Accounting for scattering asymmetry in recollision probability models

Philip Lewis

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Plant Canopy Modeling

IGARSS'90

THA–2

1. *Two-Layer Reflectance Models*—Hapke, B. 1733

2. *Principles of the Radiosity Method for Canopy Reflectance Modeling*—Gerstl, S.A.W., Borel, C.C. 1735

3. *Botanical Plant Modelling for Remote Sensing Simulation Studies*—Lewis, P., Muller, J.–P. 1739

4. *Information Content of Canopy BDRF: A Monte Carlo Approach*—Ross, J., Marshak, A. 1743

5. *Thermal Emissivity and Infrared Temperature Dependence on Plant Canopy Architecture and View Angle*—Norman, J.M., Chen, J.–l., Goel, N. 1747

6. *Bidirectional Reflectance Modeling of Forest Canopies Using Boolean Models and Geometric Optics*—Strahler, A.H., Jupp, D.B. 1751

7. *Geometric–Optical Modeling of Blue Oak Woodland in California*—Franklin, J., Davis, F., Lefebvre, P. 1757

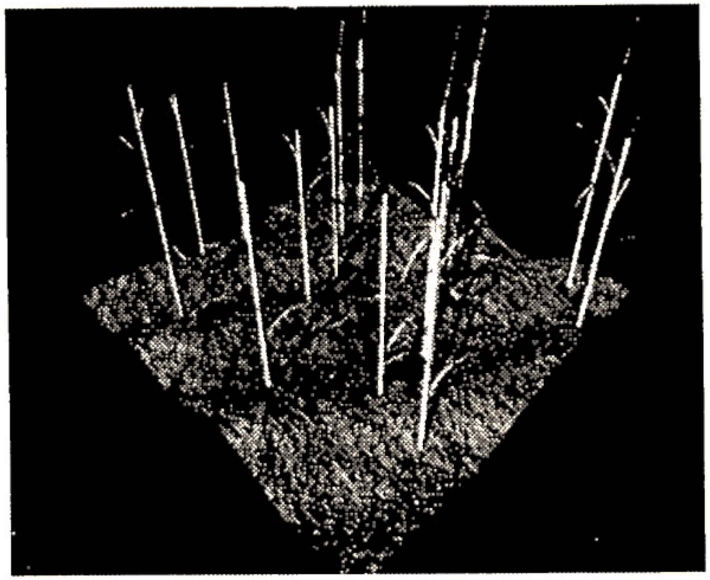
8. *Inferring Hemispherical Reflectance Using a Knowledge-Based System*—Kimes, D.S., Harrison, P.R. 1759

Poster: *Computer Simulation of Plant Growth Dynamics*—Goel, N.S., Knox, L.B., Norman, J.M. 1765

MCRT 1990

Figure 3: ray-traced simulation of plants and fractal soil (processing time approximately 15 cpu hours on a Sun-4)

1990



Lewis, P., and J-P. Muller, 1990b. Botanical plant modelling for remote sensing simulation studies. In: Proc. IGARSS'90, Washington DC-USA, Vol. 3, pp 1739-1742.

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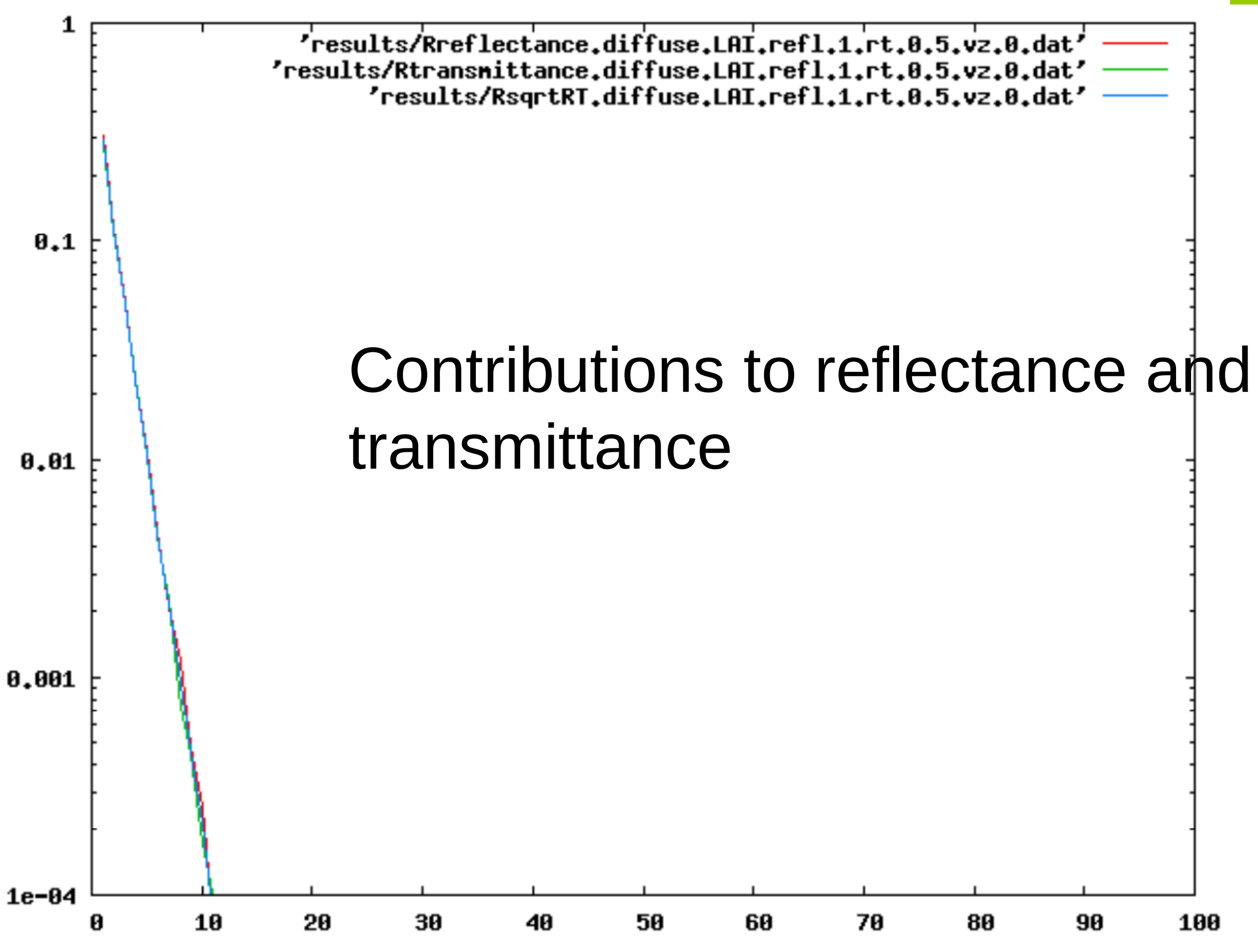
Multiple Scattering



Scattering order

LAI 1

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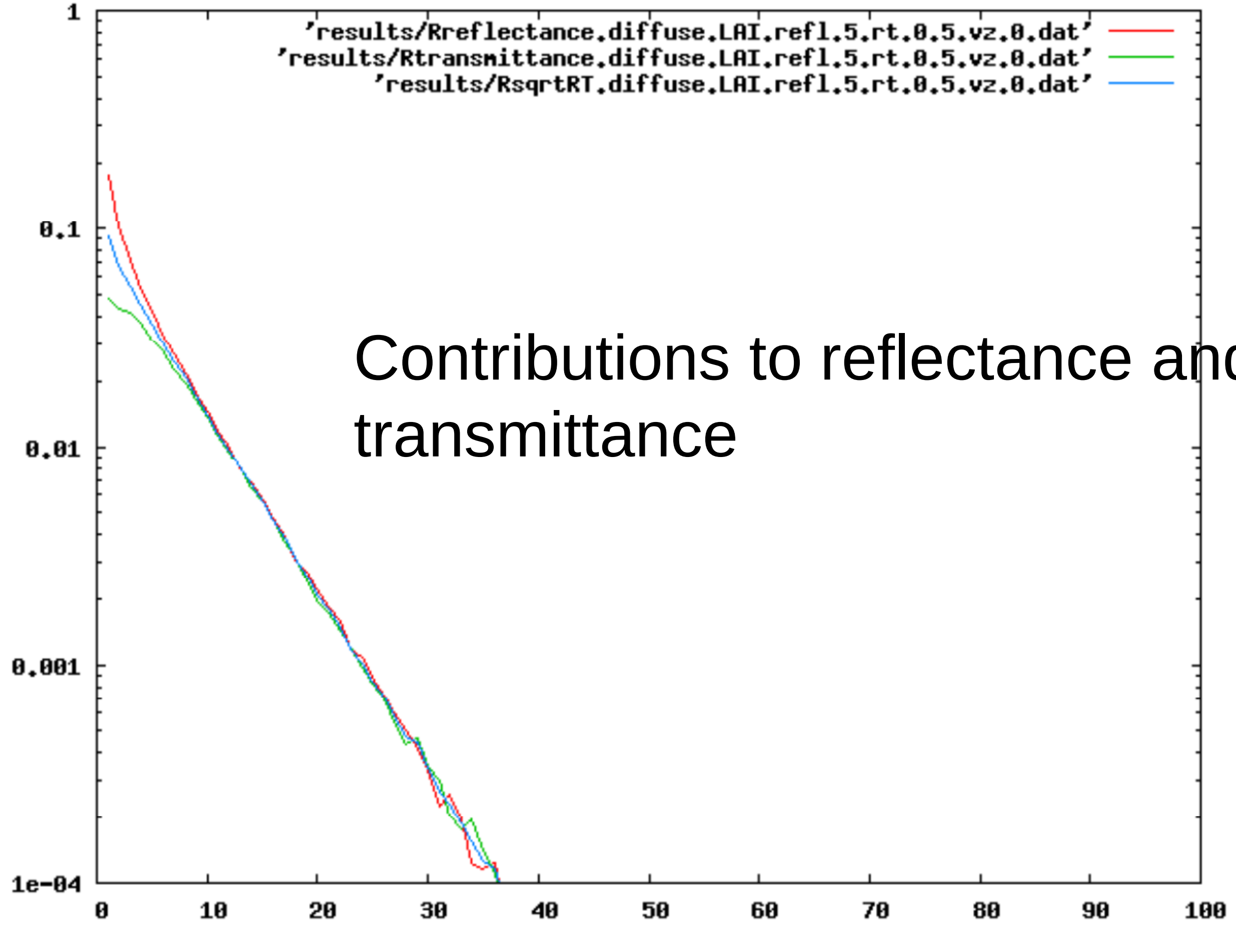
Multiple Scattering



