

Zombie Apocalypse: An Epidemic Model



REDay 2013
Cait Witkowski
Brian Blais

Overview

- Our interest
- Zombie basics
- Epidemic (SIR) model
- Munz et al., 2009
- Modifications

Chapter 4

WHEN ZOMBIES ATTACK!: MATHEMATICAL MODELLING OF AN OUTBREAK OF ZOMBIE INFECTION

Philip Munz^{1}, Ioan Hudea^{1†}, Joe Imad^{2‡}, Robert J. Smith^{2§}*

¹School of Mathematics and Statistics, Carleton University,
1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada

²Department of Mathematics, The University of Ottawa,
585 King Edward Ave, Ottawa ON K1N 6N5, Canada

²Department of Mathematics and Faculty of Medicine, The University of Ottawa,
585 King Edward Ave, Ottawa ON K1N 6N5, Canada

What is a zombie?

- “Undead”
- Eat human flesh
- Infect healthy
- Difficult to kill
(destroy brain)



What is a zombie?

Main dynamics:

1. How you become a zombie
Sick, Bitten, Die
2. How you get rid of zombies
Cure, Death



Loglinear Models Using Capture–Recapture Methods to Estimate the Size of a Measles Epidemic

C. A.

ANI



Available online at www.sciencedirect.com



ScienceDirect

Mathematical Biosciences 208 (2007) 76–97

Mathematical
Biosciences

www.elsevier.com/locate/mbs

Stability and bifurcation
incidence and treatment

Xue-Zhi Li^{a,*}, Wen-Sheng Li^{a,b},

^a Department of Mathematics, Xinyang Normal Univ

^b Fugou Middle School, Fugou 461300, Henan Provin

^c School of Mathematics and Computer Application,

Some properties of a simple stochastic epidemic model of SIR type

Henry C. Tuckwell^{a,*}, Ruth J. Williams^b

^a Max Planck Institute for Mathematics in the Sciences Inselstr. 22, Leipzig D-04103, Germany

^b Department of Mathematics, University of California San Diego, La Jolla, CA 92093, USA

Received 27 May 2005; received in revised form 1 May 2006; accepted 20 September 2006

Available online 11 October 2006

• Vaccina

OPEN ACCESS Freely a

A Bayesian
Dynamical

Flávio Codeço Coe

1 Instituto Gulbenkian de Ciê

Científica, Fundação Oswaldo

Rap
lympho

David D. Ho
John M. Leo

Aaron Diamond AIDS Research Center, NYU School of Medicine, 455 First Avenue, New York, New York 10016, USA

* Santa Fe Institute, Santa Fe, New Mexico 87501, USA

† Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

‡ Pharmaceutical Products Division, Abbott Laboratories, Abbott Park, Illinois 60064, USA

Cruz, Rio de Janeiro, Rio de Janeiro, Brazil

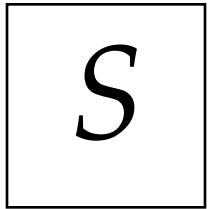
Global stability analysis with a discretization approach for an age-structured multigroup SIR epidemic model

Toshikazu Kuniya^{*,1}

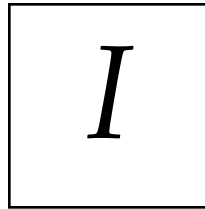
Graduate School of Mathematical Sciences, University of Tokyo, 3-8-1 Komaba Meguro-ku, Tokyo 153-8914, Japan

Epidemic Model

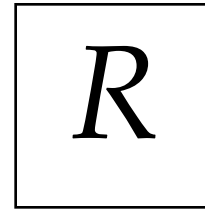
Susceptible



Infected



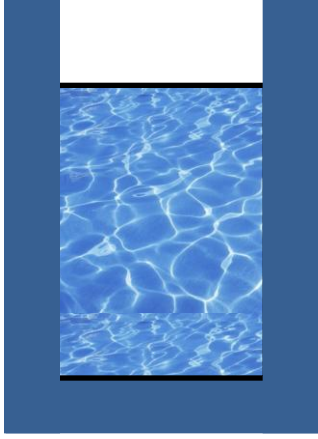
Recovered



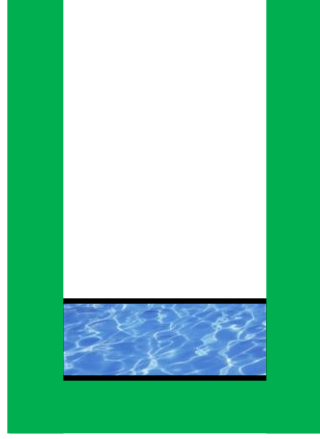
Total
Pop

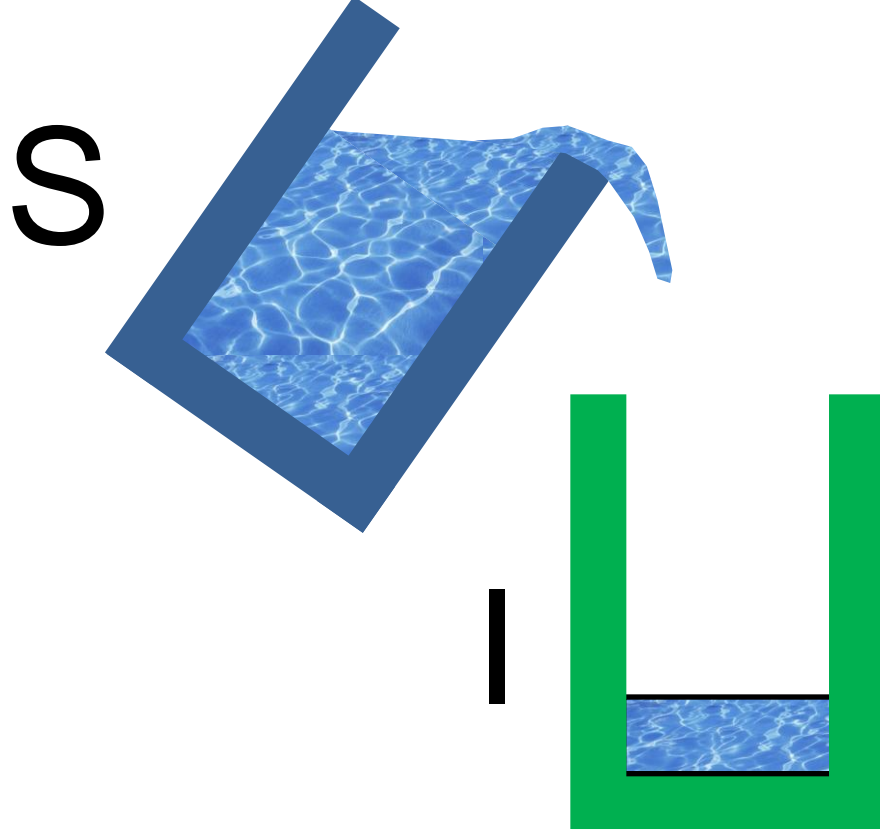


s

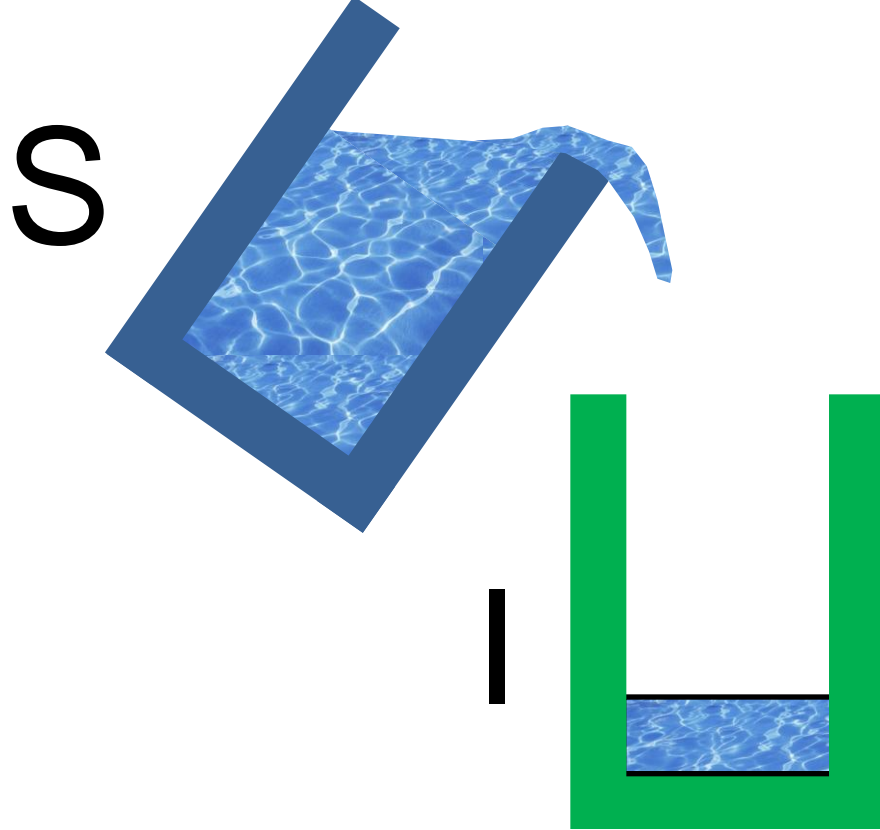


i



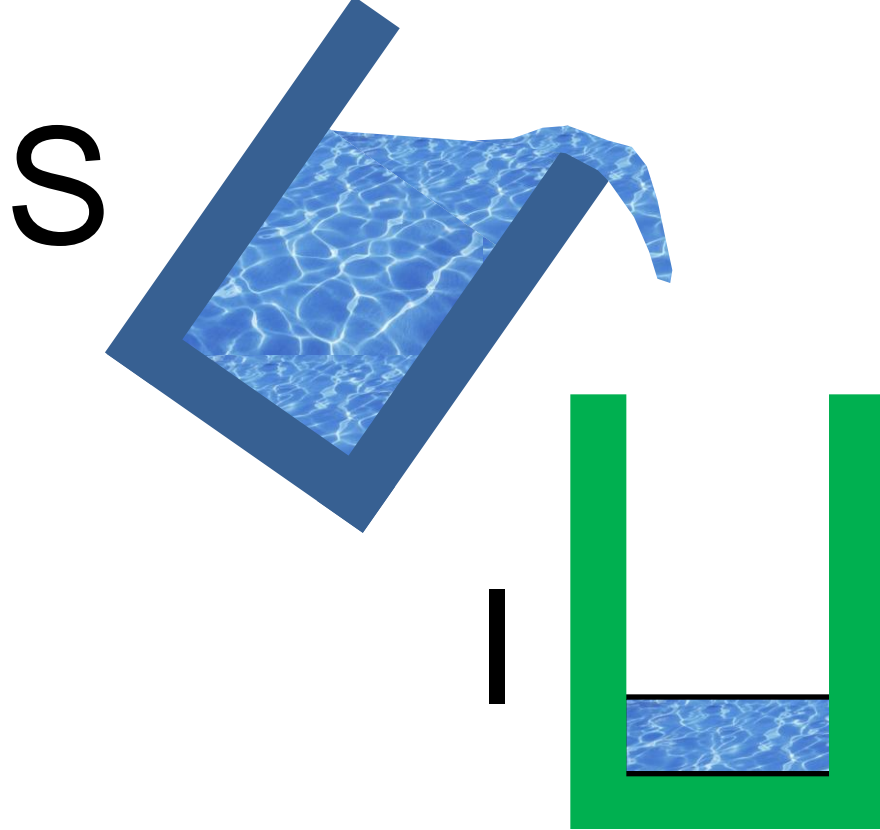


(change in quantity S) = -(constant)



