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► **To cite this version:**

Chiara Nicolò, Michalis Mastri, Amanda Tracz, John M.L. Ebos, Sébastien Benzekry. Mathematical modeling of differential effects of neo-adjuvant Sunitinib on primary tumor and metastatic growth. AACR Annual Meeting 2018, Apr 2018, Chicago, United States. 78 (13 Supplement), pp.4264, 2018, 10.1158/1538-7445.AM2018-4264 . hal-01968917

**HAL Id: hal-01968917**

**<https://inria.hal.science/hal-01968917>**

Submitted on 8 Jan 2019

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# Mathematical modeling of differential effects of neo-adjuvant Sunitinib on primary tumor and metastatic growth

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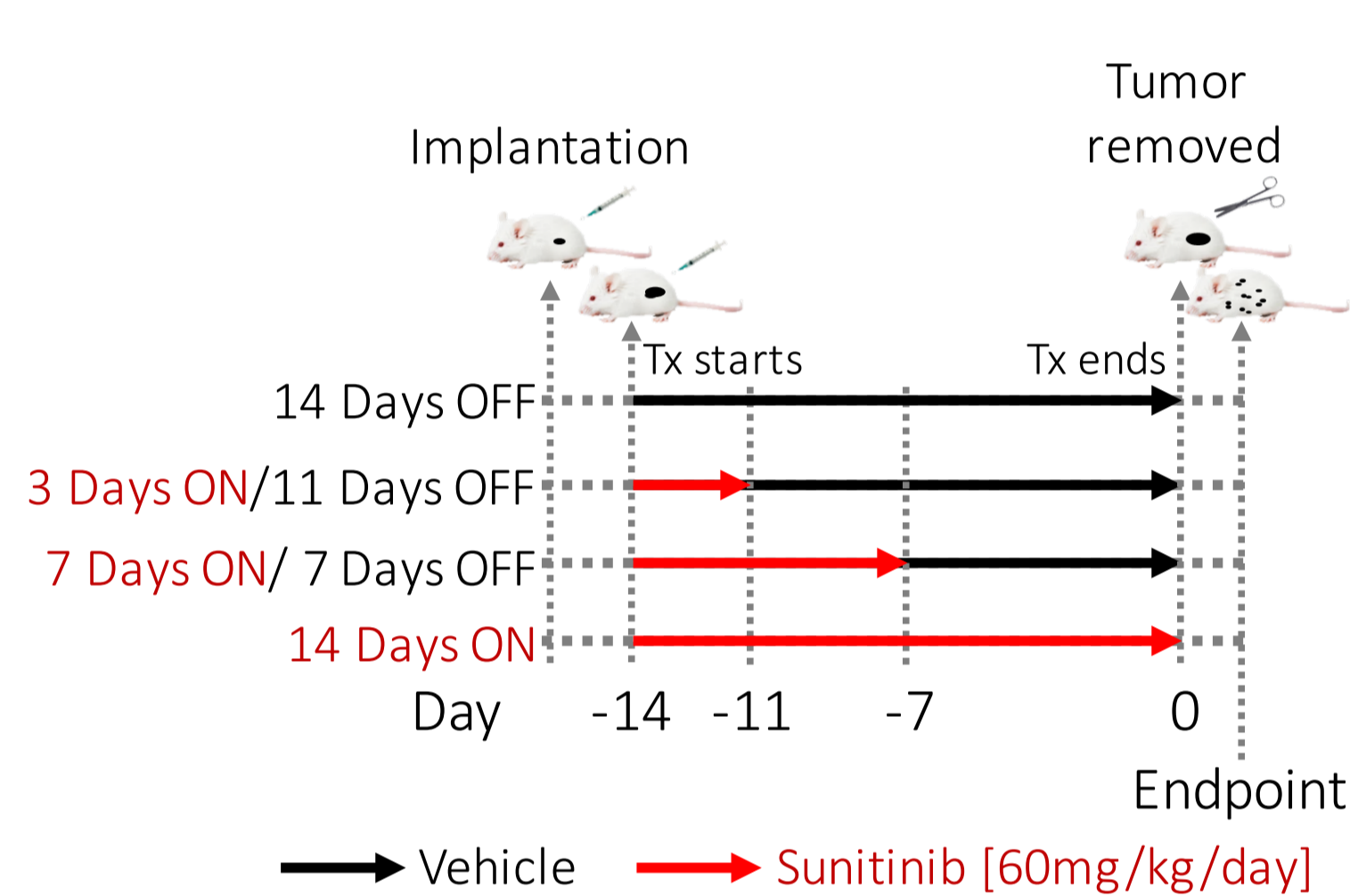
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## BACKGROUND