Contributions to reflectance and transmittance

Scattering order

LAI 5

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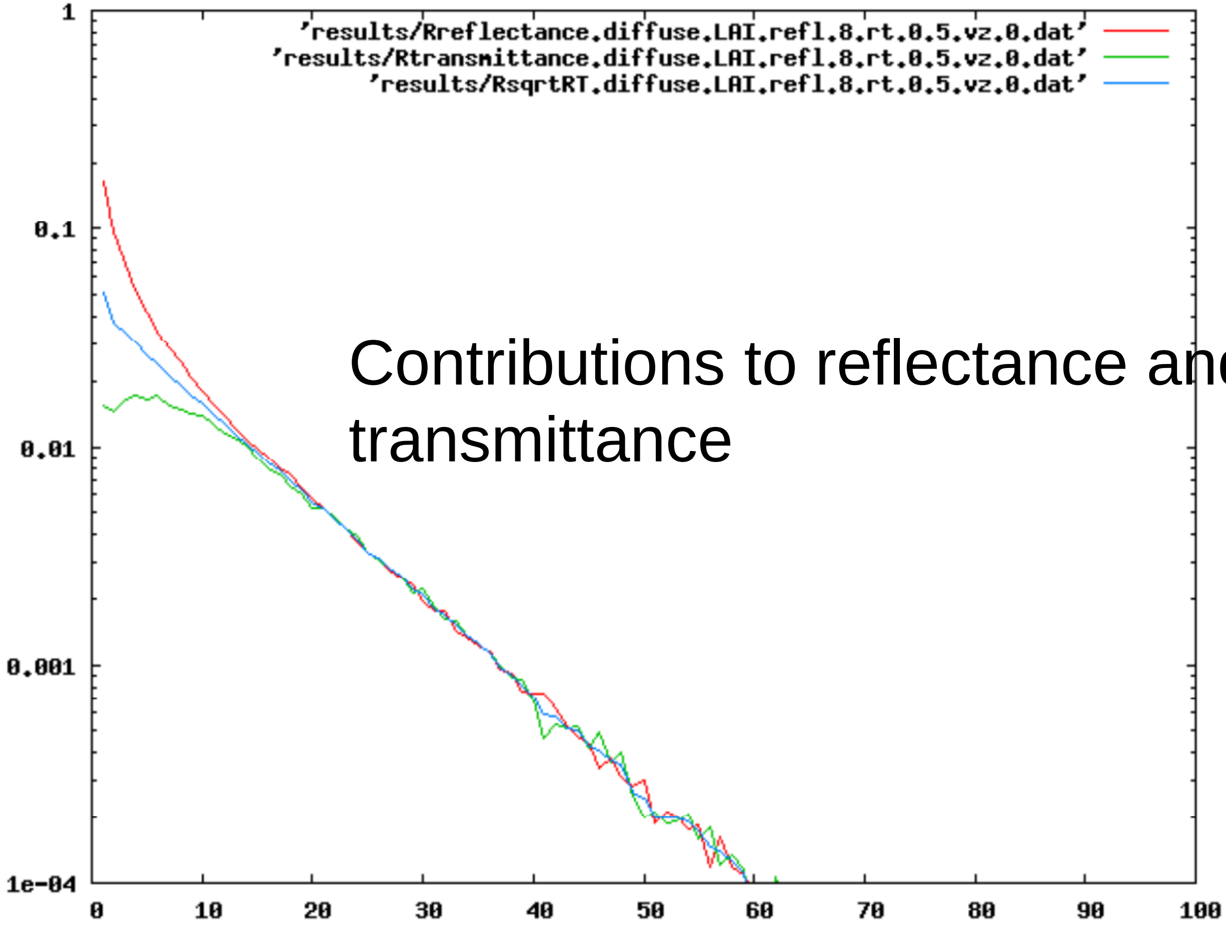
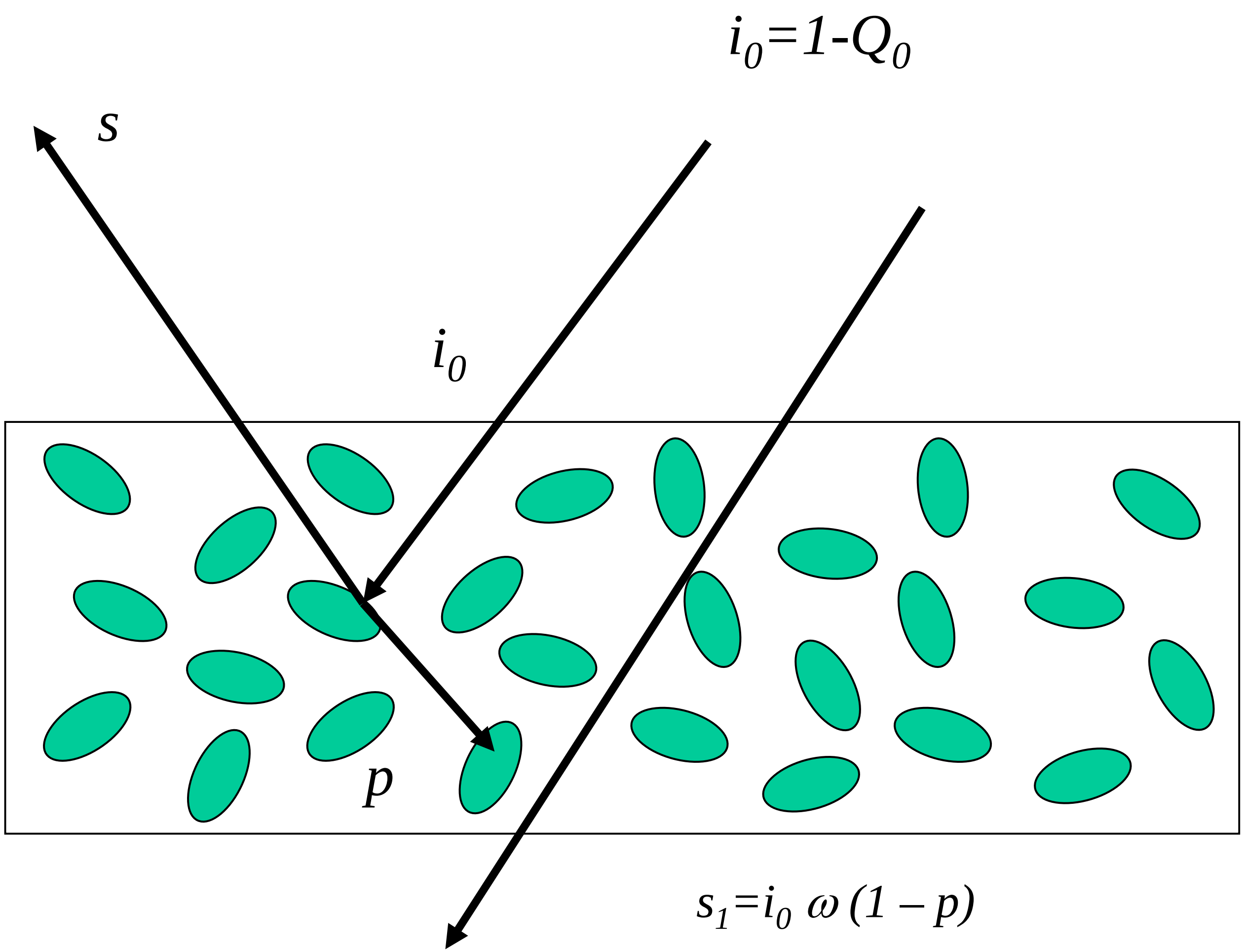
Multiple Scattering



Contributions to reflectance and transmittance

Scattering order

LAI 8



Q_0

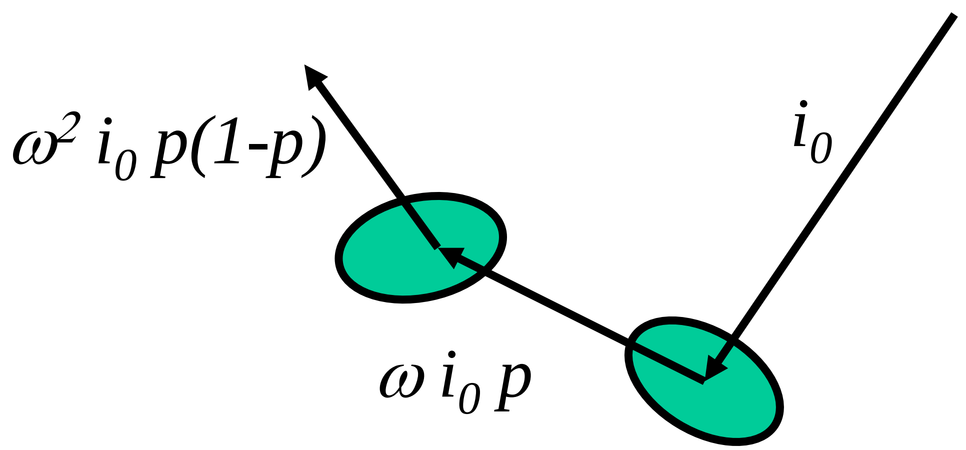
p: recollision probability

ω: single scattering albedo of leaf

Assuming p constant with n

2nd Order scattering:

$$\frac{s_1}{i_0} = \omega(1-p)$$



$$\frac{s_2}{i_0} = \frac{s_1}{i_0}\omega p$$

$$\frac{s}{i_0} = \omega(1-p) + \omega^2(1-p)p + \omega^3(1-p)p^2 + \cdots$$

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Assuming p constant with n

$$\frac{s}{i_0} = \omega(1-p) + \omega^2(1-p)p + \omega^3(1-p)p^2 + \cdots$$

$$\frac{s}{i_0} = \omega(1-p)\left[1 + \omega p + \omega^2 p^2 + \cdots\right]$$

$$\frac{s}{i_0} = \frac{\omega(1-p)}{1-p\omega}$$

‘single scattering albedo’ of canopy

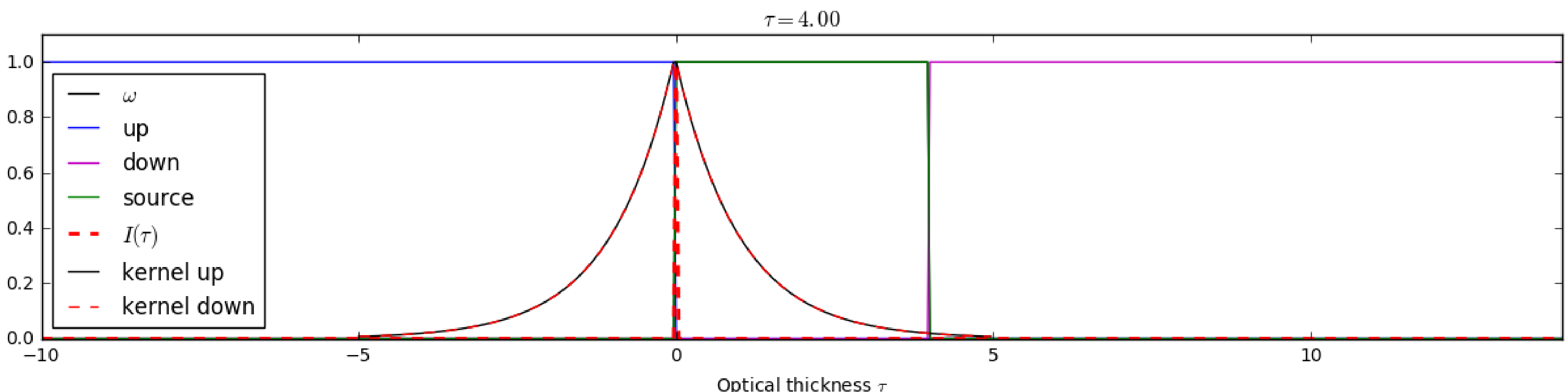
Theory unsatisfactory …

- ‘simple’ p model fails for high LAI
  - p not constant with n
  - p becomes effective value

