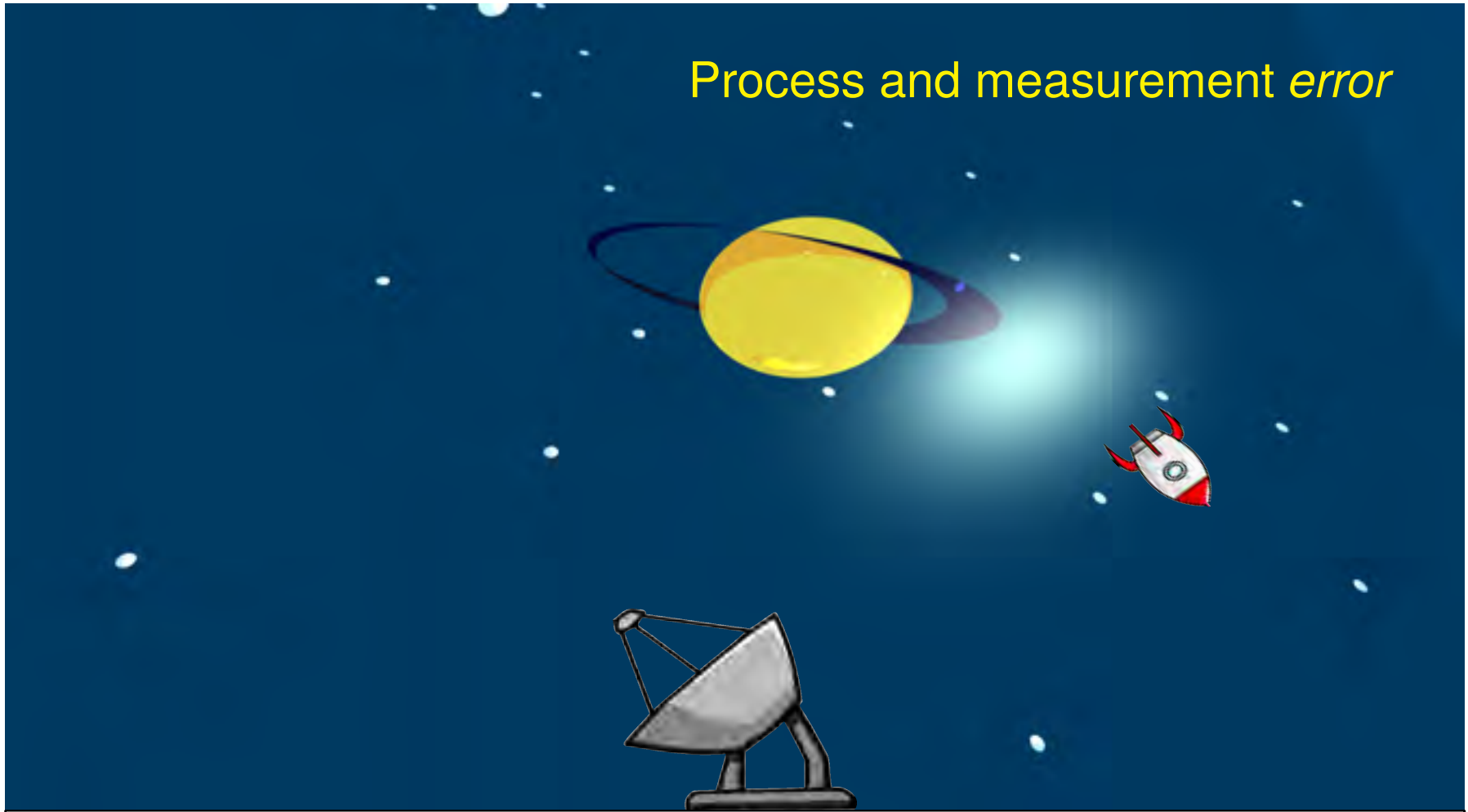
Observed

Process and measurement *error*



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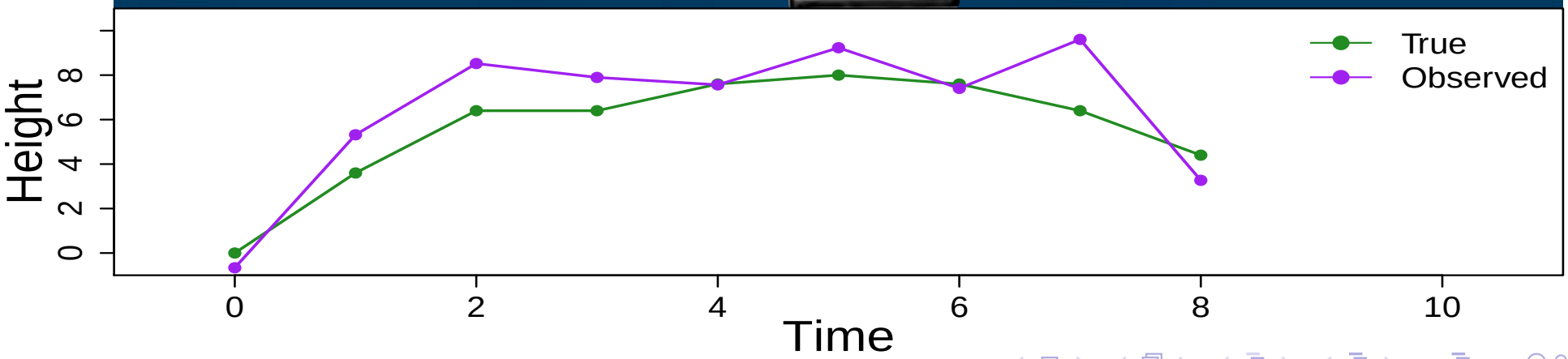
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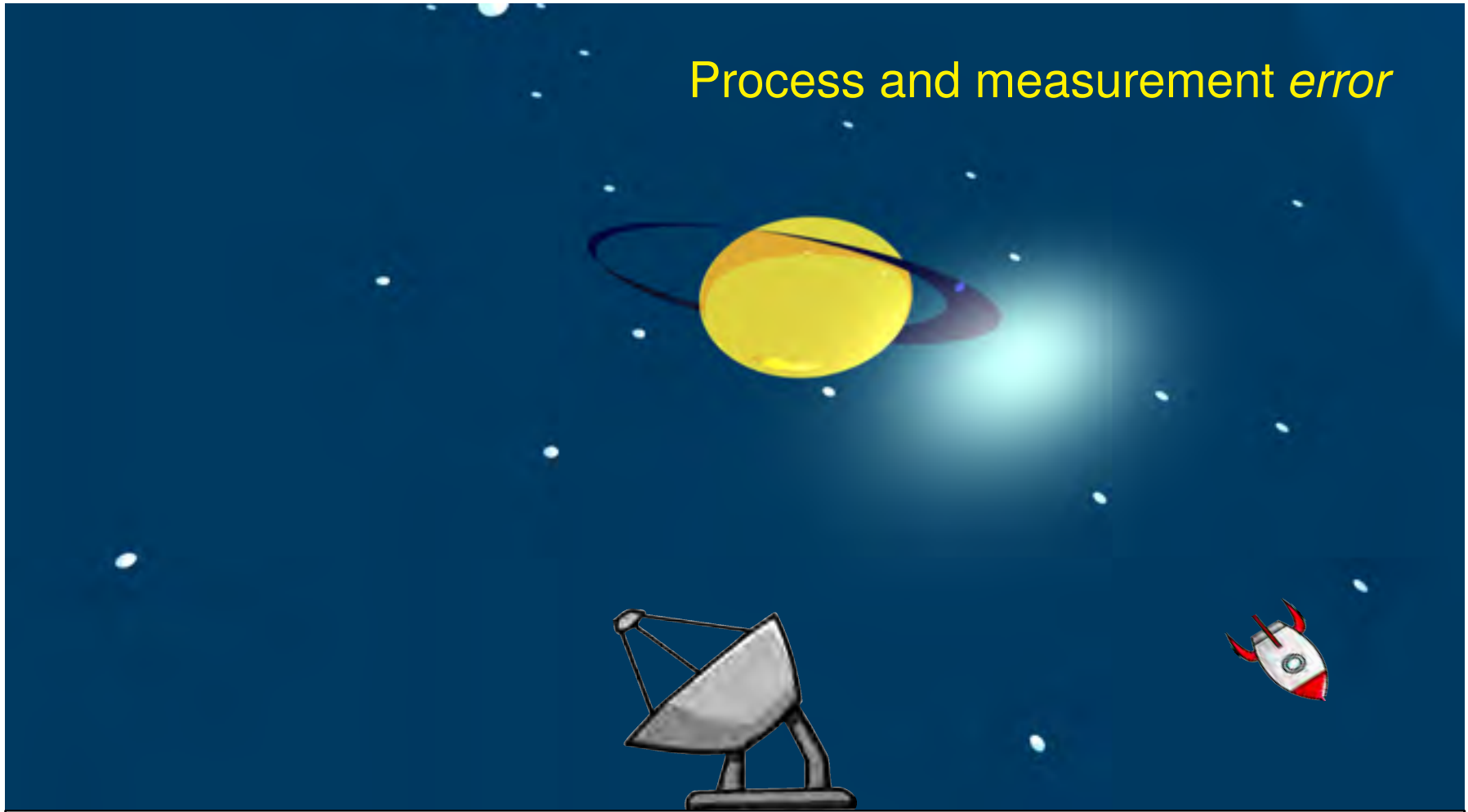

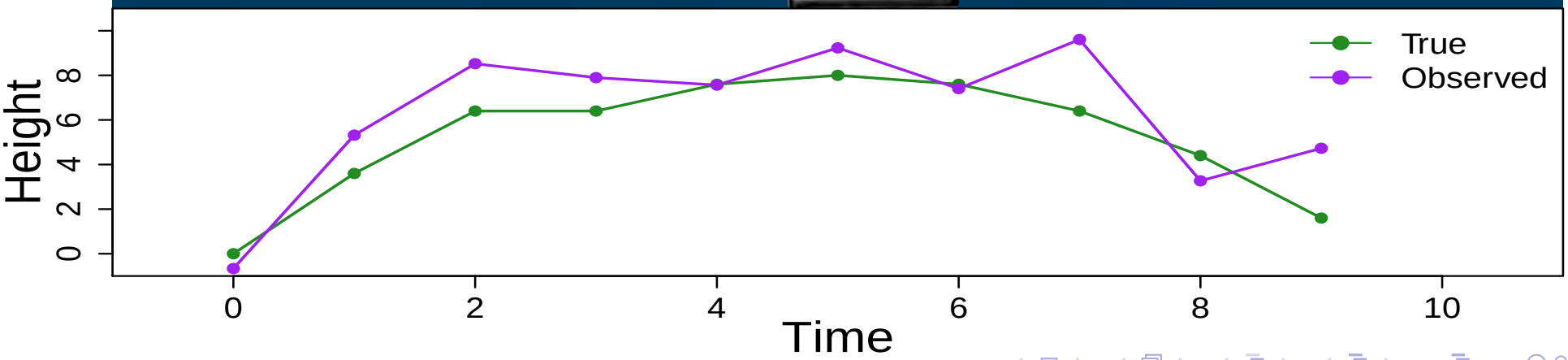

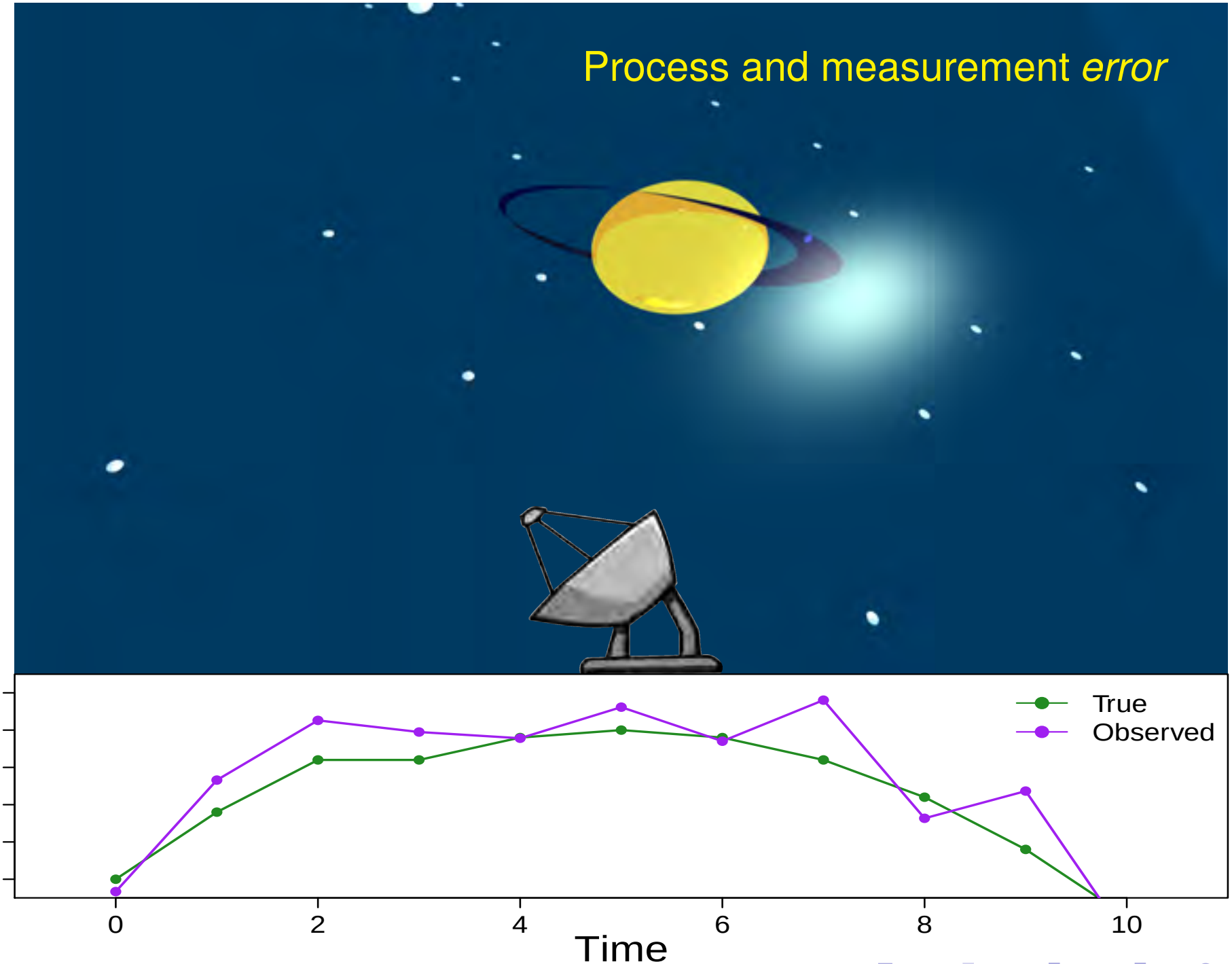
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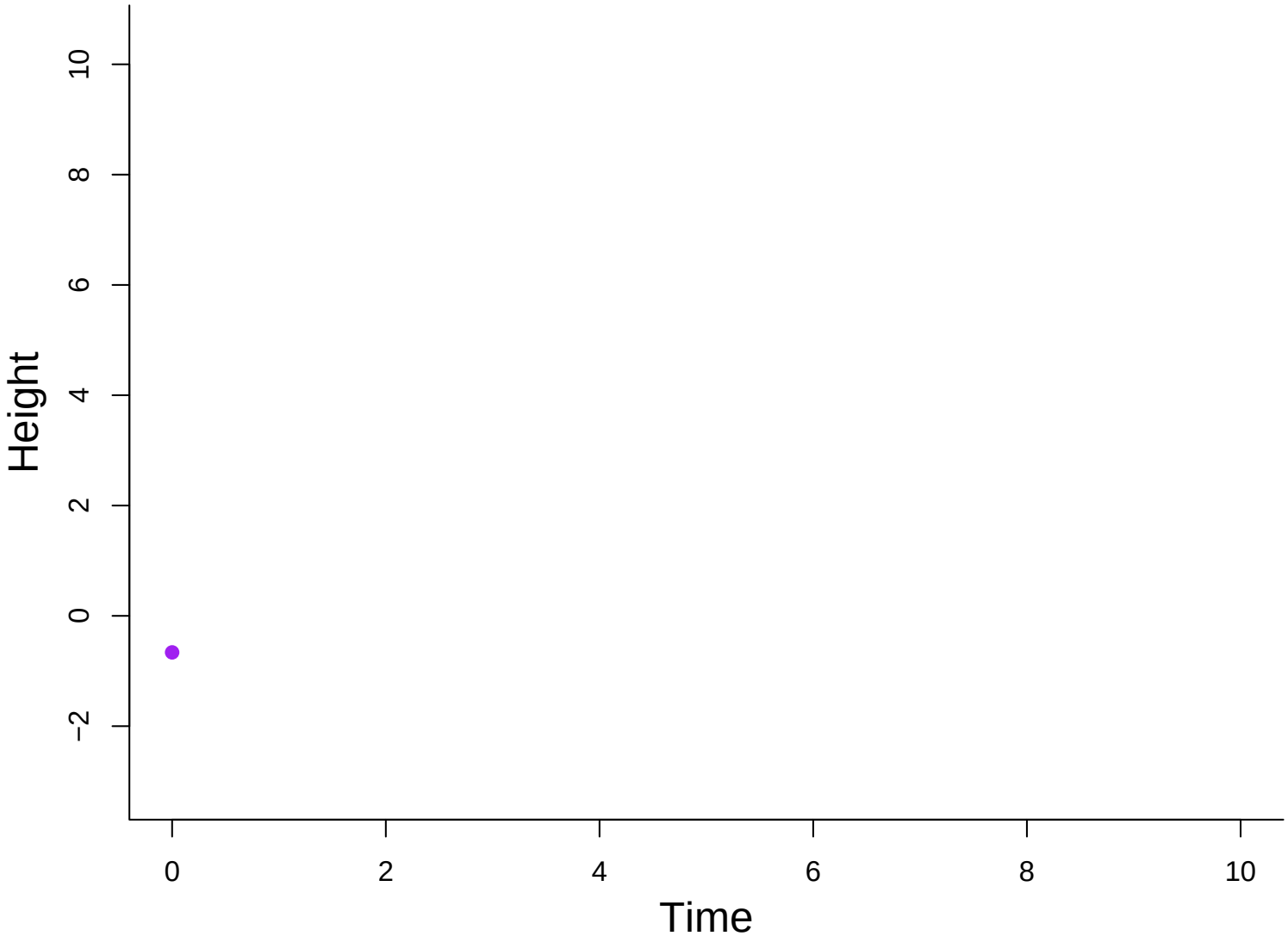
Process error only



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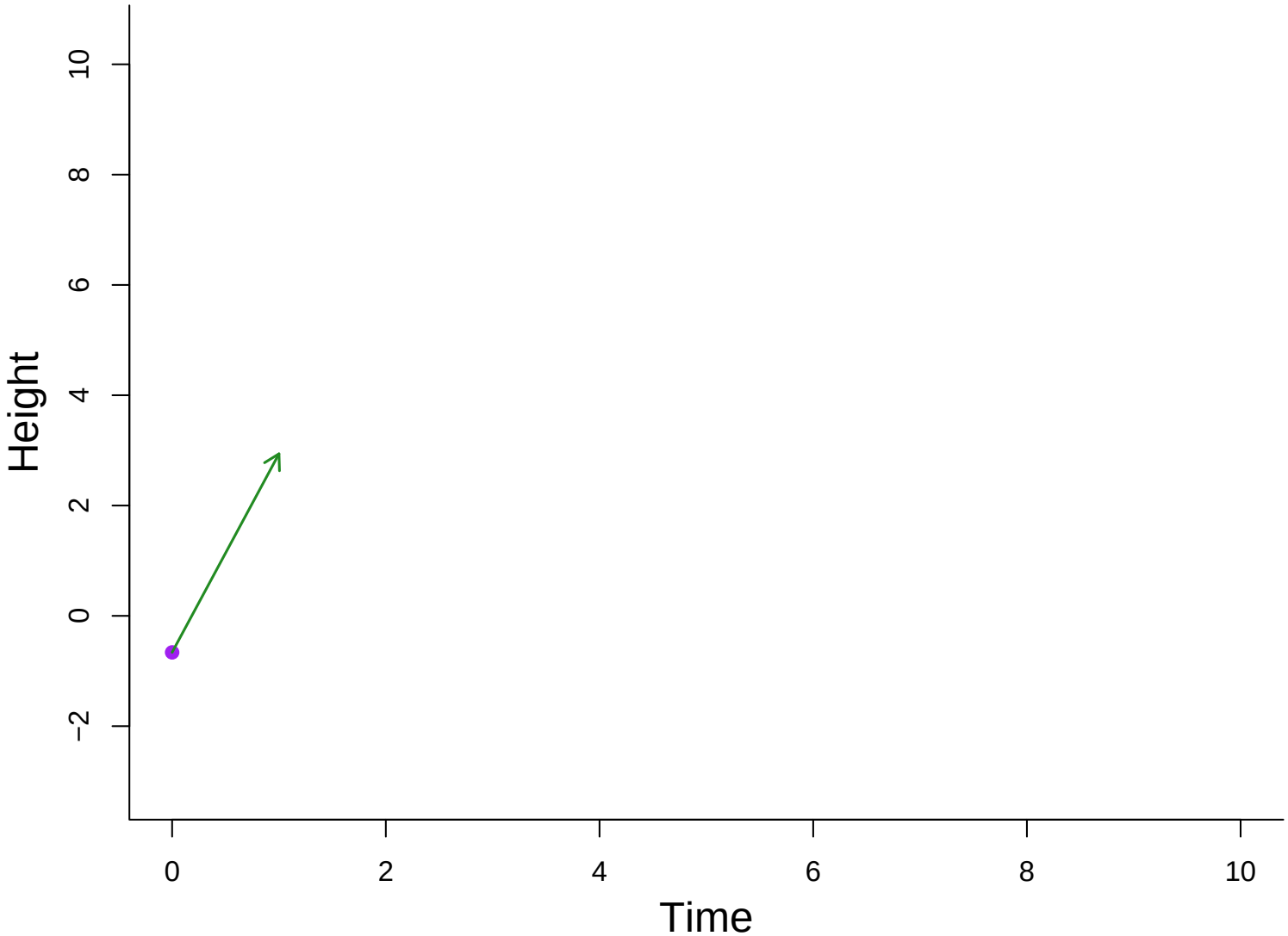

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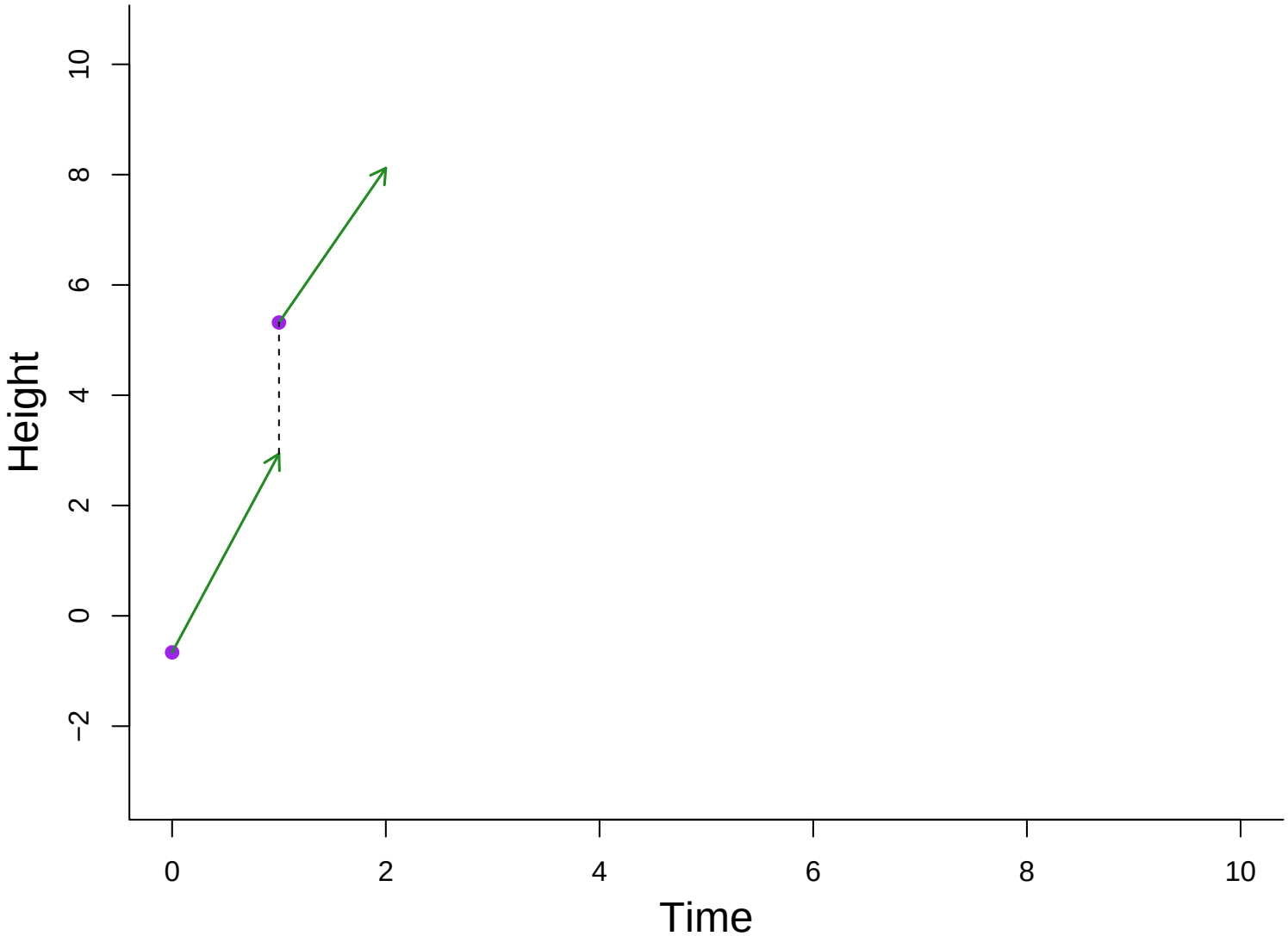

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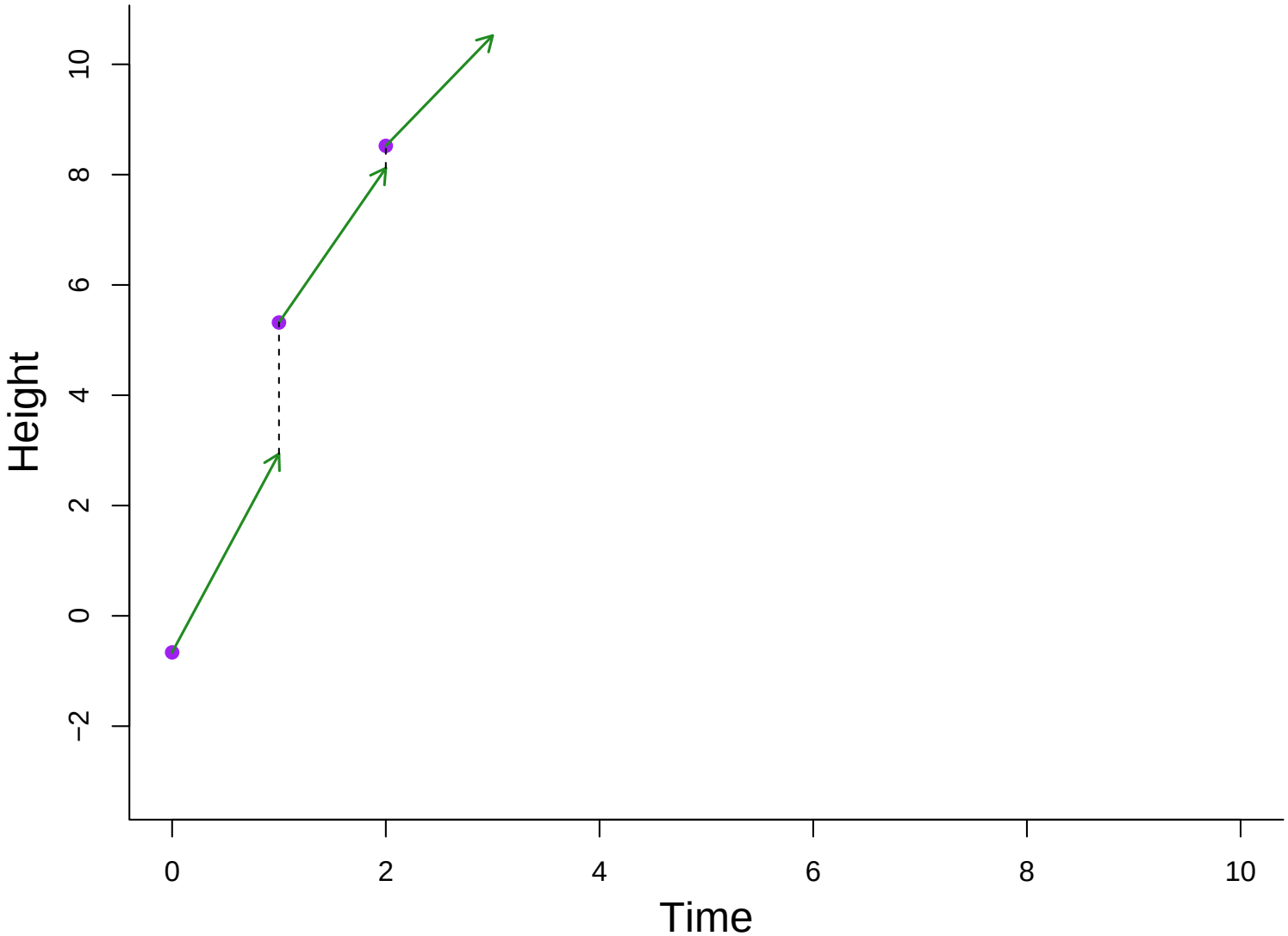

