Imaging through turbulence (2)

EC 522 Computational Optical Imaging

Lei Tian

Admins

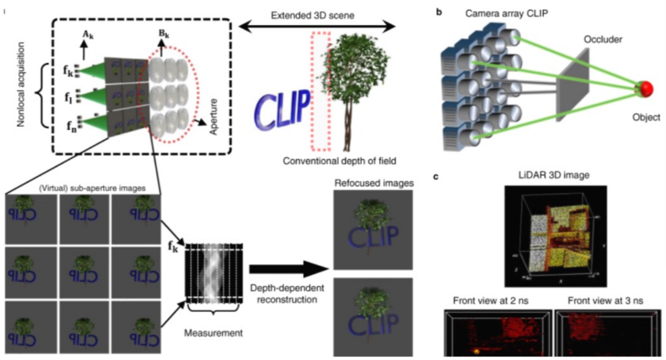
- HWs
  - HW 6: posted, due 4/17
- **Group lecture**
  - Reach out to me & your student mentor for discussions if needed
  - All questions are good questions
  - Grades are based on the demonstration of technical comprehension during the presentation

Group lectures begin					
3/18 (M)	Selected Topic in computational imaging		Group 1	**HW 5: inverse problem 2**	**HW 4**
3/20 (W)	Selected Topic in computational imaging		Group 2		
3/25 (M)	Selected Topic in computational imaging		Group 3		
3/27 (W)	Selected Topic in computational imaging		Group 4		
4/1 (M)	Selected Topic in computational imaging		Group 5	**HW 6: inverse problem 3**	**HW 5**
4/3 (W)	Selected Topic in computational imaging		Group 6		
4/8 (M)	Selected Topic in computational imaging		Group 7		
4/10 (W)	Selected Topic in computational imaging		Group 8		
4/15 (M)	**Patriots' Day Holiday**				
4/17 (W)	Selected Topic in computational imaging		Group 9		**HW 6**
4/22 (M)	Cancelled				
4/24 (W)	**Final Projects**		**Group 1-3**		
4/29 (M)	**Final Projects**		**Group 4-6**		
5/1 (W)	**Final Projects**		**Group 7-9**		

Check the updated syllabus on Blackboard

Theme: Computational photography

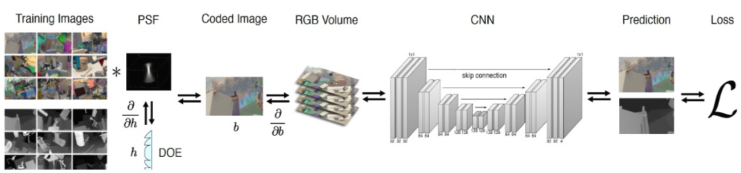
Group Lecture / Class Project 3: Lightfield imaging



Team 4 - **3/27 (W) / / 4/29 (M)**
Paper: CLIP
- Saini Ye
- Chen Qian
- Yuxiang Su

Student mentor:
Qianwan Yang

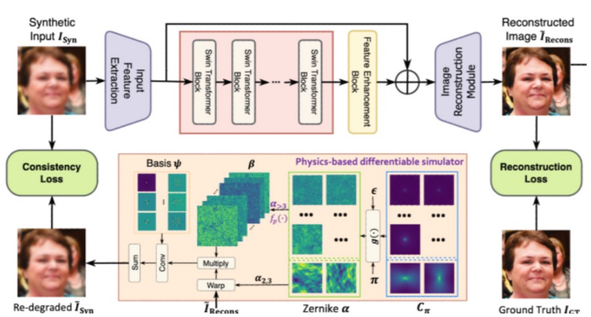
Group Lecture / Class Project 5: Computational 3D photography



Team 5 - **4/1 (M) / 4/29 (M)**
Paper: Depth from defocus
- Ian Lee
- Susan Zhang
- Wangyi Chen

Student Mentor:
Qianwan Yang

Group Lecture / Class Project 9: Computational imaging in complex media



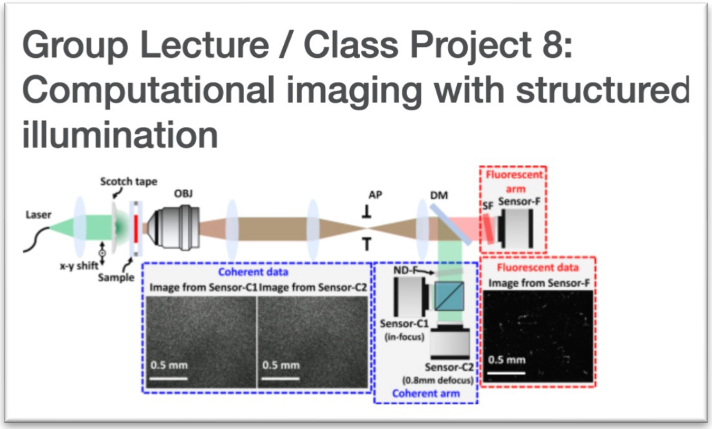
Team 6 - **4/3 (W) / 4/29 (M)**
Paper: Turbulence
- Shuyue Jia
- Hua Tong
- Yujie Zheng