- How might we extend it?
  - Seek conditions where P ~= constant with n
  - ‘trick’ is consider asymmetry

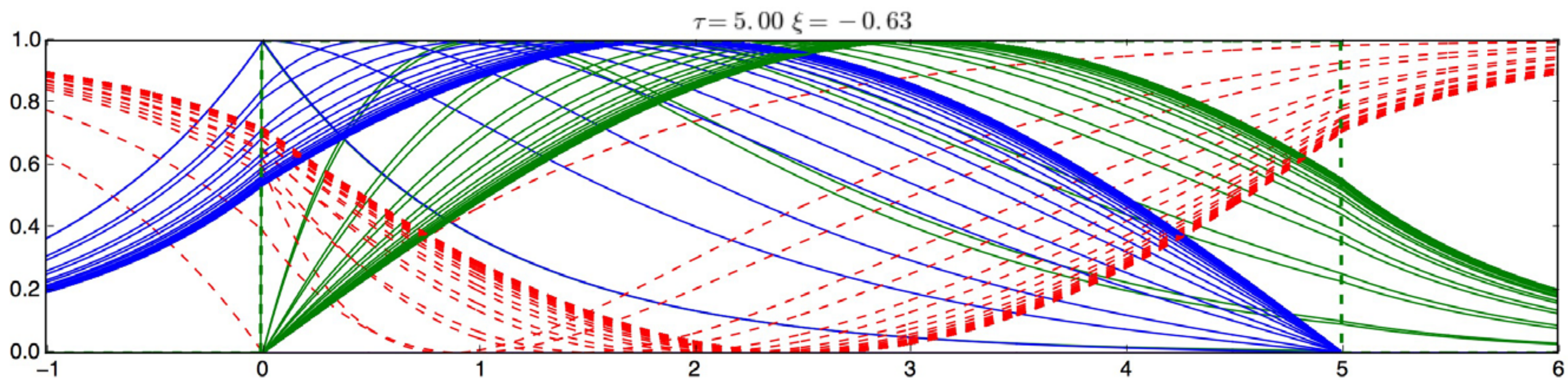
The tools

Analytical 2-stream

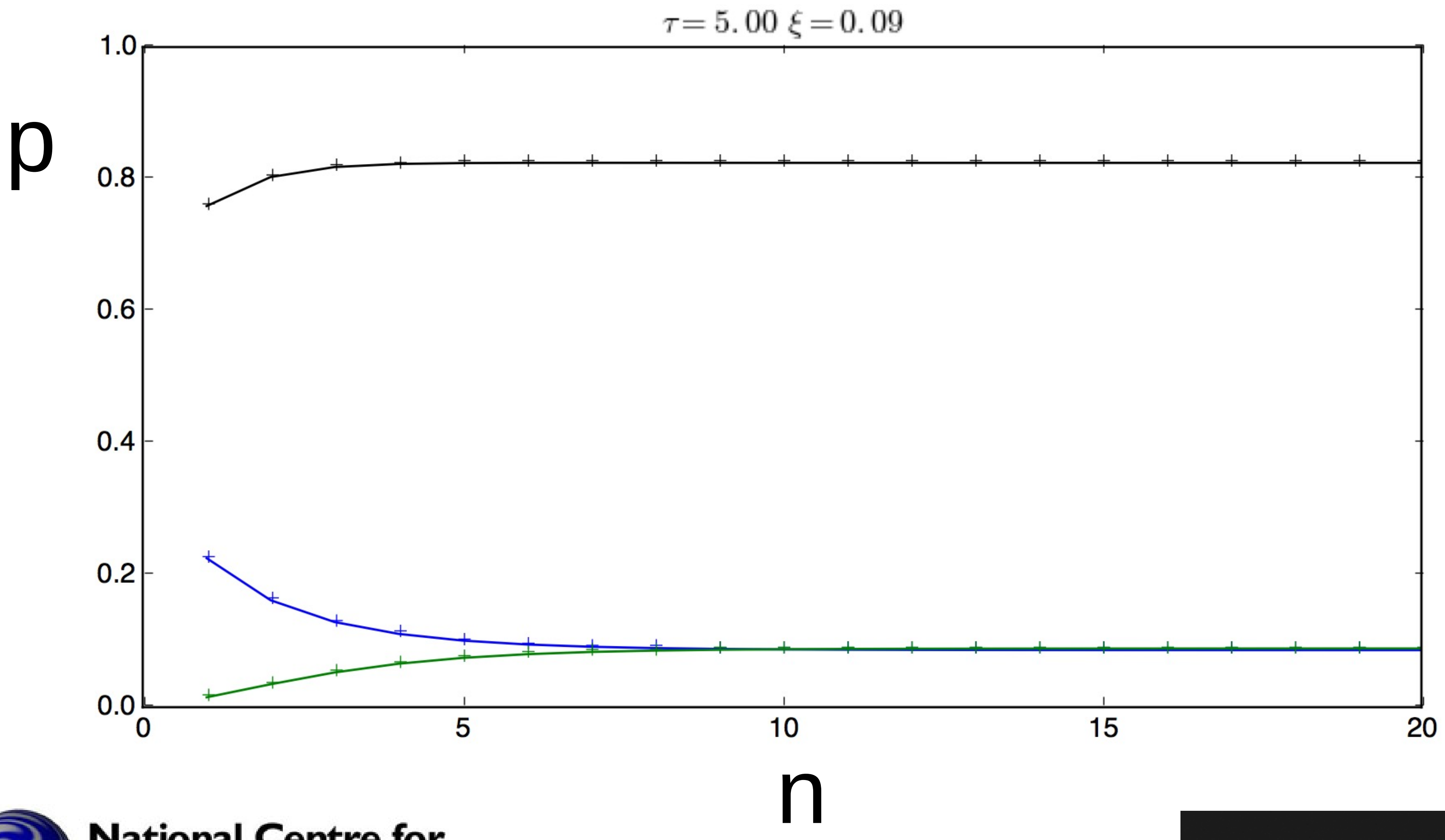


Numerical 2-stream

Source terms



The tools



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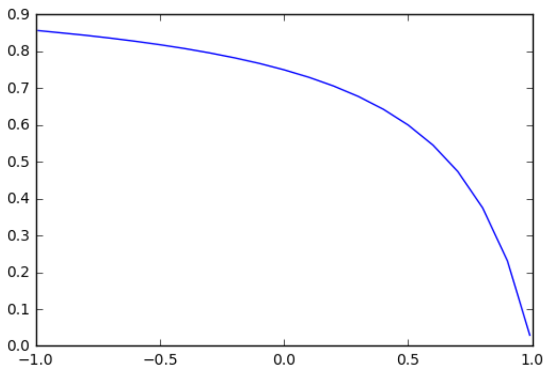
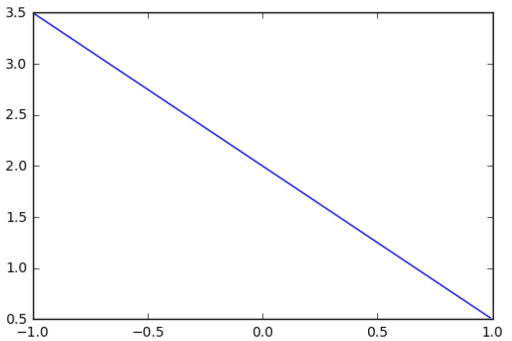
Similarity relations

$$\omega^* = \frac{(1-\xi)\omega}{1-\xi\omega}$$



$$\tau^* = (1-\xi\omega)\,\tau$$



Van de Hulst (1974)