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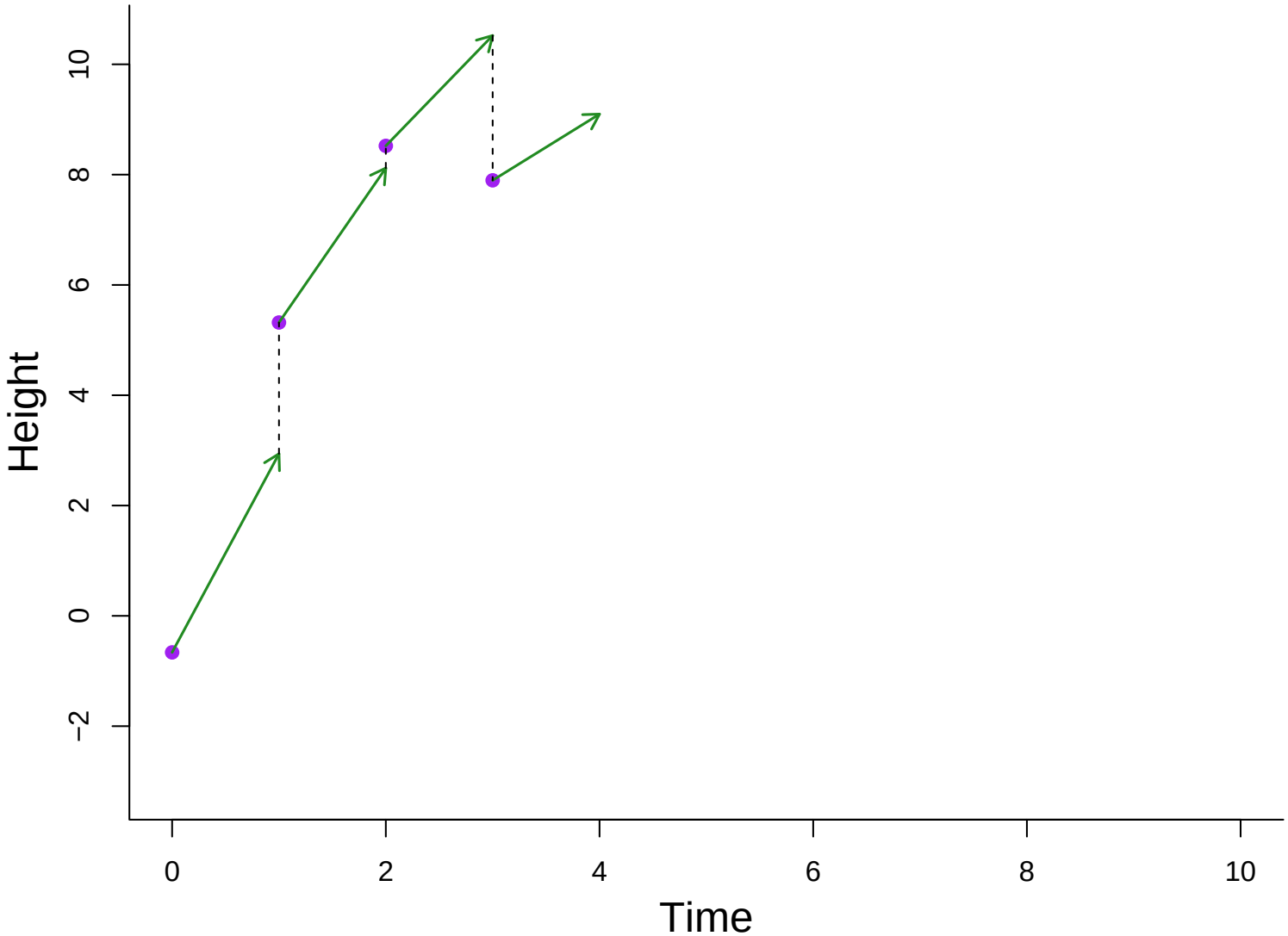

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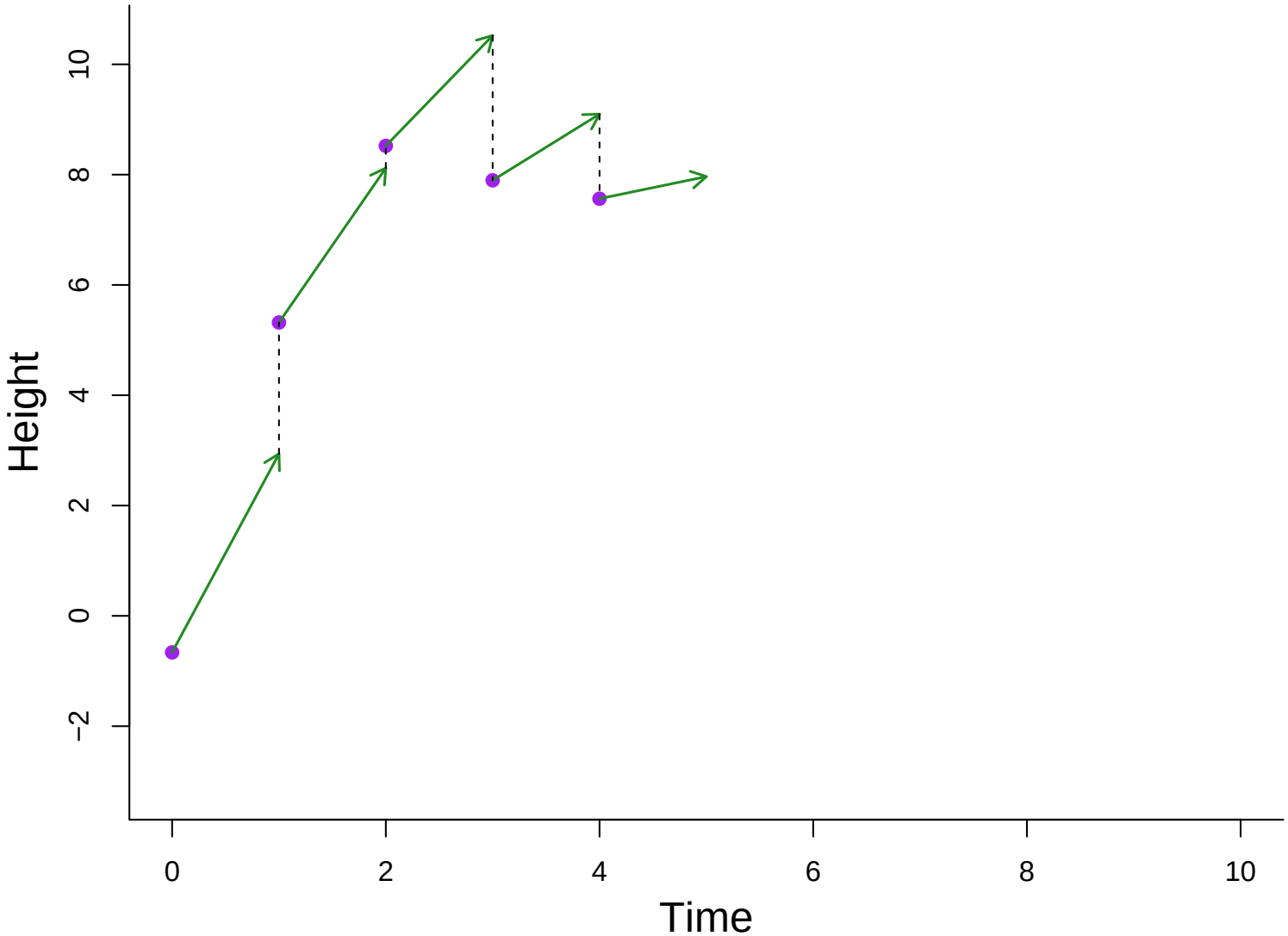

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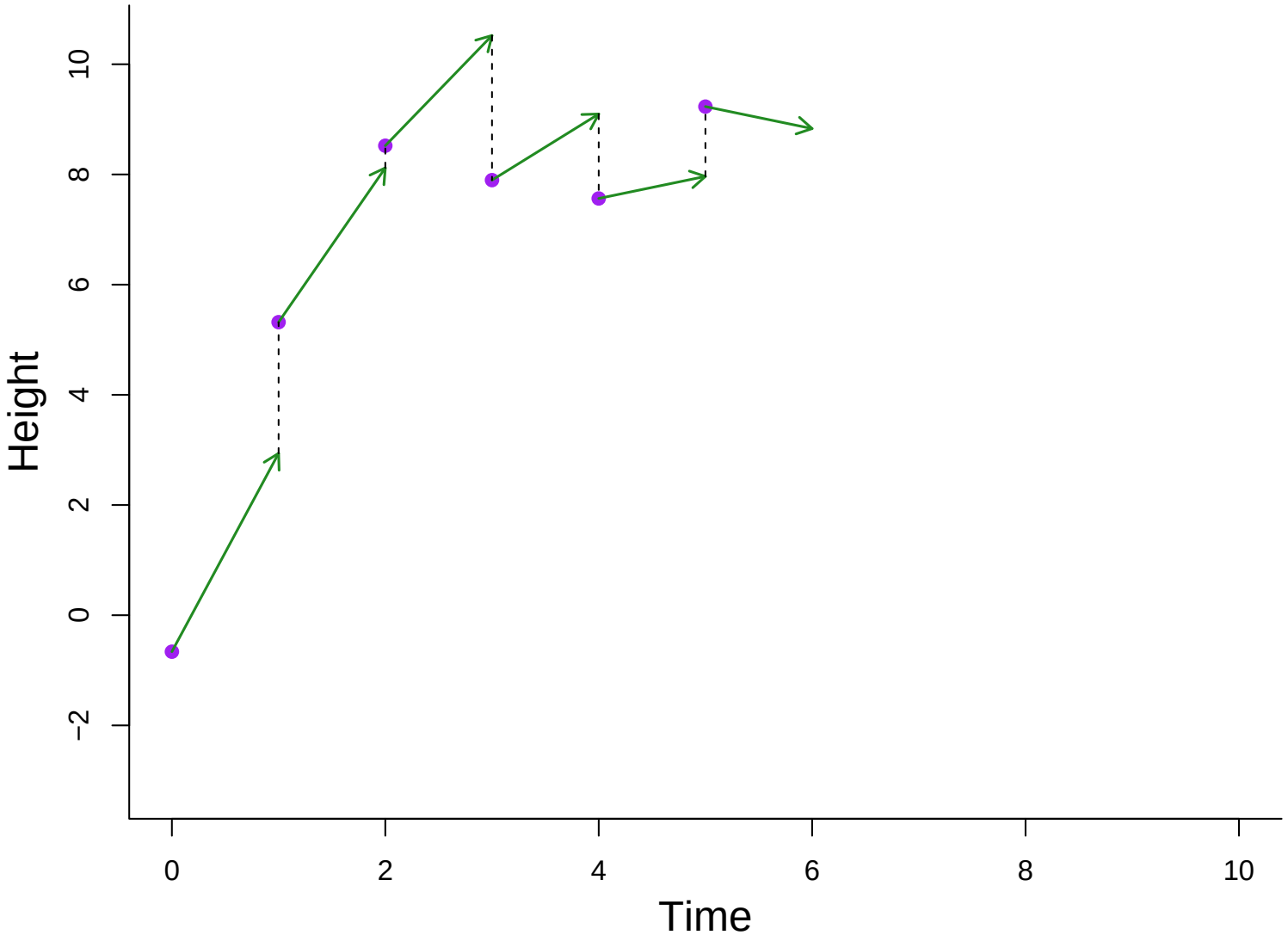

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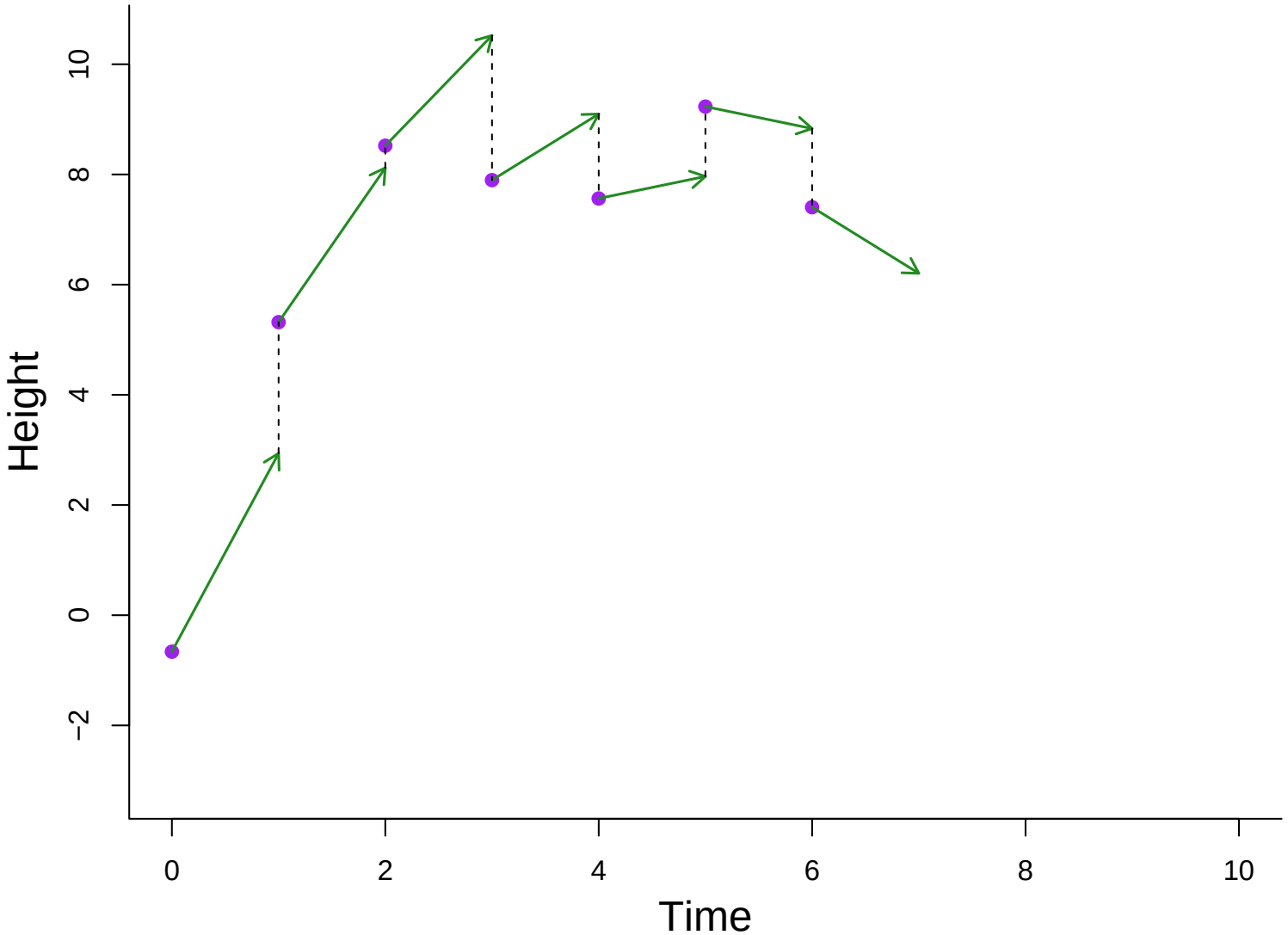

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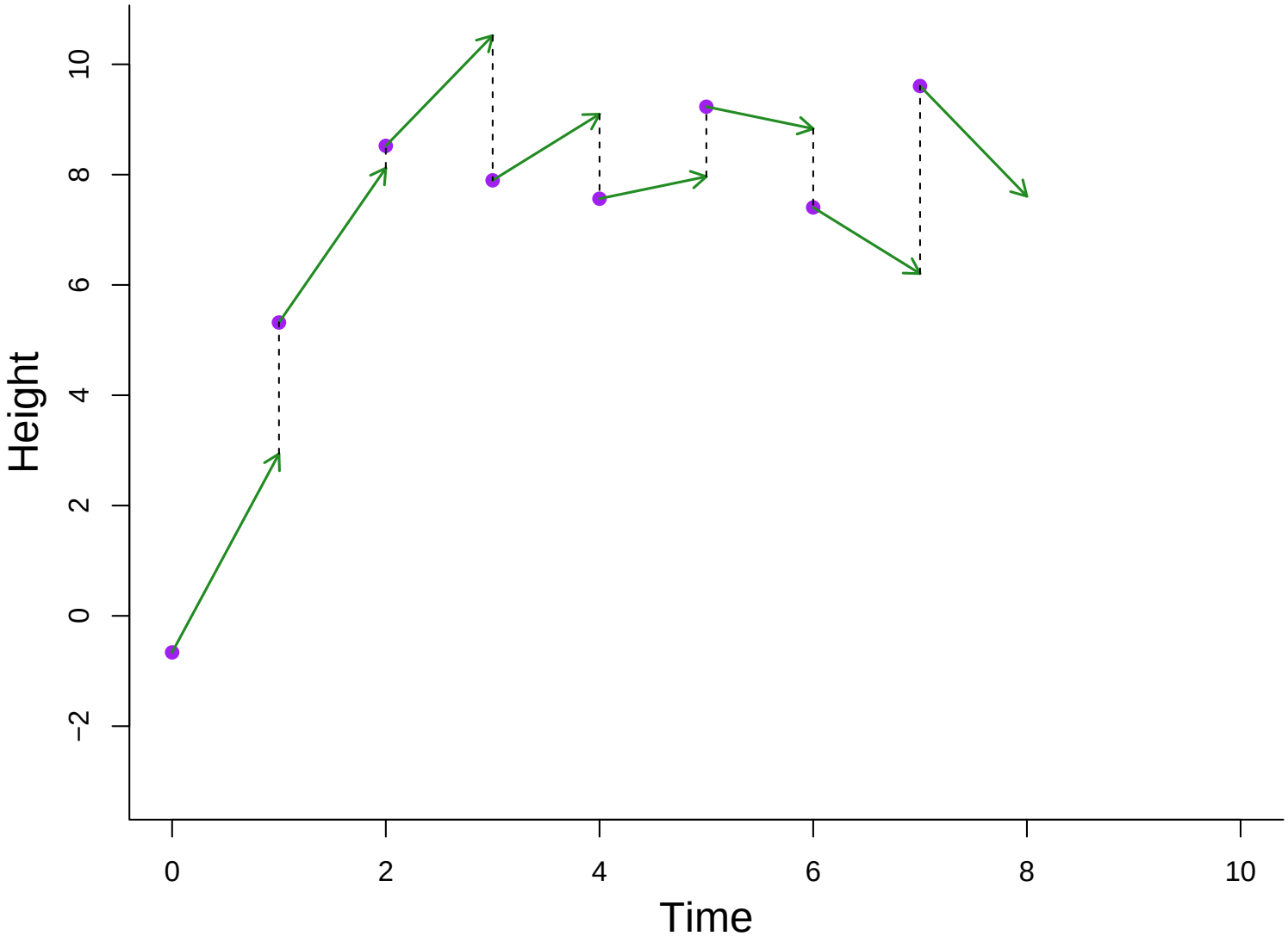

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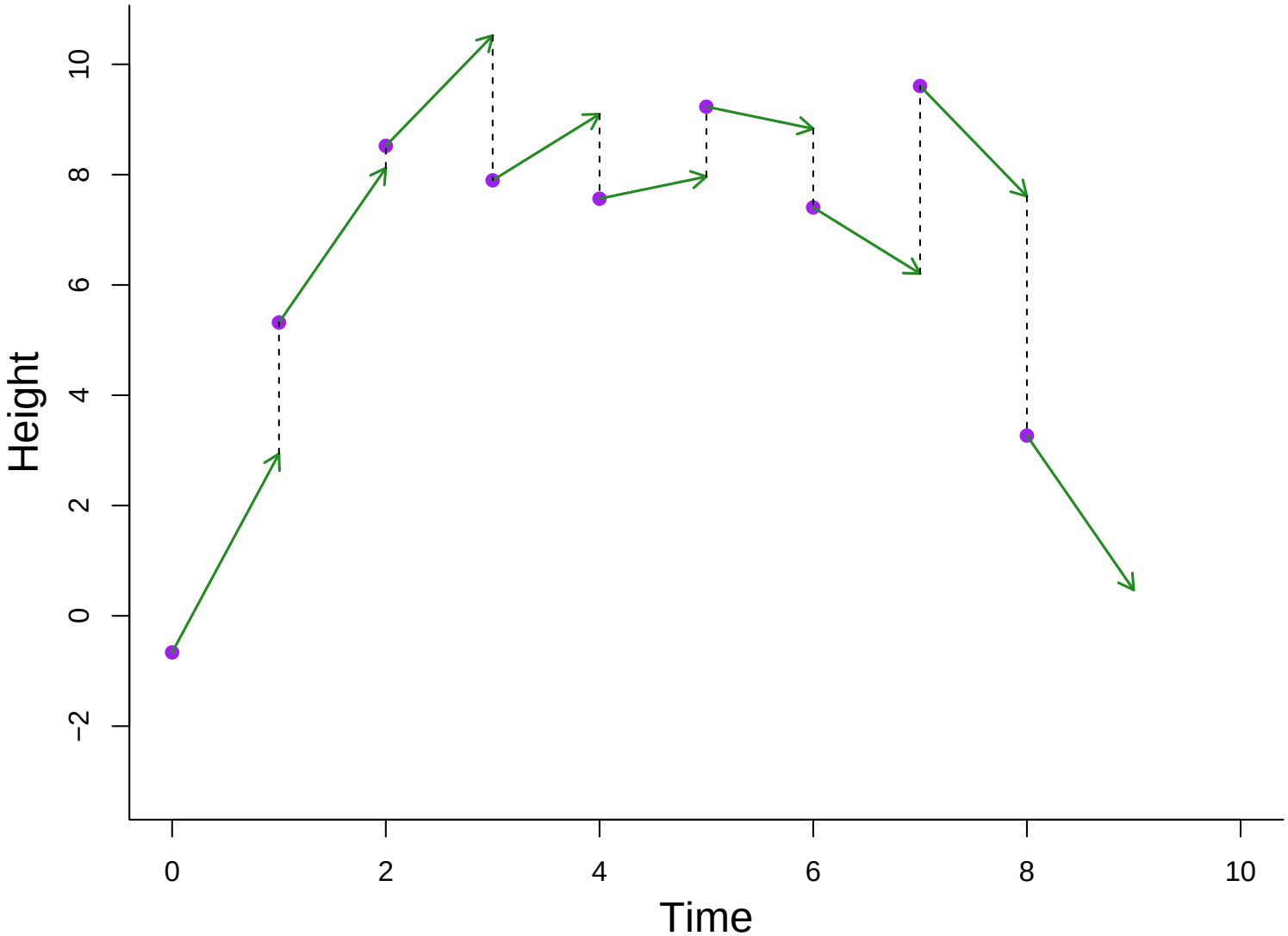

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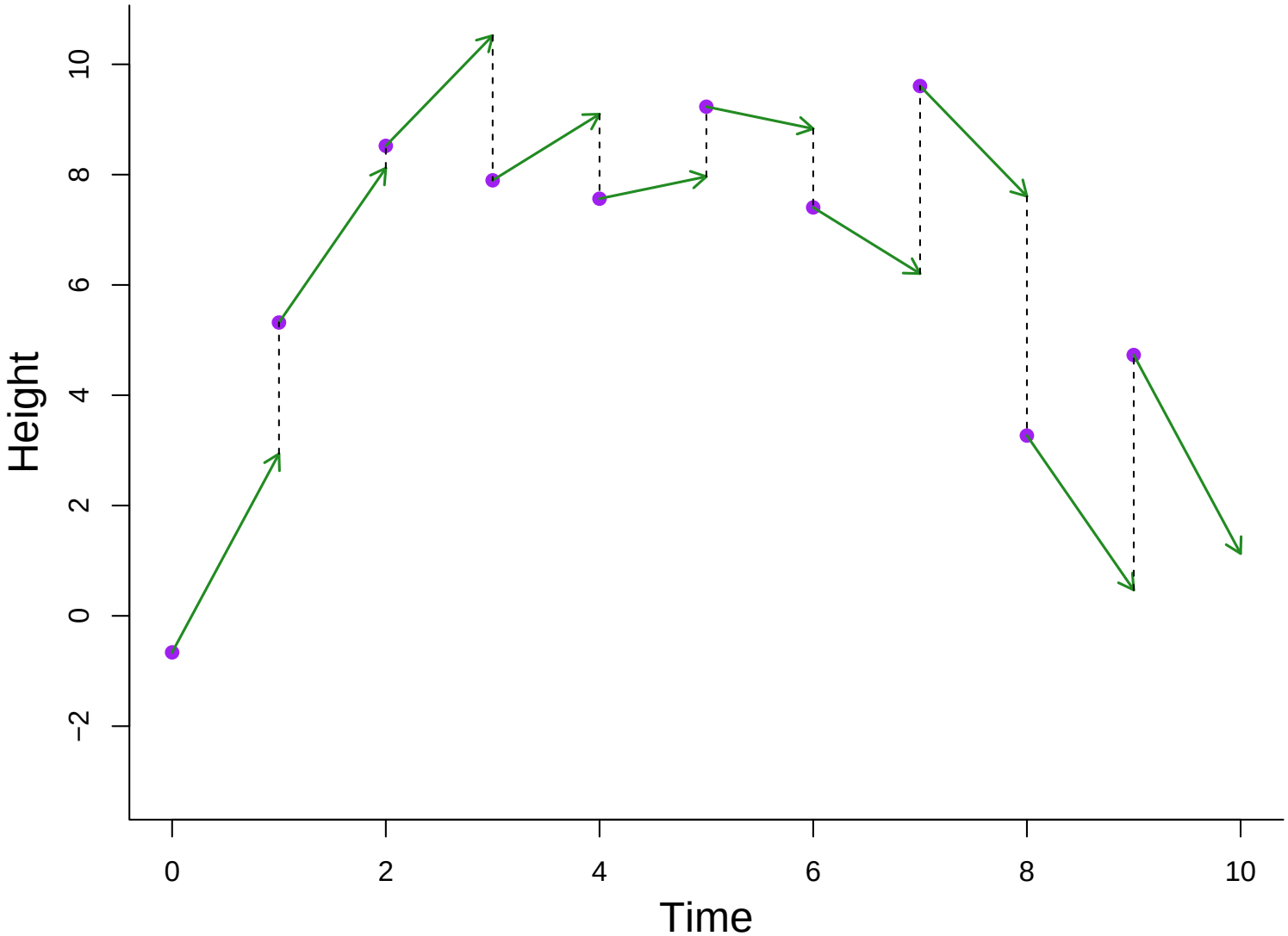

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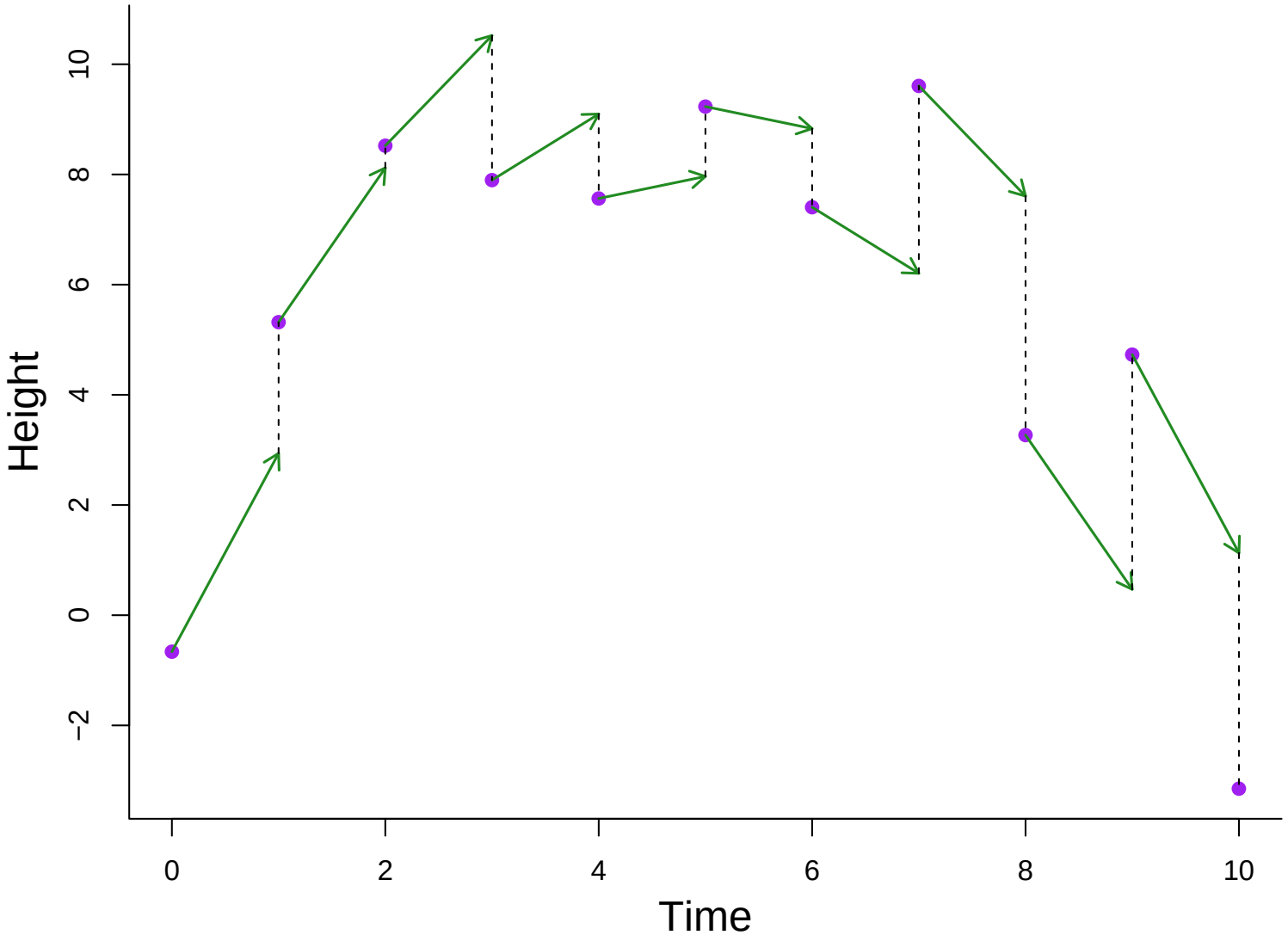