- **Sunitinib** is a drug with anti-angiogenic activity used in the treatment of patients with metastases from renal cell carcinoma or gastrointestinal tumors.
- It is currently evaluated in clinical trials in the neo-adjuvant setting.
- Despite clear efficacy in reducing established tumor growth, recent preclinical studies have shown **limited**, or even opposing, **efficacies in preventing metastatic spread**.
- In this work, we evaluated a **mathematical model of the metastatic process** to describe primary tumor and metastatic dynamics in response to sunitinib in a clinically relevant **ortho-surgical mouse model of spontaneous metastatic breast cancer**.

## EXPERIMENTAL DATA

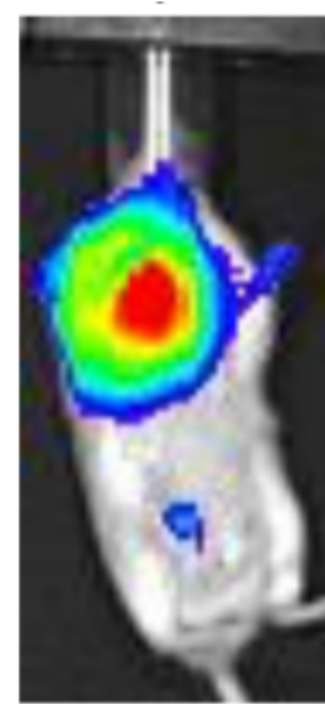


Measurements of

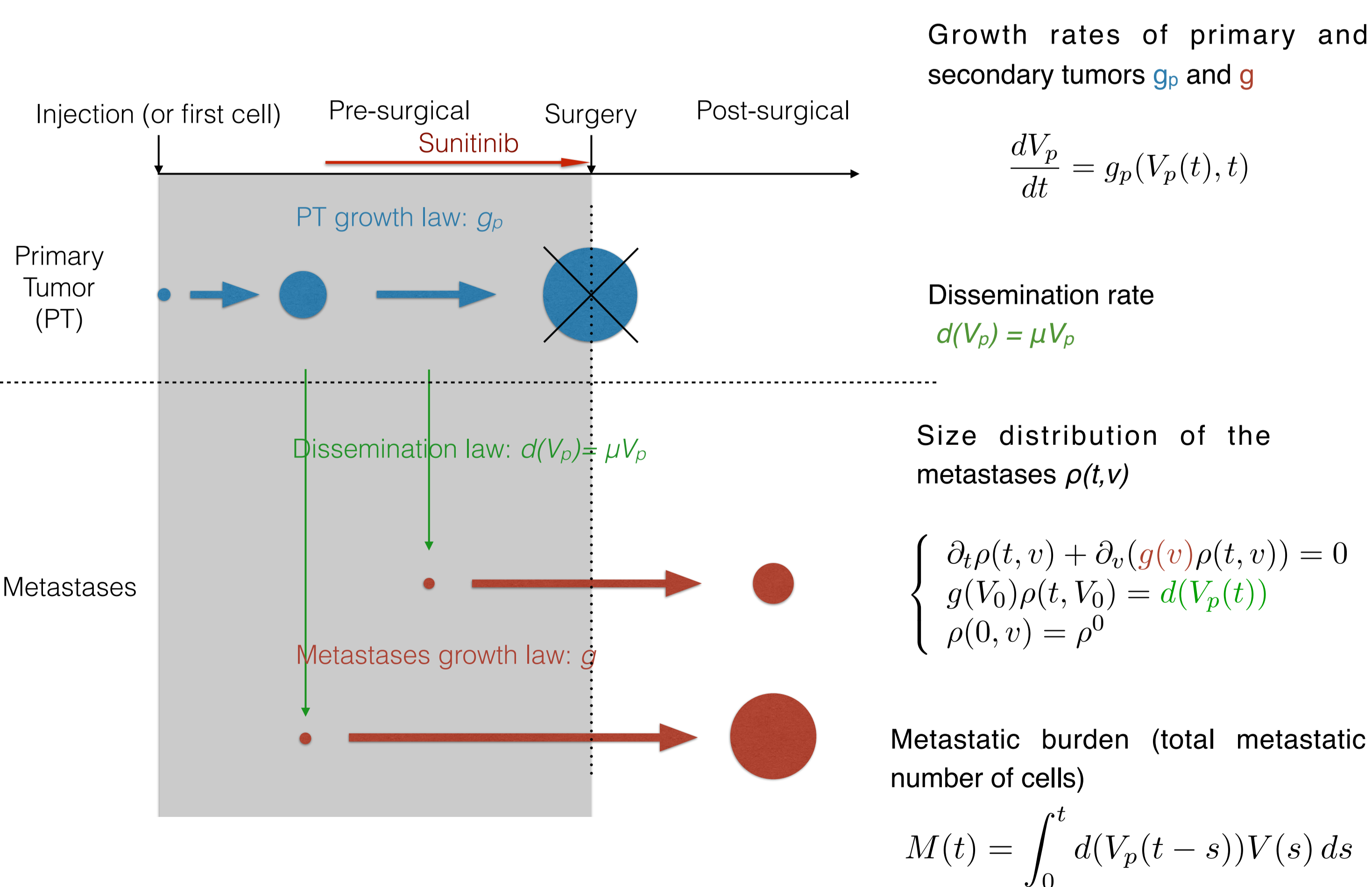
- primary tumor kinetics,
- metastatic burden (bioluminescence)
- pre-surgical molecular and cellular biomarkers, including Ki67 and CD31 expression, circulating tumor cells (CTCs) and myeloid derived suppressor cells (MDSCs).