(change in quantity S) = -(constant)

$$S' = -\theta$$

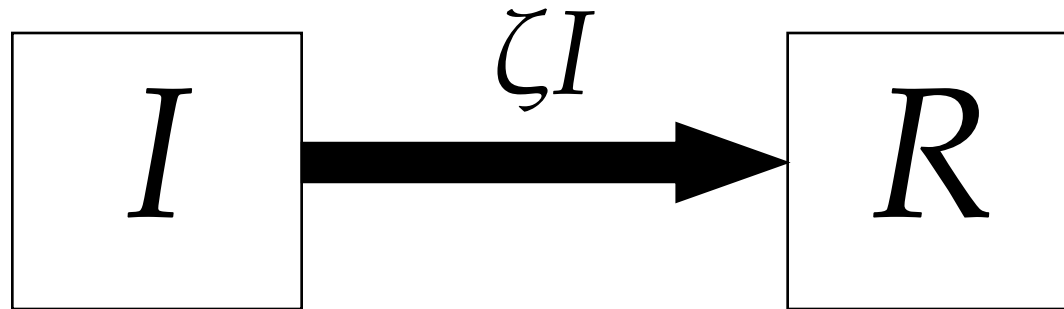


(change in quantity S) = -(constant)

$$S' = -\theta$$

$$I' = +\theta$$

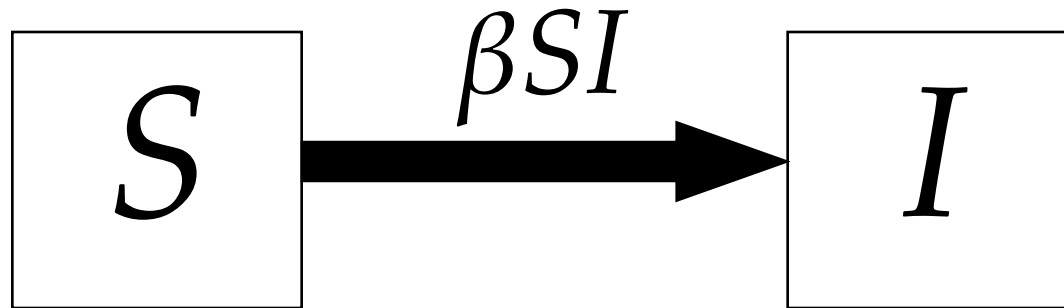
Epidemic Model



$$I' = -\zeta I$$

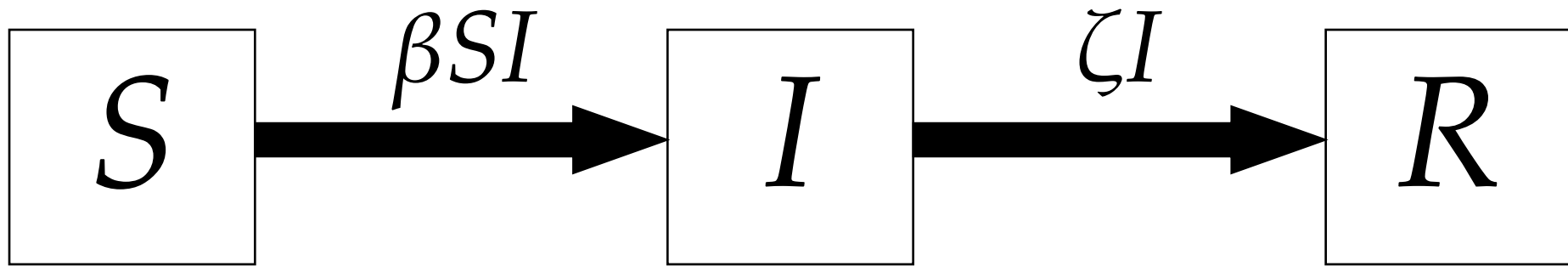
$$R' = +\zeta I$$

Epidemic Model



$$S' = -\beta SI$$
$$I' = +\beta SI$$

Epidemic Model



$$S' = -\beta SI$$

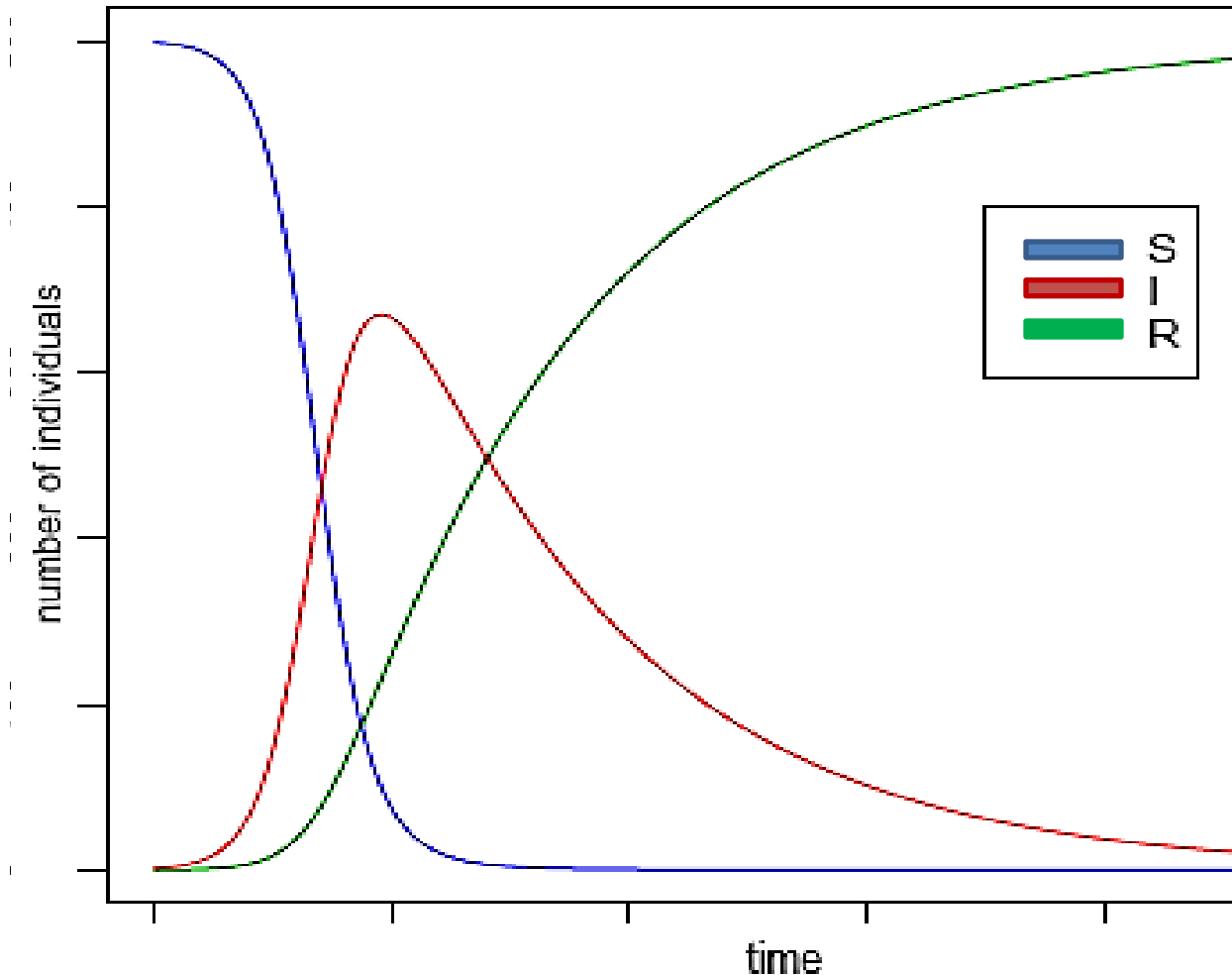
$$I' = +\beta SI - \zeta I$$

$$R' = +\zeta I$$

Epidemic Model

Example of
SIR dynamics
for influenza

Sebastian Bonhoeffer,
SIR models of epidemics



Epidemic Model

Modifications

- Death rates
- Latent periods (SEIS)
- Ability to recover (SEIR)
- Ability to become susceptible again (SIRS)

“When Zombies Attack!: Mathematical Modelling of an Outbreak Zombie Infection”

Munz, Hudea, Imad, Smith (2009)

Goals:

- Model a zombie attack, using biological assumptions based on popular zombie movies
- Determine equilibria and their stability
- Illustrate the outcome with numerical solutions
- Introduce epidemic modeling with fun example

“When Zombies Attack!: Mathematical Modelling of an Outbreak Zombie Infection”

Munz, Hudea, Imad, Smith (2009)

Conclusions:

- Disastrous outbreak unless aggressive tactics
- Collapse of civilization

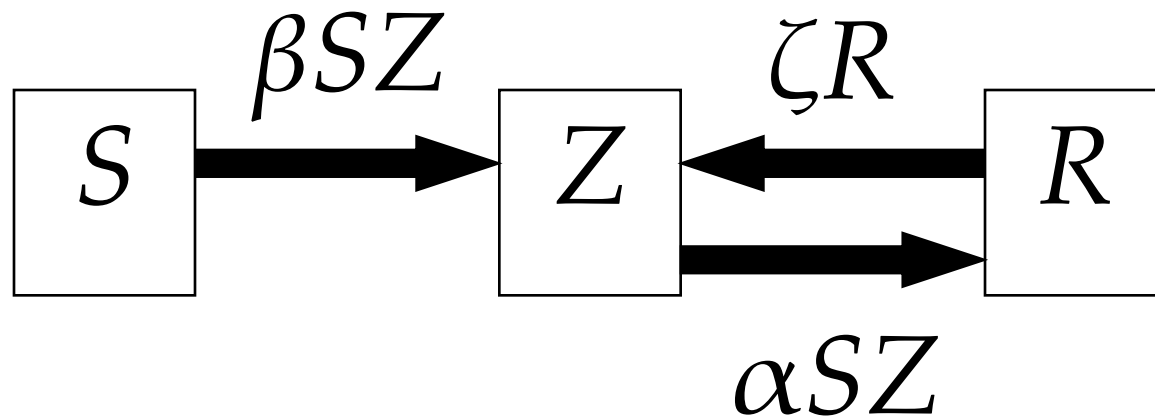
“When Zombies Attack!: Mathematical Modelling of an Outbreak Zombie Infection”

Munz, Hudea, Imad, Smith (2009)

Great idea, *but...*

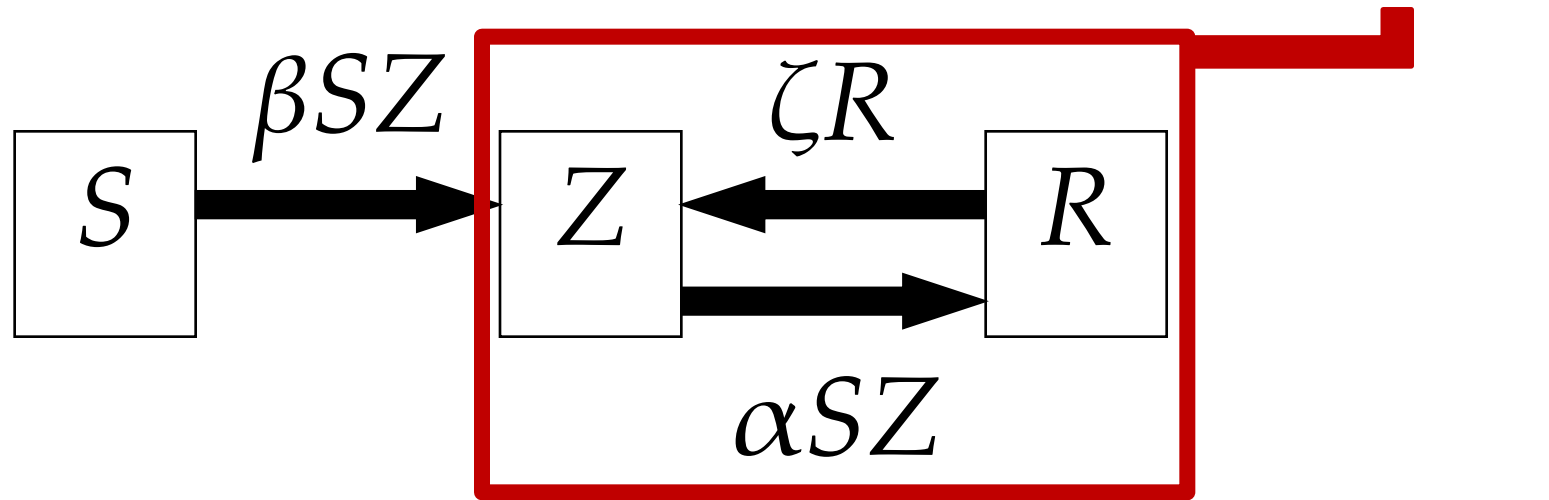
- Models don't match any film
- All results depend on poor model assumptions
- No data is used
- Wrong parameters given

Munz Model



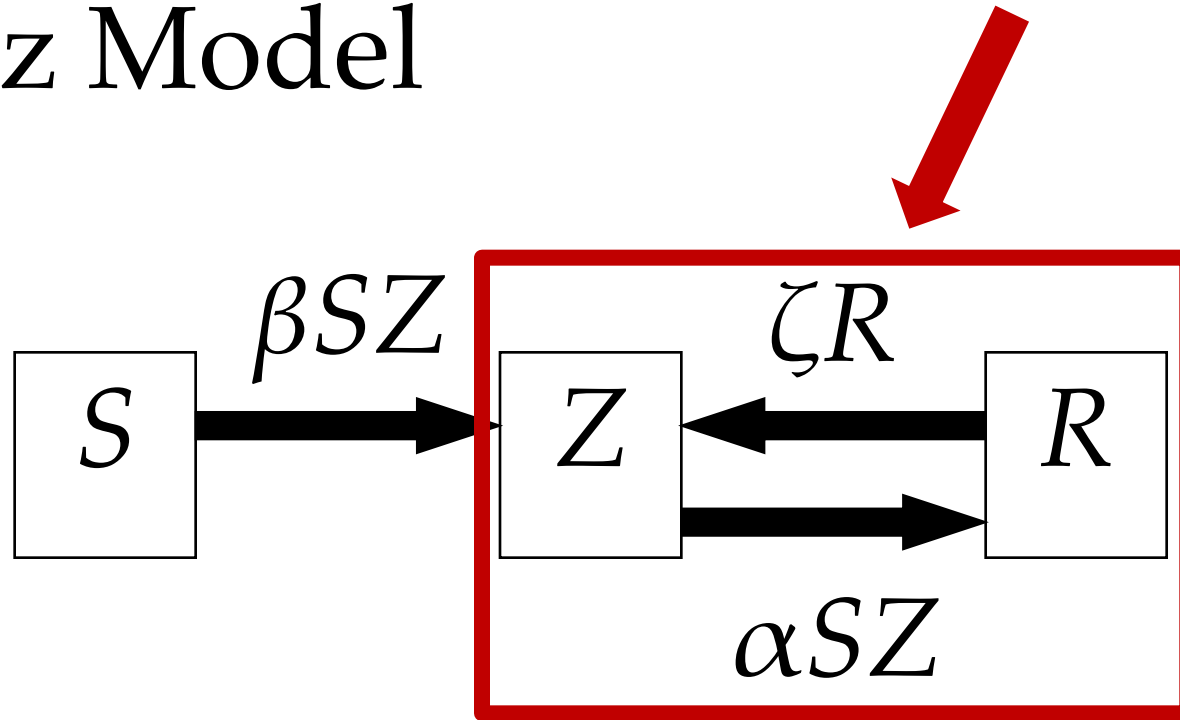
<u>S</u> sceptible	\longrightarrow	$S' = -\beta SZ$
<u>Z</u> ombie	\longrightarrow	$Z' = \beta SZ + \zeta R$
<u>R</u> emoved	\longrightarrow	$R' = -\zeta R$

Munz Model



If zombies are killed, they are soon recycled into the zombie population

Munz Model



We can find no movies where the ζR term is a reasonable assumption

Reproduce results

- Before starting our models, replicate theirs
- Parameters are drastically wrong

Based on paper:

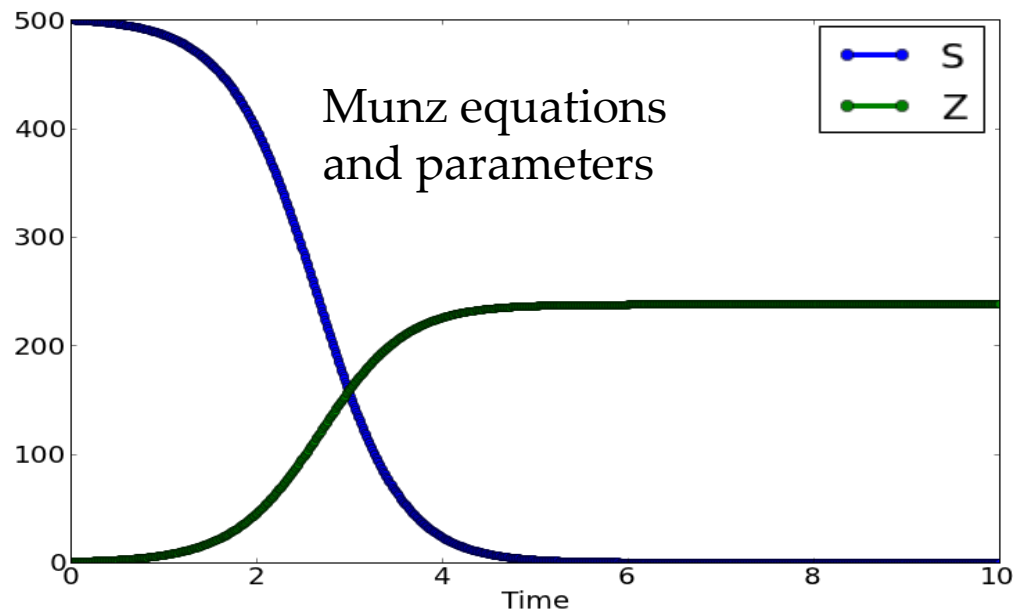
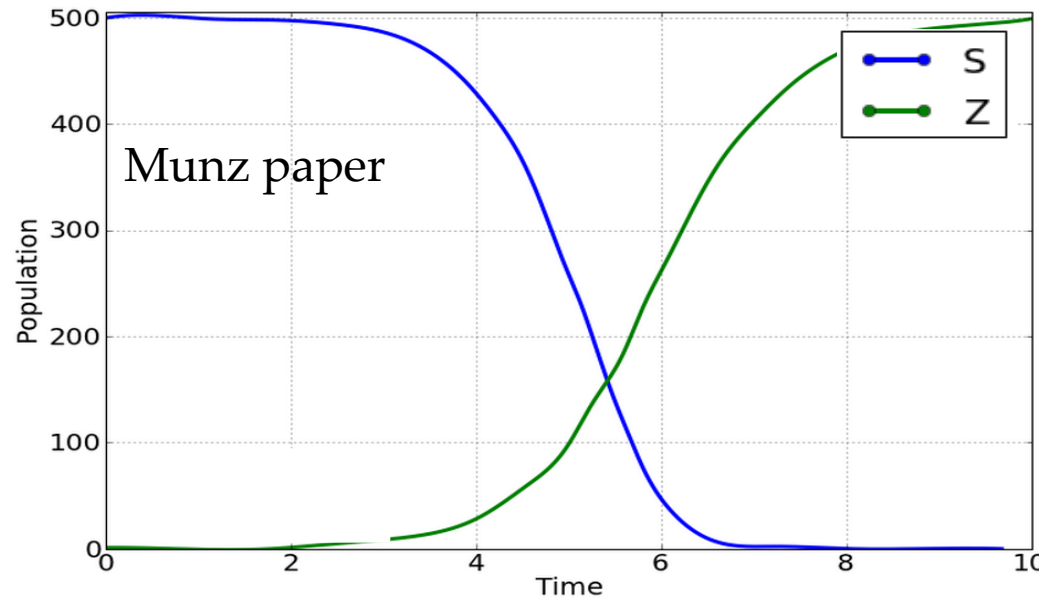
Based on model:

$$\beta = .0095 \quad \longrightarrow \quad \beta = .0028$$

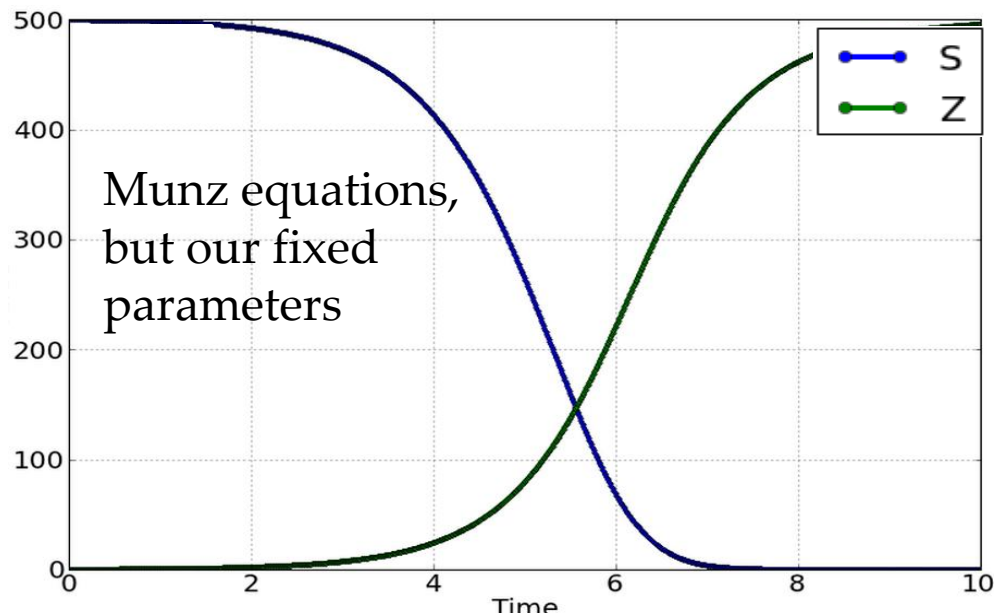
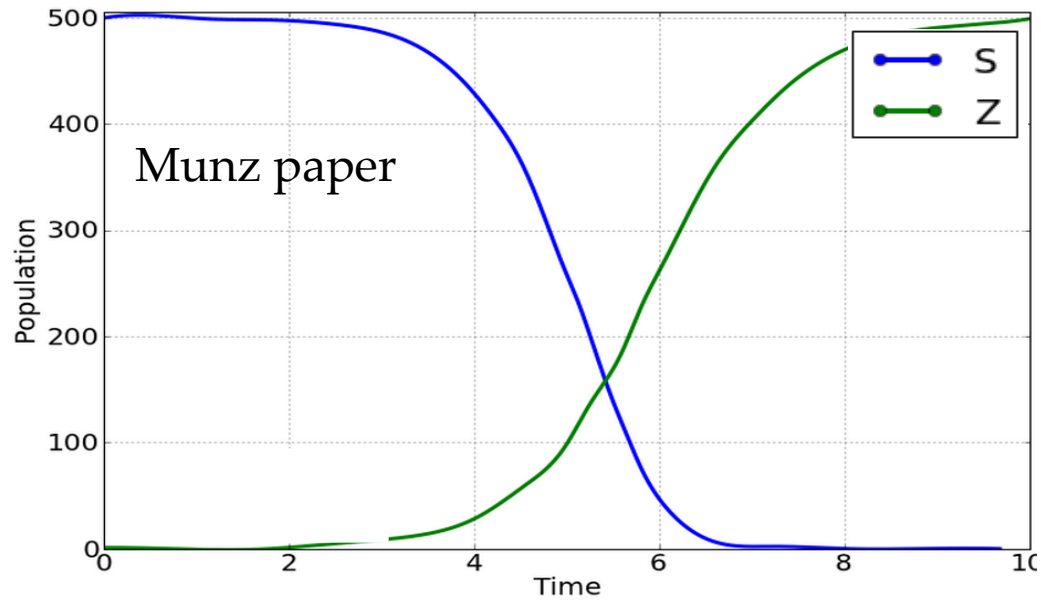
$$\rho = .005 \quad \longrightarrow \quad \rho = 5$$

$$\zeta = .0001 \quad \longrightarrow \quad \zeta = 5$$

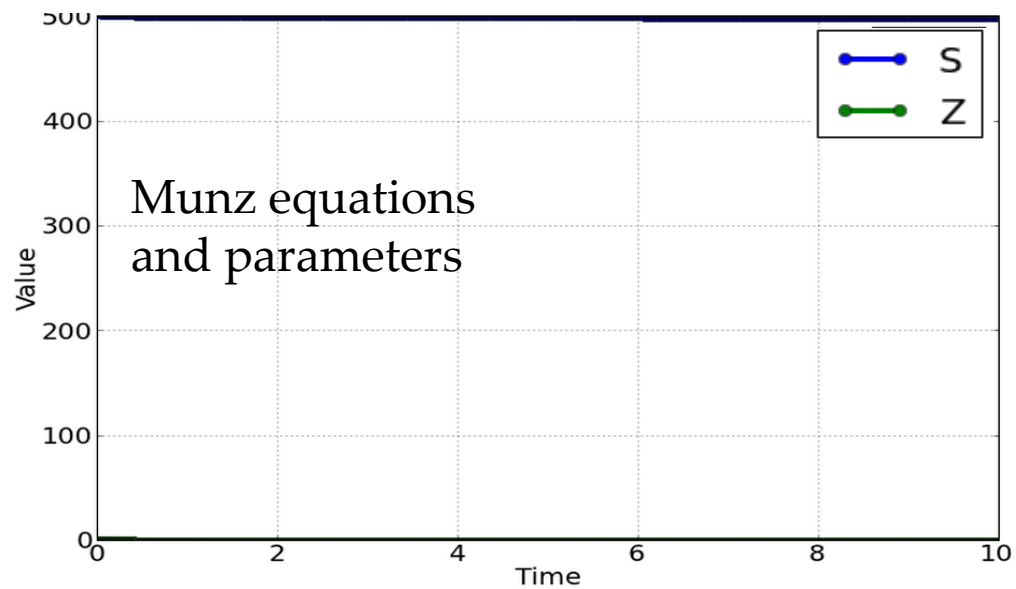
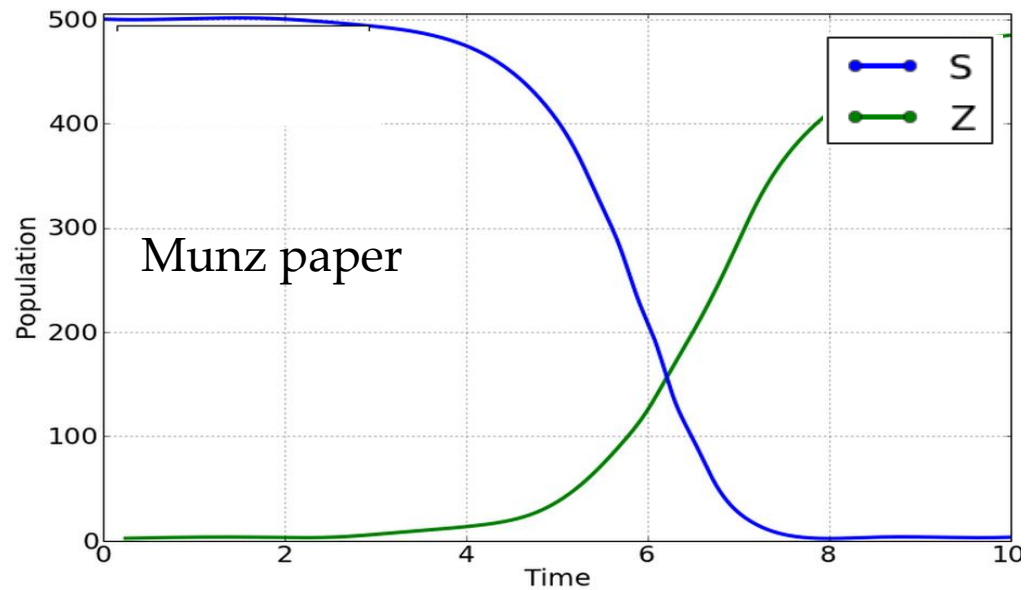
Latent Outbreak