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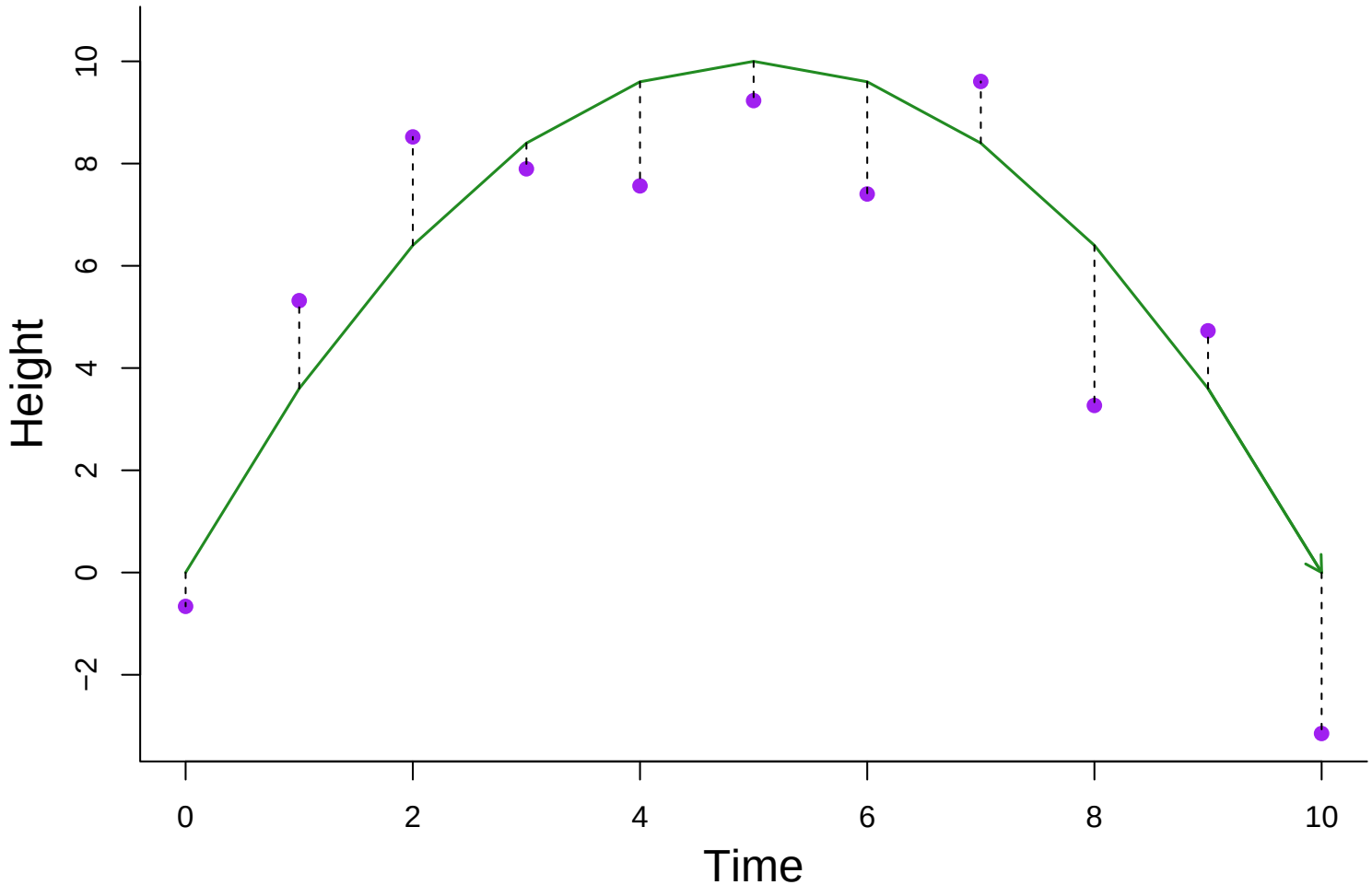
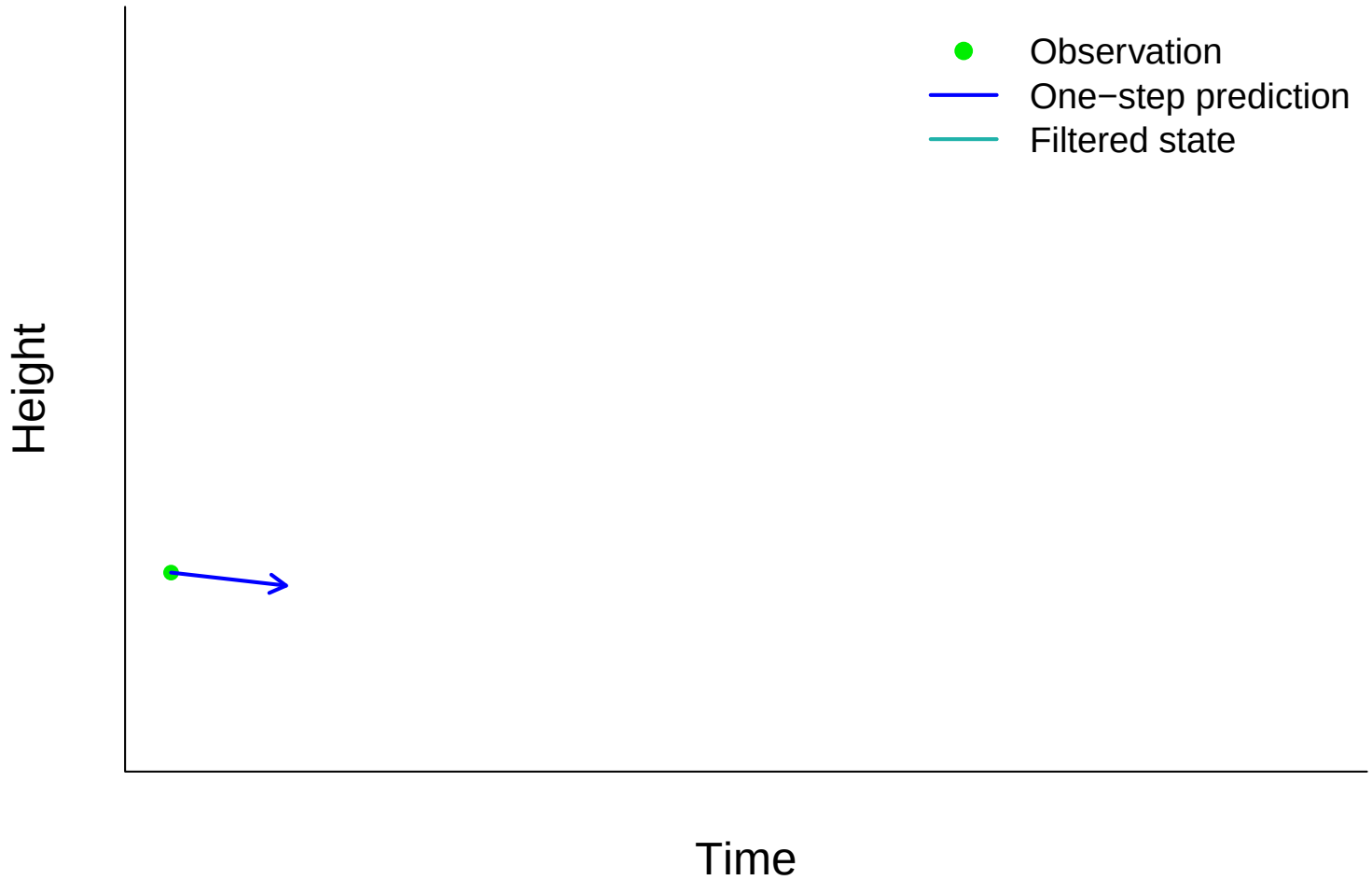
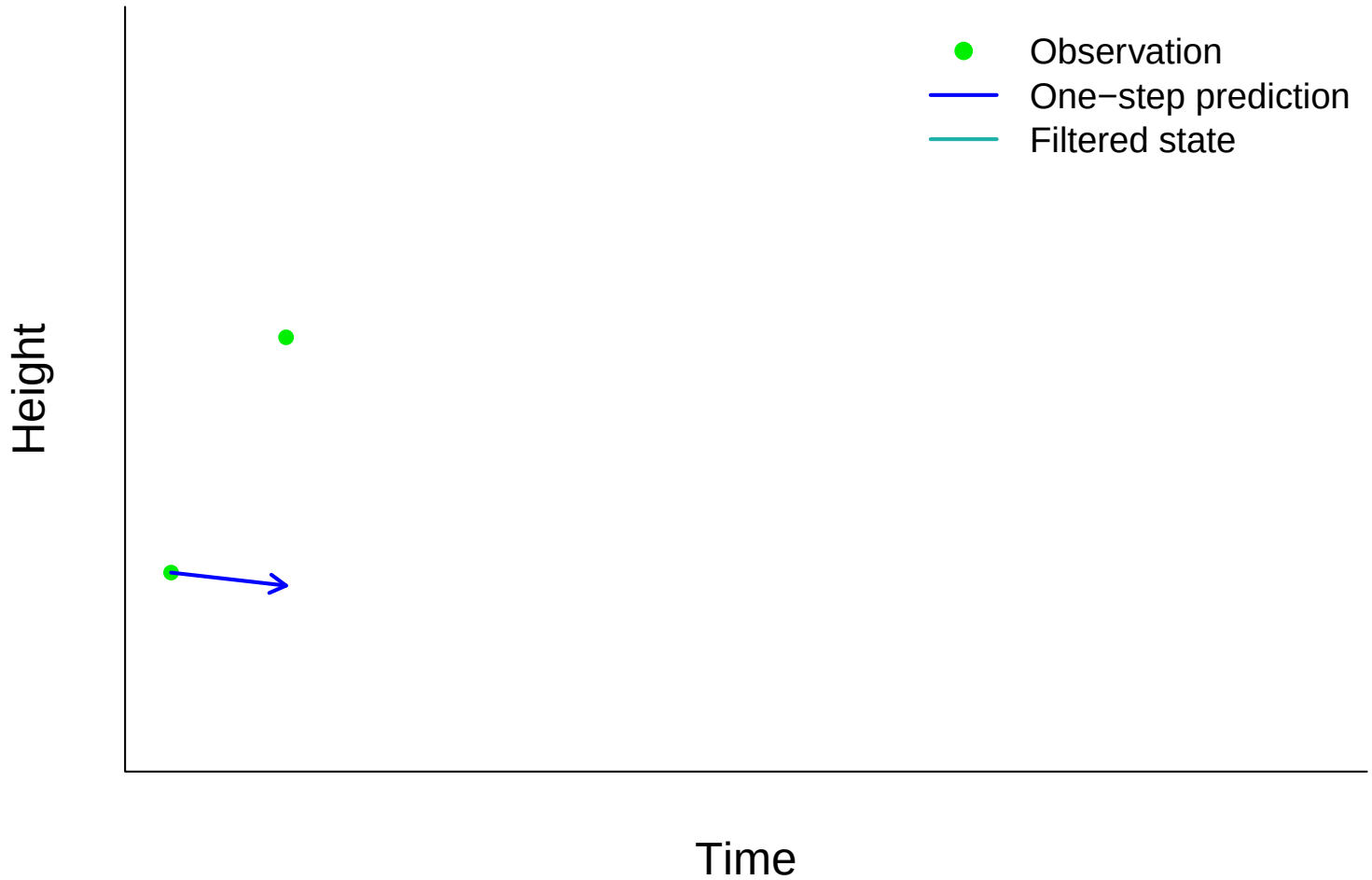