Orthotopic xenograft breast model: LM2-4<sup>LUC+</sup> human metastatic breast carcinoma cells.

Bioluminescence monitoring of post-surgical metastasis



## AN ELEMENTARY THEORY OF METASTATIC DYNAMICS: DISSEMINATION + GROWTH



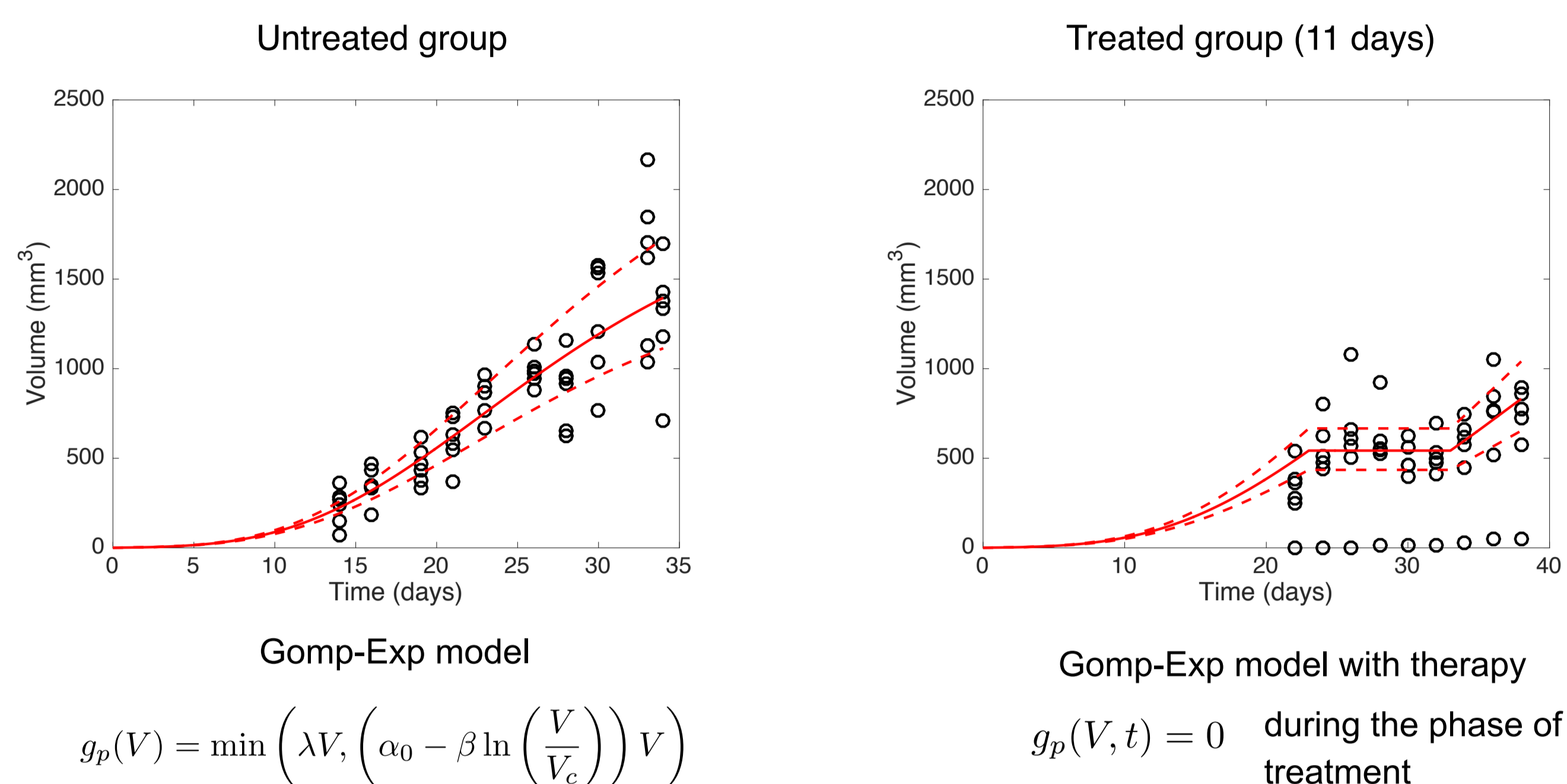
## REFERENCES

[1] Ebos, J. M. L., Matri, M., Lee, C. R., Tracz, A., Hudson, J. M., Attwood, K., Cruz-Munoz, W. R., Jedezsko, C., Burns, P., and