Student mentor:
Tongyu Li

Team 7 - **4/8 (M) / 5/1 (W)**
Paper: NeuWS
- Noa Margolin
- Nolan Vild
- Adhithi Ramasubramanian

Student Mentor:
Hao Wang

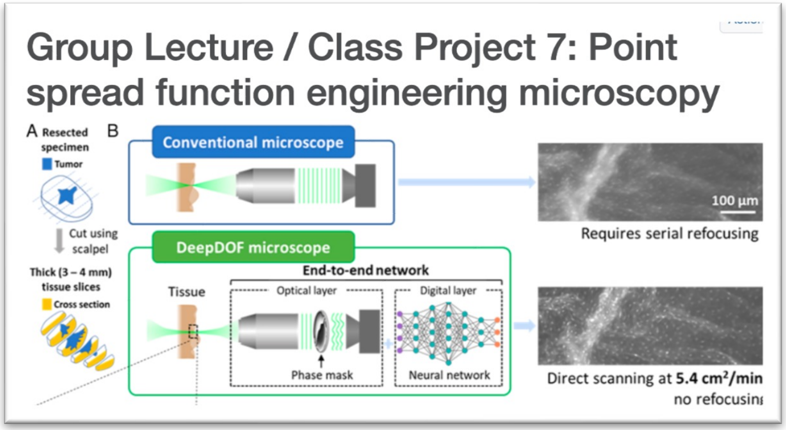
Theme: computational microscopy



Team 8 - **4/10 (W) / 5/1 (W)**

- Yi Shen
- Deming Li
- Kara Stratton

Student mentor:
Tongyu Li

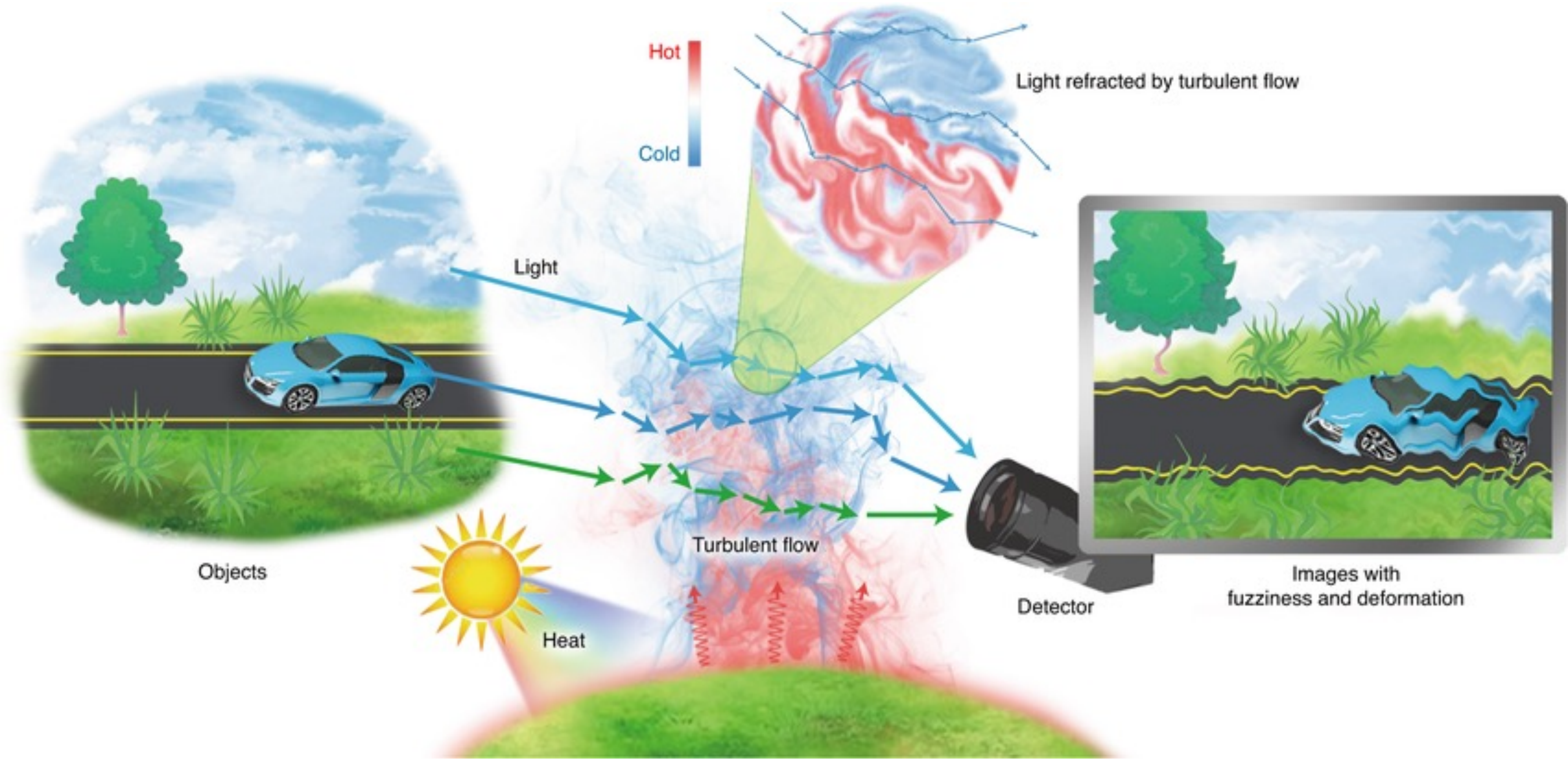


Team 9 - **4/17 (W) / 5/1 (W)**