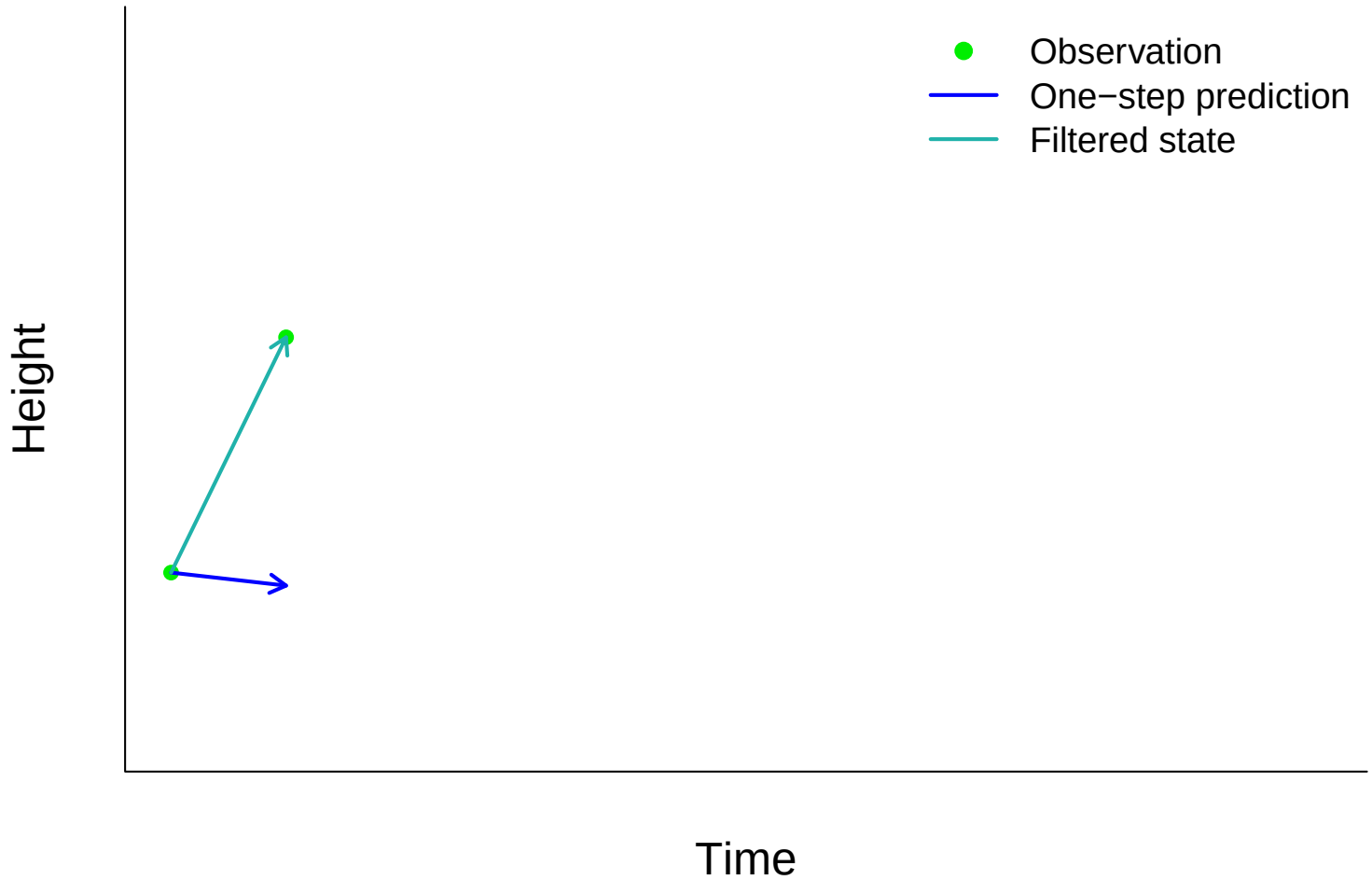
Both – Kalman filter



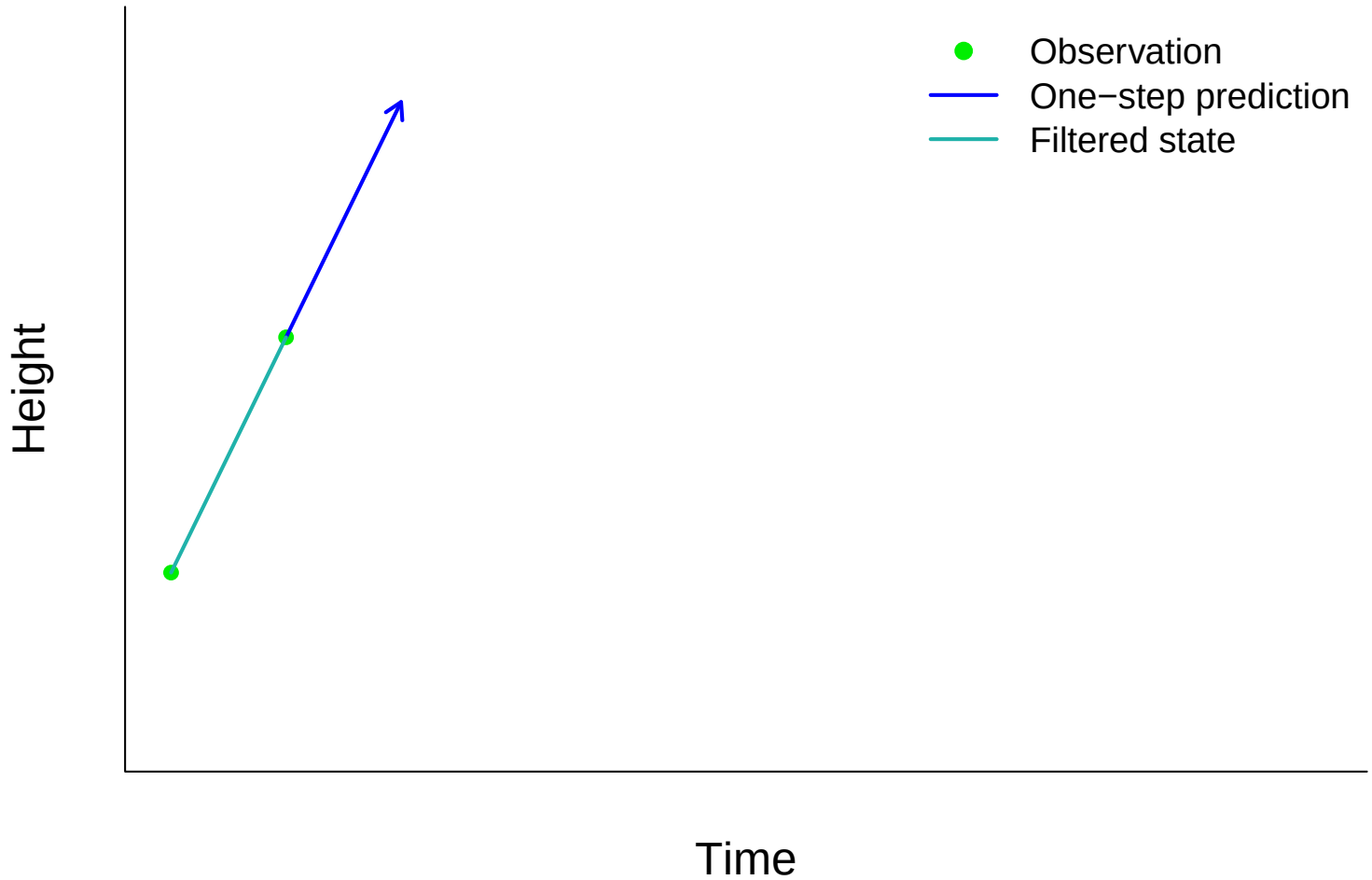
Both – Kalman filter



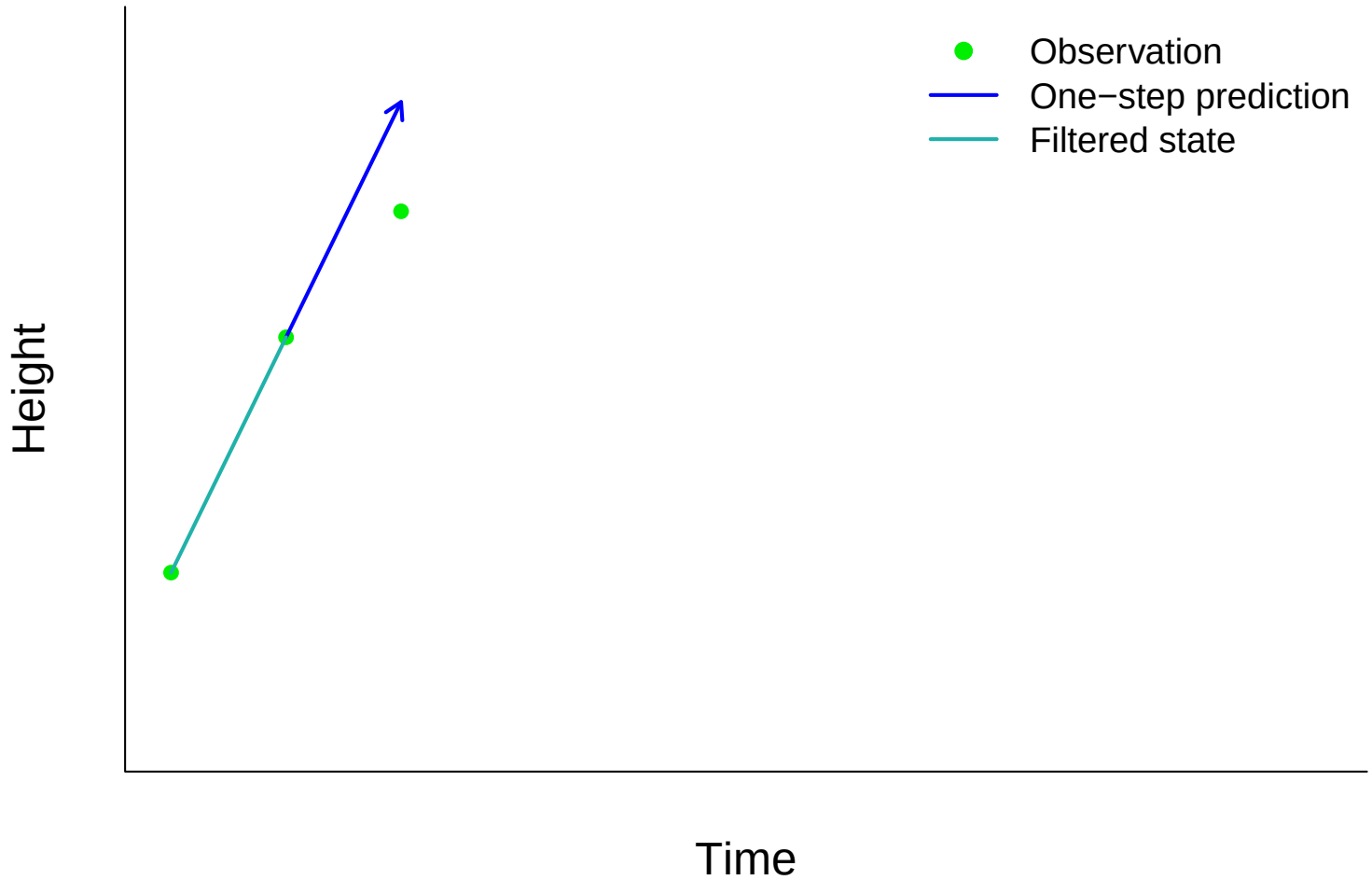
Both – Kalman filter



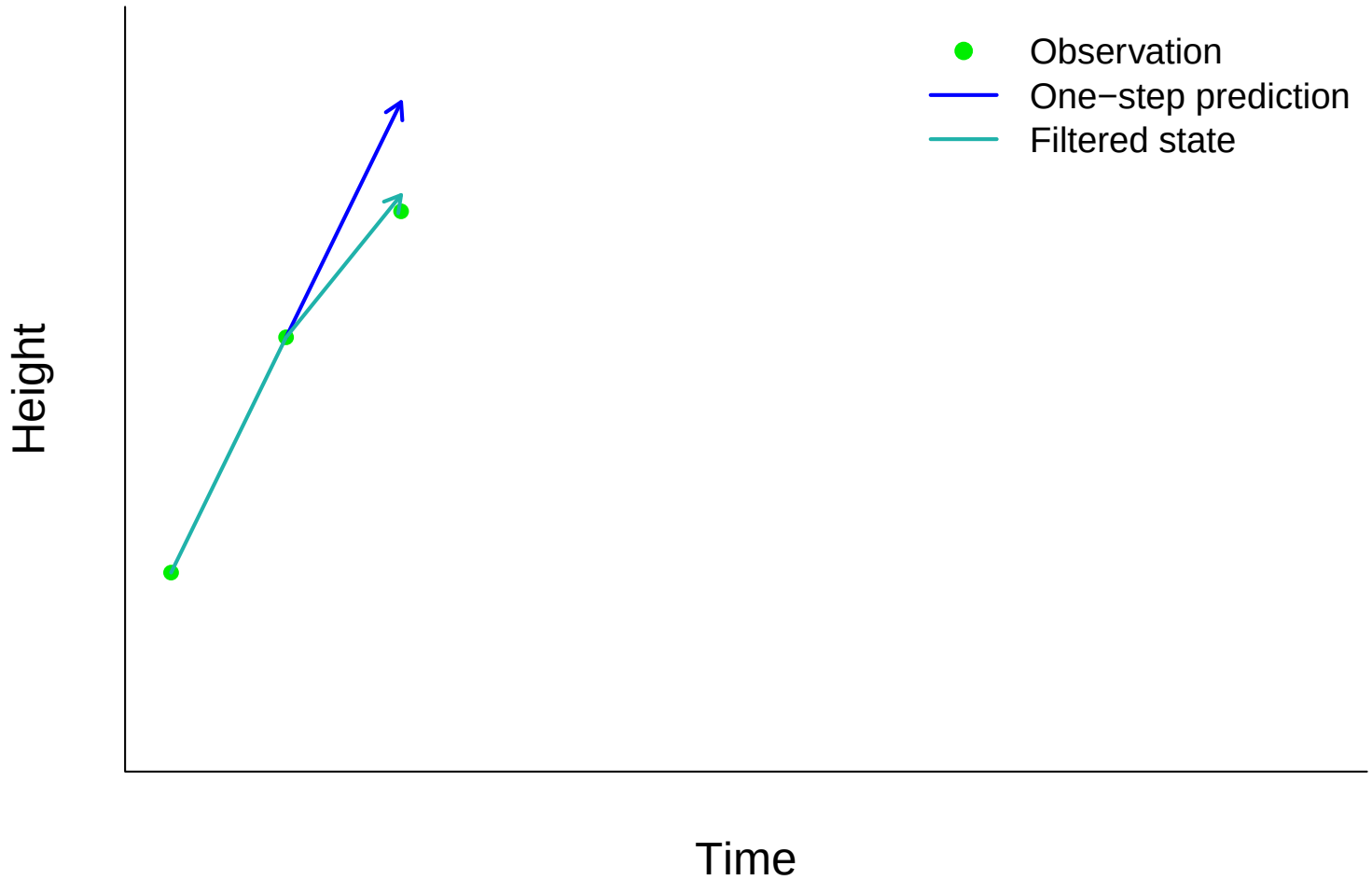
Both – Kalman filter



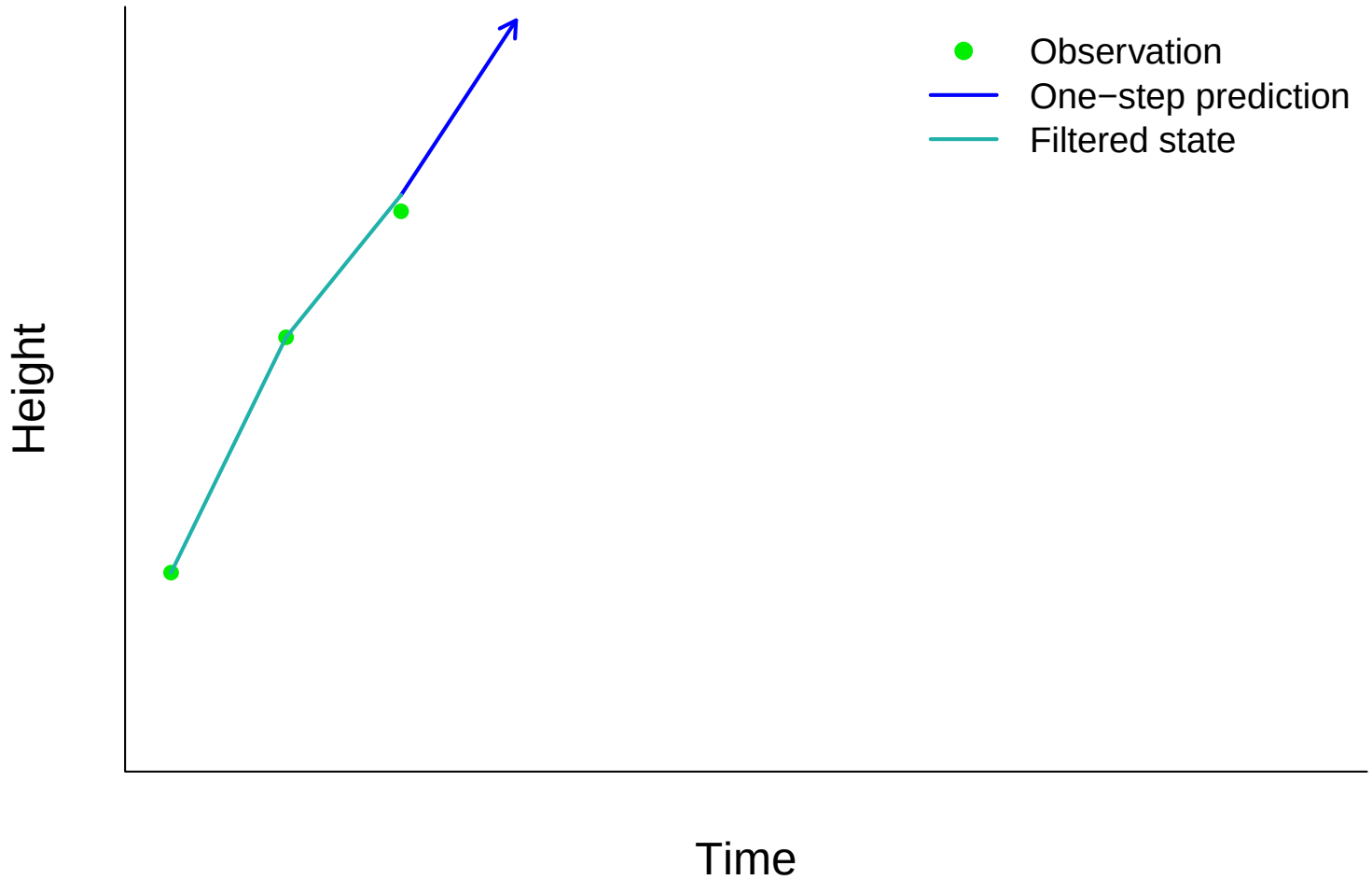
Both – Kalman filter



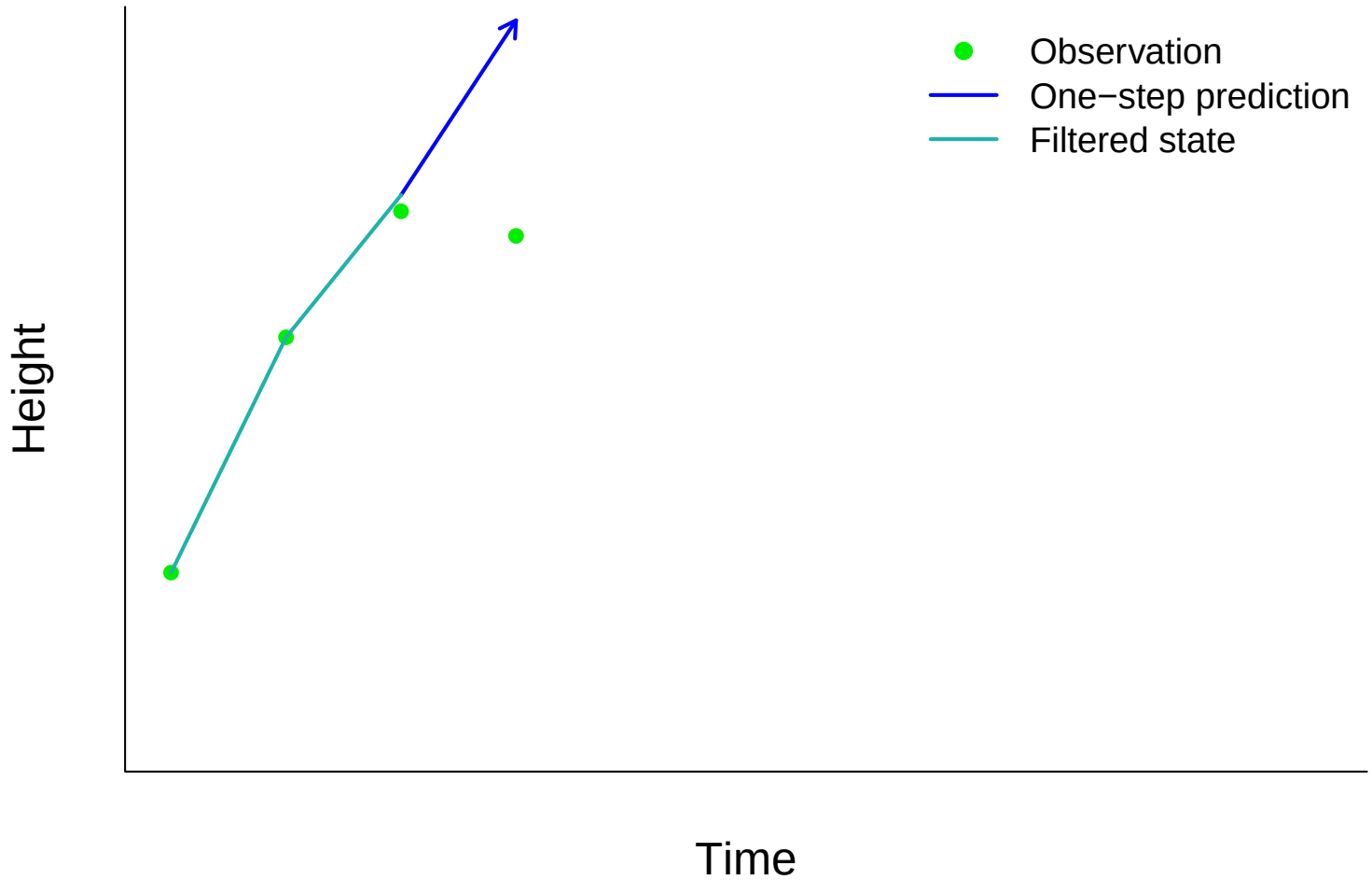
Both – Kalman filter



Both – Kalman filter



Both – Kalman filter



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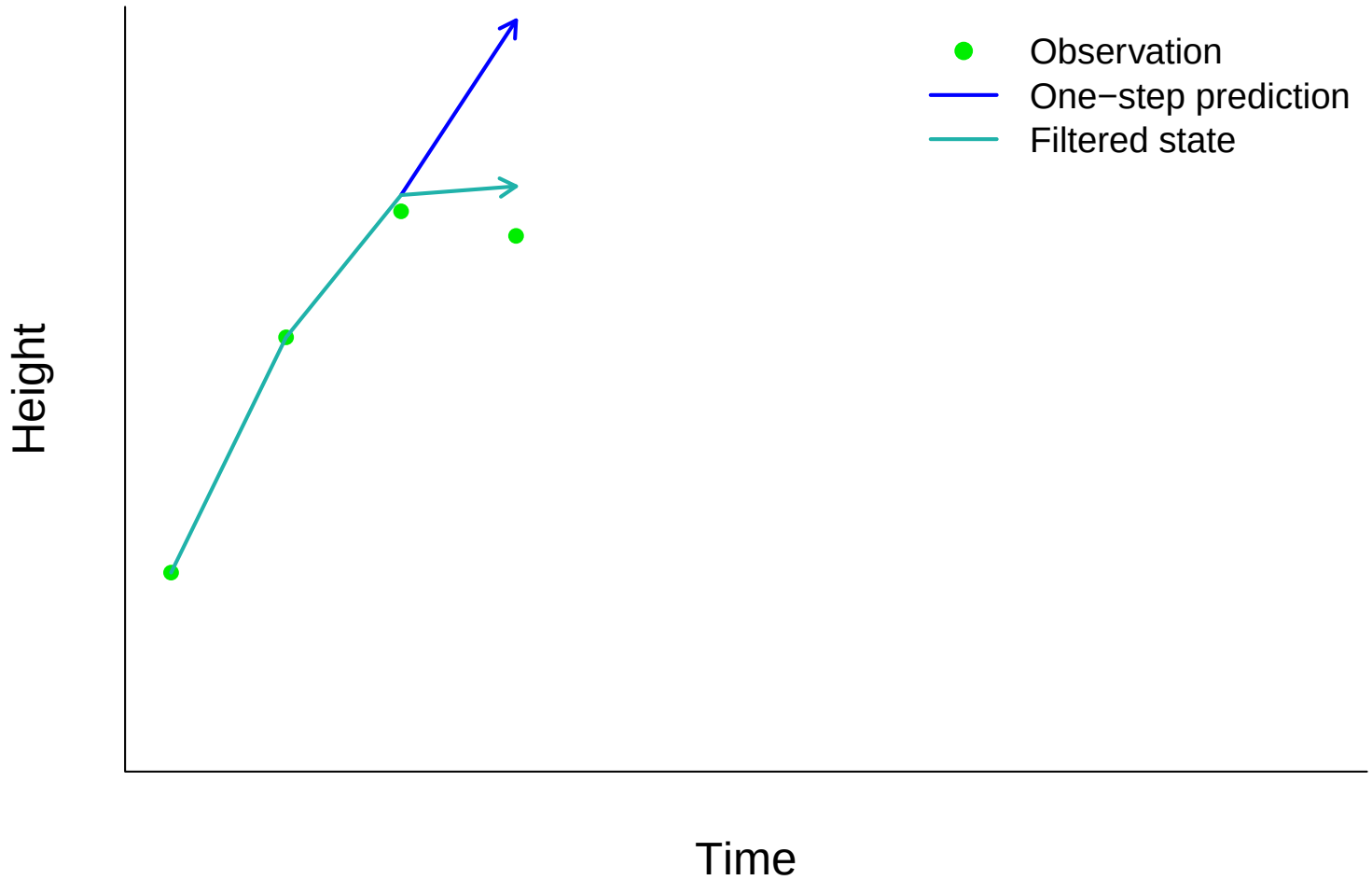
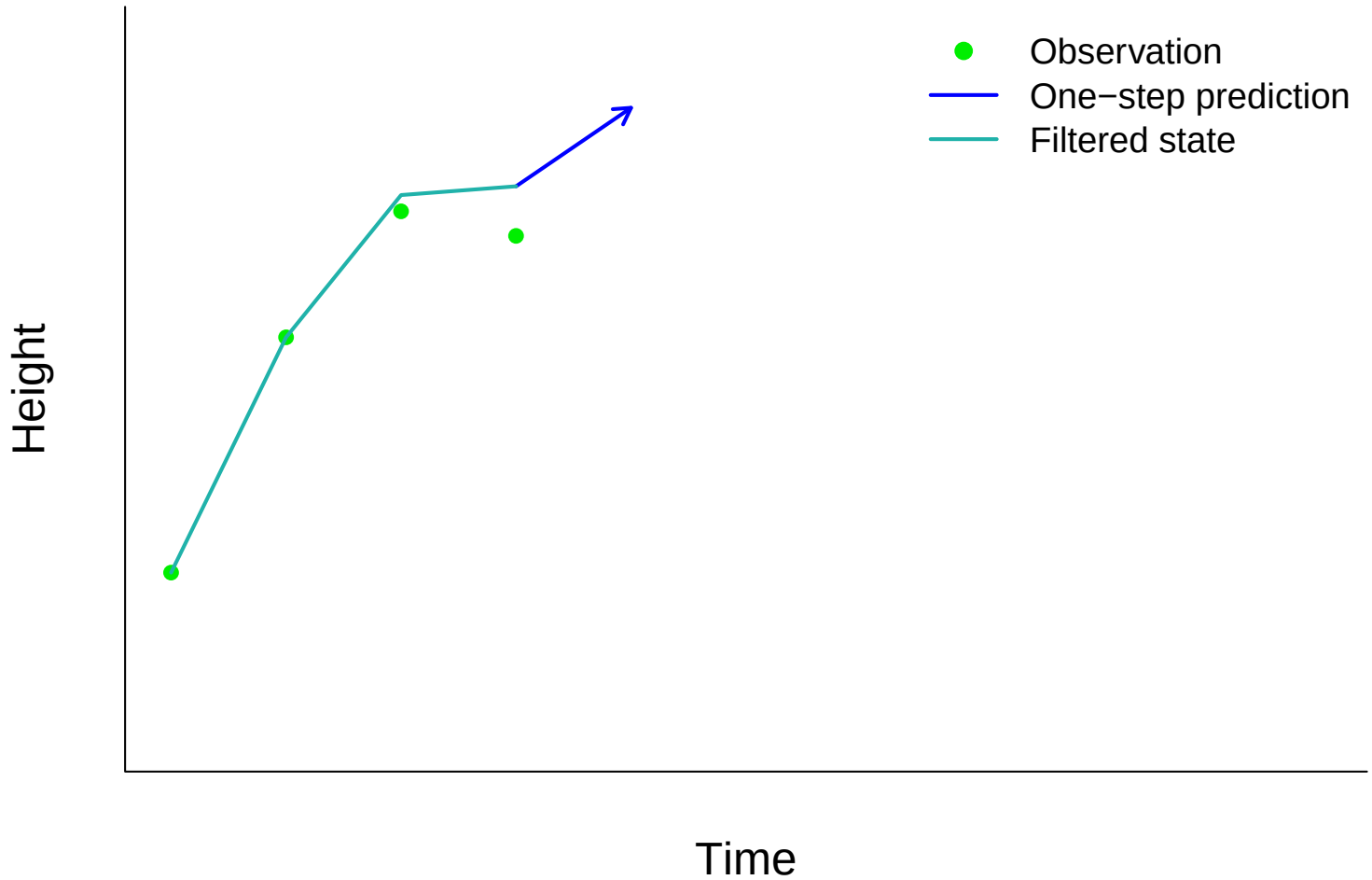
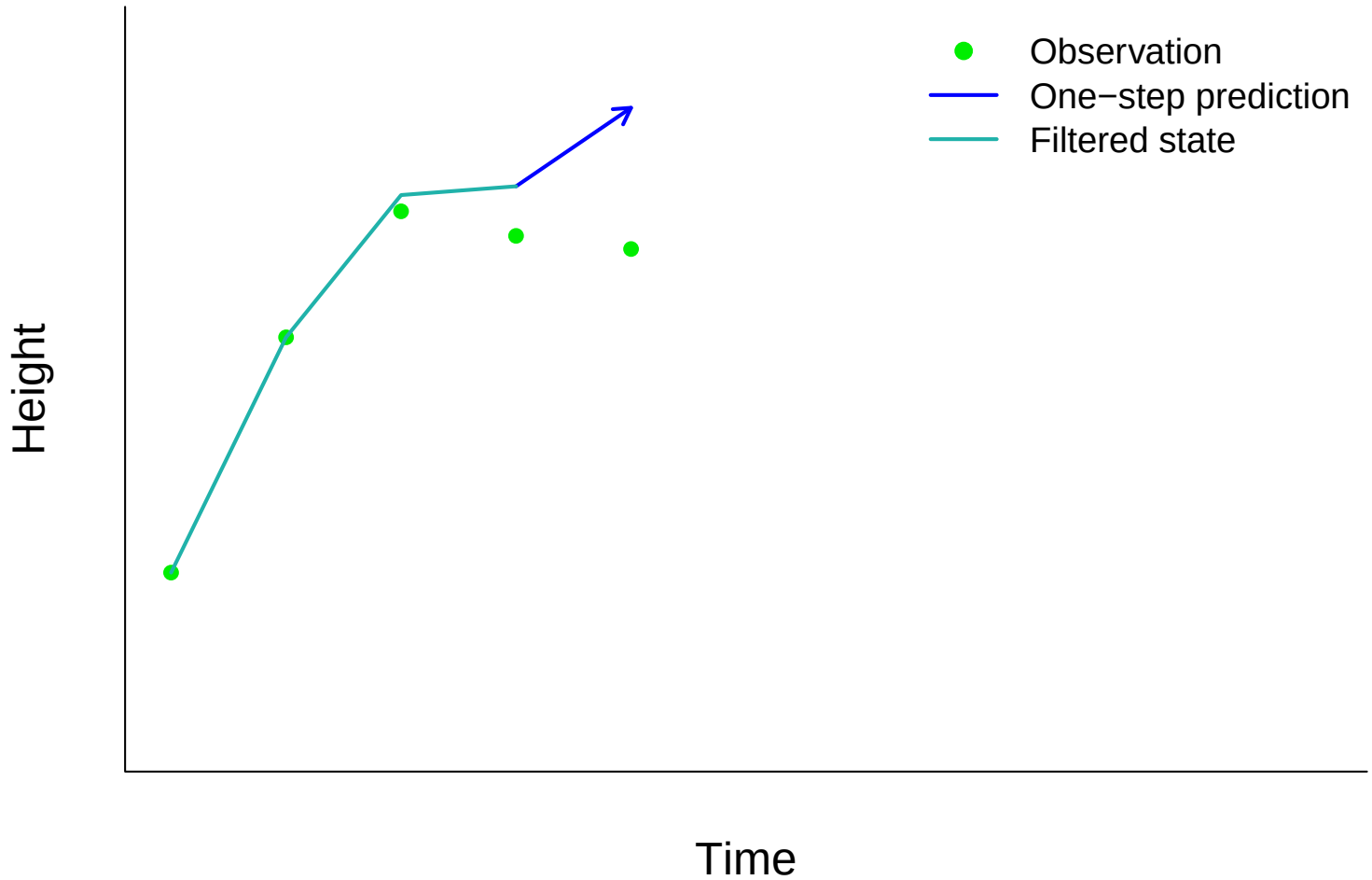


Both – Kalman filter



Both – Kalman filter



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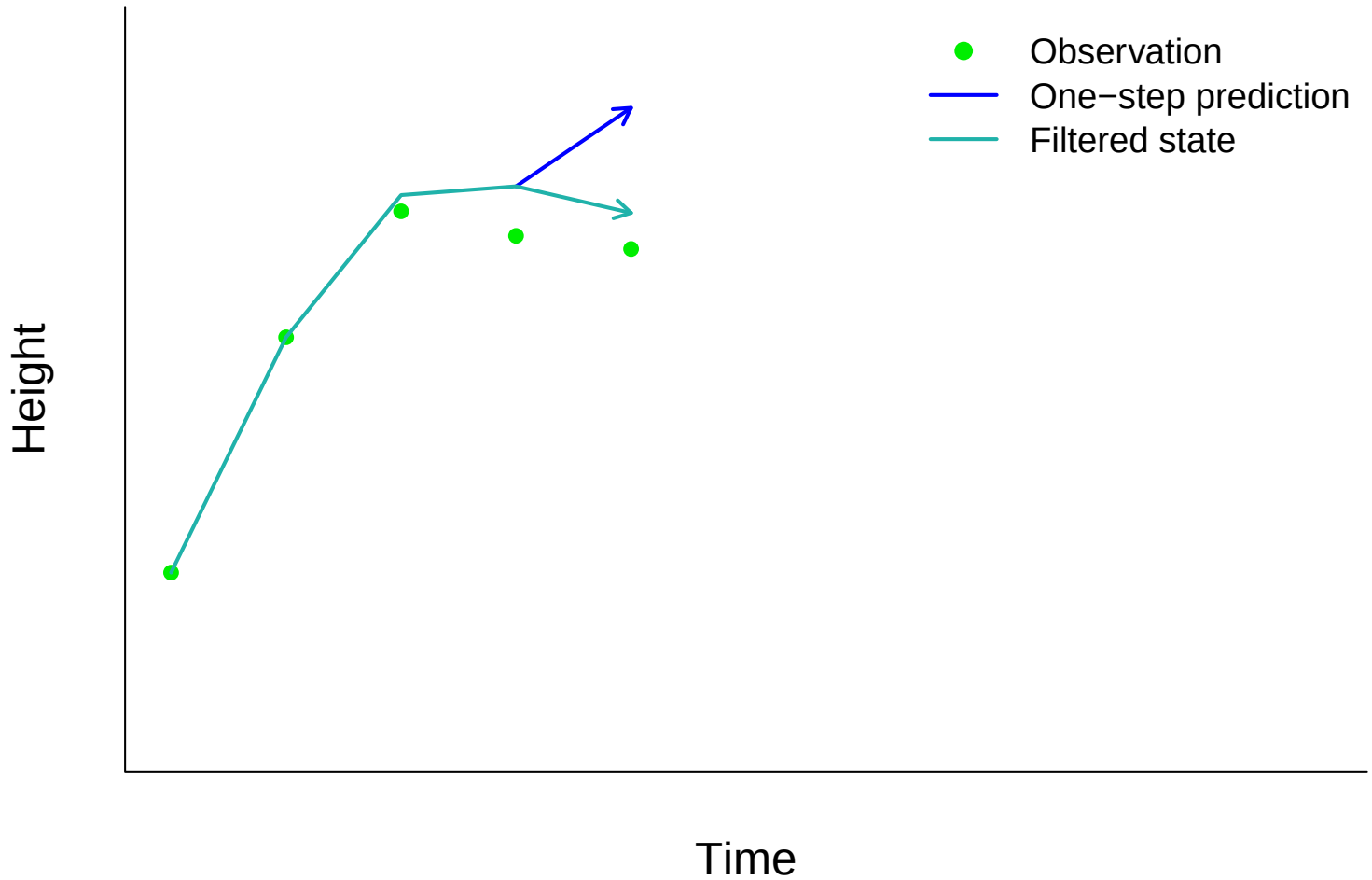
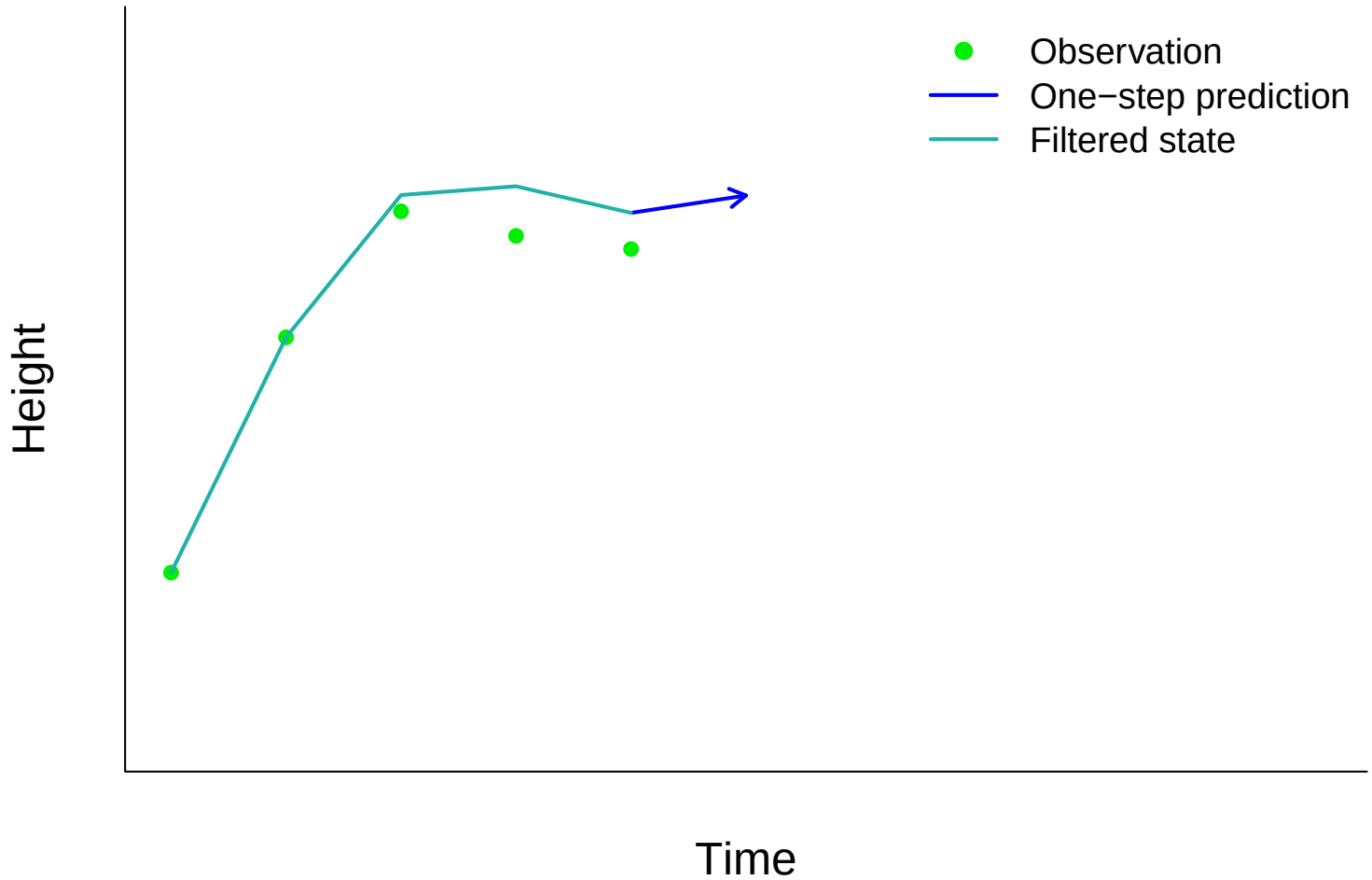
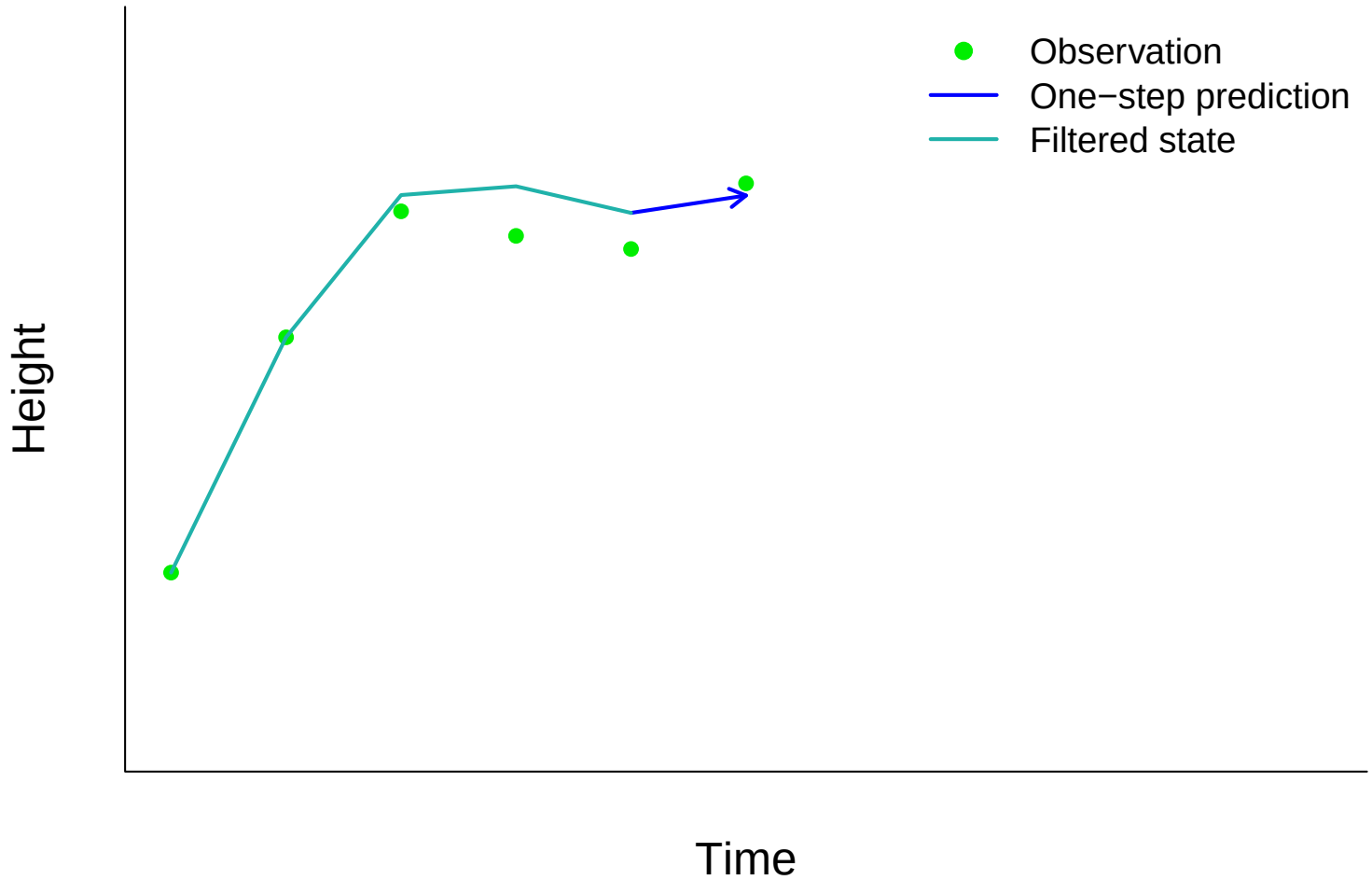


