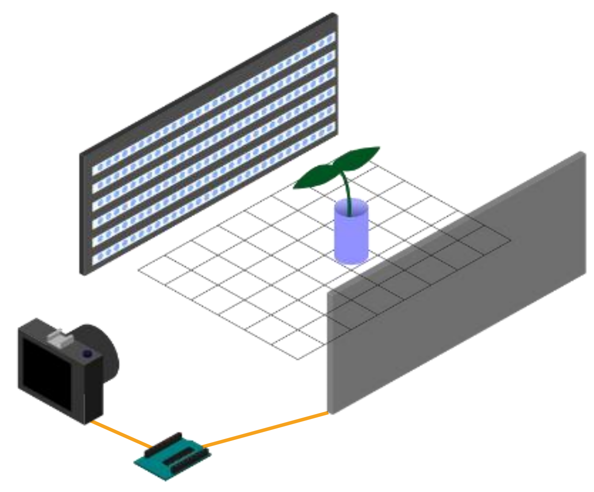
Plants Integrate Multiple Stimuli Using a Vectorial Representation

Ahron Kempinski[1], Amir Porat[1,2], Mathieu Rivière[1,3], Yasmine Meroz[1]

1. School of Plant Sciences and Food Security, Tel Aviv University, Israel
2. Sainsbury Laboratory, University of Cambridge, UK
3. Institut Universitaire des Systèmes Thermiques Industriels, CNRS, Aix-Marseille University, France

Tracked plant movement

Introduction:

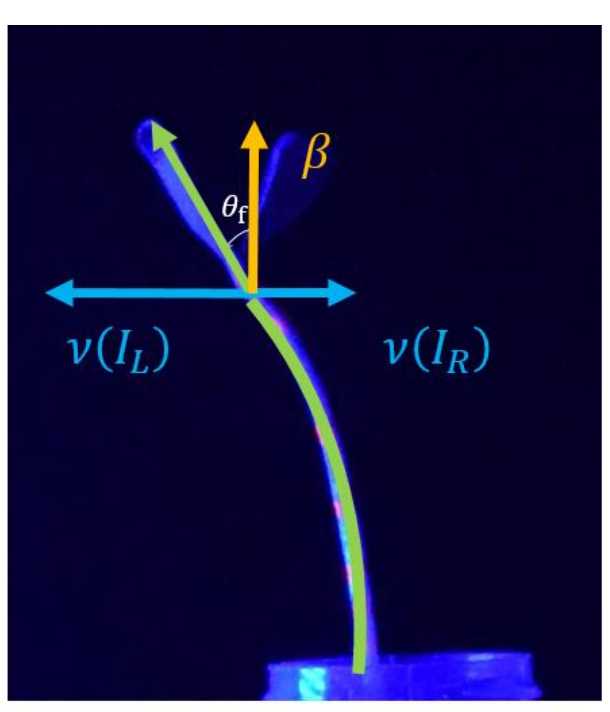


Though rooted in place, plants can prosper in harsh and changing environments, thanks to their **remarkable ability to integrate a variety of different environmental signals**, and respond to them. We built an experimental setup limited to 2 opposing light sources to learn more about **how plants integrate multiple light stimuli: Do they sum a transduced signal or the raw signal?**

This setup allows us to control the light intensity on either side of a plant while tracking it's growth response.

Model:

Using a 3D vector model [1] adapted from an earlier model [2] in our lab we predict the **steady state angle at the tip - θ_f** for different Unilateral and Bilateral light conditions:



Signal	Transduced (sensitivity)
Gravity	β
Light Intensity (I)	$\nu(I)$

$$\tan(\theta_f) = \frac{\nu(I_L) - \nu(I_R)}{\beta}$$

Extracting the Light Sensitivity Function $\nu(I)$ from Unilateral Experiments:

We studied the response of seedlings subjected to different light intensities. Tracking the angle at the tip of the plant allows us to find the steady state angle - θ_f. **[A]**