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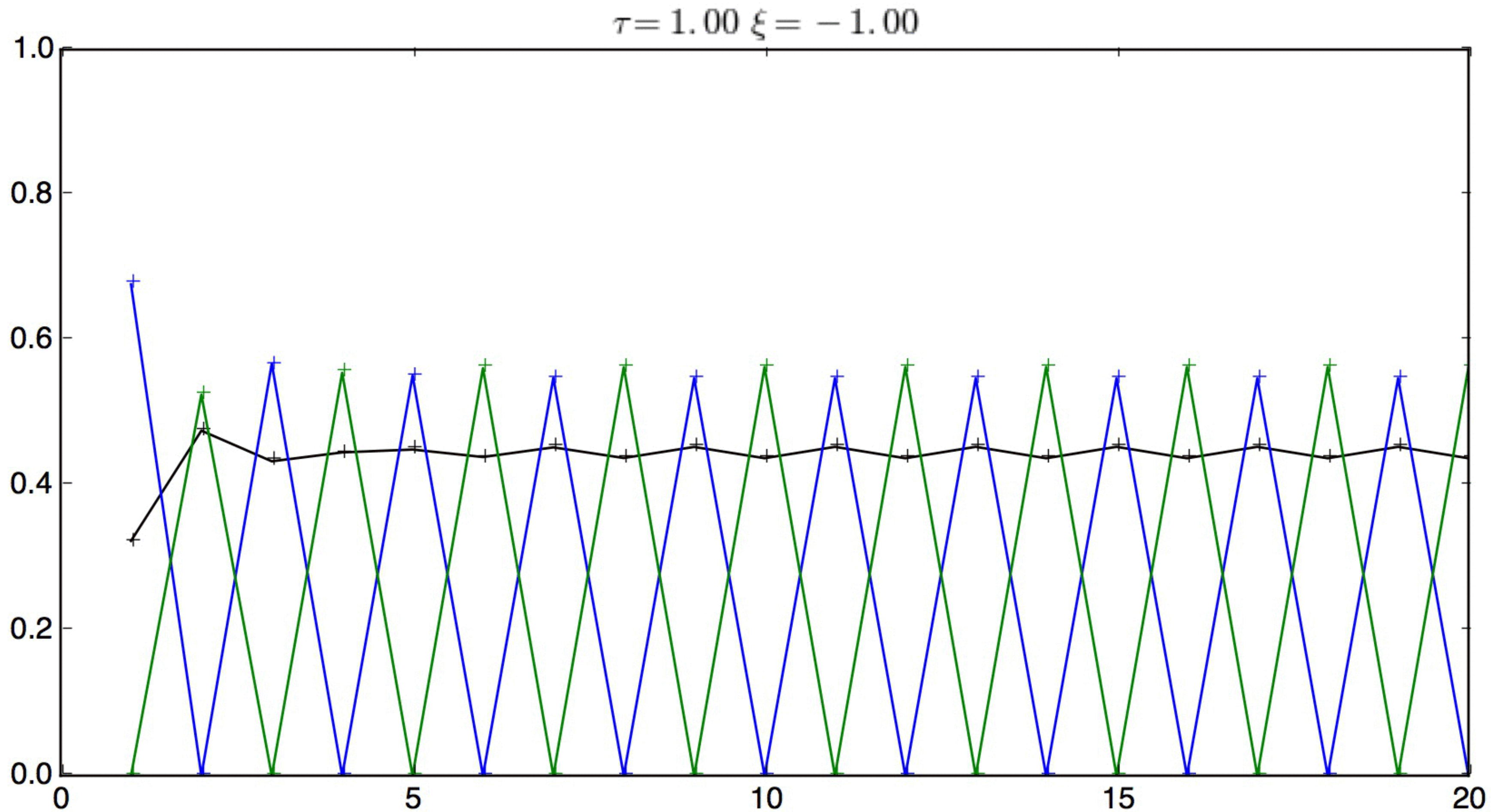
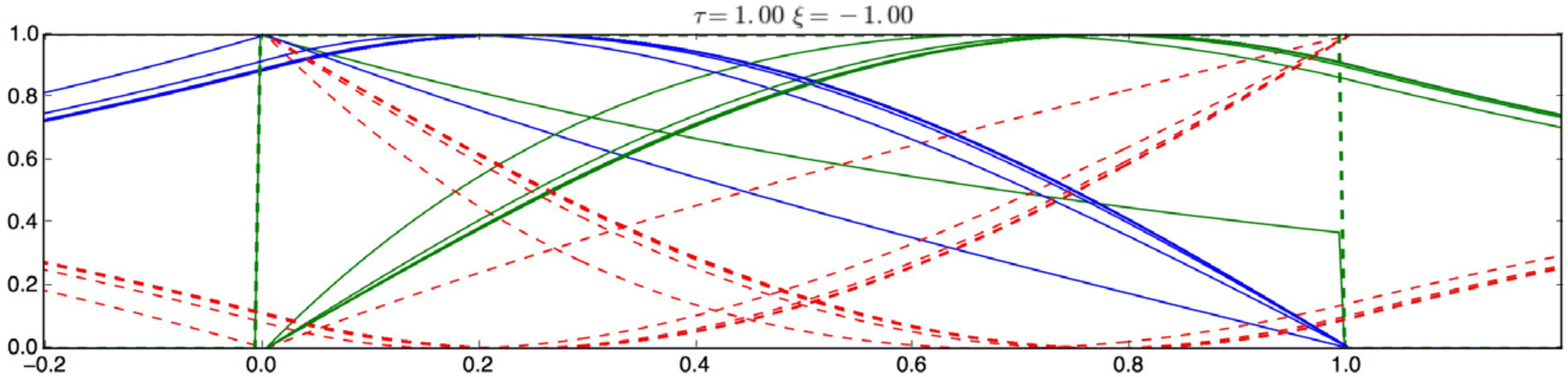
Examine impact of xi on recollision probabilty



Examine impact of xi on source



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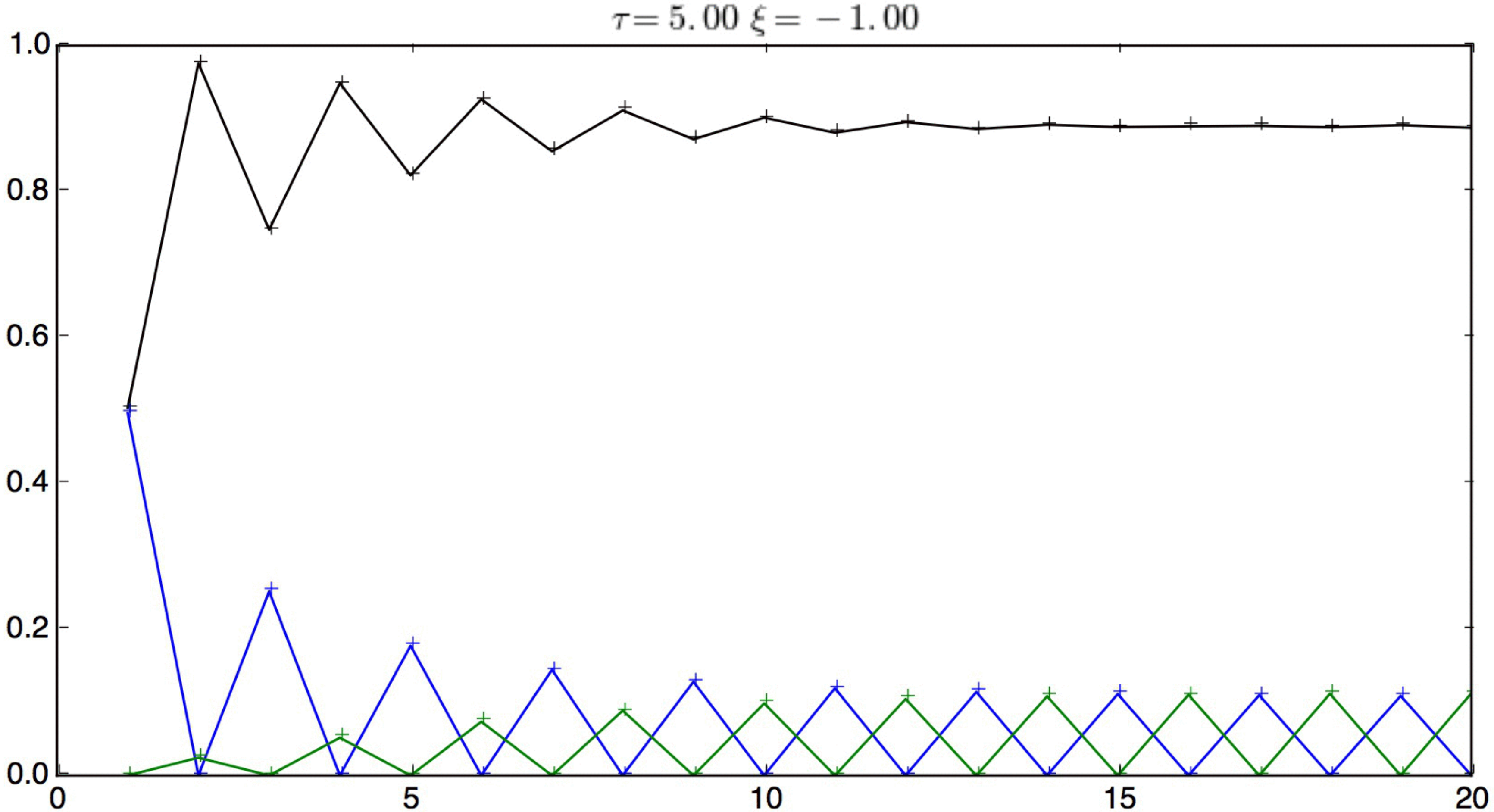
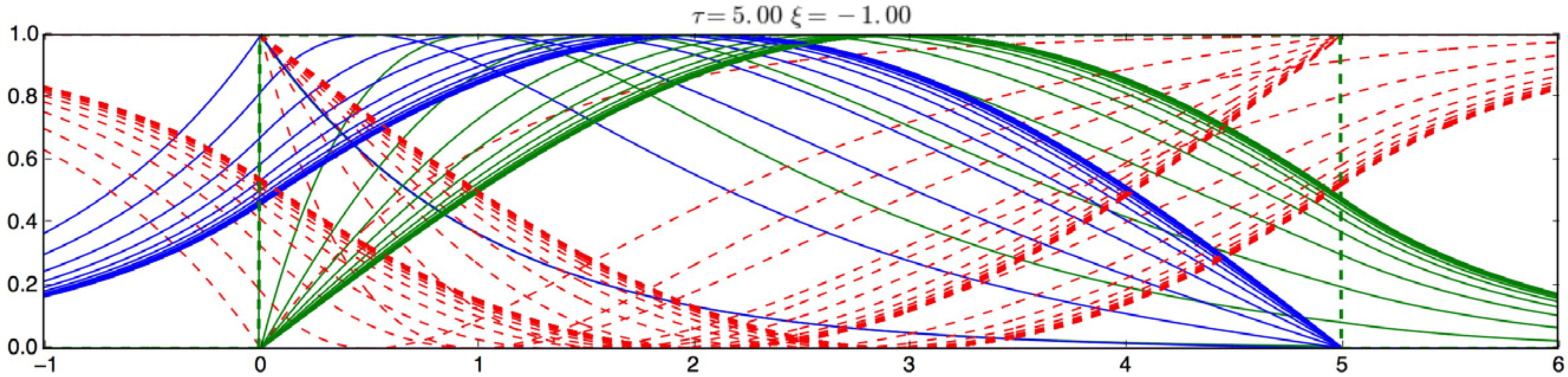
Examine impact of xi on recollision probabilty