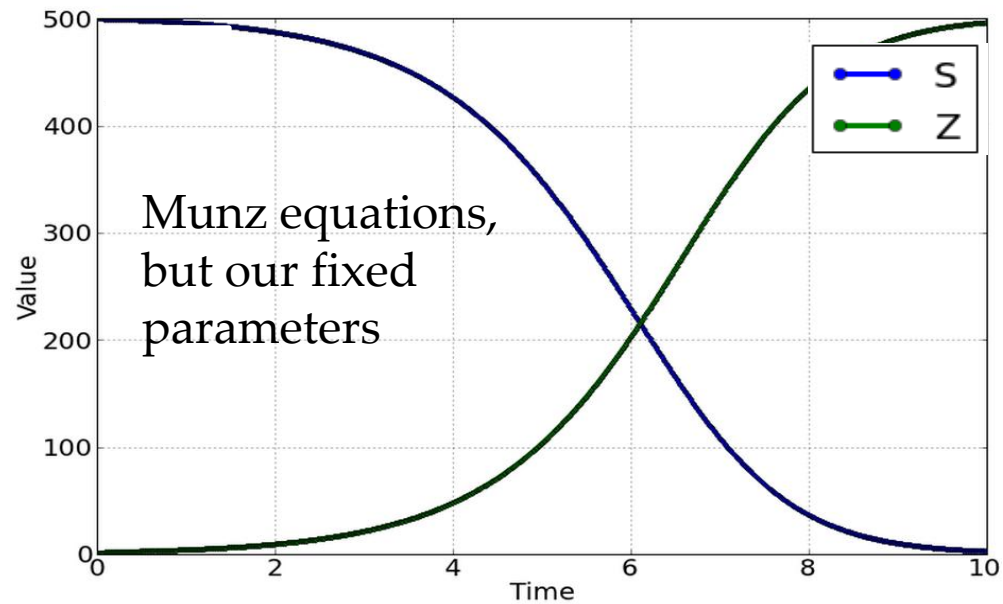
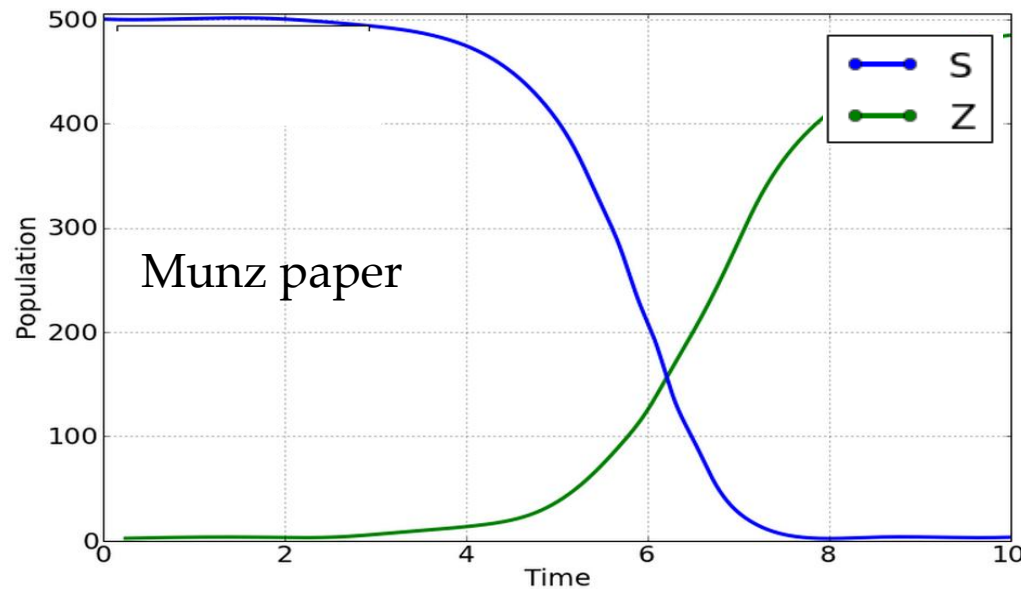
Latent Outbreak