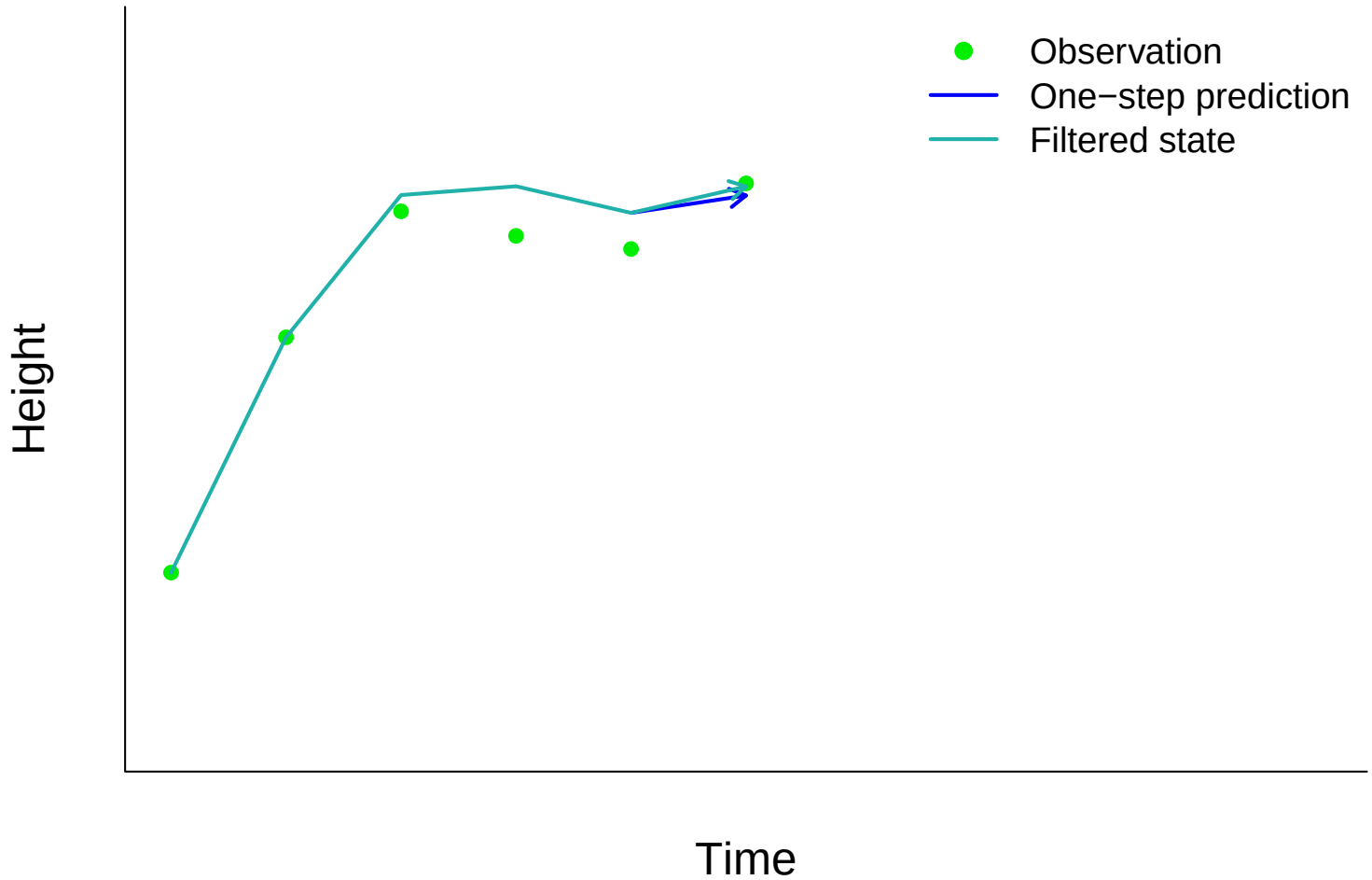
Both – Kalman filter



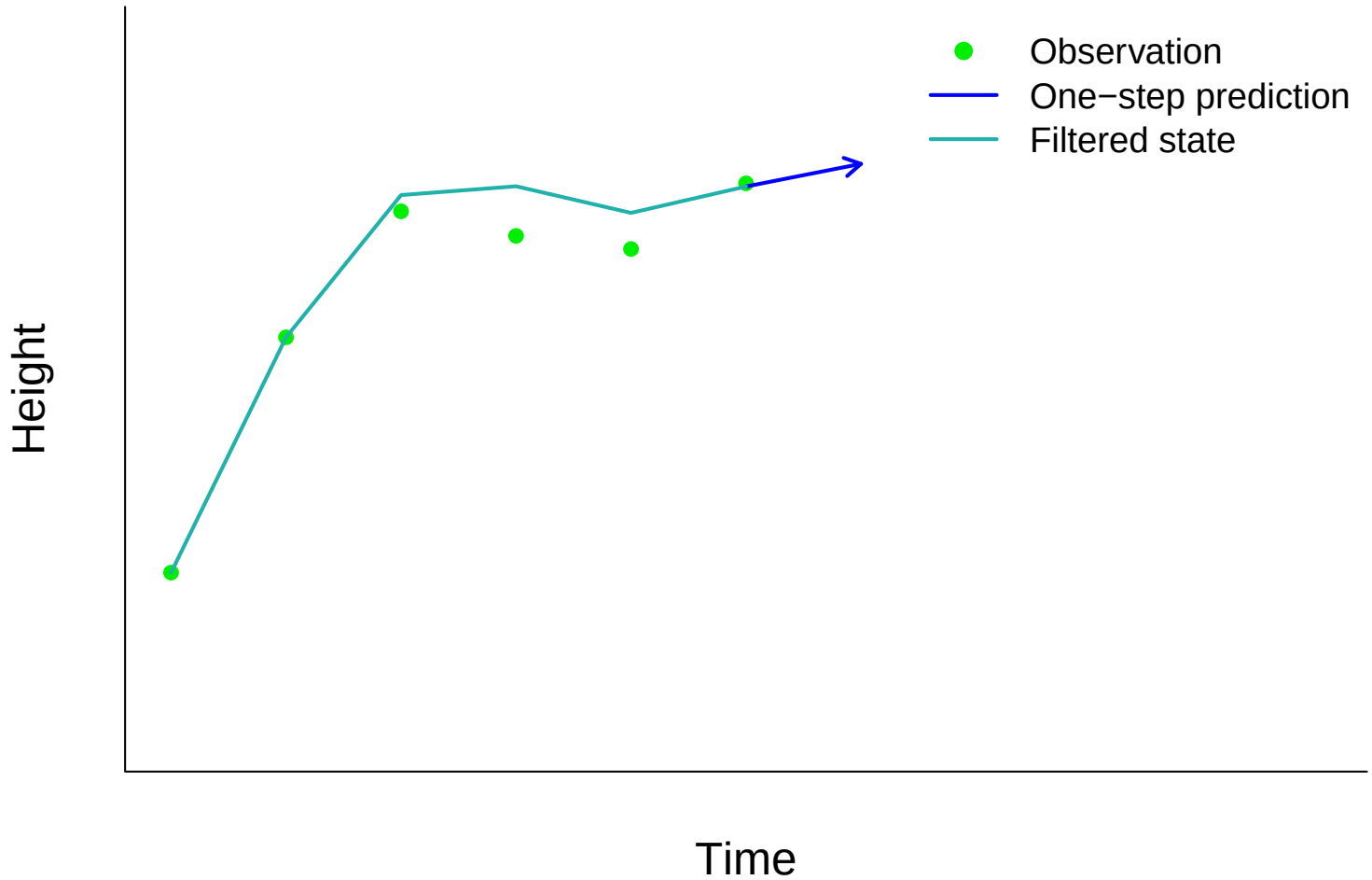
Both – Kalman filter



Both – Kalman filter



Both – Kalman filter



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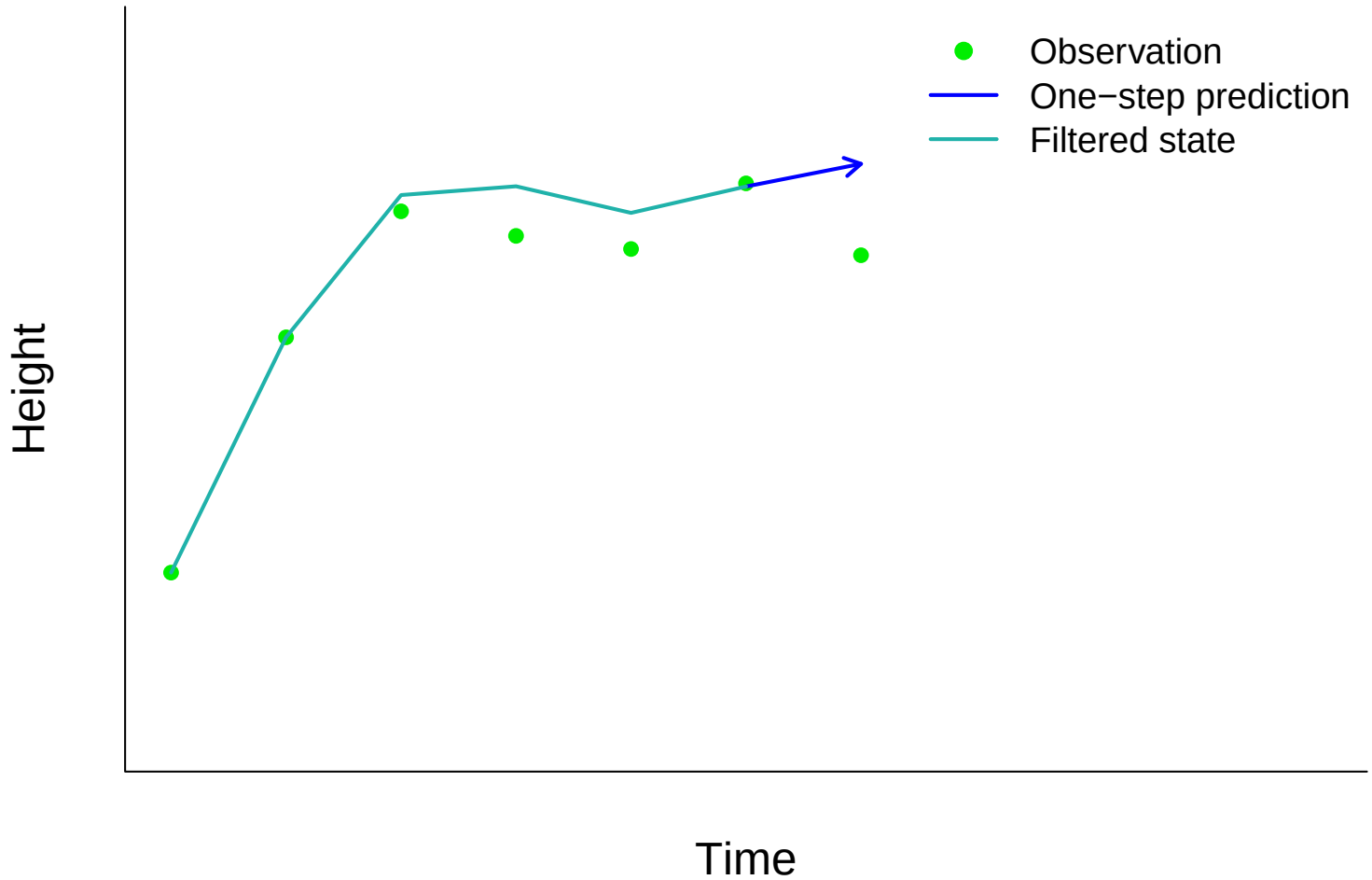

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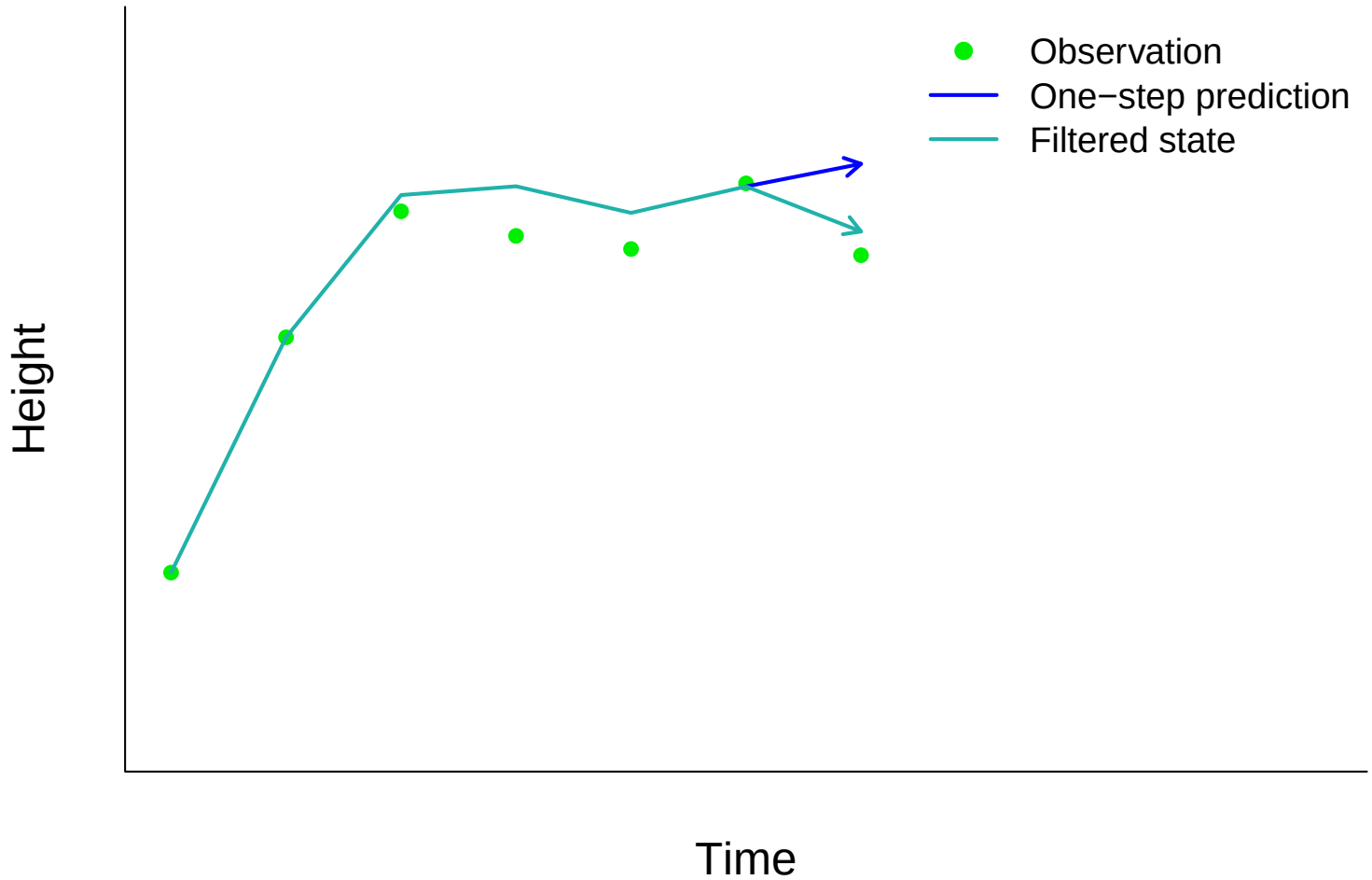

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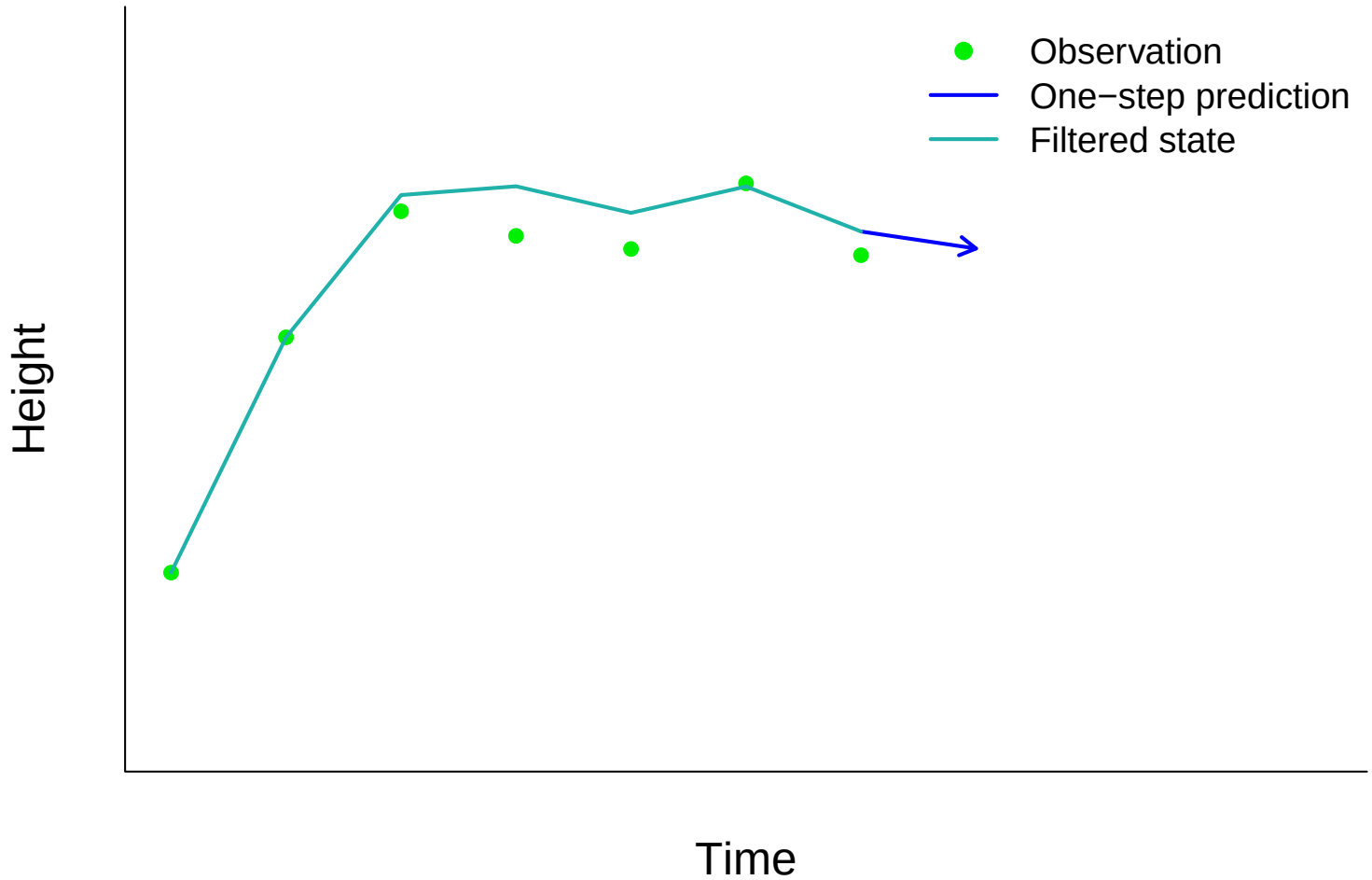

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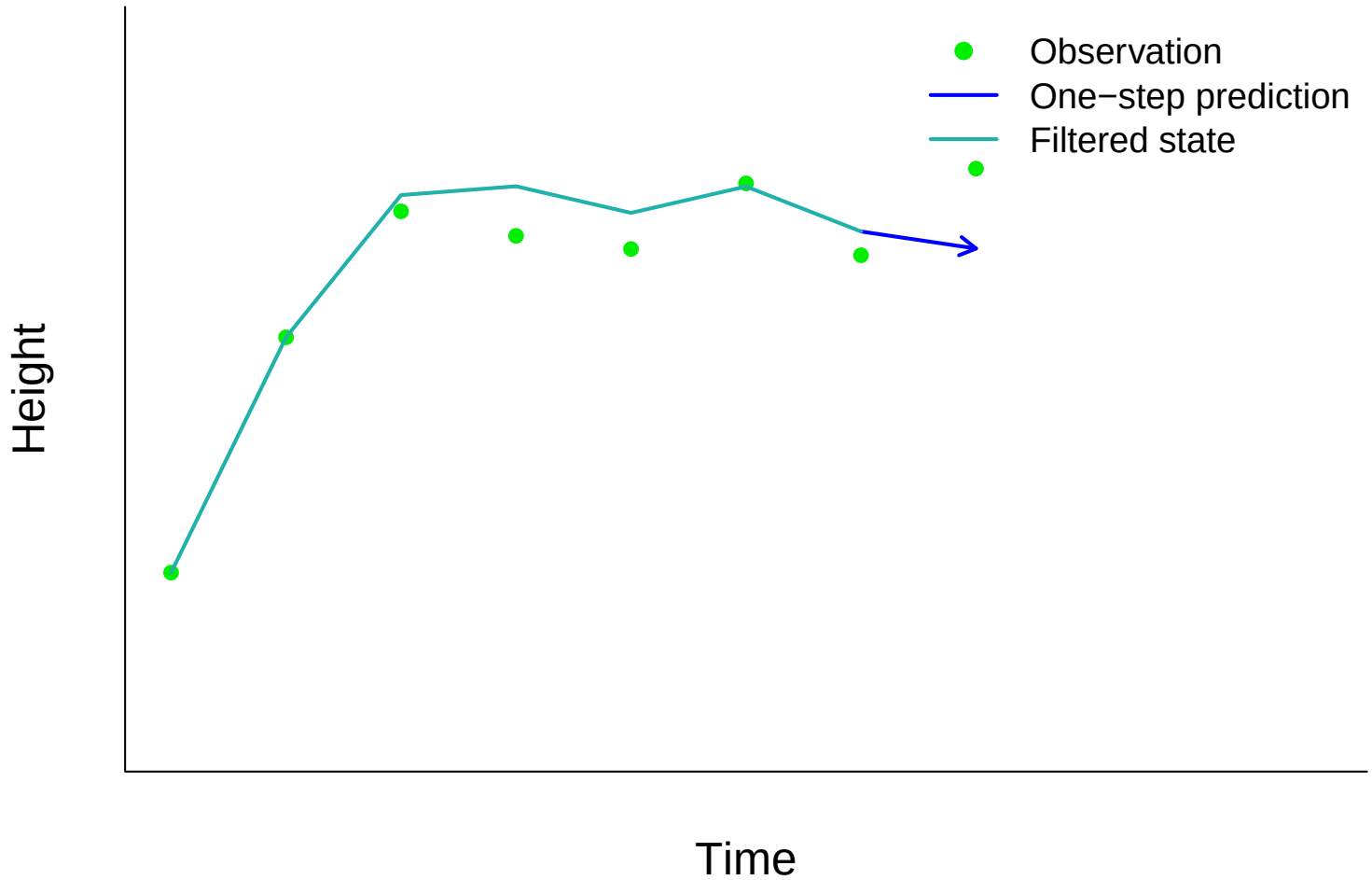

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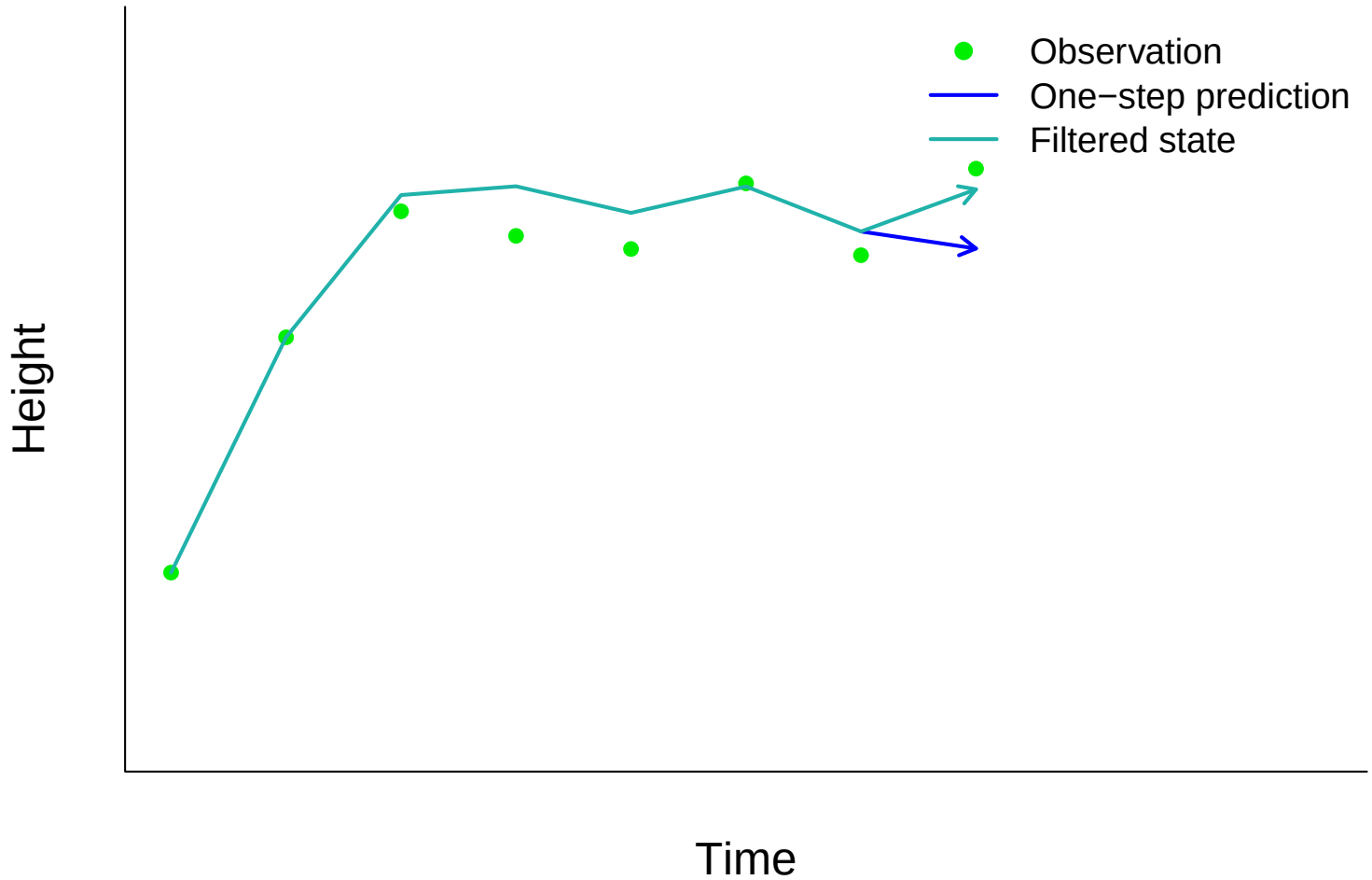

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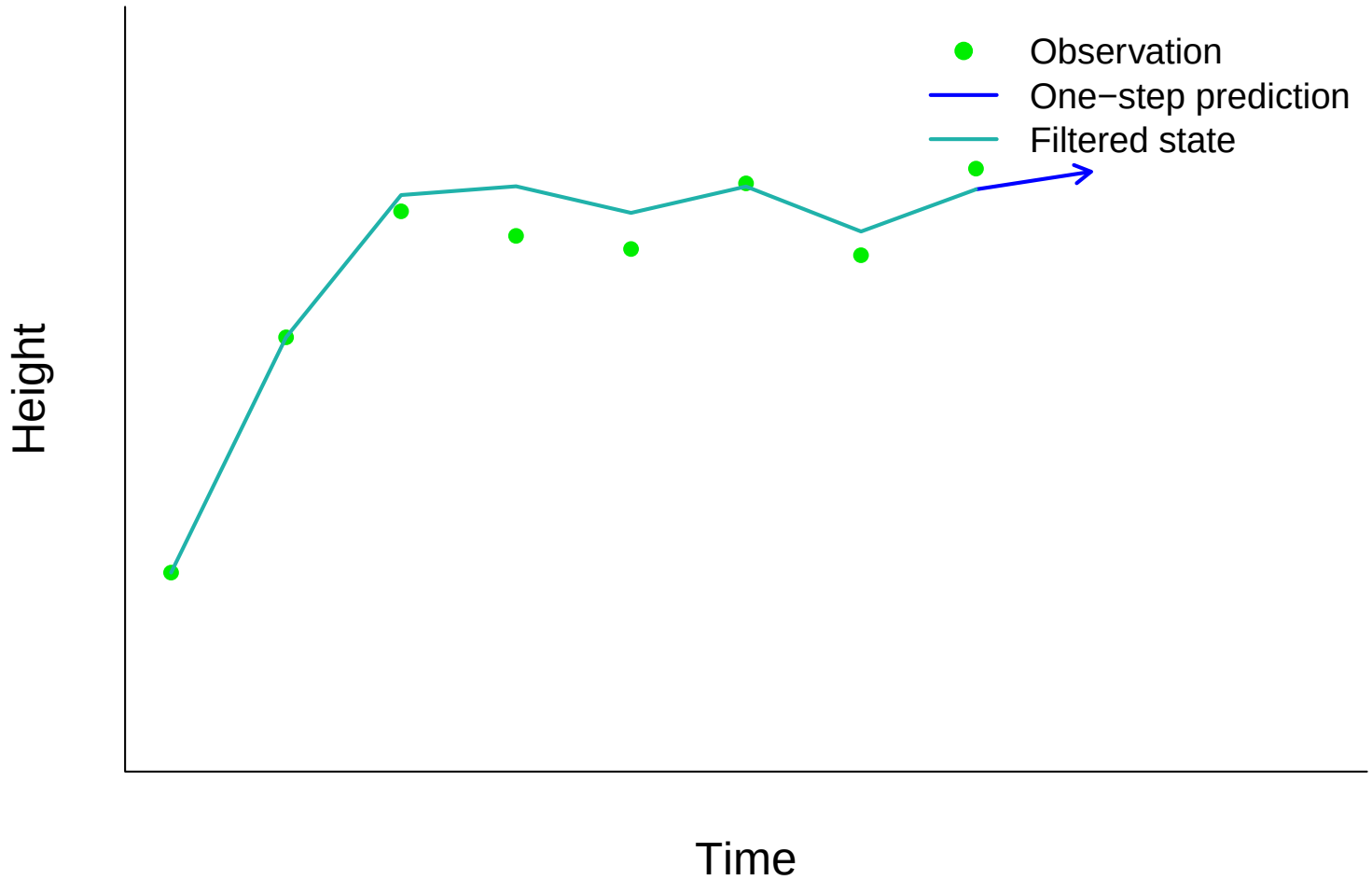