Examine impact of xi on source



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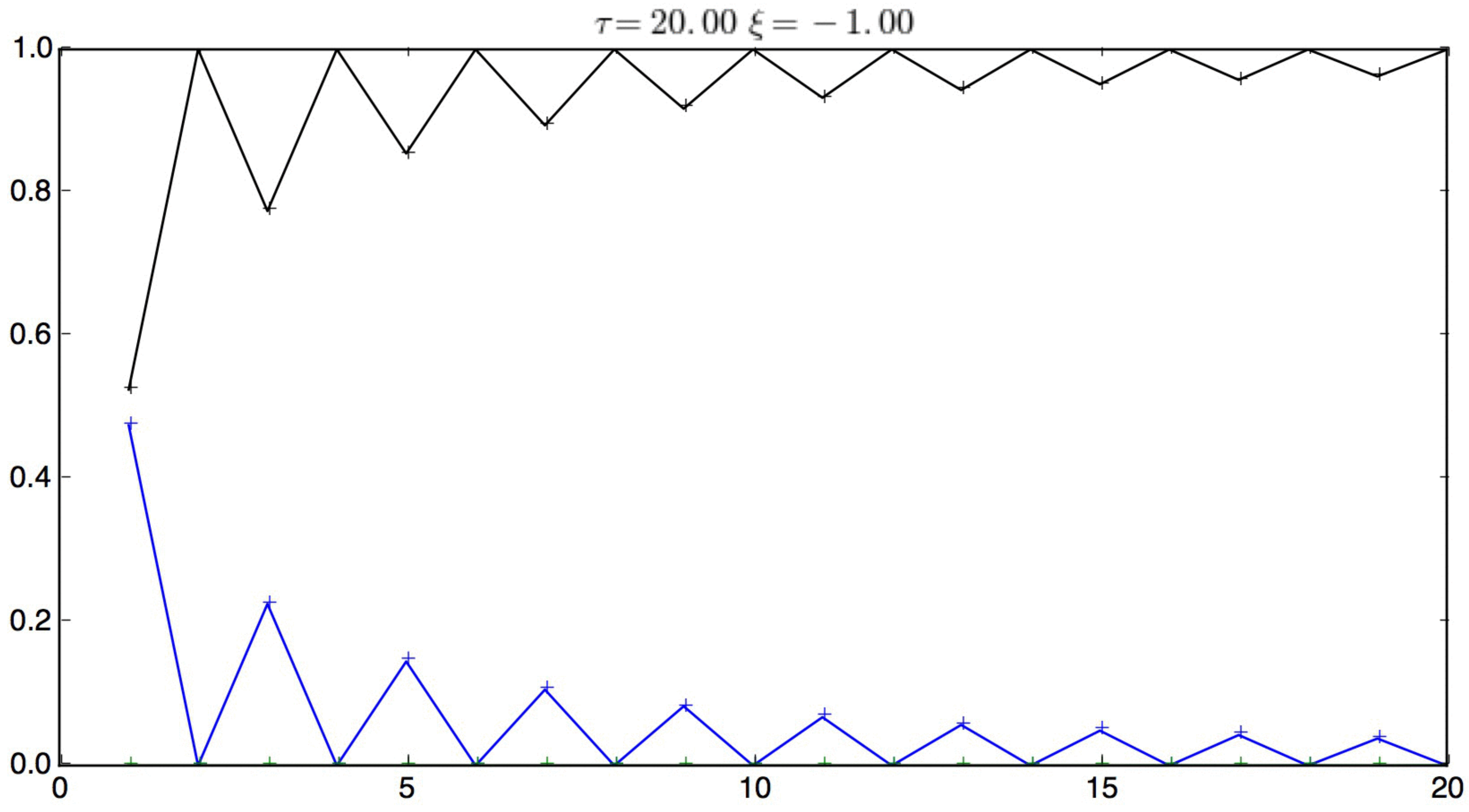
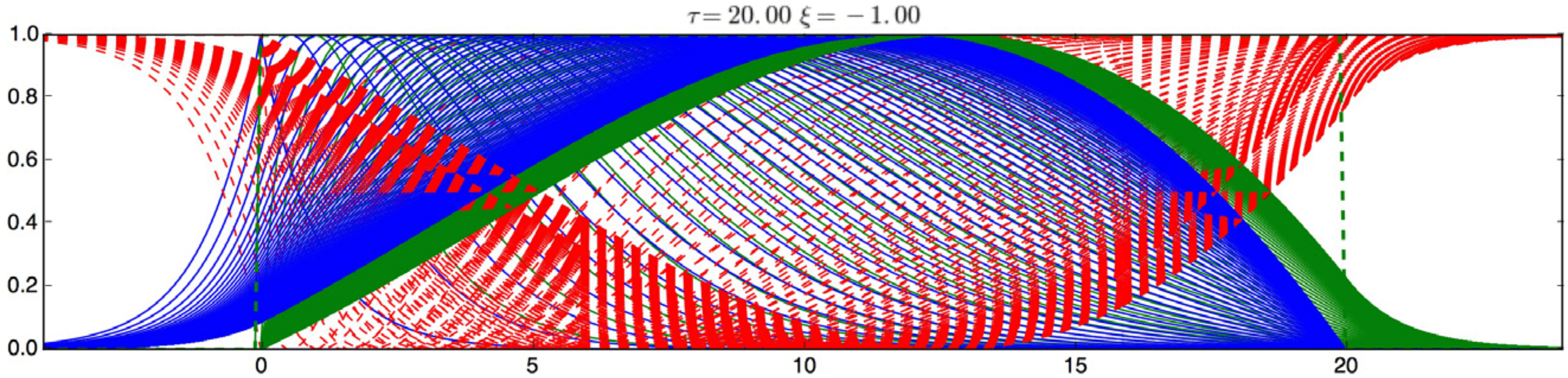
Examine impact of xi on recollision probabilty



Examine impact of xi on source



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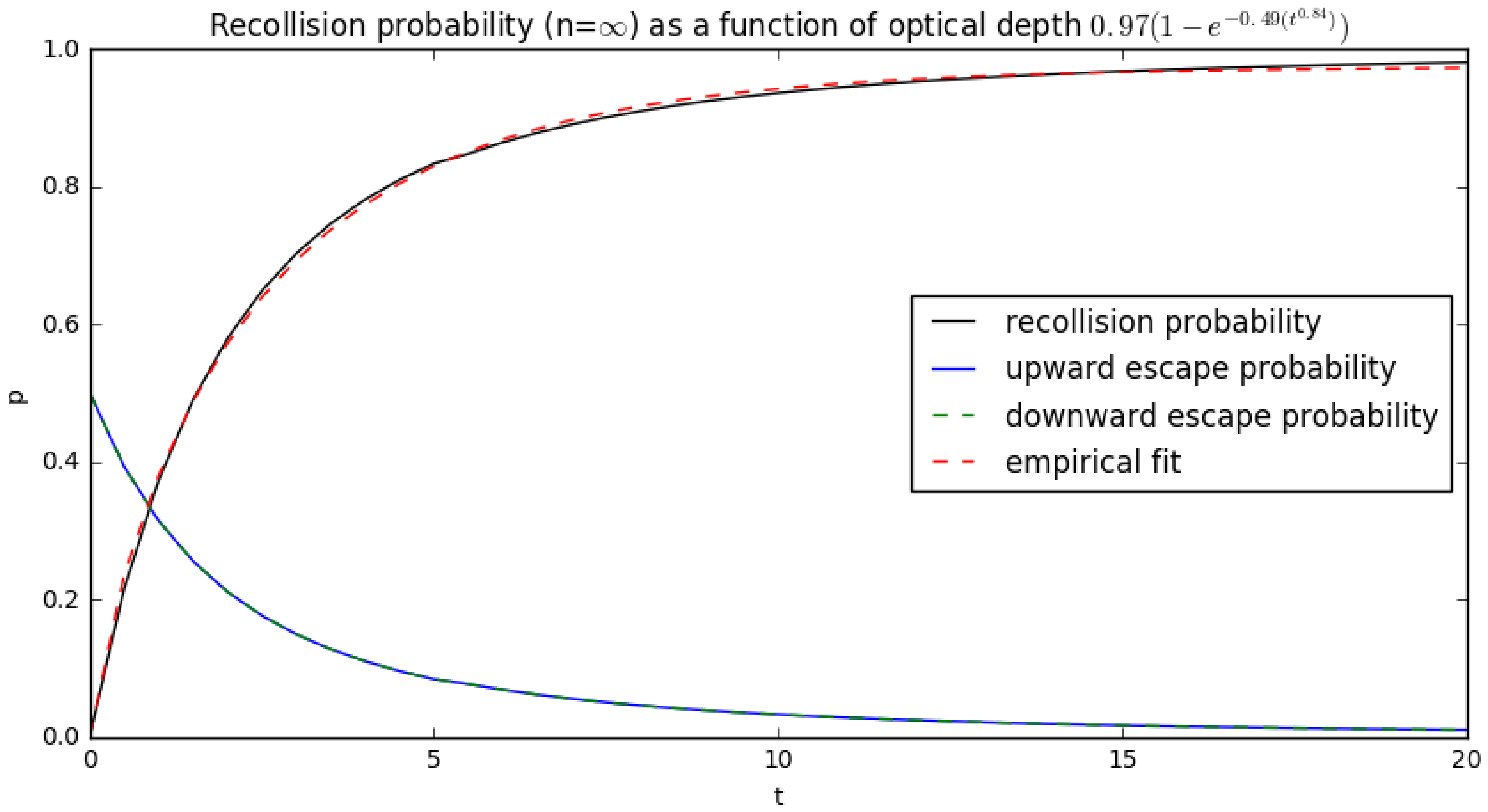
p



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Hypothesis

- There exists a ‘critical’ value of (+ve) xi at which p is effectively constant with scattering order

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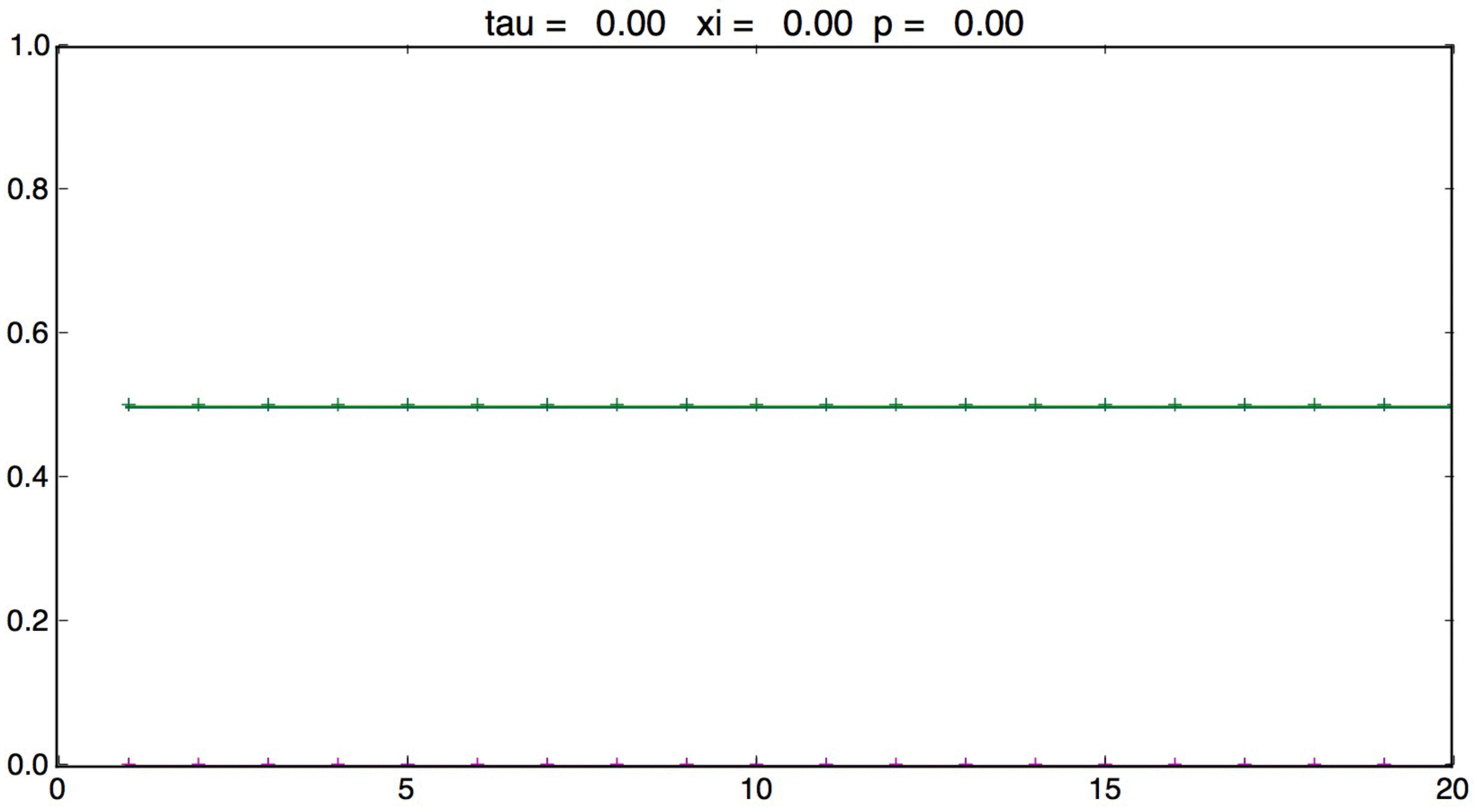