Kerbel, R. S. (2014). Neoadjuvant antiangiogenic therapy reveals contrasts in primary and metastatic tumor efficacy. *EMBO Mol Med*, 6(12):1561–1576

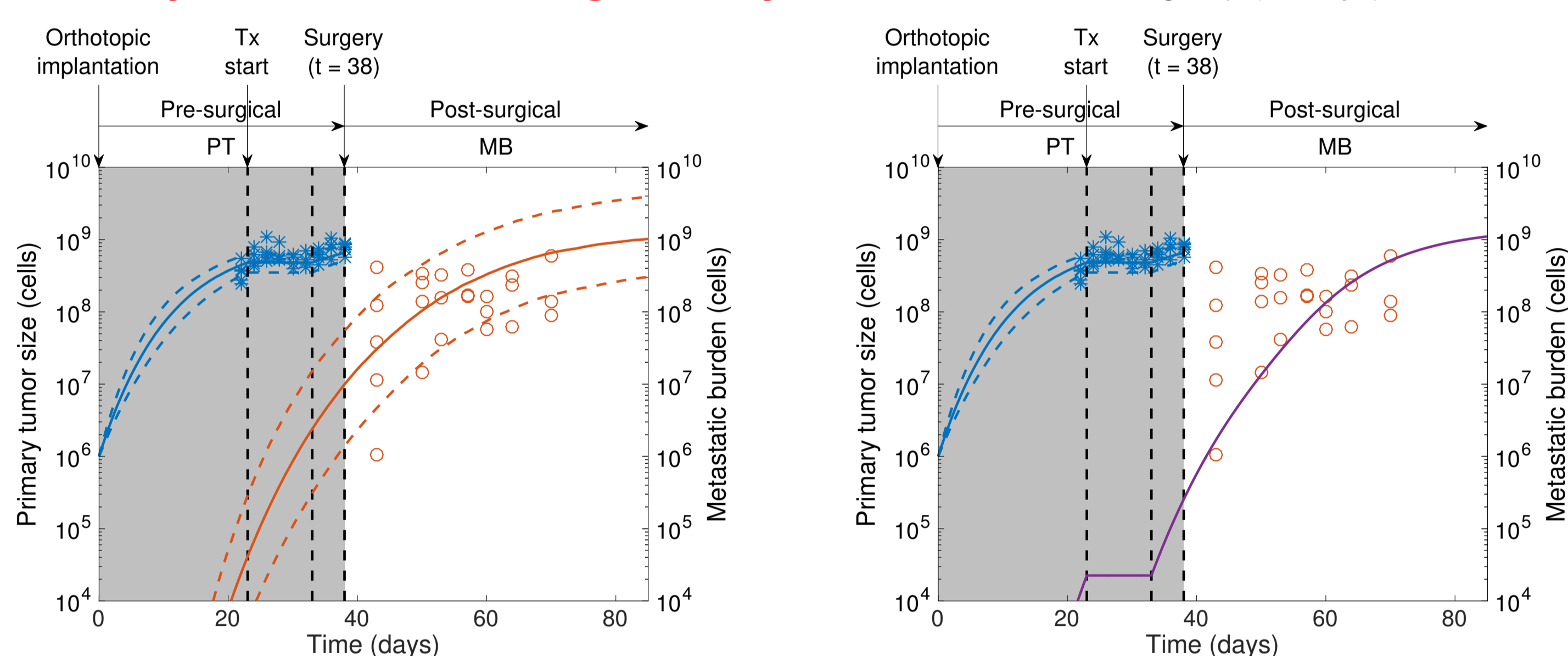
[2] Benzekry, S., Tracz, A., Matri, M., Corbelli, R., Barbolosi, D., and Ebos, J. M. L. (2016). Modeling spontaneous metastasis following surgery: an in vivo-in silico approach. *Cancer Res*, 76(3):535–547.