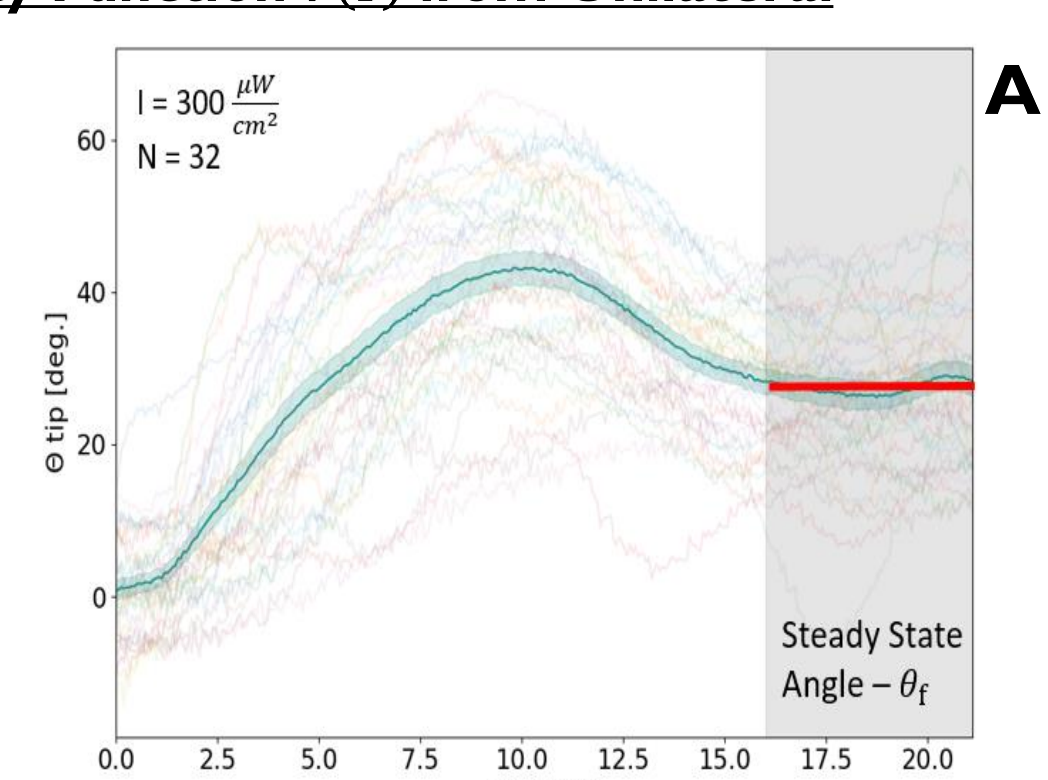
It has been shown[2] that the **light sensitivity** follows a power-law:

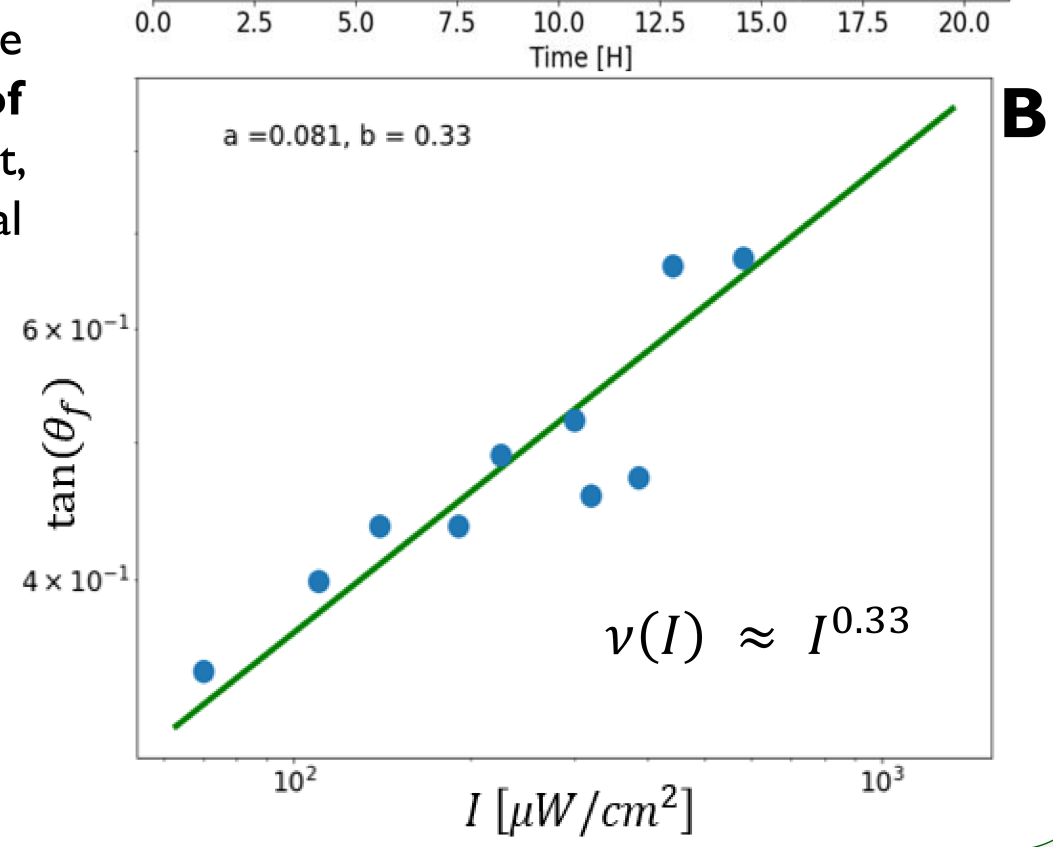
$$\nu(I) = \nu_0 I^b$$

When combined with our steady state solution from the model as well as the assumption that **a percentage of light- C travels through** the plant, we can relate $\nu(I)$ to experimental variables:

$$\tan(\theta_f) = \frac{\nu_0}{\beta}(1 - C^b) I_L{}^b$$

Using the data collected from unilateral light experiments we extracted these parameters [B] and used them to compare theoretical and experimental results for experiments with bilateral lighting.



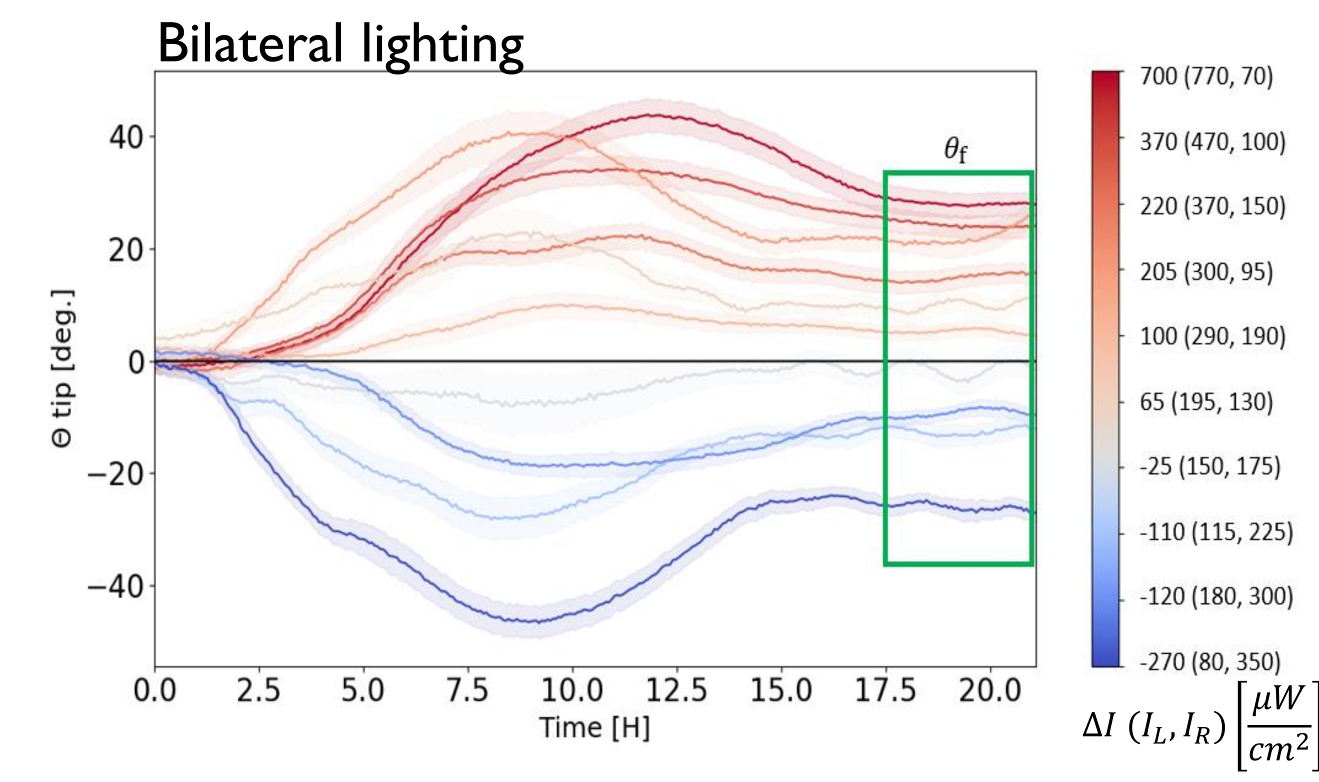


Conclusion:

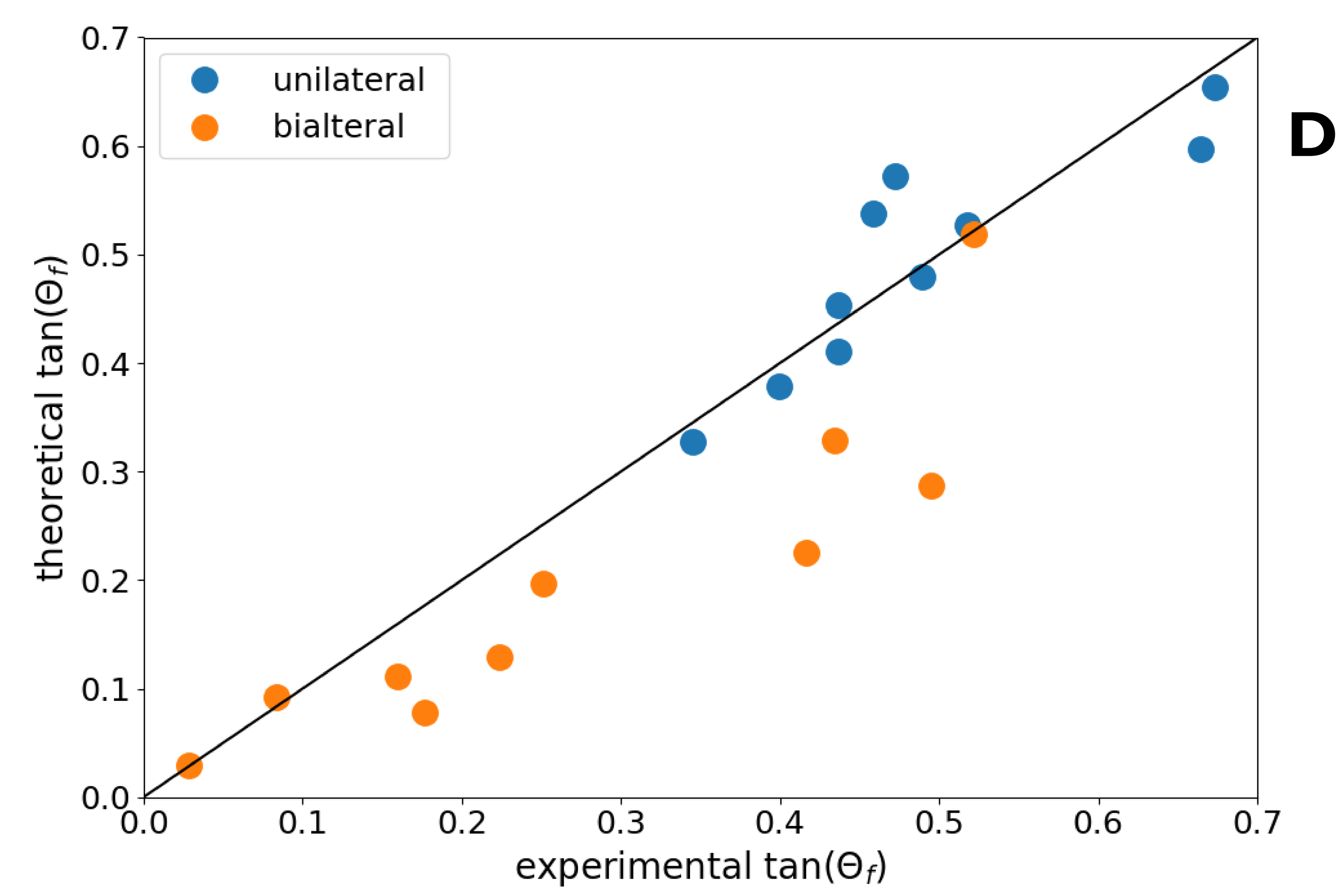
- We find that plants integrate multiple stimuli by performing a vectorial sum of transduced signals.
- This work suggests that the vectorial representation of signals may be encoded in growth hormone gradients.

Identifying Stimuli Integration in Bilateral Experiments:

Using different light intensities on two opposing side of the plants we again followed the angle at the tip and extracted θ_f **[C]**



From the trajectories can see a trend where the plant grows in the direction of the stronger light source. However, when comparing θ_f for both unilateral and bilateral light we found the relation does not merely depend on the difference between the intensities, but rather the transduced signal.