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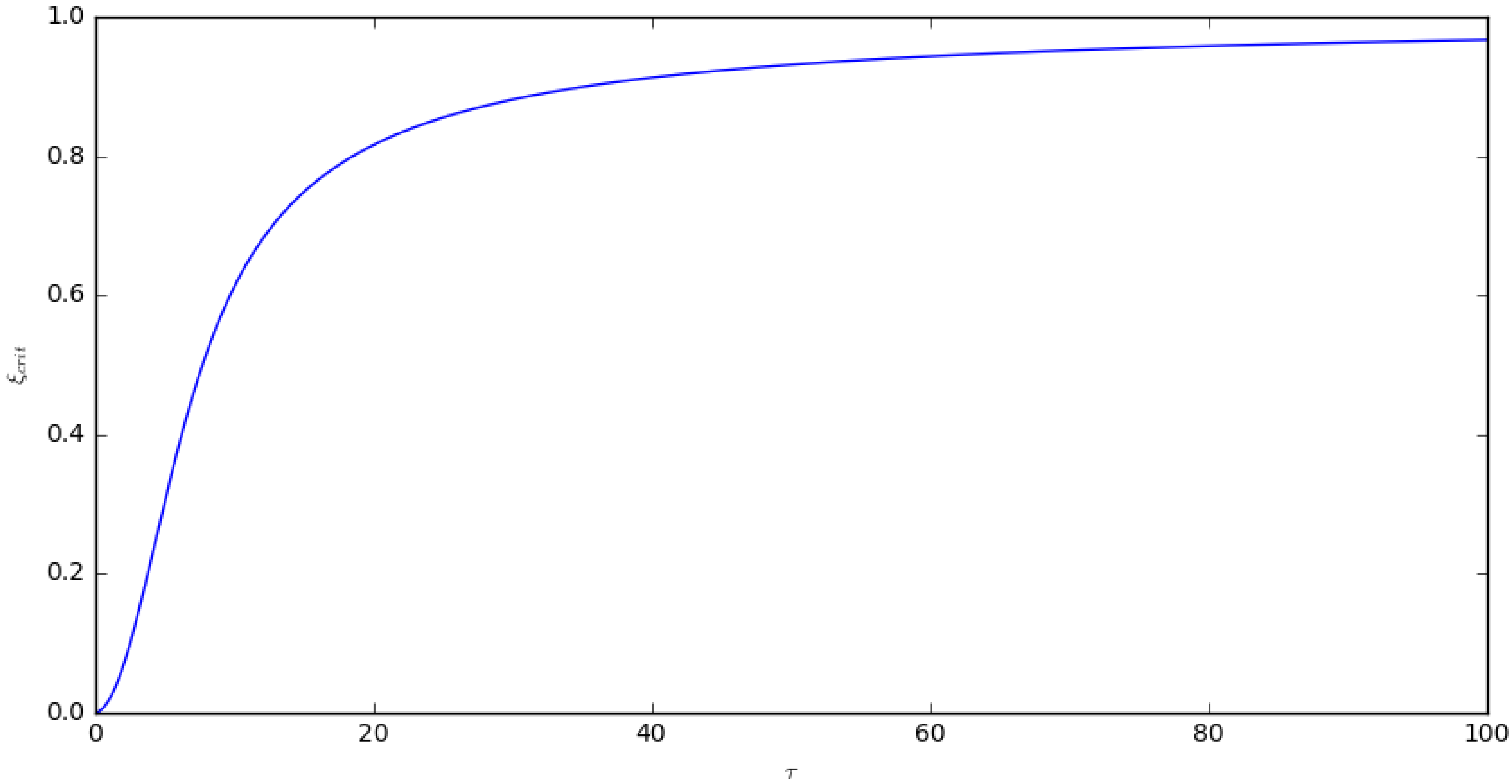
There exists a 'critical' value of (+ve) xi at which p is effectively constant with scattering order



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So what?

- Shown empirical evidence to support hypothesis
- Can model canopy scattering under conditions

$$W(\tau, \omega, \xi = \xi_{crit}) = \frac{(1-p)\omega^*}{1-p\omega^*}$$

- p takes 'true' value (infinite scattering order p)

$$p = p(\tau, \xi = 0)$$

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But …

- We wanted (e.g.) $W(\tau, \omega, \xi = 0)$ …
- So apply xi in reverse:

$$\omega^* = \frac{(1-\xi)\omega}{1-\xi\omega}$$

(plus scalar α)

$$W^* = W(\tau, \omega, \xi = \xi_{crit})$$
$$W^0 = W(\tau, \omega, \xi = 0)$$

$$W^0 = \frac{\alpha W^*}{1 - \xi + \xi\alpha W^*}$$

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Full model V0.1

$$\omega^* = \frac{(1-\xi)\omega}{1-\xi\omega} \qquad W^* = \frac{(1-p)\omega^*}{1-p\omega^*}$$

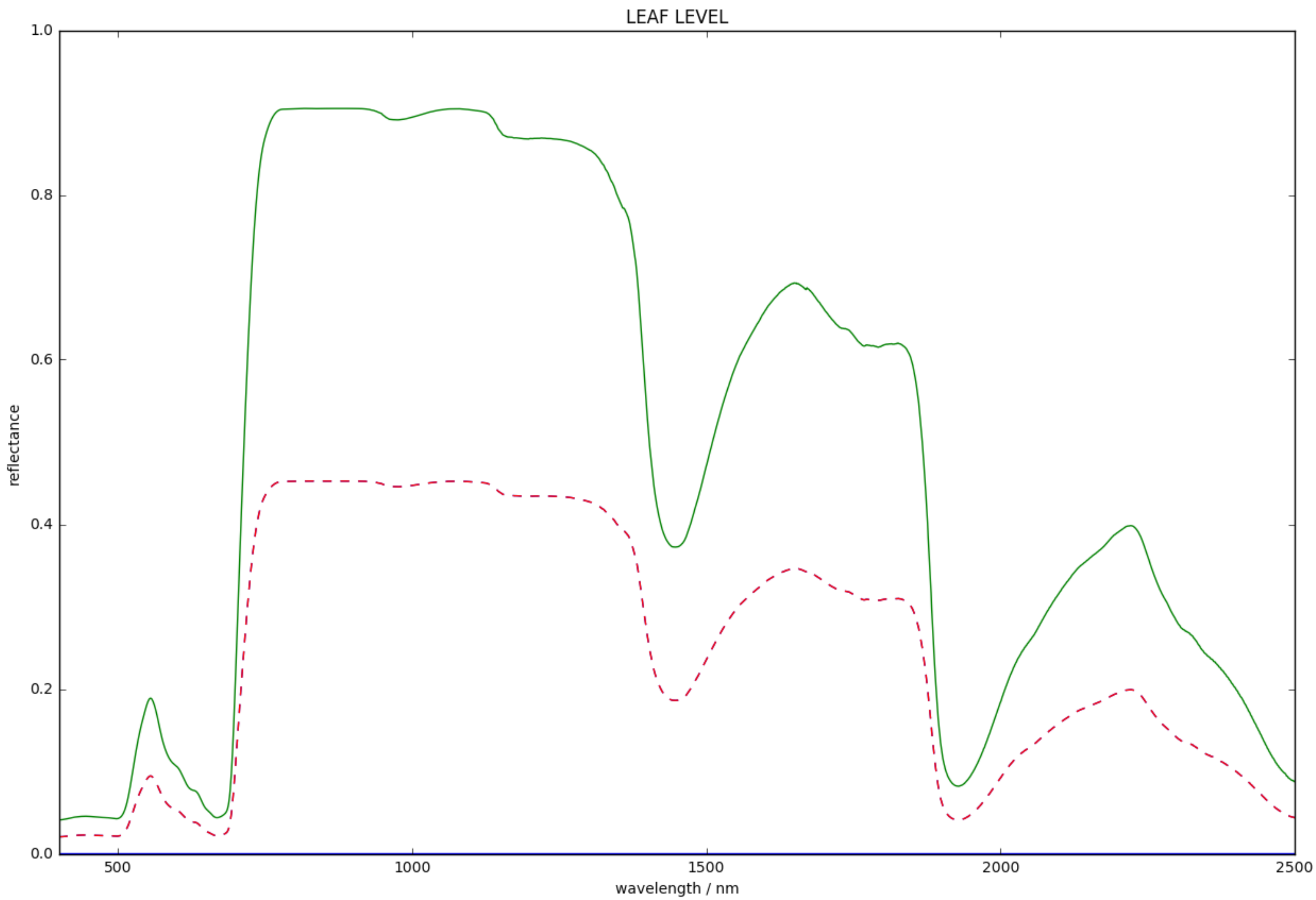
$$W^0 = \frac{\alpha W^*}{1-\xi+\xi\alpha W^*}$$