Quarantine



Quarantine



Upgrades

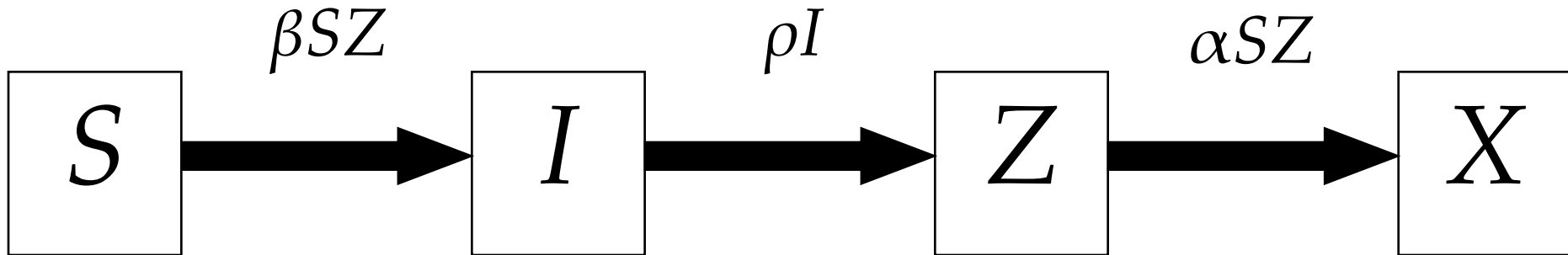
Shaun of the Dead

Walking Dead

Zombieland

28 Days Later

Resident Evil

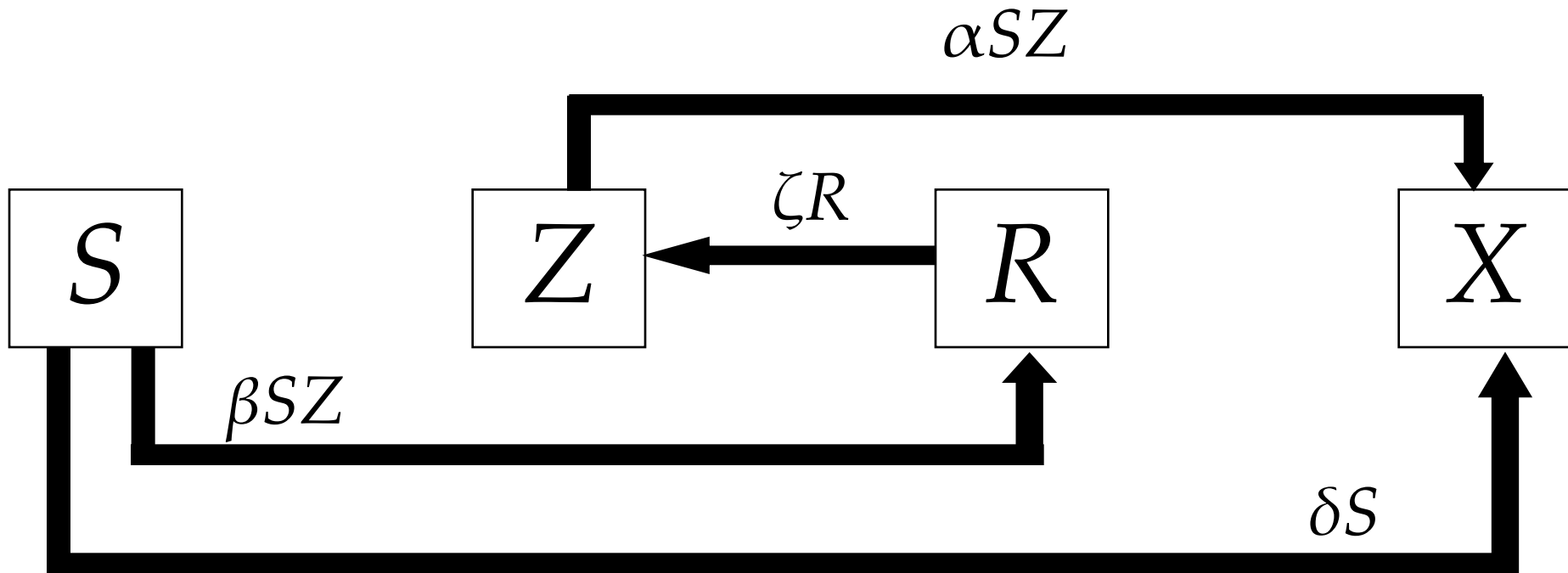


Upgrades

Night of the Living Dead

Dawn of the Dead

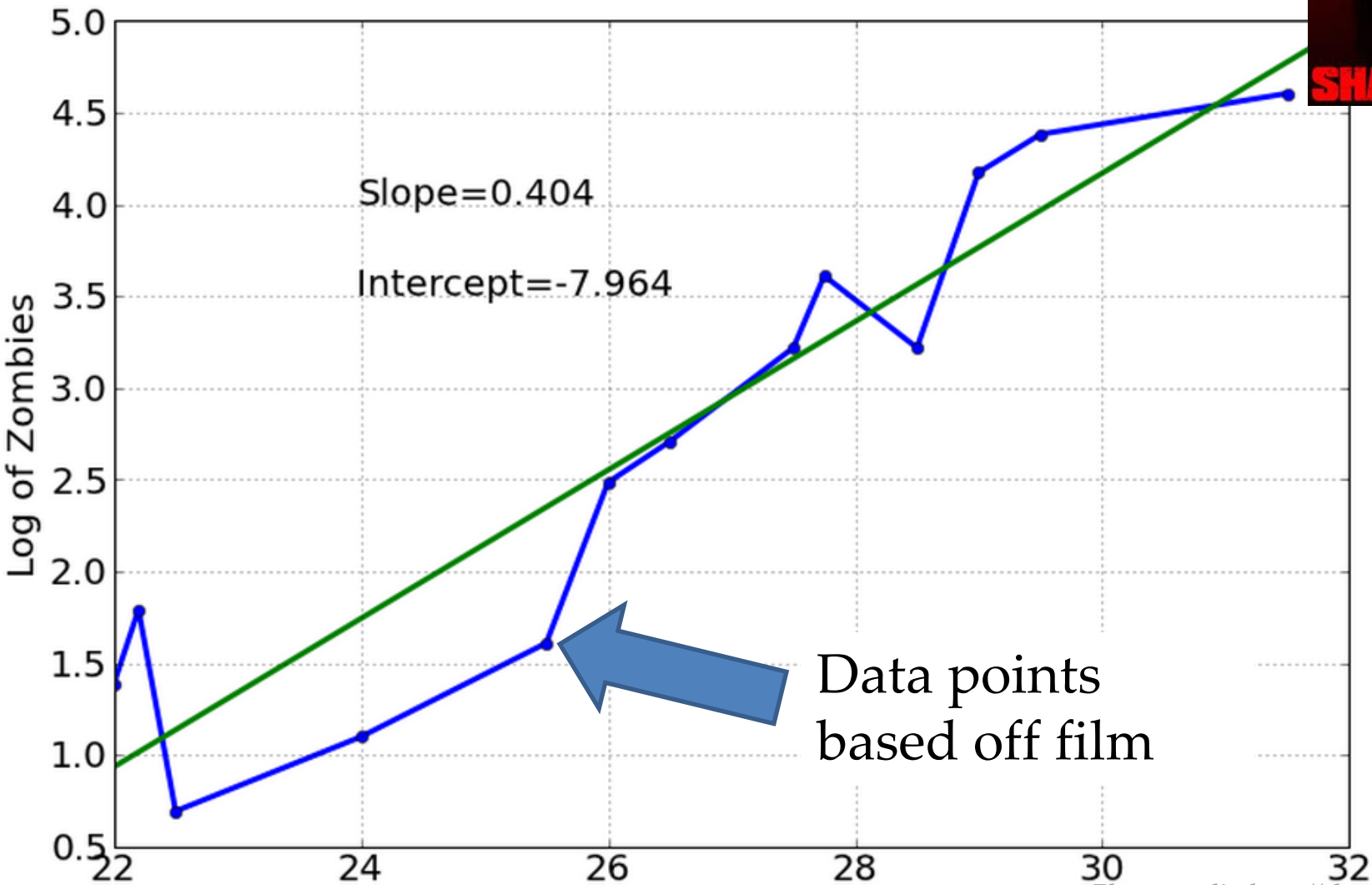
Day of the Dead



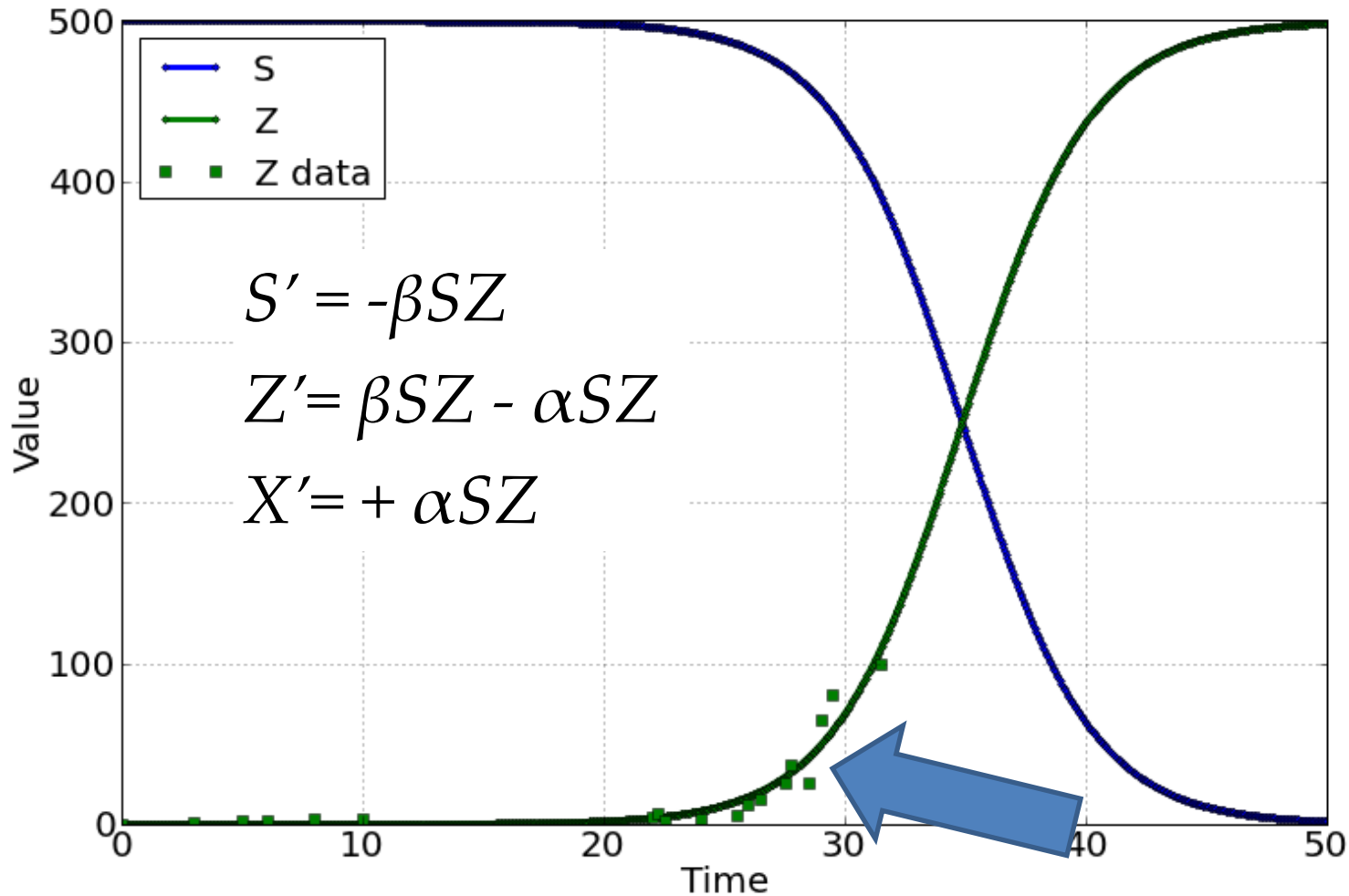
Data Collection

- Watch films, pause to take population count whenever zombies are in the scene
- Record time (within film's world) versus population increase

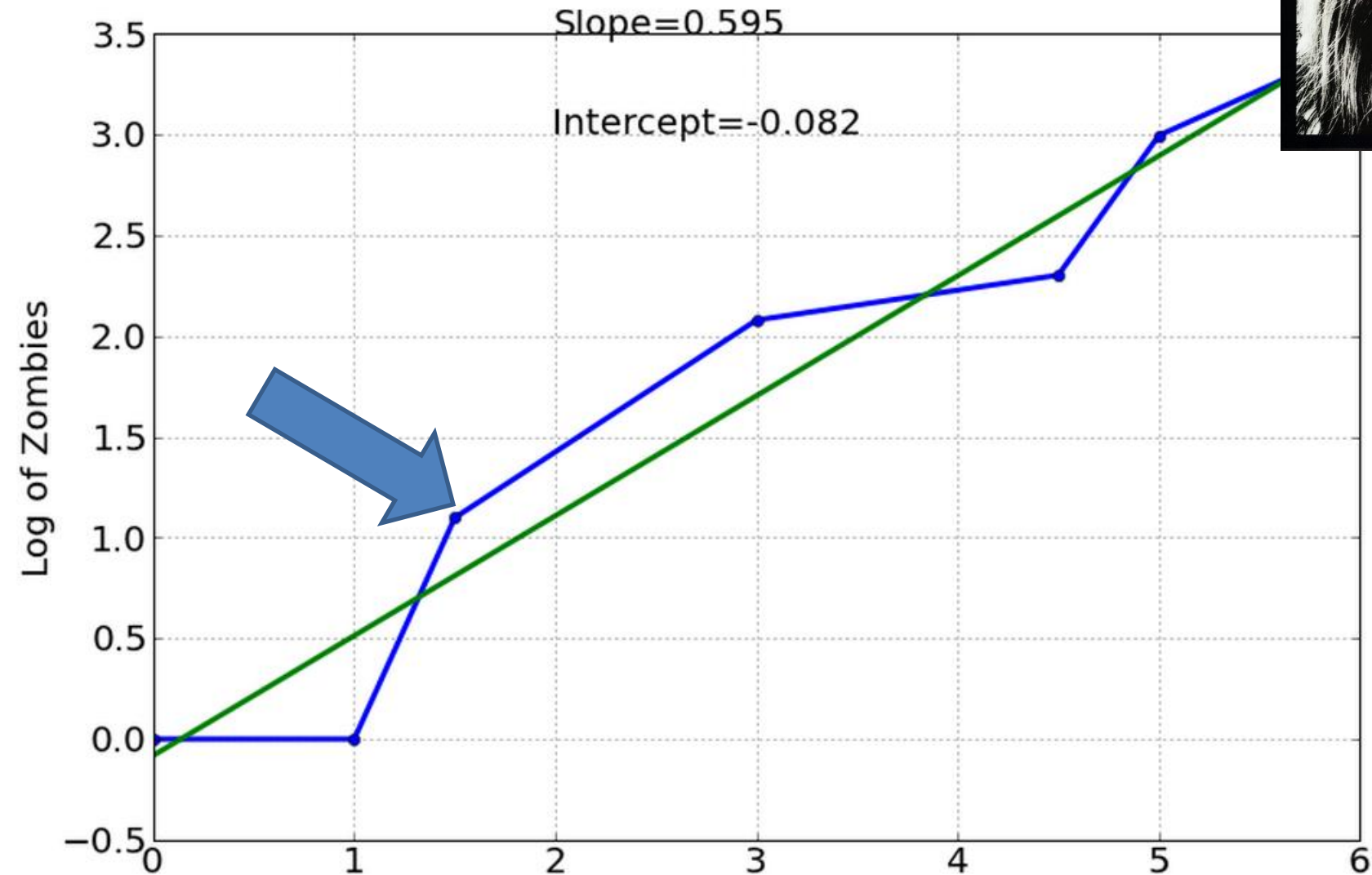
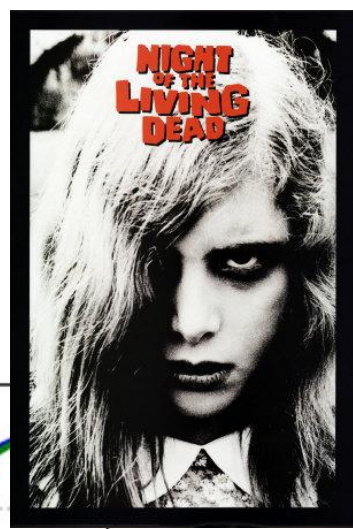
Shaun of the Dead