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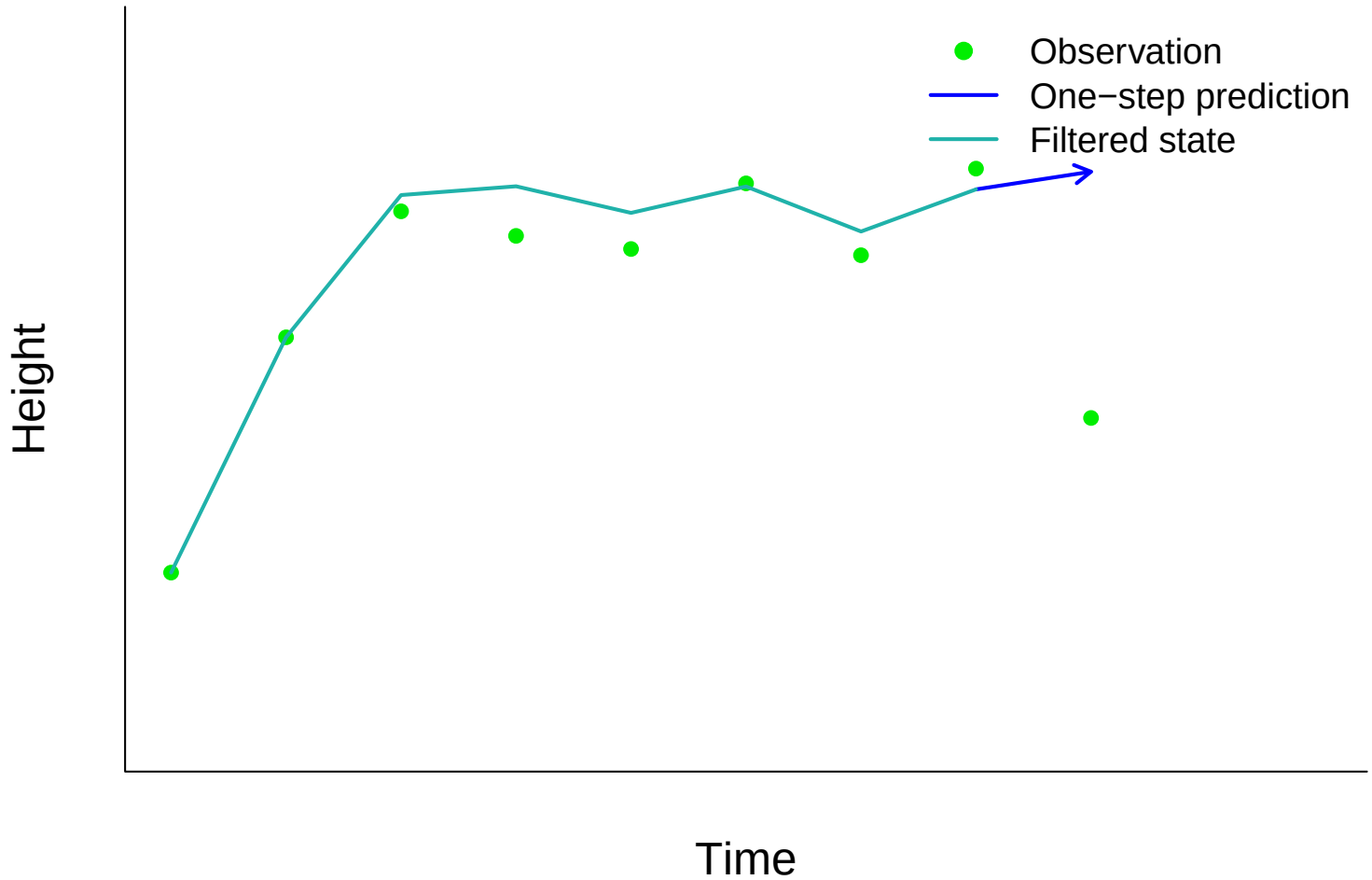

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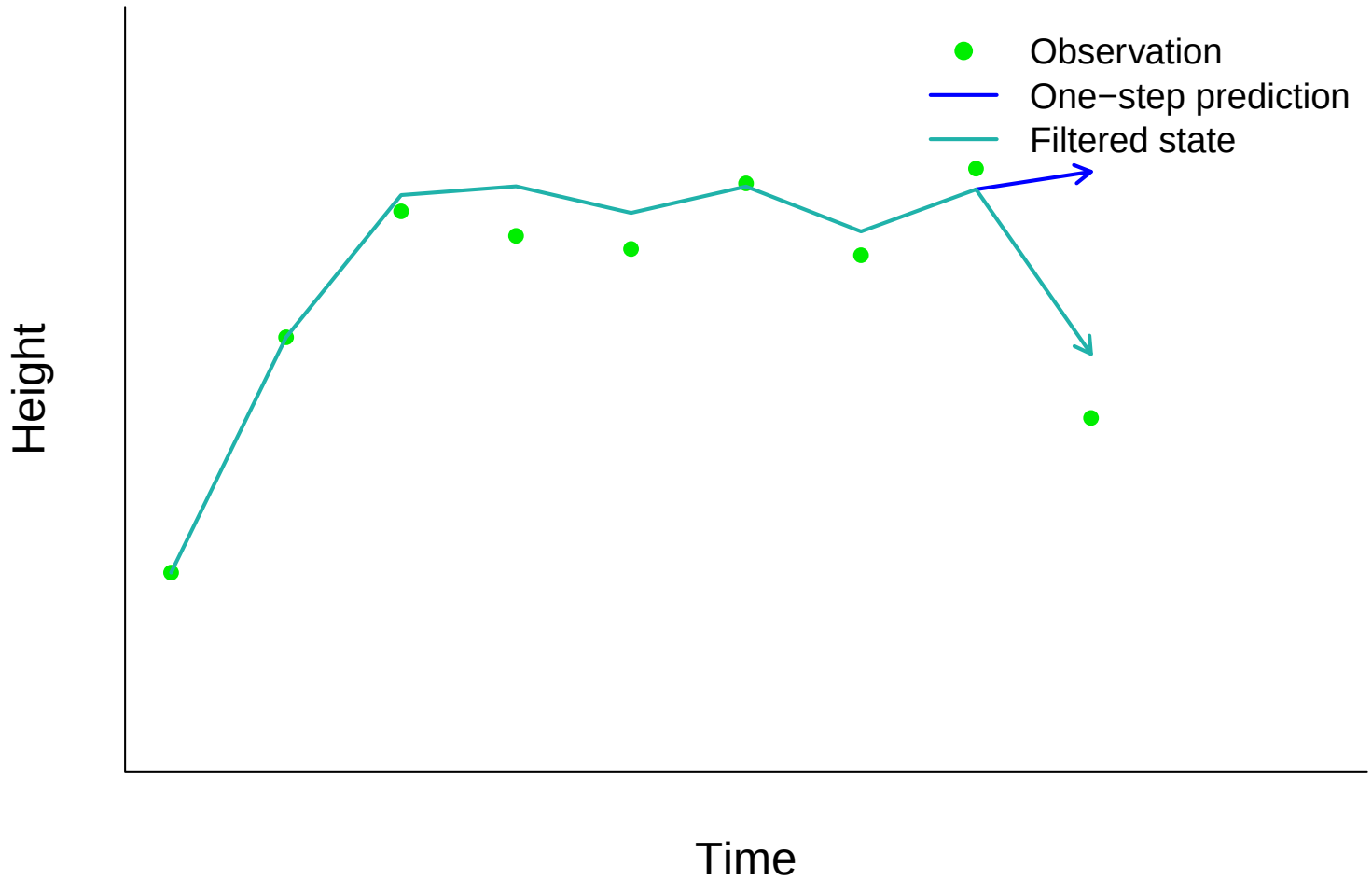

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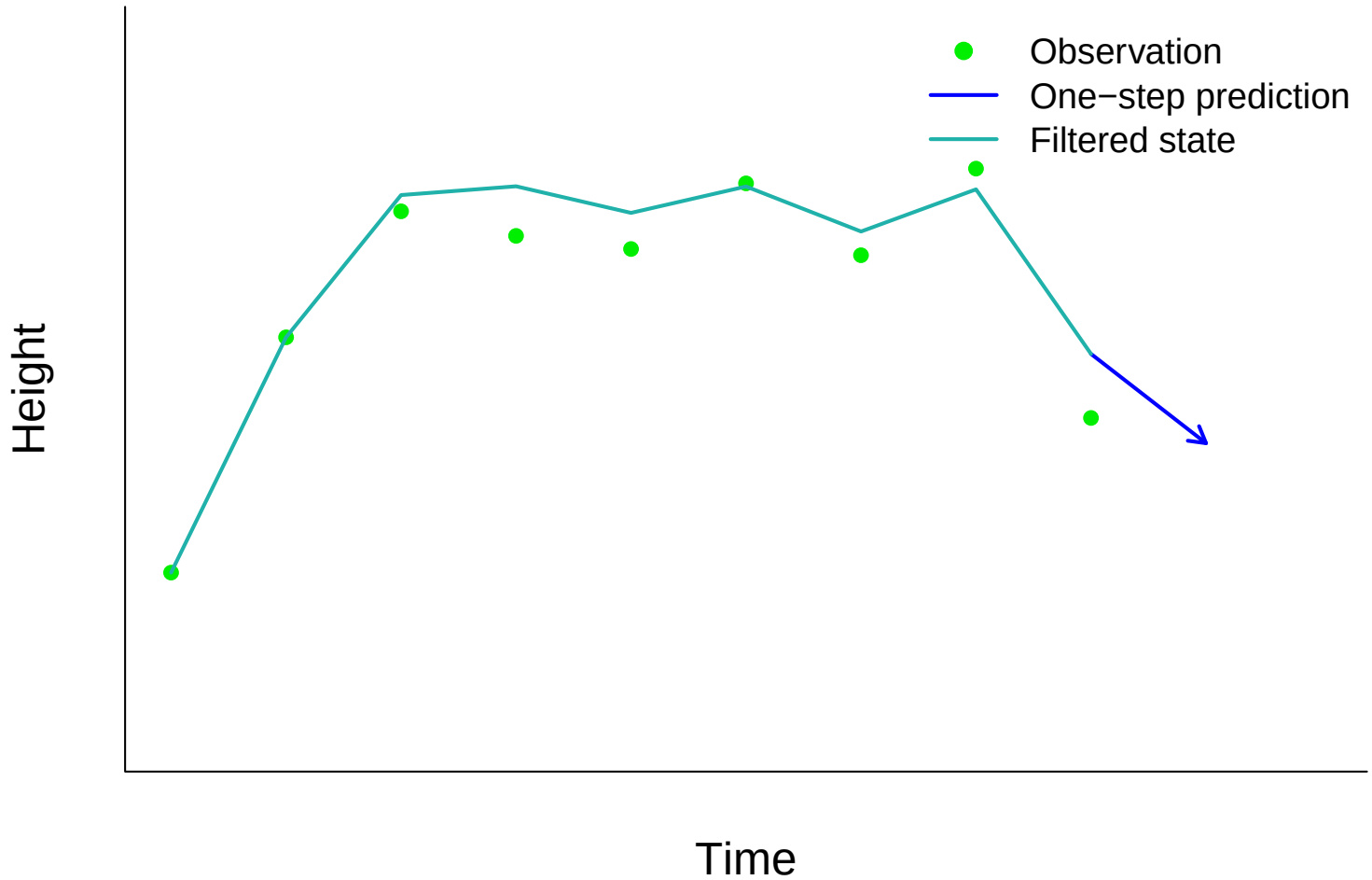

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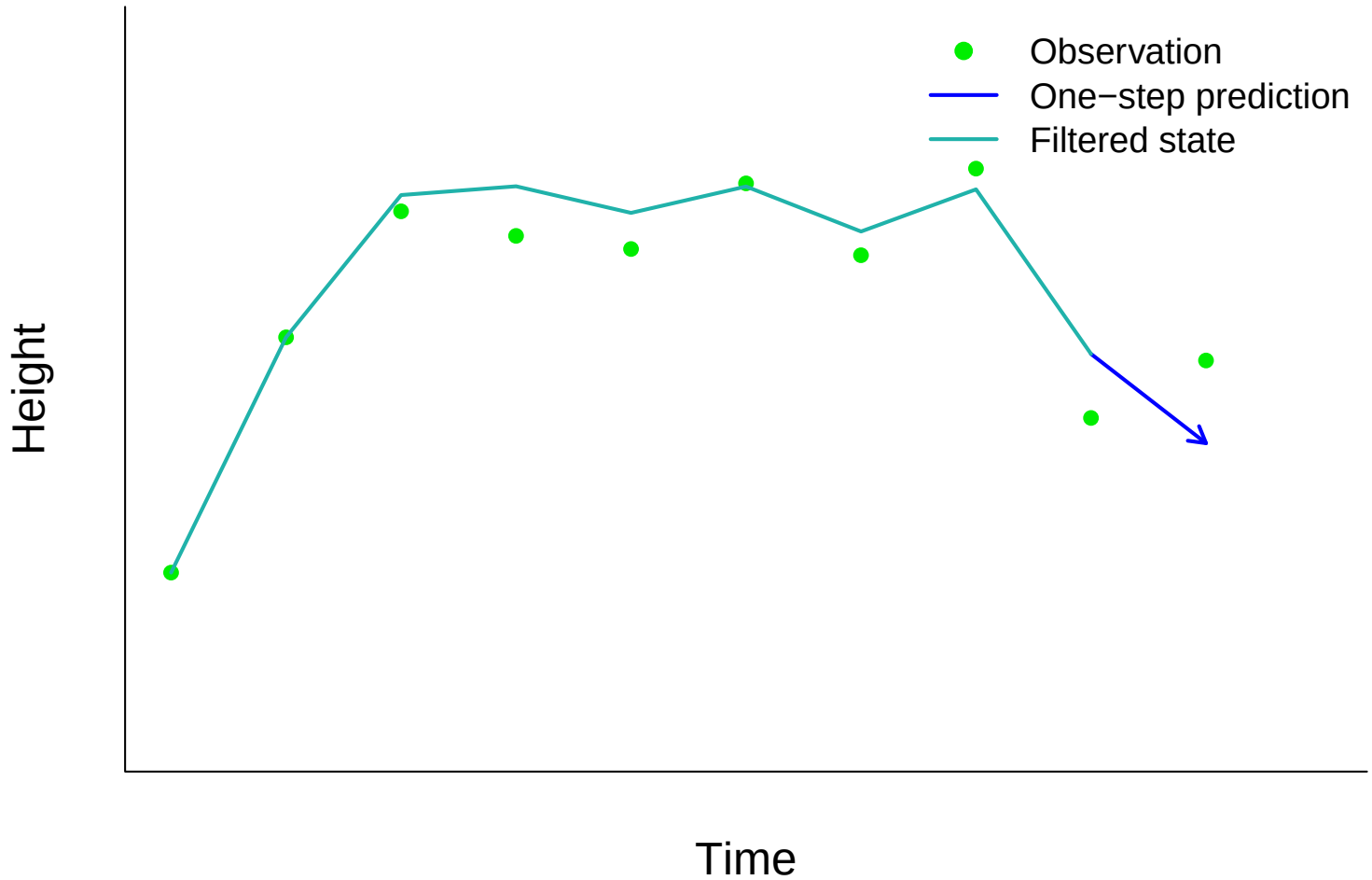

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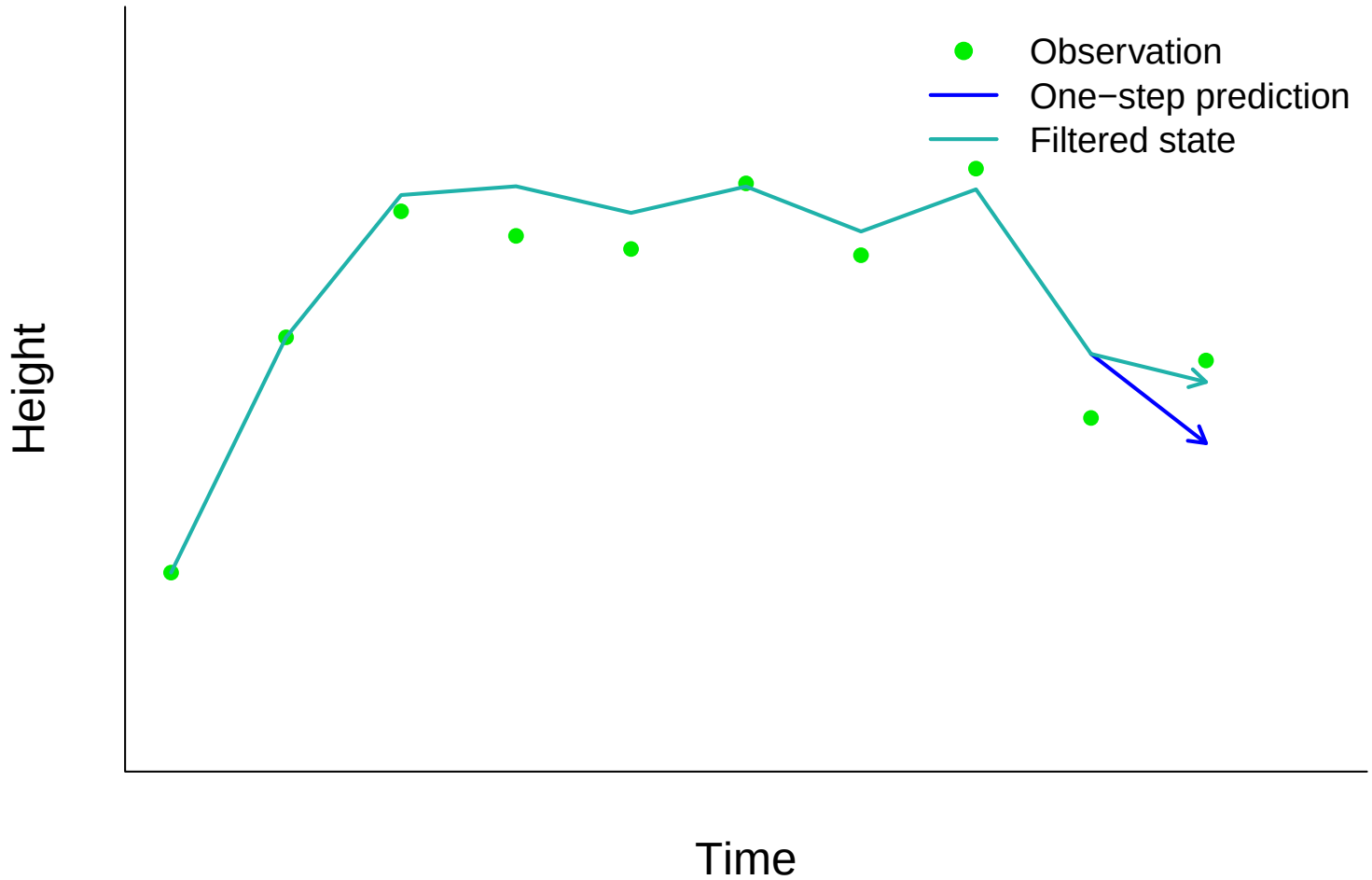

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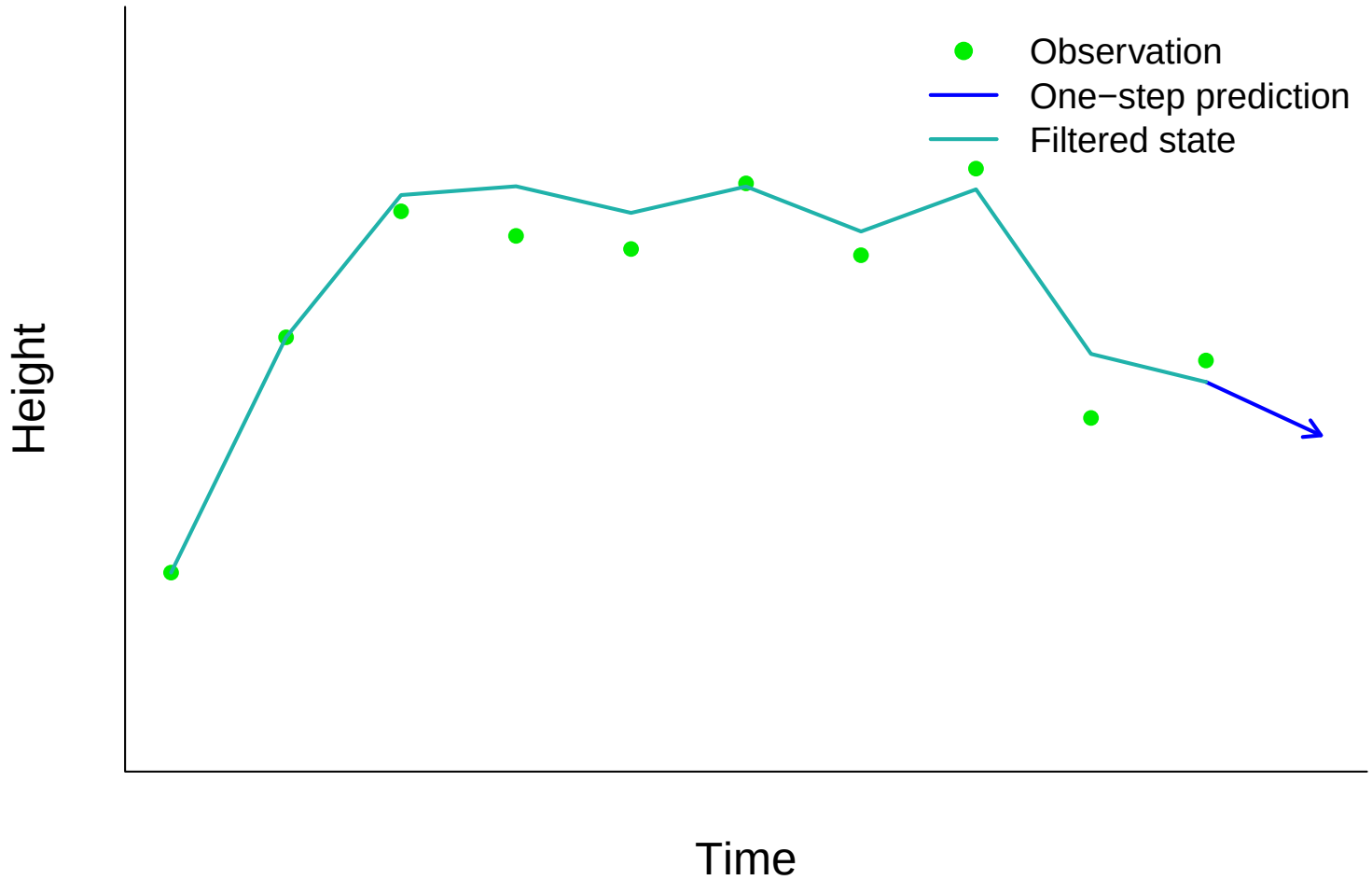

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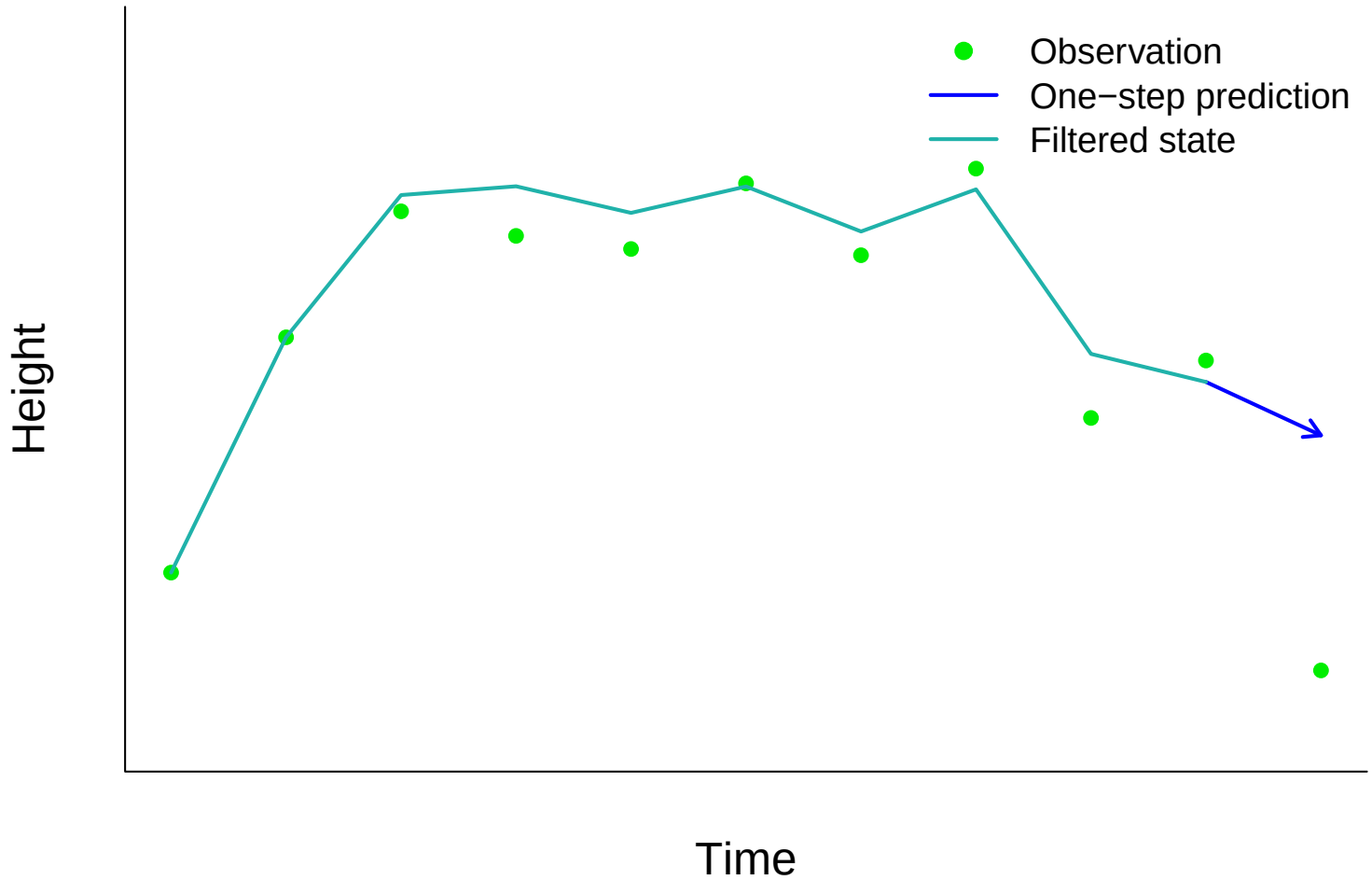

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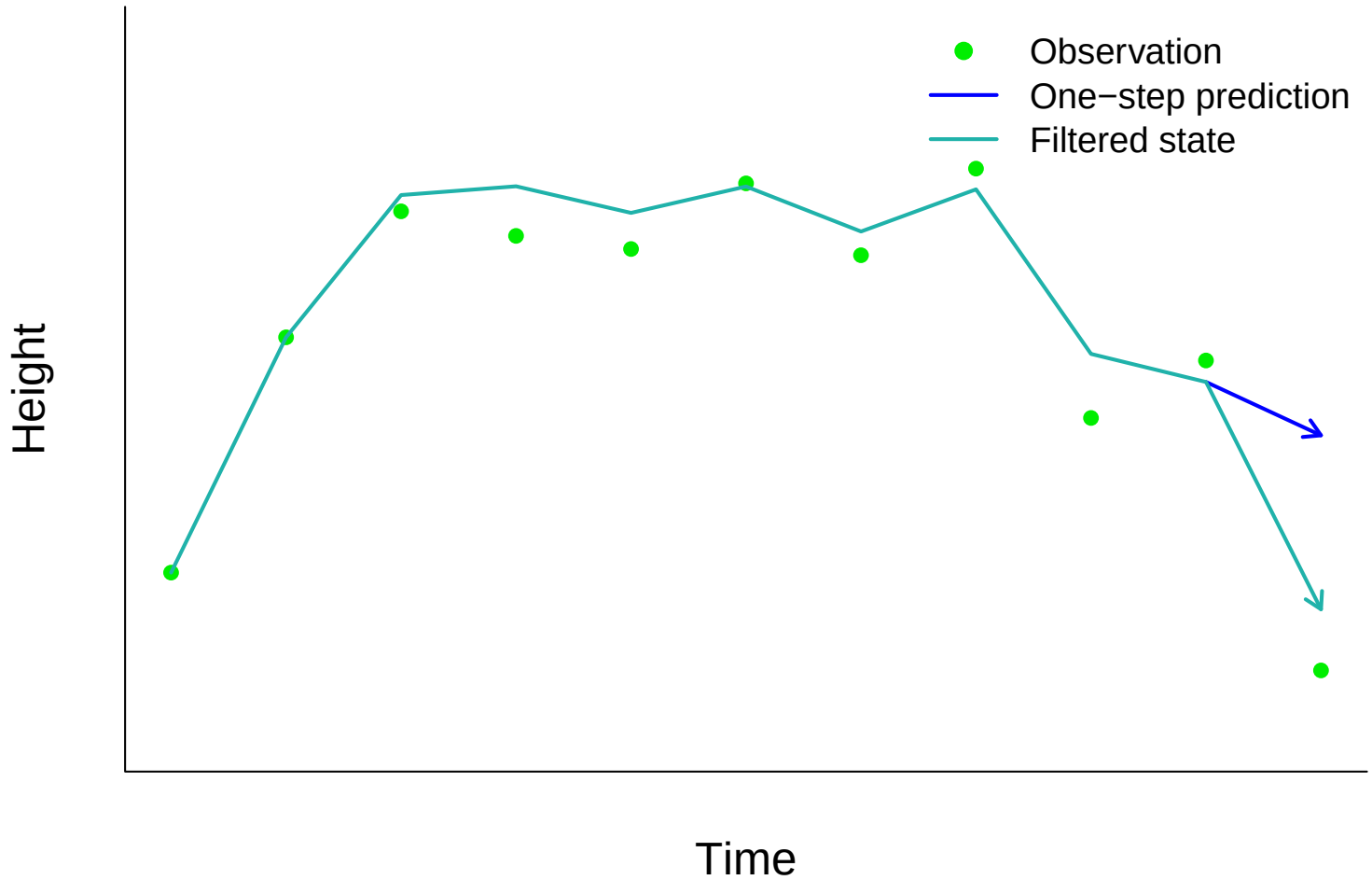
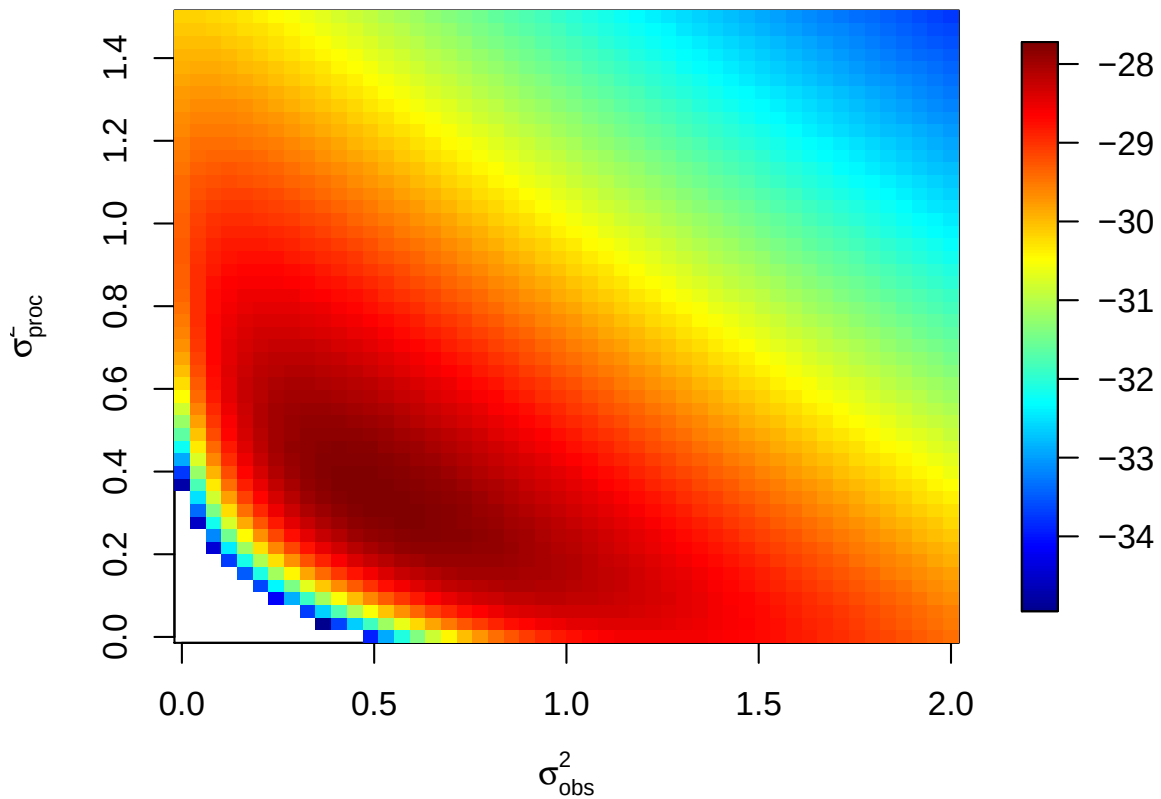


Kalman filter

- Behaviour greatly influenced by ratio of process and measurement variances (*signal to noise ratio*)
  - If very noisy, reverts to measurement error-only model (structural dynamics)
  - If not noisy at all: believes each point and estimates model plus process variability
  - Filter attempts to estimate both (from a single series, even)



Importance of Kalman filter

- Optimal method for coupling process and observation
- Incorporates complex physical linear/linearized models
- Extracts signals from noisy data

Obama meets Kálmán

Draper prize 2008: *For the development and dissemination of the optimal digital technique (known as the Kalman Filter) that is pervasively used to control a vast array of consumer, health, commercial and defense products.*
Also used in the Furuno/Lowrance GPS plotters in the wheelhouse.