α =1, ω=1

α is clearly fn of ω

Which is a little unsatisfactory

Leaf scattering



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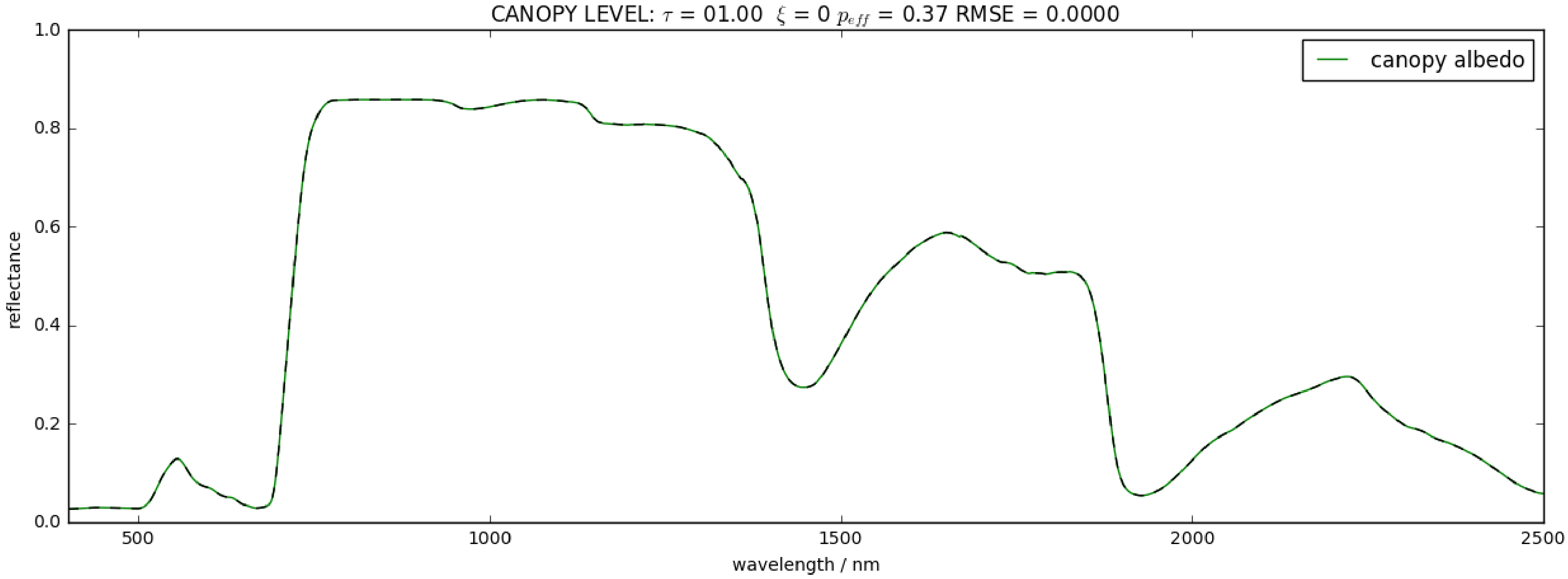
Tau = 1
xi = 0



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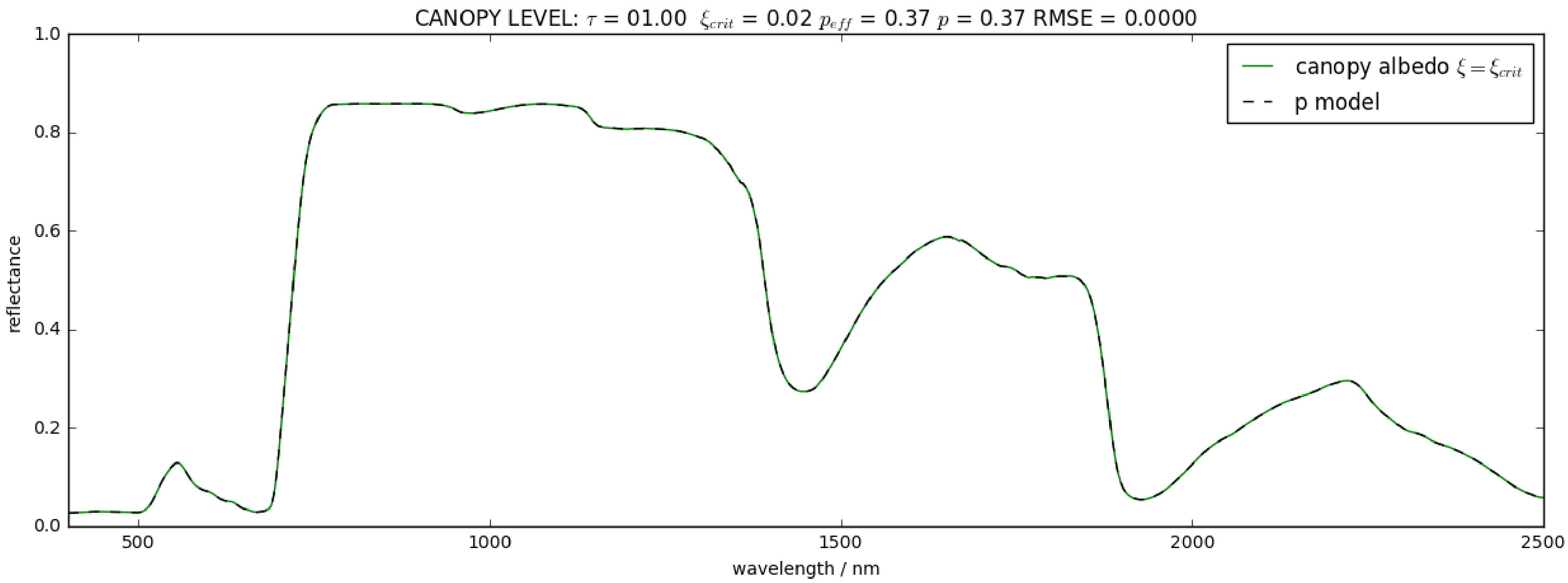
Tau = 1
xi = xi_crit



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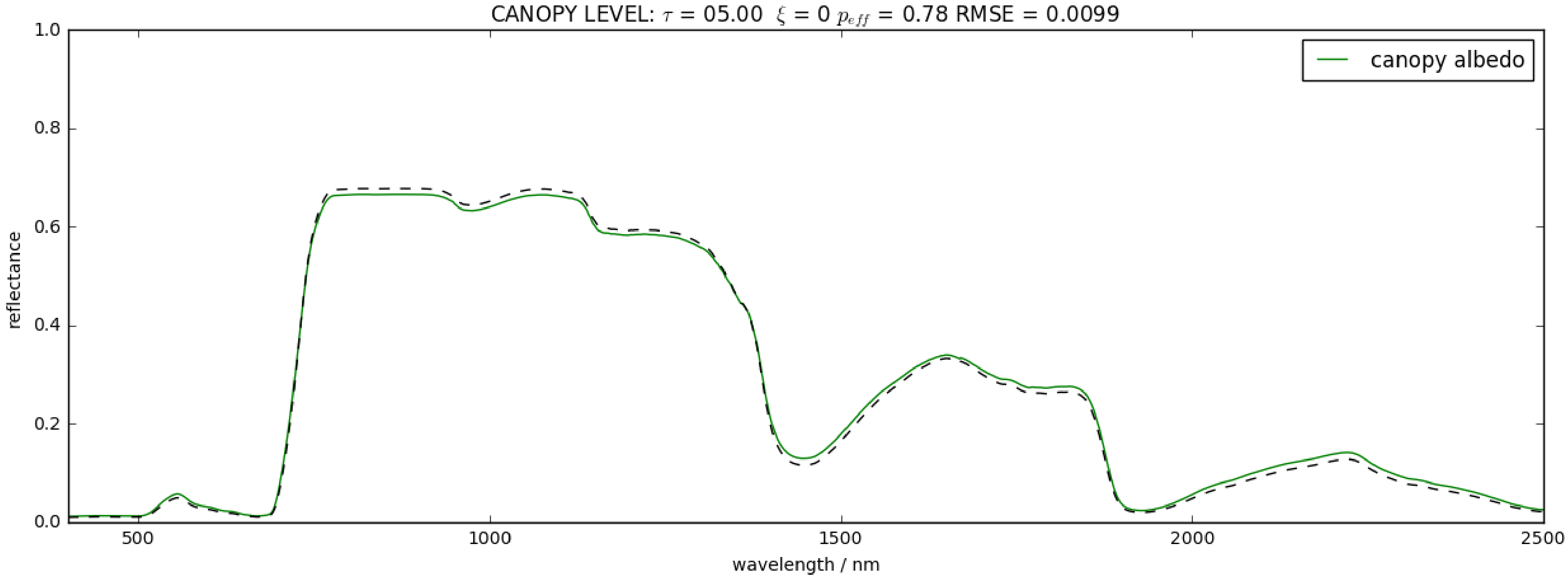
Tau = 5
xi = 0



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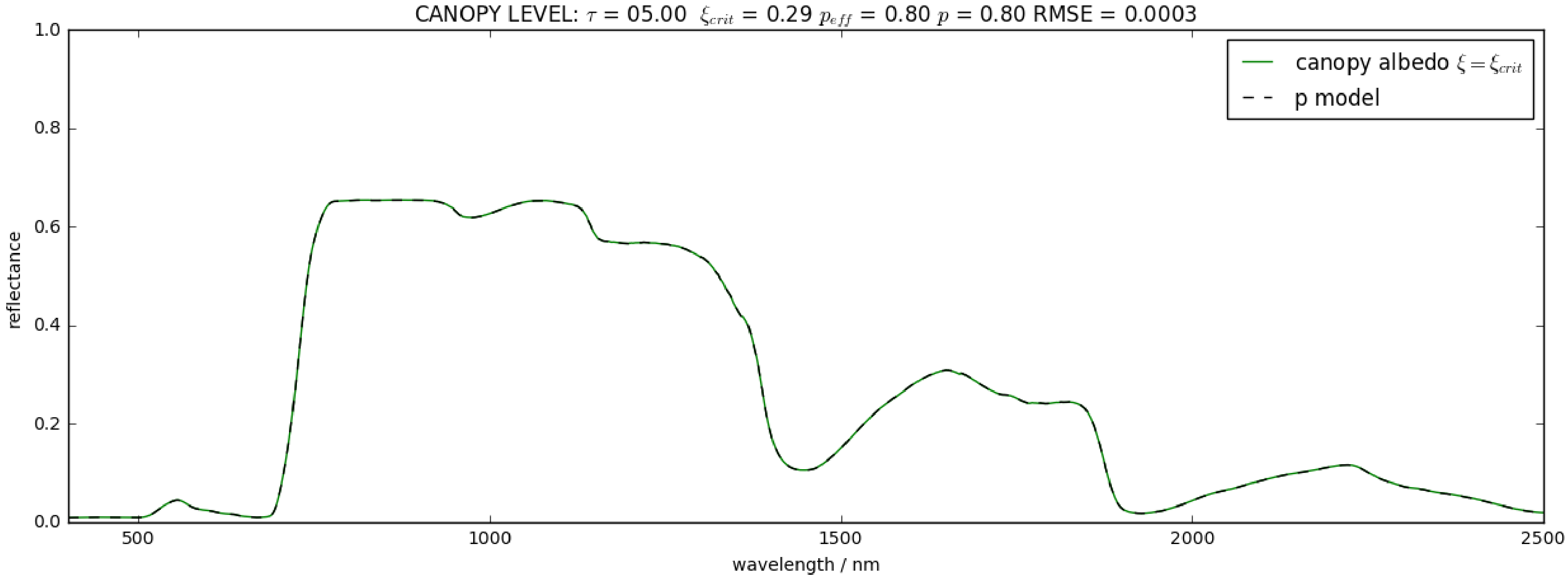
Tau = 5
xi = xi_crit