## DIFFERENTIAL EFFECTS OF SUNITINIB ON PRIMARY TUMOR AND METASTASIS

### Primary tumor growth:



### Primary tumor - metastatic growth dynamics:



Population fit assuming **no effect of treatment on metastasis**

Simulation of **treatment also on metastasis**

**Treatment acts differently on primary and secondary tumor growth**

Mixed-effects population approach.

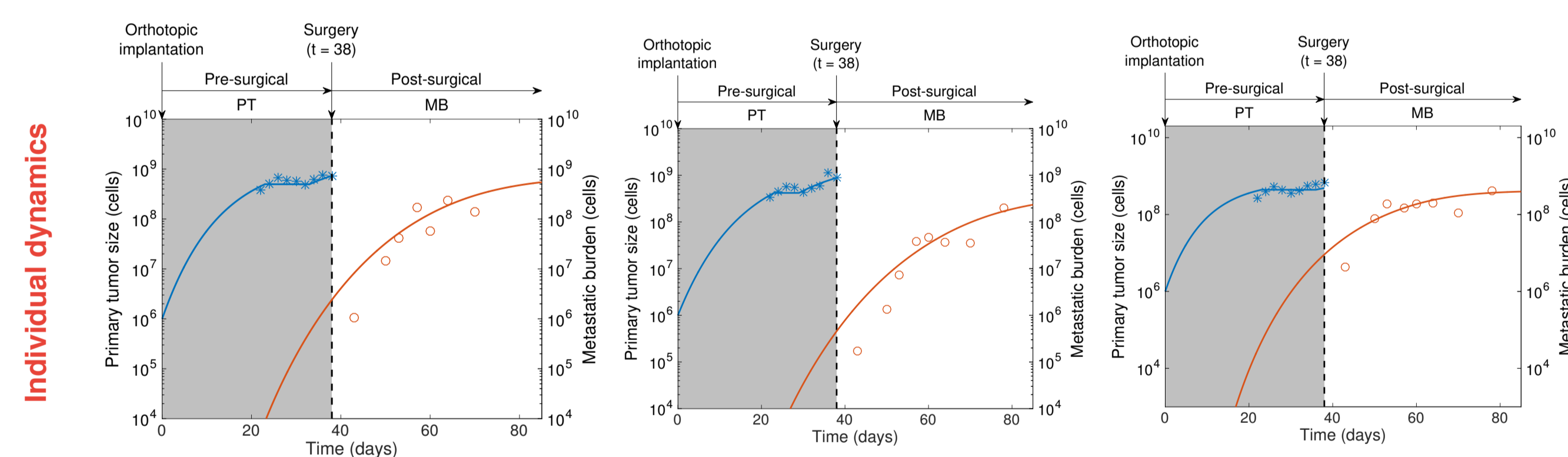
Log-normal distribution for the individual parameters:

$$\log(\psi_i) \sim \log(\psi_{pop}) + \eta_i, \quad \eta_i \sim \mathcal{N}(0, \omega^2)$$

MLE of  $\psi_{pop}$  through the SAEM algorithm.