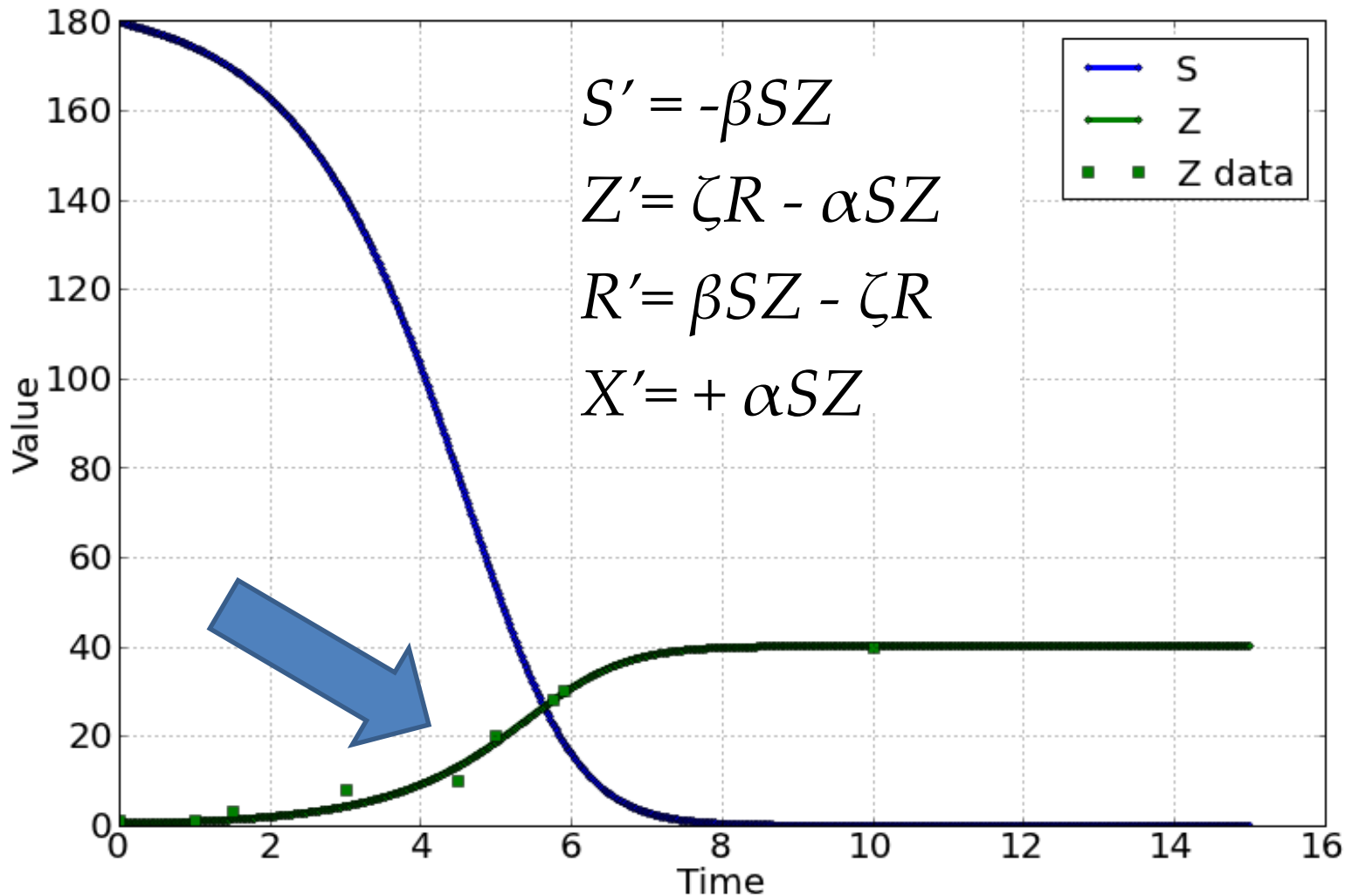
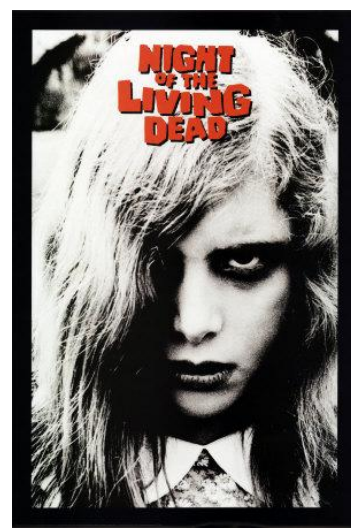
Shaun of the Dead



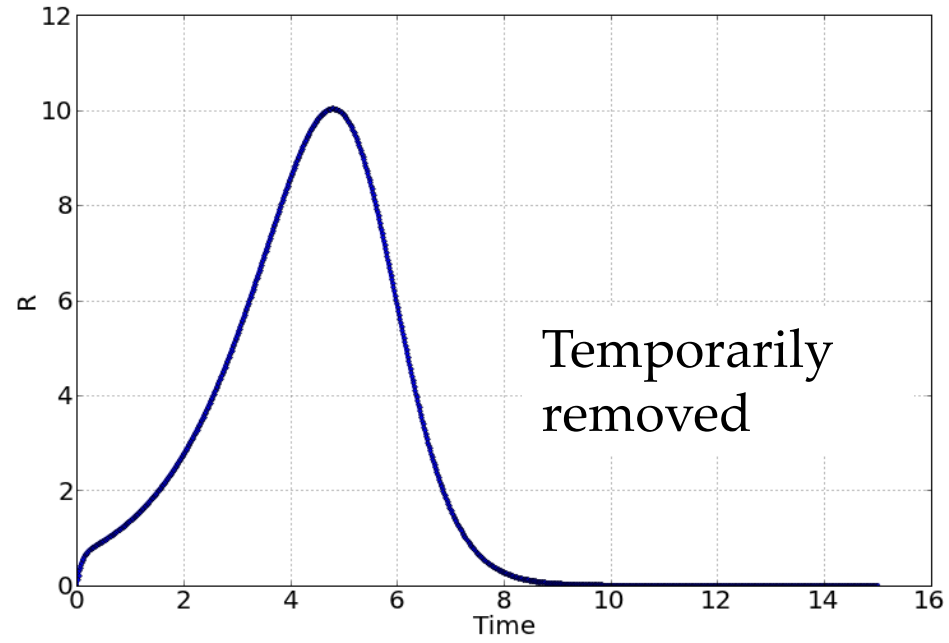
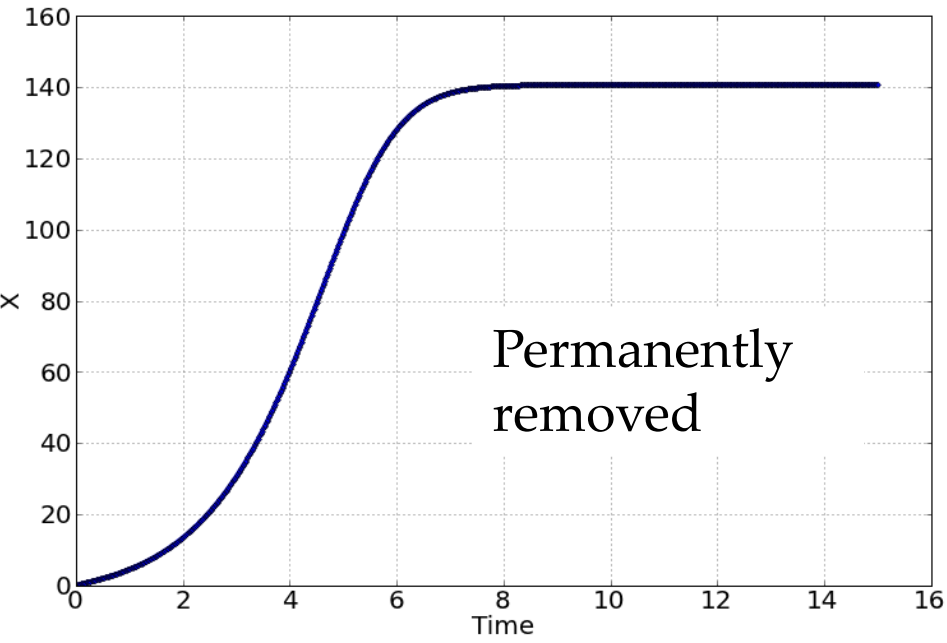
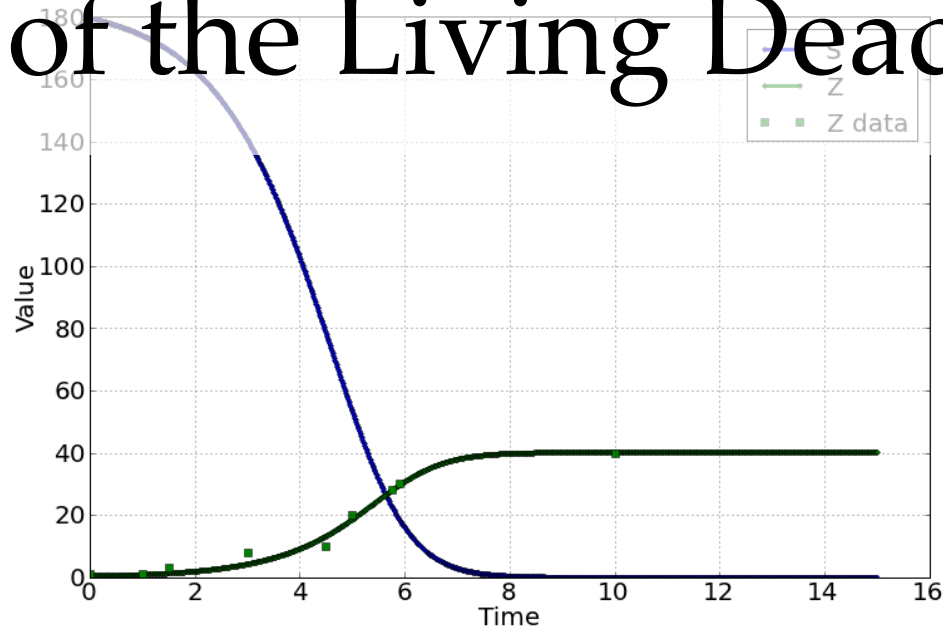
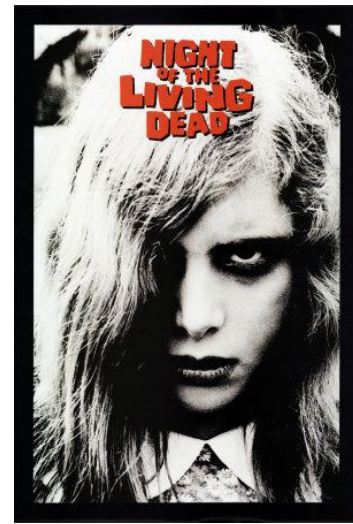
Night of the Living Dead