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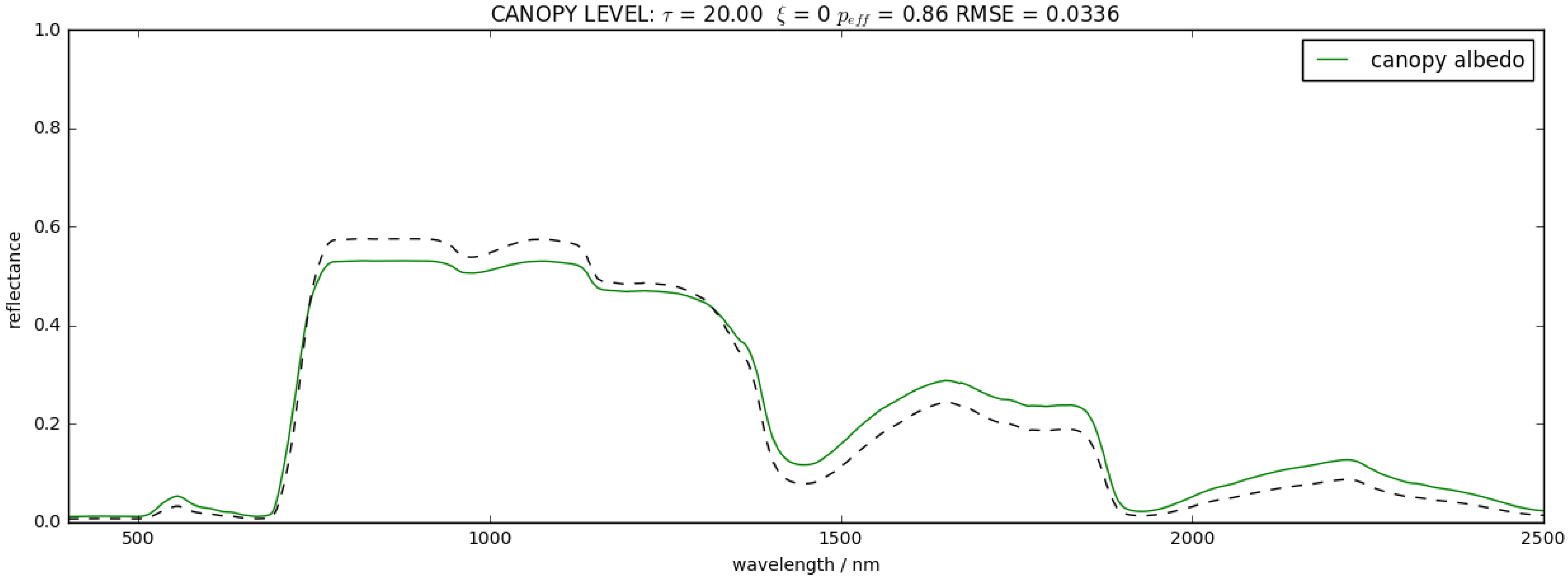
Tau = 20
xi = 0



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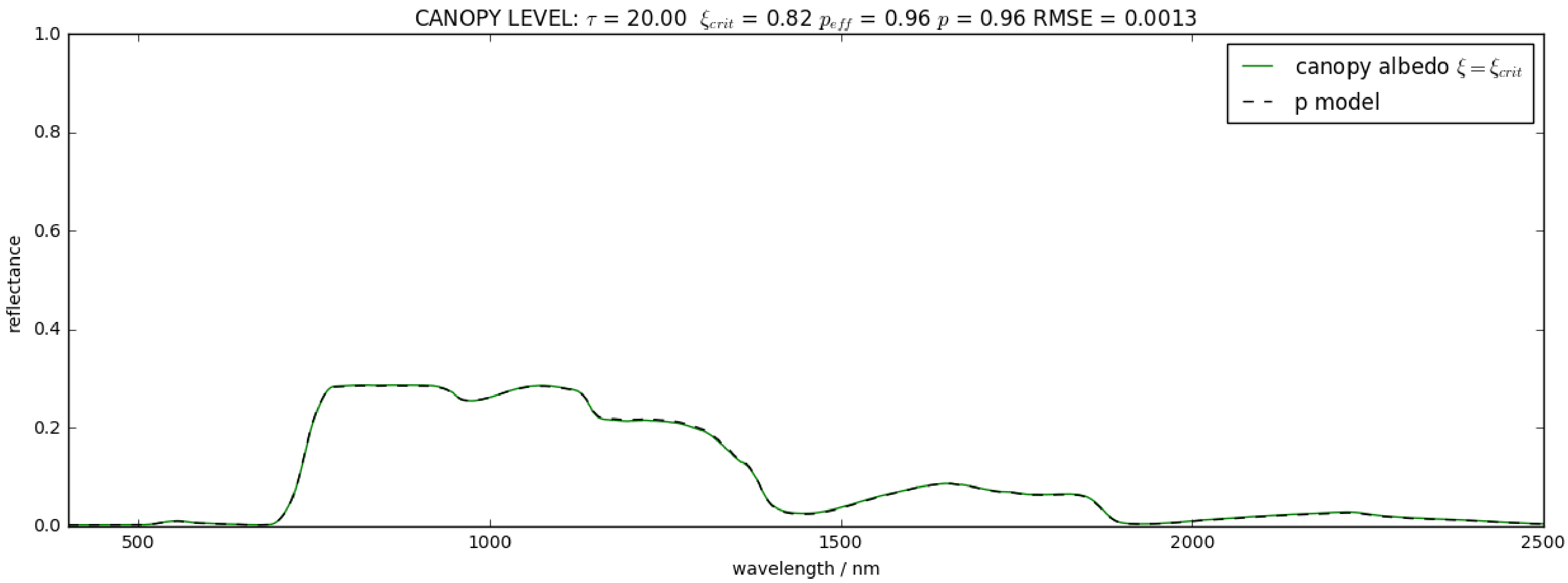
Tau = 20
xi = xi_crit



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Discussion

- Interesting phenomenon p constant
- Uses similarity relations for ω
  - Known impact on τ
  - But what is impact on p?
- Interesting that solution provides true p

Conclusions

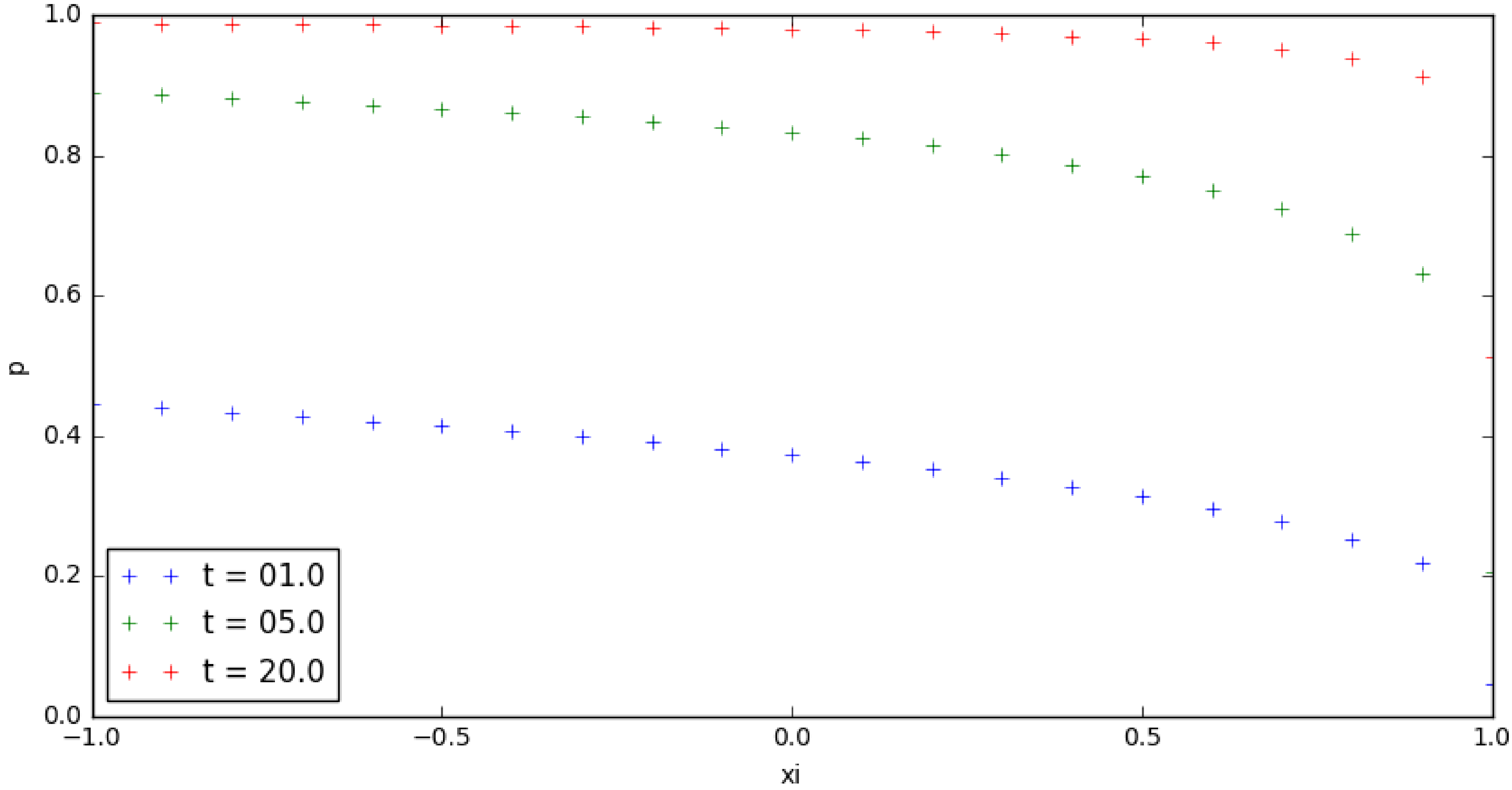
- Empirical evidence for **condition of constant p**
- Can model canopy scattering under conditions, even for high τ

$$W(\tau, \omega, \xi = \xi_{crit}) = \frac{(1-p)\omega^*}{1-p\omega^*}$$

- p takes 'true' value (infinite scattering order p)

$$p = p(\tau, \xi = 0)$$

- $W(\tau, \omega, \xi = 0)$ recovery needs more thought …



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