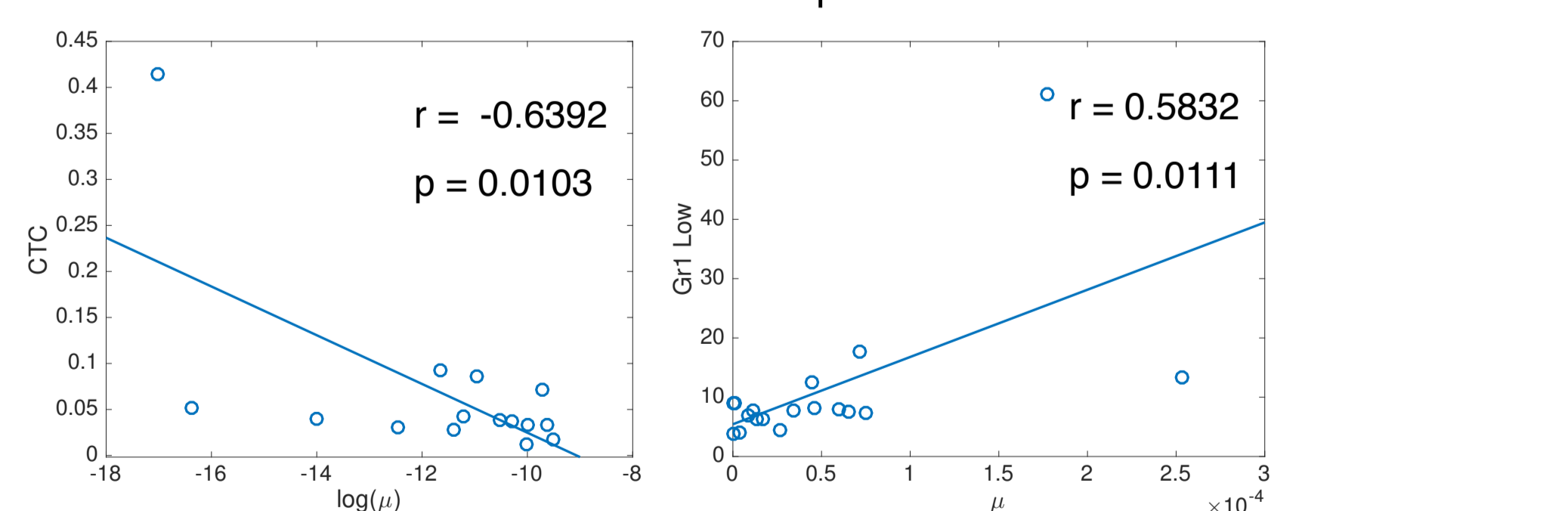
**Table:** Population parameters for the treated group.

	estimate (CV %)	unit	r.s.e. (%)
$\mu_{pop}$	1.009e-04 (117.476)	$\text{mm}^{-3} \cdot \text{day}^{-1}$	23.483
$\alpha_{0, pop}$	1.907 (22.919)	$\text{day}^{-1}$	6.208
$\beta_{pop}$	9.116e-02 (24.490)	$\text{day}^{-1}$	6.682



## COVARIATES ANALYSIS

### Biomarkers VS individual parameters



- Biomarkers can be included in the model as covariates in order to explain part of the variability in the individual parameters

$$x_i : \text{individual covariate} \longrightarrow \log(\mu_i) = \log(\mu_{pop}) + \beta x_i + \eta_i, \quad \eta_i \sim \mathcal{N}(0, \omega^2)$$

## CONCLUSIONS

These results confirm a differential effect of sunitinib on primary (localized) tumors compared to secondary (metastatic) disease. Our results suggest that **Ki67+/CD31+, CTCs and MDSCs** measurements **might help in personalized prediction of metastatic potential** and thus aid in predicting benefit in overall **survival** for preoperative antiangiogenic treatments.