Kalman filter & fisheries science

- Walters (1986): adaptive management
- Sullivan (1992): catch-at-length
- Pella (1993): biomass dynamic
- Reed and Simons (1996): catch-effort
- Peterman et al. (2000): Stock-recruitment

1 Marmalade review of dynamic productivity

2 Status quo(ta)

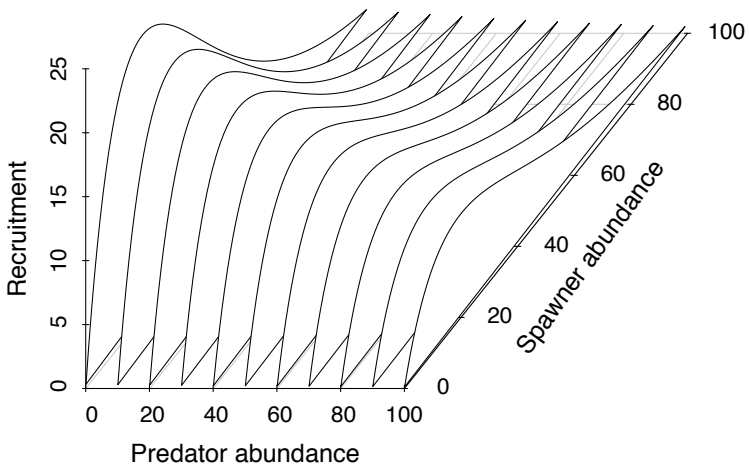
3 Spacing out

4 Peterman's productivity method

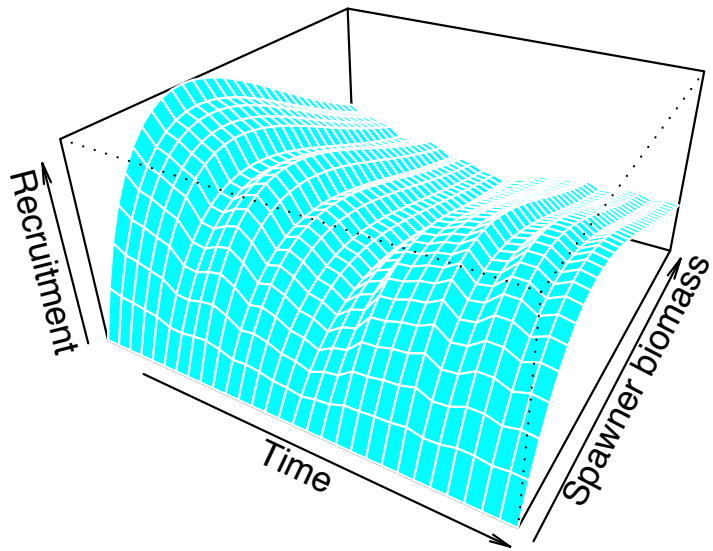
5 Future forecasts

Why vs. How

Some approaches to change



(a) Explicit drivers



(b) Time-varying parameters

(will propose a combo third)

Explicit drivers

Huge array of hypothesized drivers of recruitment productivity

- Physical environment
  - Temperature
  - Salinity
  - Hydrodynamics
- Biological environment
  - Intra- and inter-specific competition and predation
  - Food availability and quality
- Life history characteristics
  - Maternal effects
  - Meta-population structure

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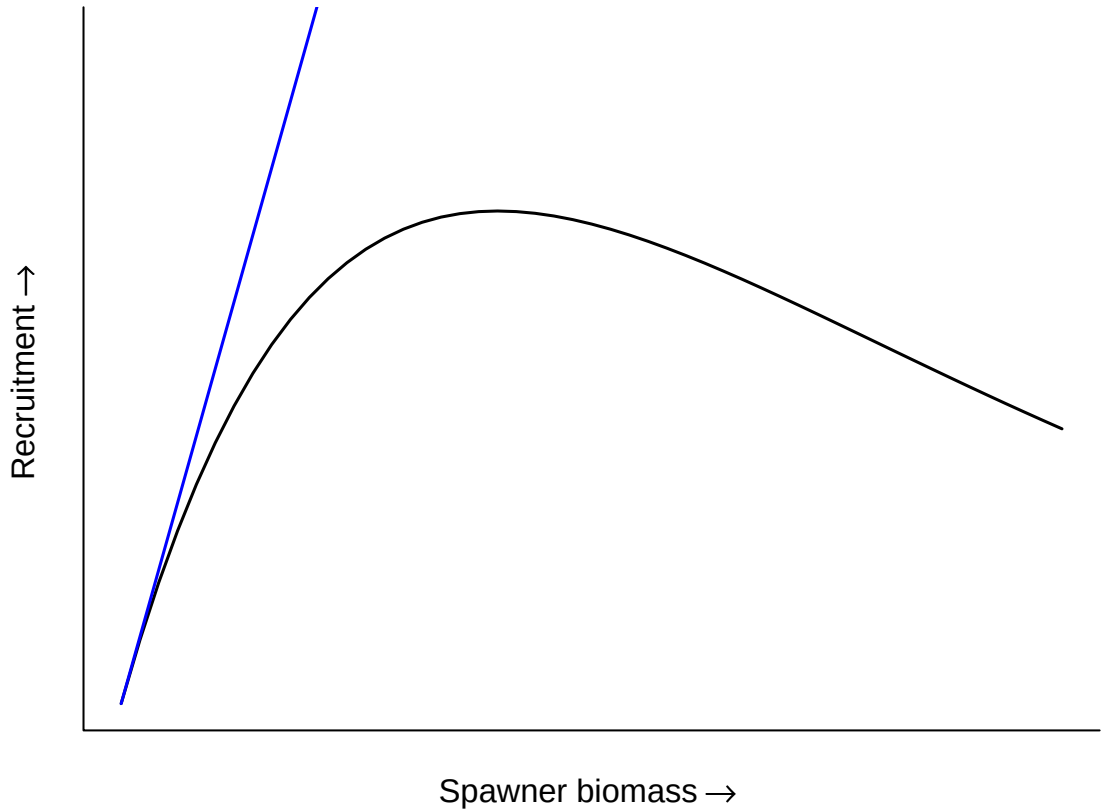
Many dimensions demanding a lot from relatively few and variable data points (we really don't understand the mechanisms very well)

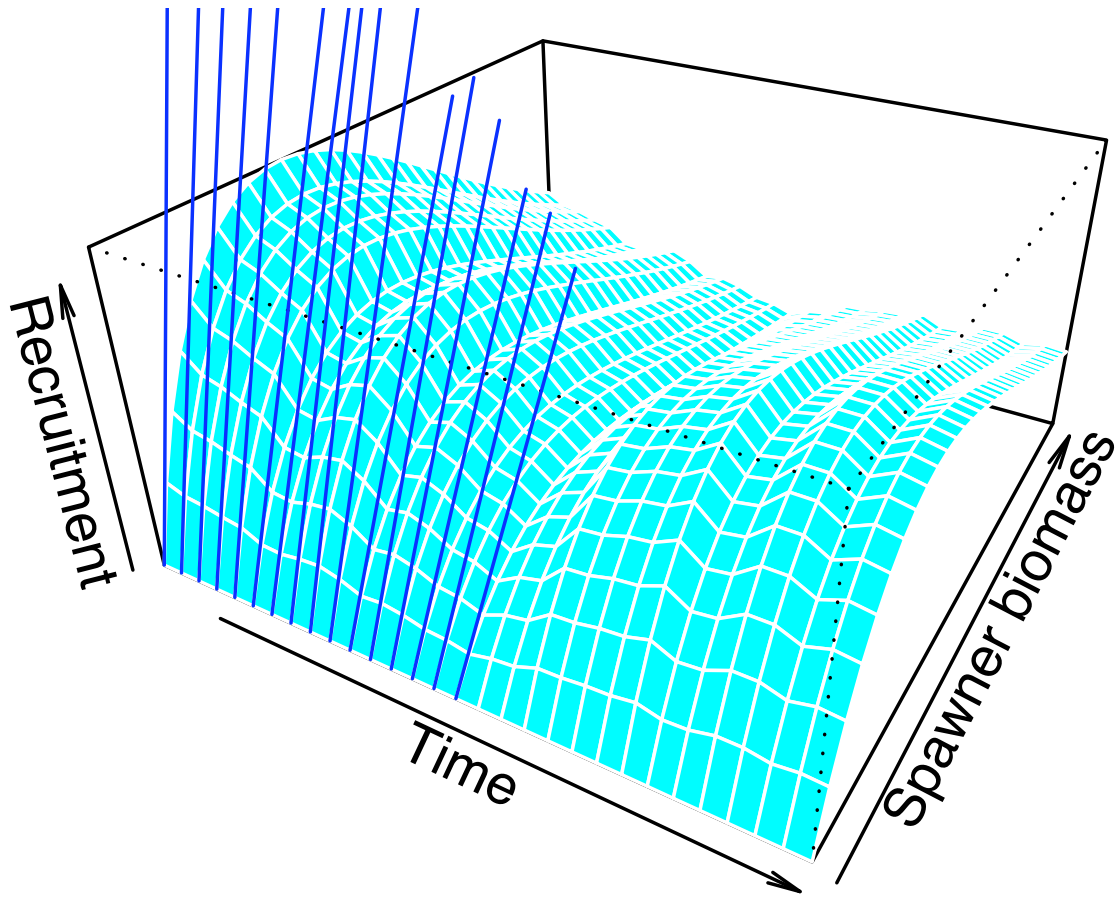
Peterman's productivity method: idea

Traditional theory



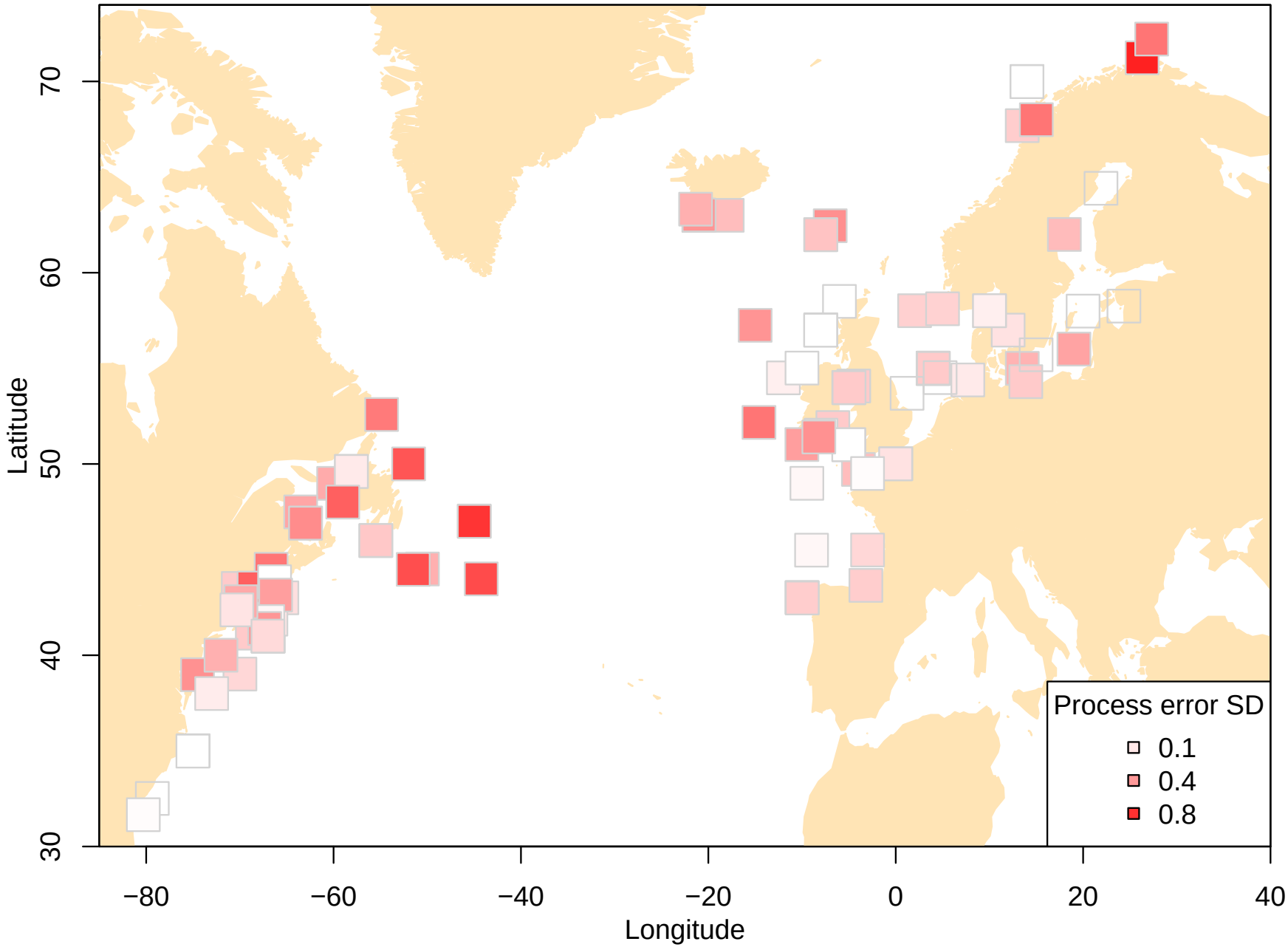
Peterman's productivity method: idea

Allow for stochastic process on some/all parameters

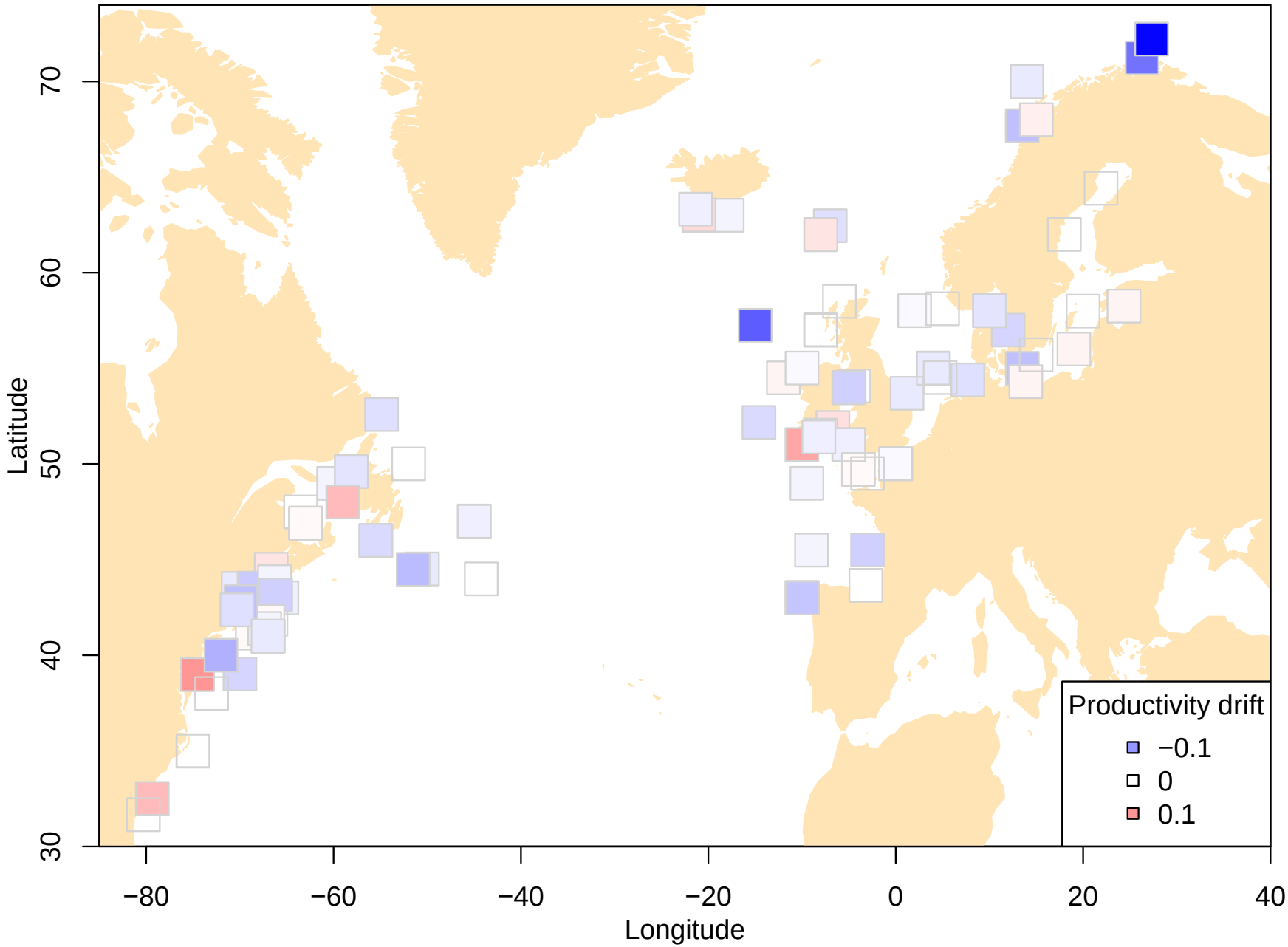


Latent state

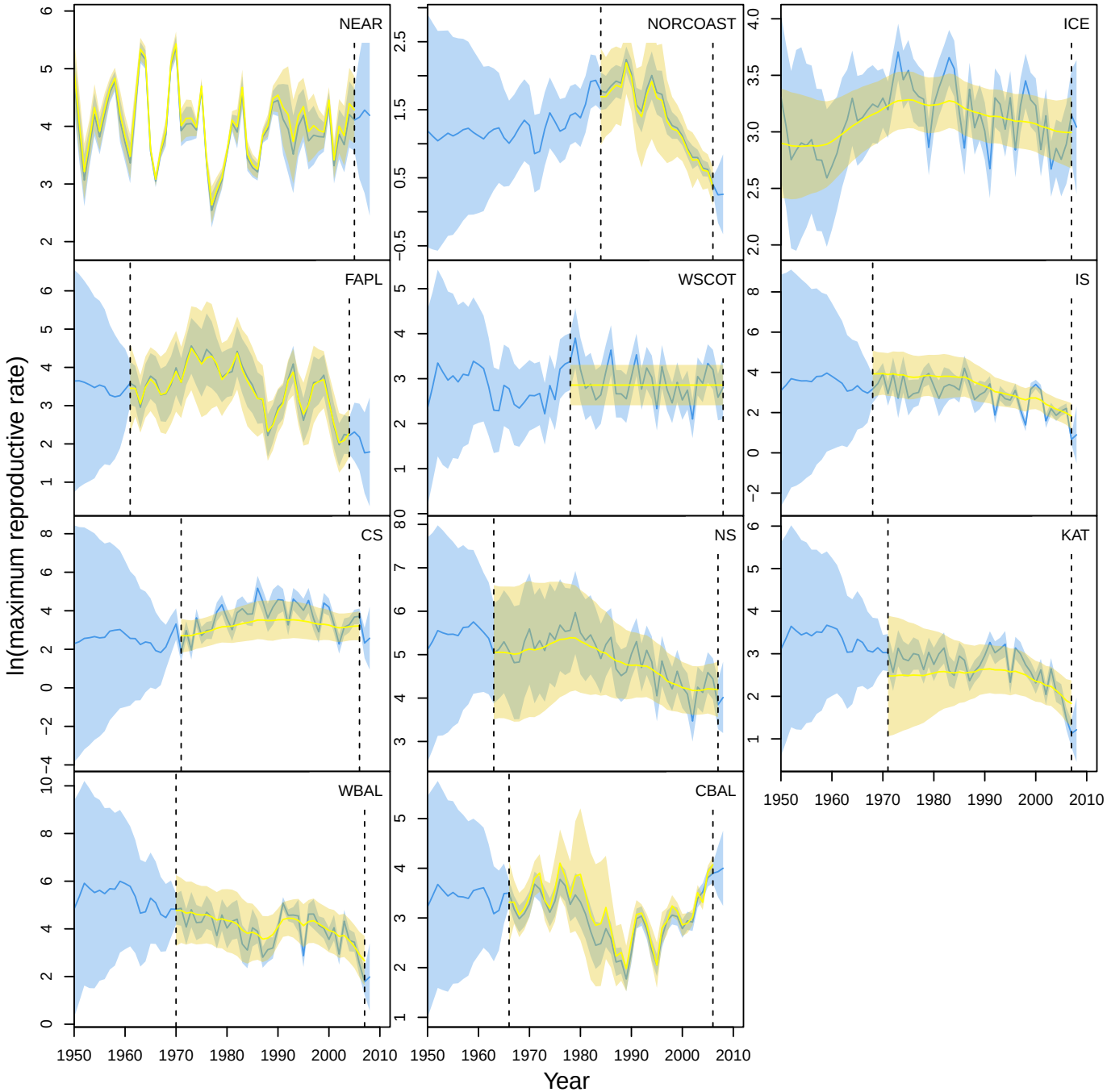
Process error variance from Ricker estimation



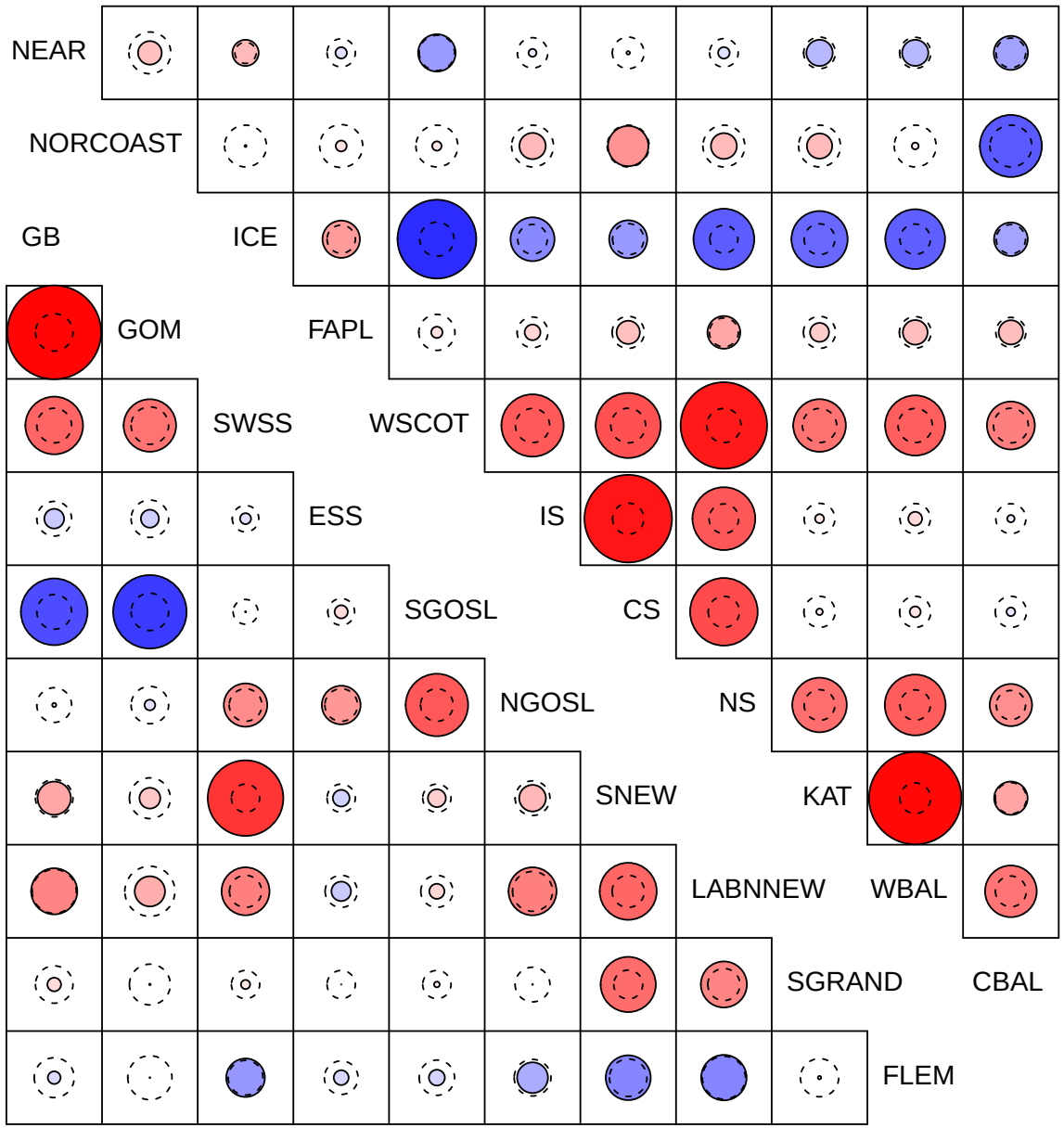
Productivity *drift*: $a_t = a_{t-1} + \underline{\delta} + \eta_t$



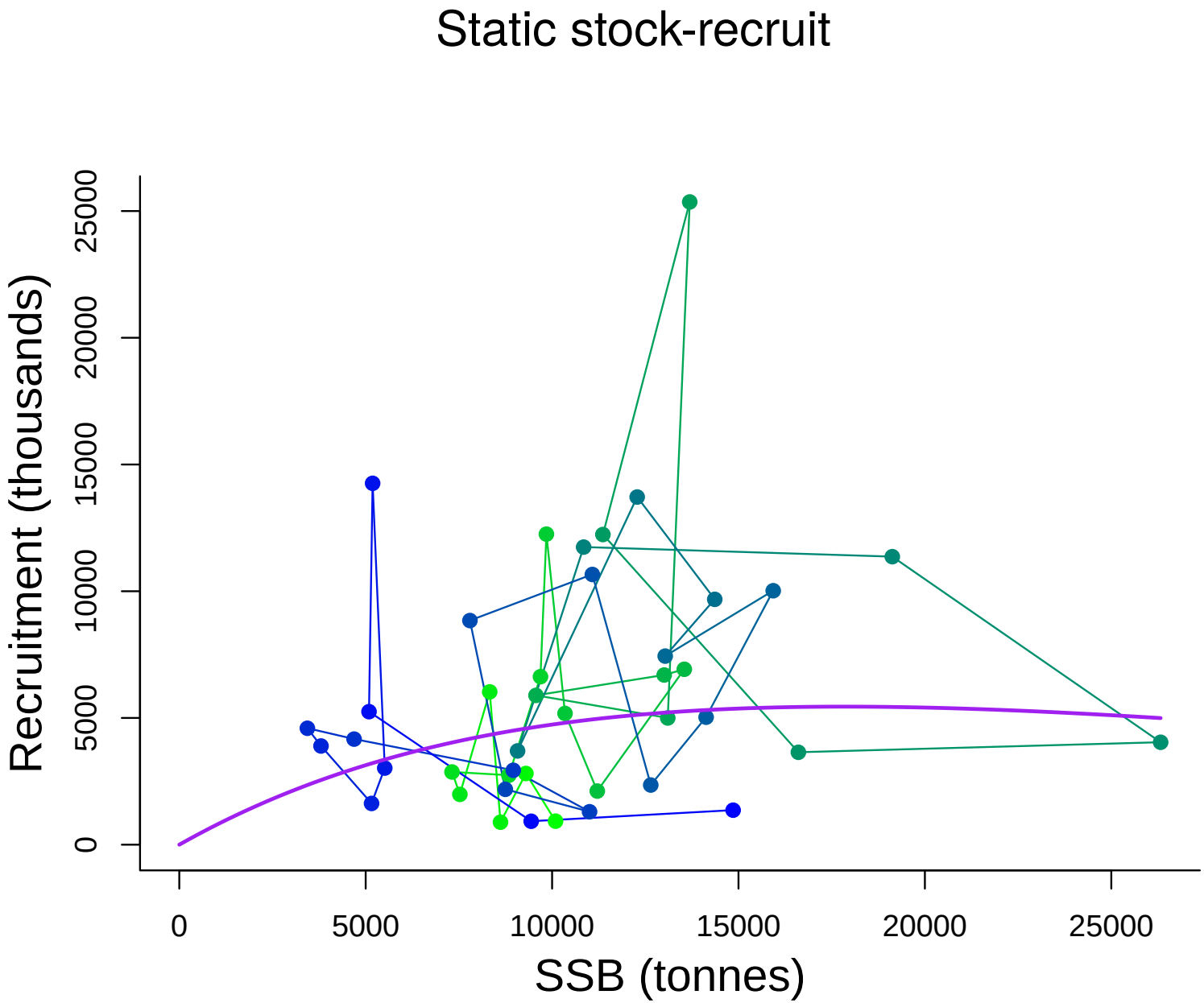
Multivariate extensions: northeast Atlantic cod



Multivariate extensions: process correlation



What it means?