In **[D]** we show a direct comparison between the theoretical and experimental results and for different combinations of light intensities and the results for experiments with the same light combinations. Note we again consider the light traveling through the plant:

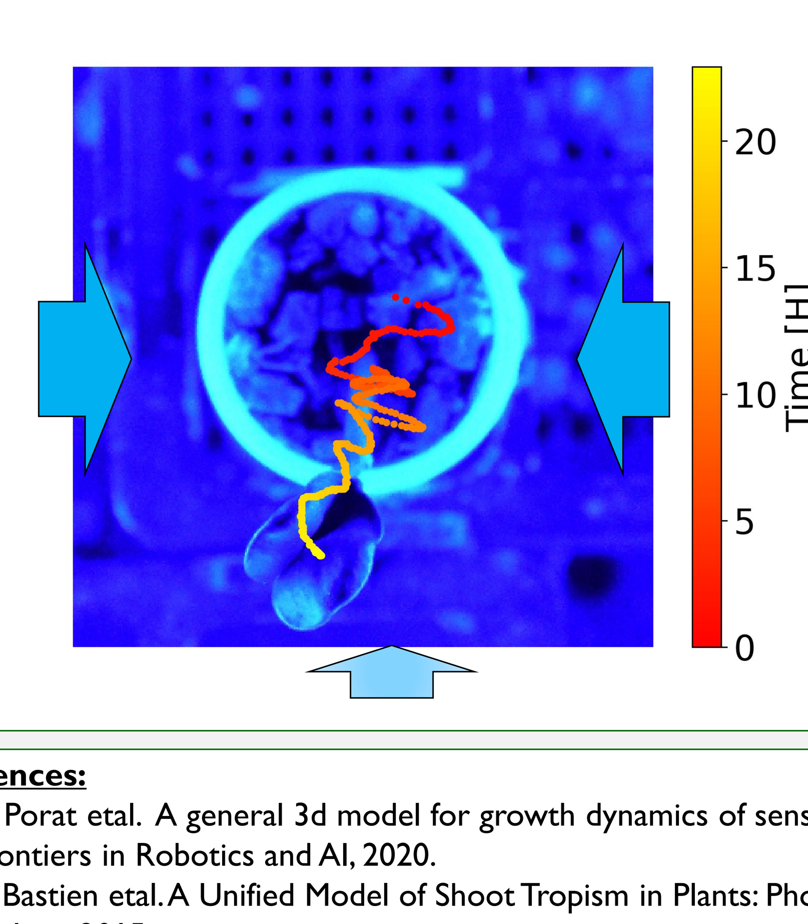
$$\tilde{I}_L = I_L + I_R C \qquad \tilde{I}_R = I_R + I_L C$$

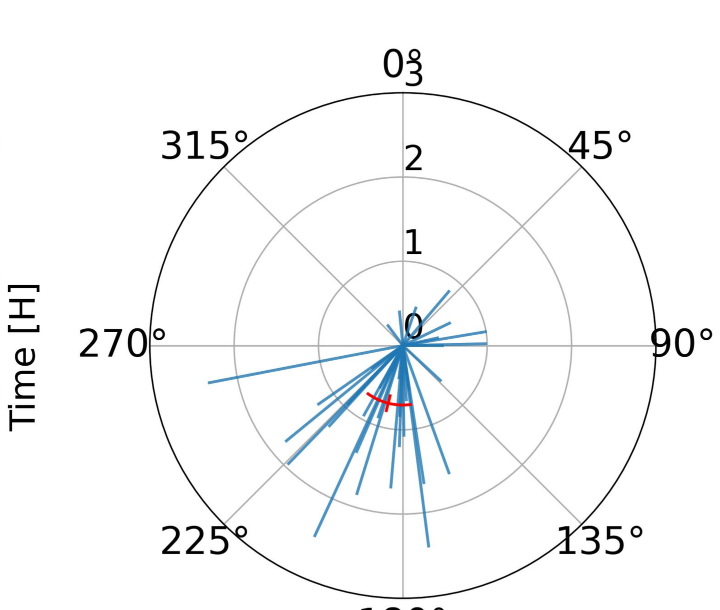
$$\tan(\theta_f) = \frac{\nu(\tilde{I}_L) - \nu(\tilde{I}_R)}{\beta} = \frac{\nu_0}{\beta}\left(\tilde{I}_L{}^b - \tilde{I}_R{}^b\right)$$

Experiments with 3 light sources further corroborate model prediction

The vectorial model predicts that when exposed to two opposing light sources of equal intensity, along with a third weaker light source perpendicular to the first two, plants will grow towards the weaker signal.

Data recorded from a top view perspective of this experiment confirms this prediction.





References:

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2. R. Bastien etal. A Unified Model of Shoot Tropism in Plants: Photo-, Gravi- and Propio-ception. PLOS Computational Biology, 2015
3. A. Kempinski etal. - in preparation