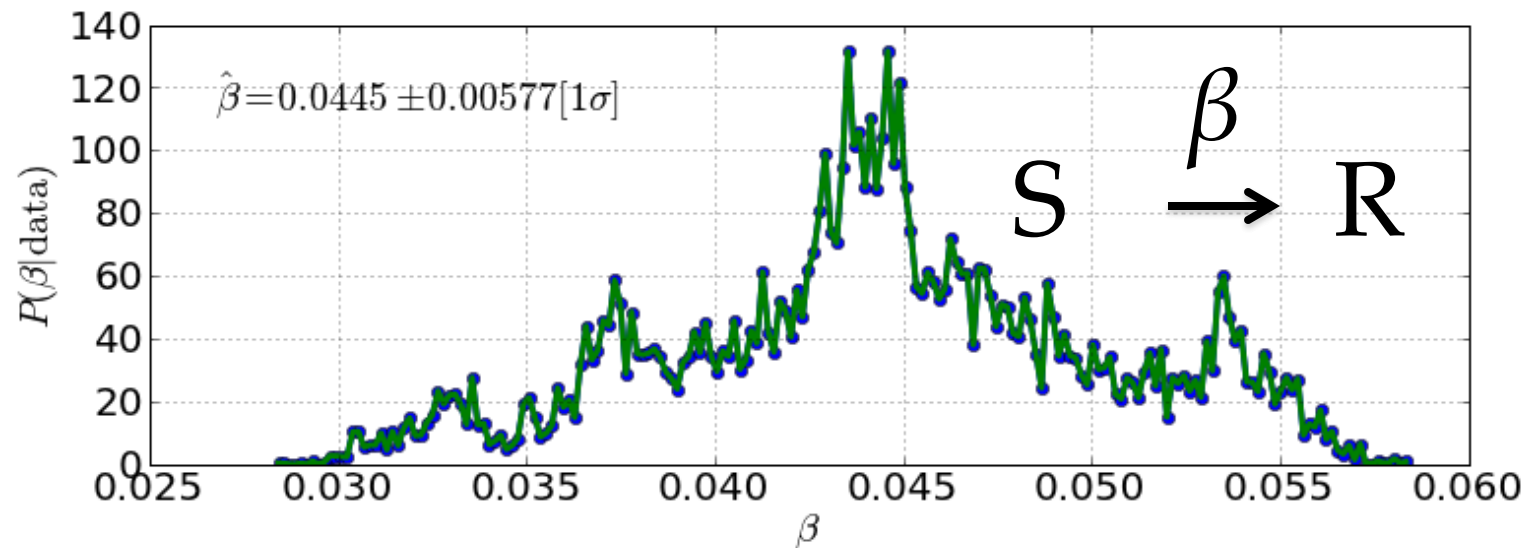
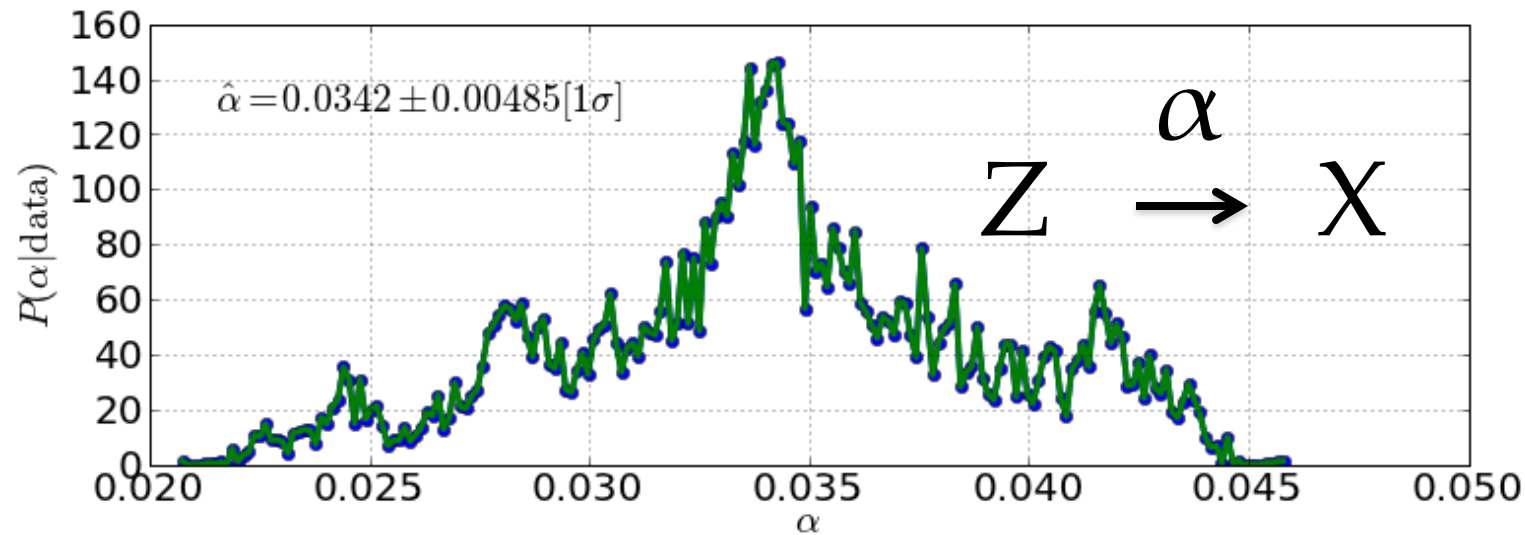
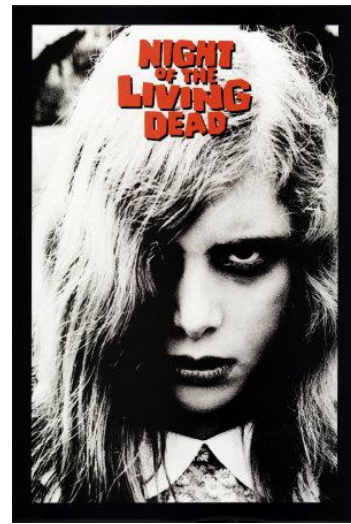
Night of the Living Dead



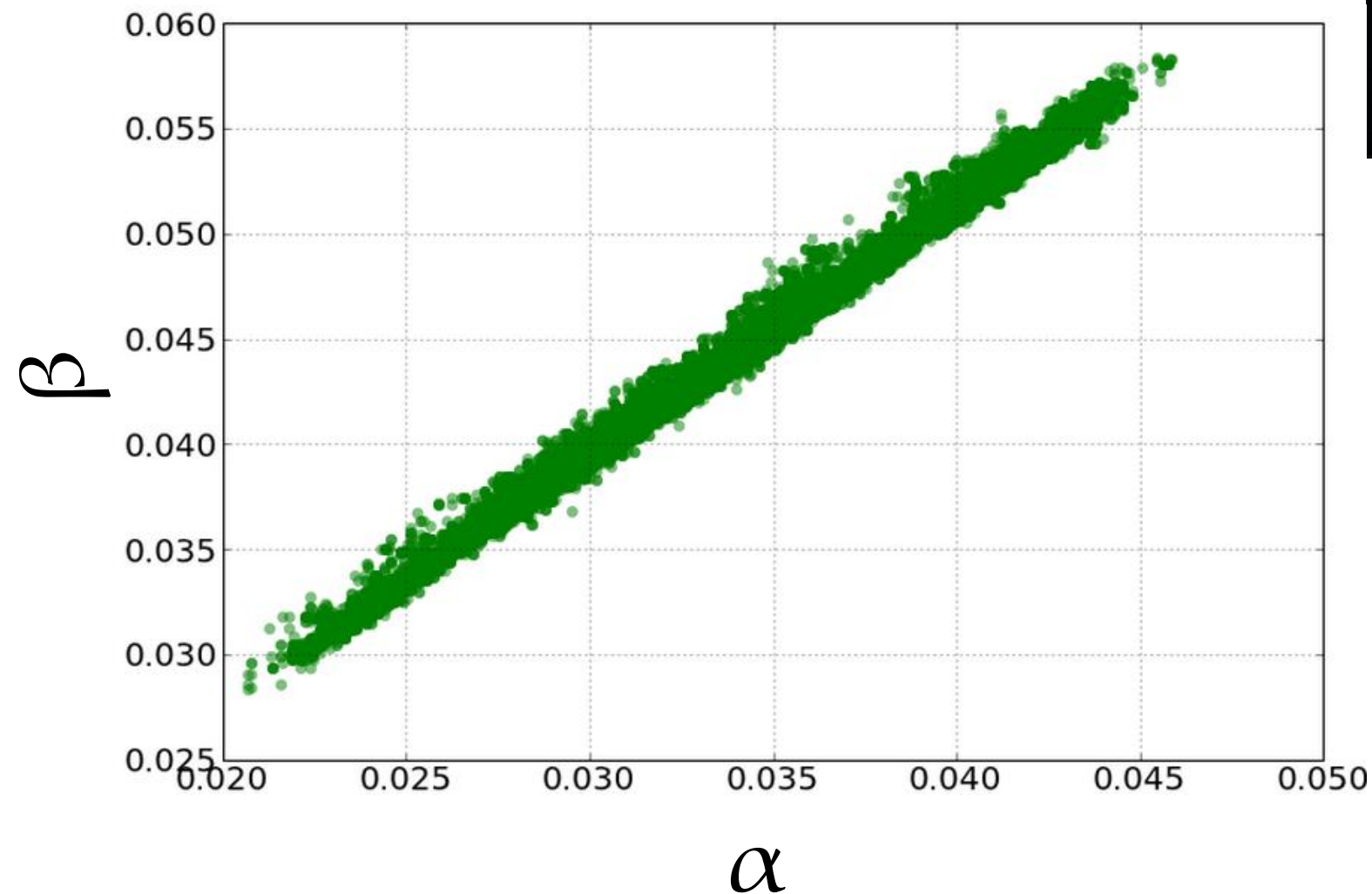
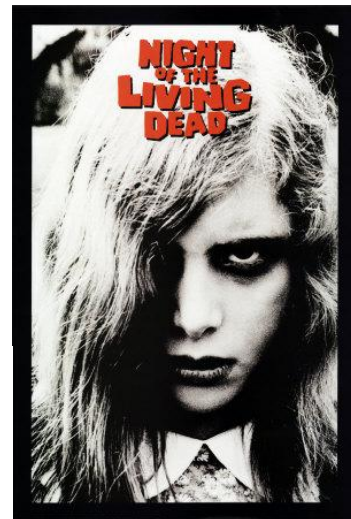
Night of the Living Dead



50000 Simulations



Joint Distribution



Conclusions

- Zombie infection would likely be disastrous, but not inevitable as Munz et al. (2009) suggestions
- Data are necessary to make reasonable models and parameter estimations