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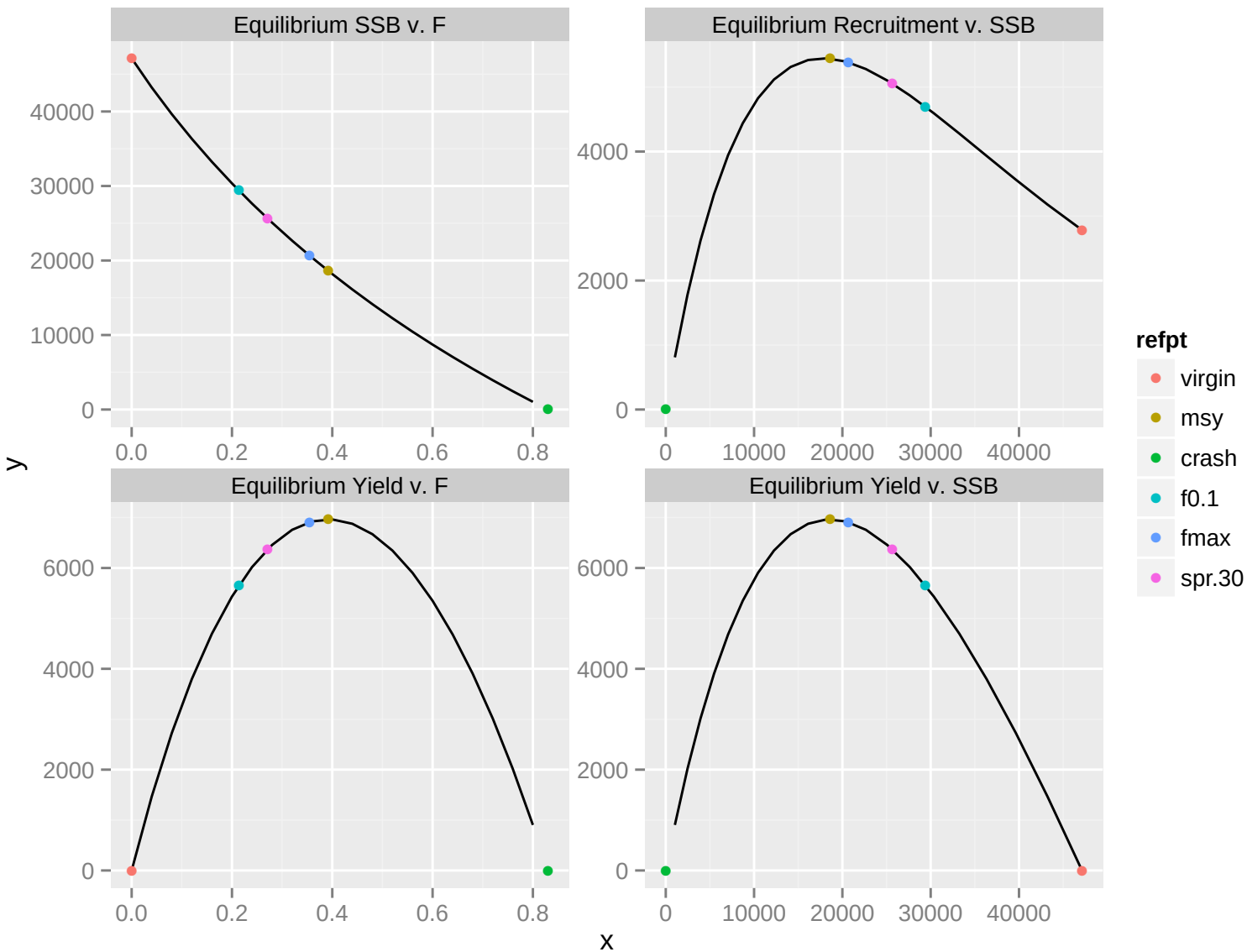
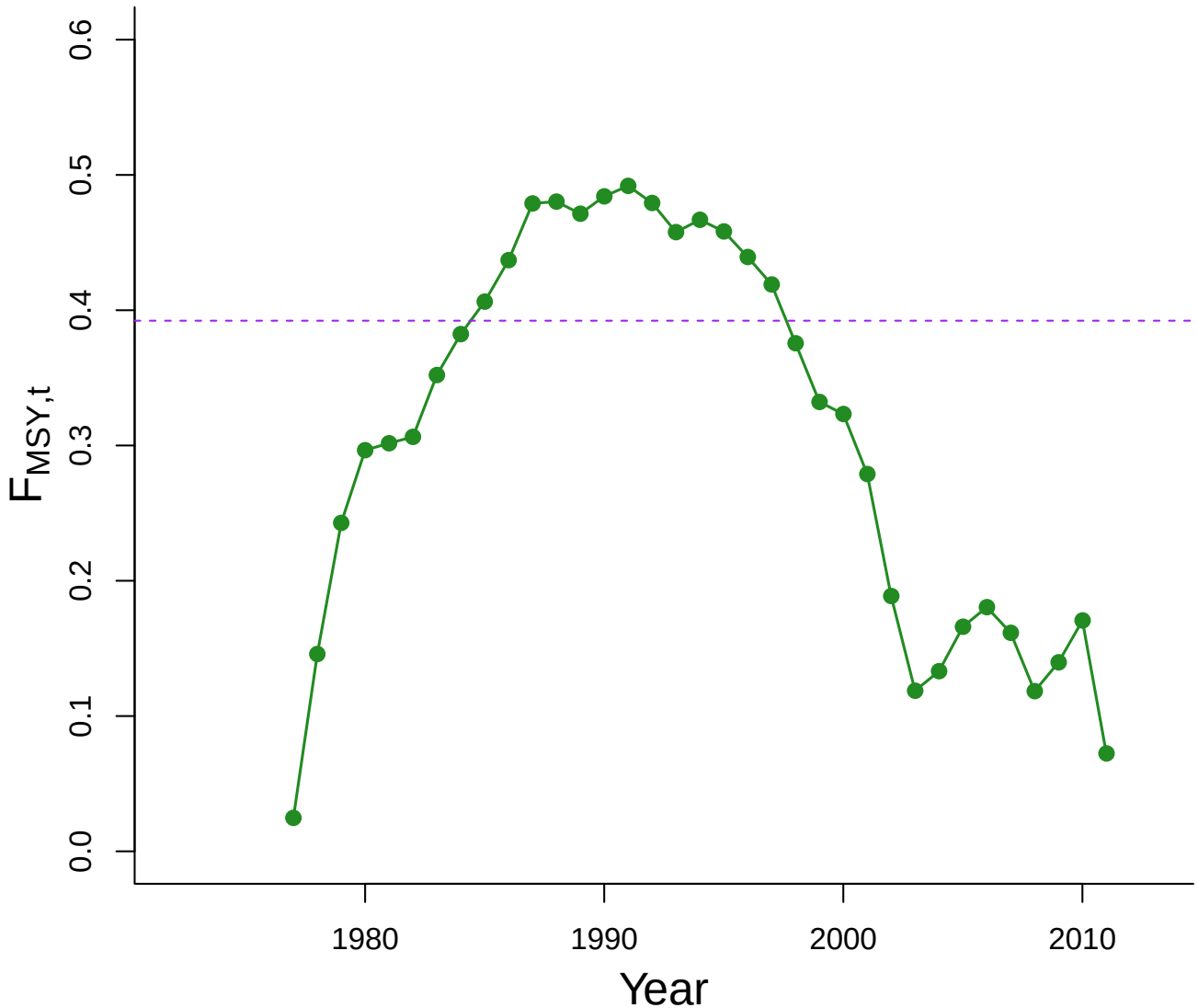


What it means?

Time-varying stock-recruit: dynamic reference points



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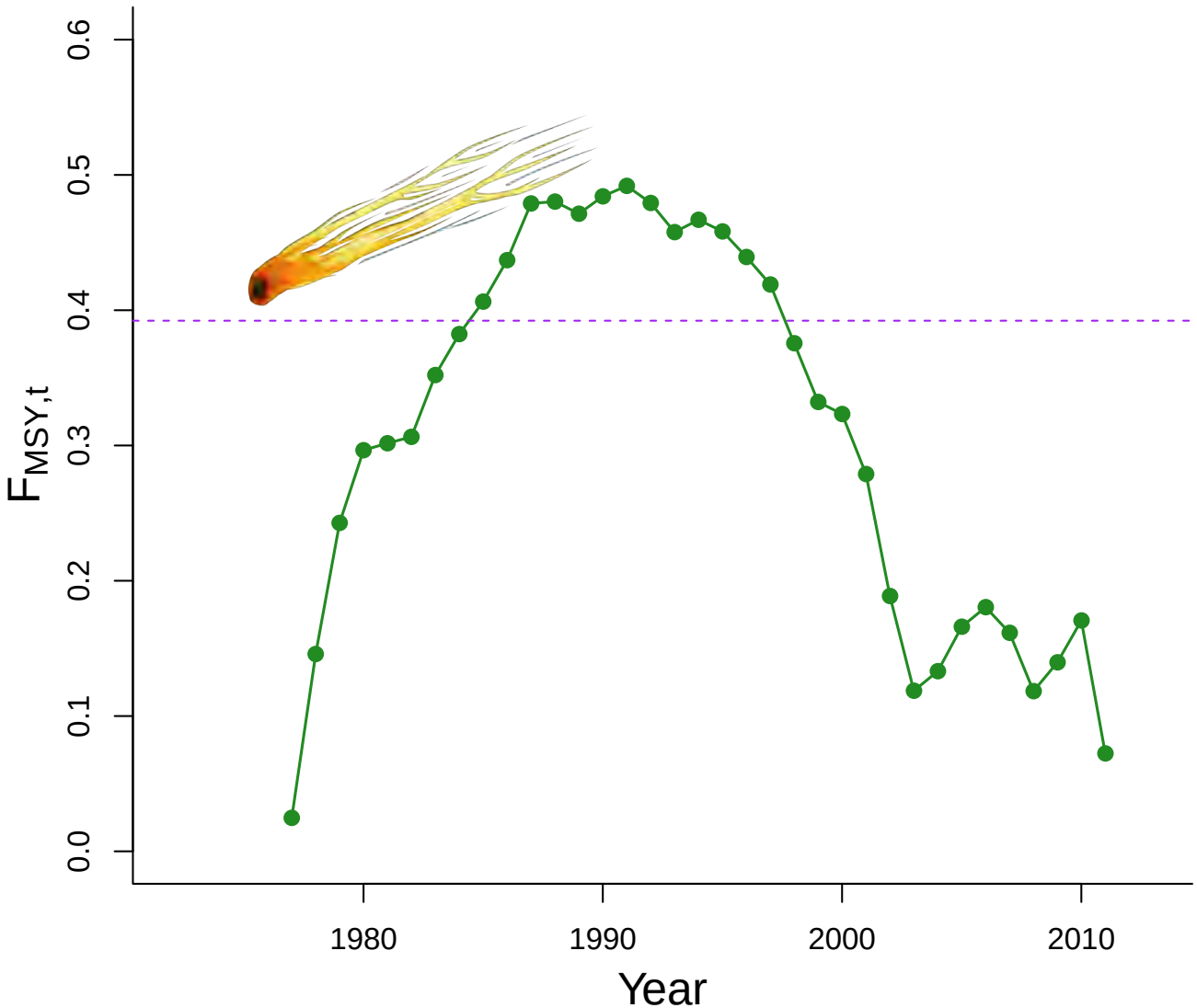

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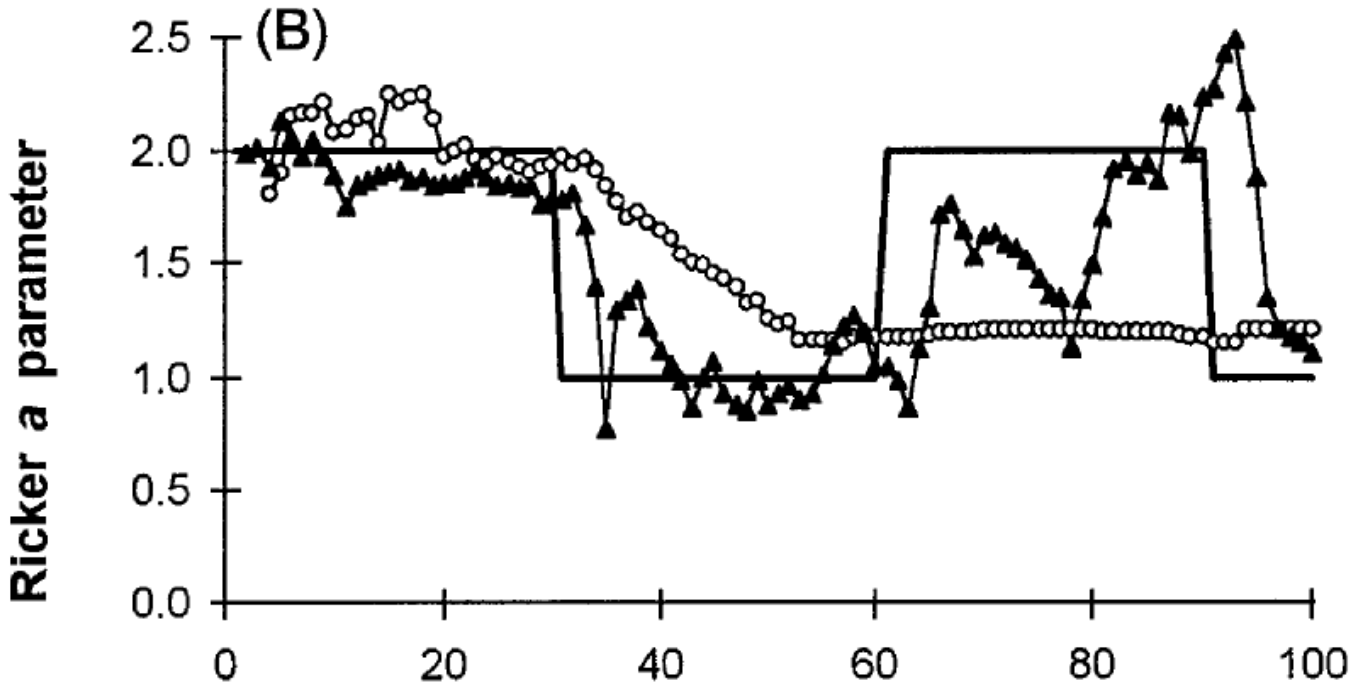
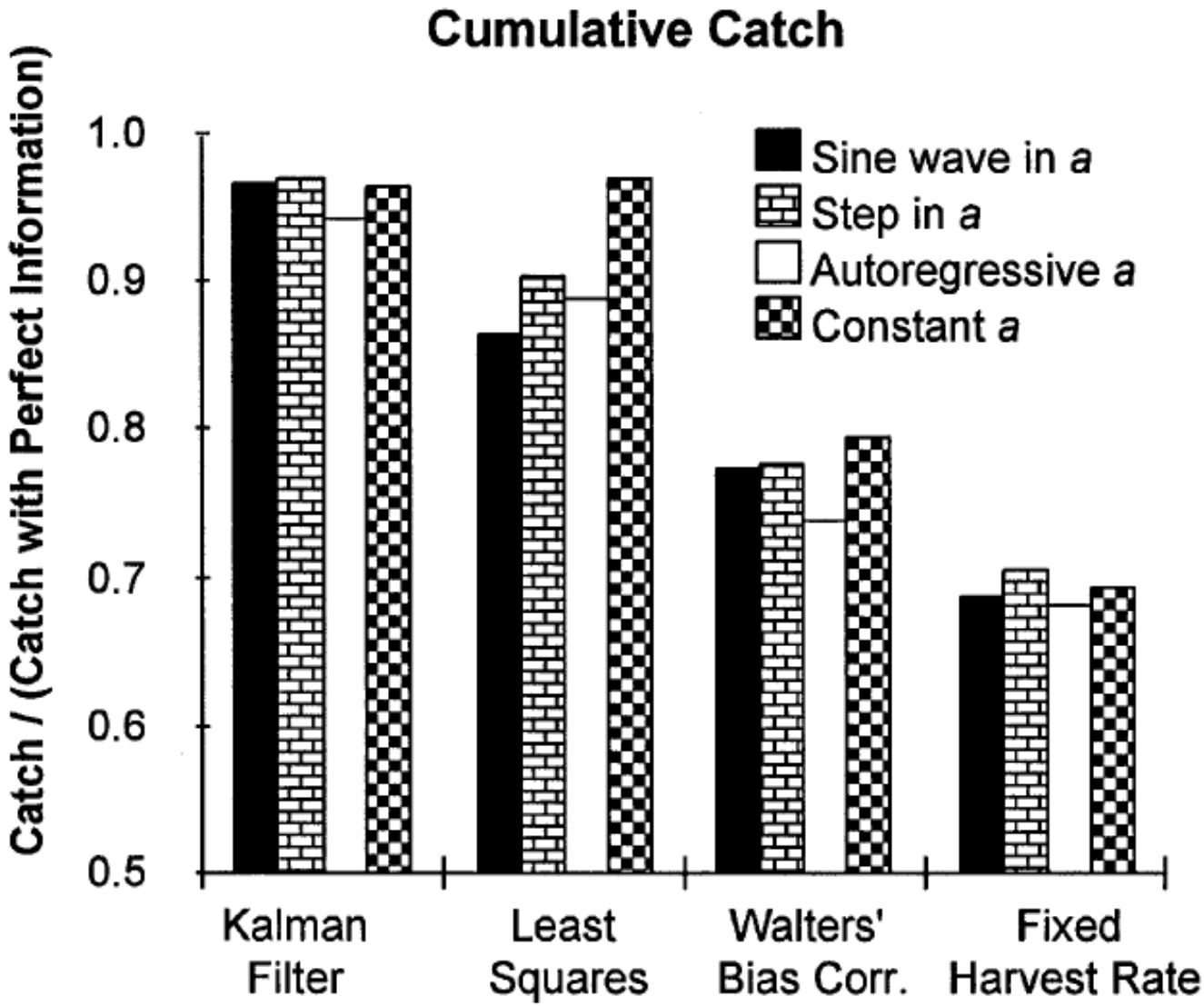


Peterman et al. (2000)

What it means?



Peterman et al. (2000)

Relaying to ground control

It was always going to happen with EBFM

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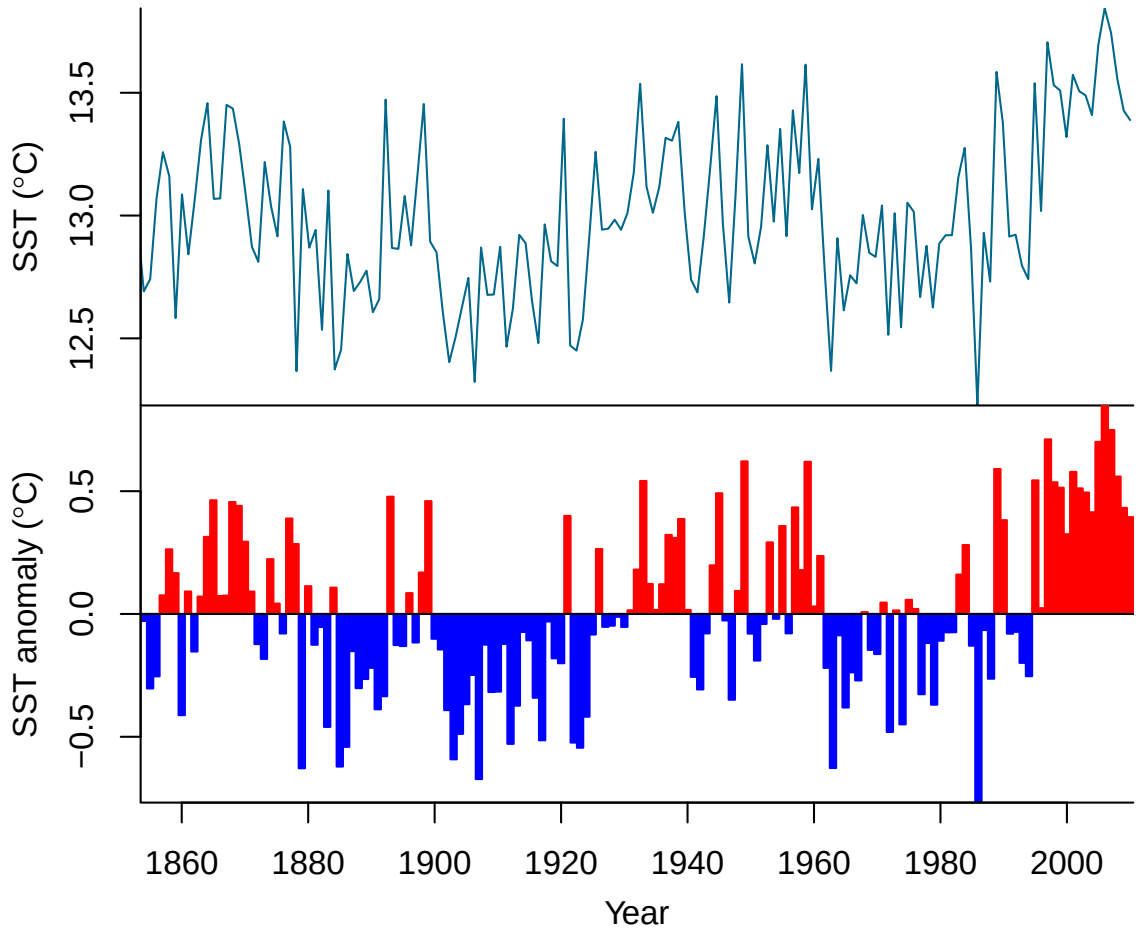
Mechanism

Computationally appealing and applied but scientifically unsatisfactory - we like to know why (long-term planning)

Including drivers

Drivers could load on a_t

$$a_t = a_{t-1} + \gamma \text{Pet hypothesis}_{sometime} + \eta_t$$



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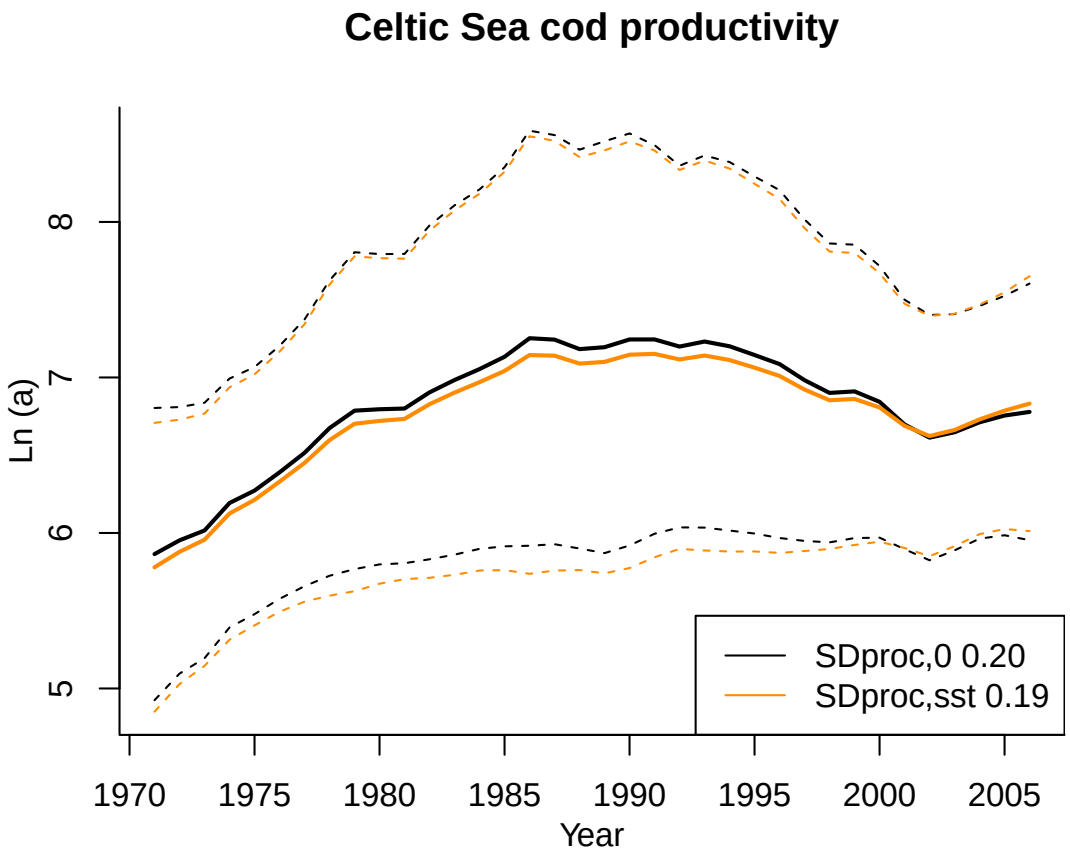

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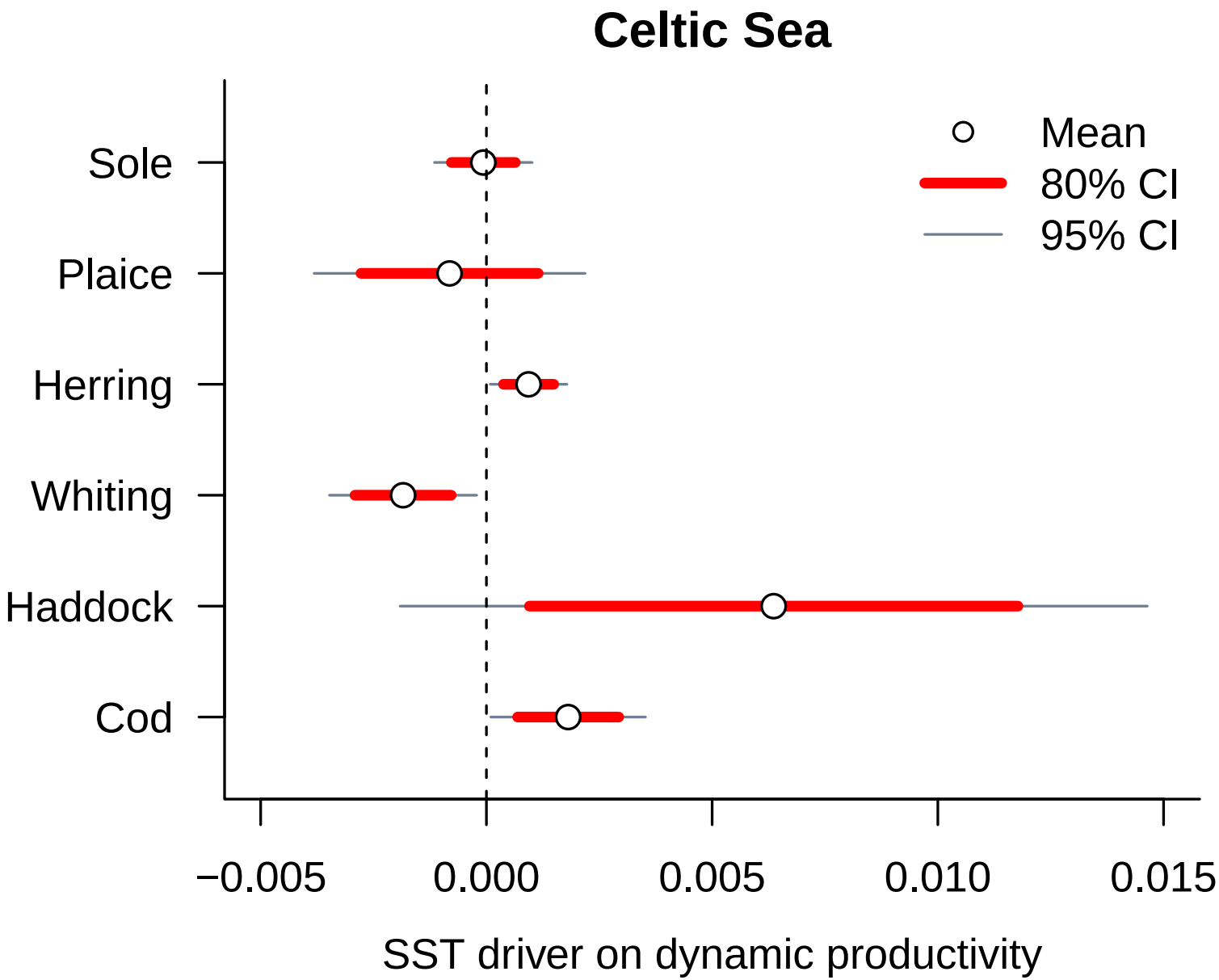

Summary

Time-varying approaches

- Offer an empirical compliment on the static–full mechanism spectrum
- Are tempered (humbled) by observation/data
- Are not very well tested (yet!)
- May raise concerns for management, collective orientation?
- Puts more science (coupling theory and observation) back on the table
- Owe a huge amount to the pioneering work of Prof. Randall Peterman

Looking to the future

Some ideas:

1. Recruitment is ever important, ever difficult but let's shake the cold shoulder of late;
2. Possible to fund basic research in stock assessment and statistical modelling?