- Rachel Chan
- Qilin Deng

Student Mentor:
Joe Greene

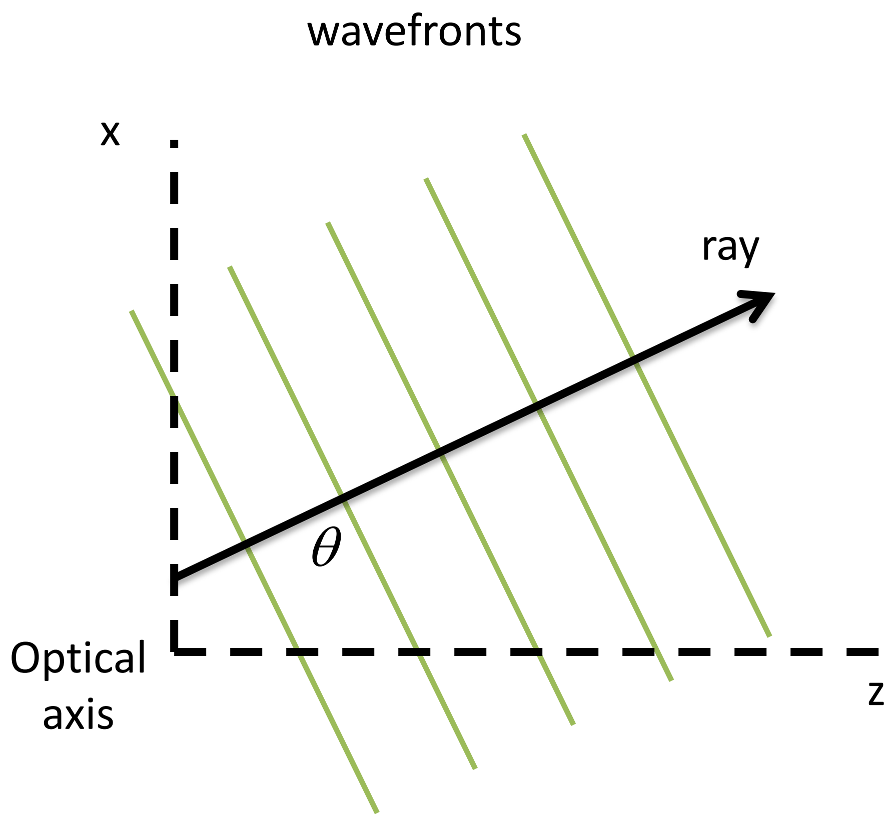
Why imaging through turbulence



https://www.nature.com/articles/s42256-021-00392-1

Introduction to Adaptive Optics

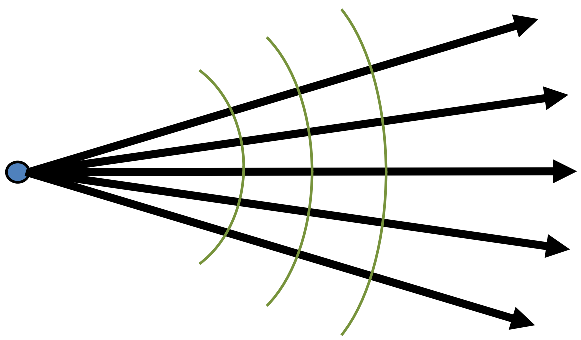
Precursor: rays & wavefront



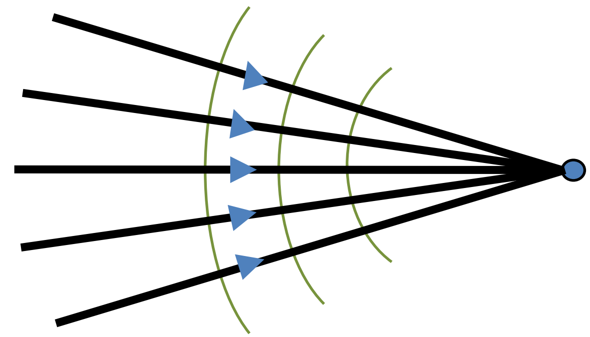
rays & wavefront

diverging spherical wave

point source
point object

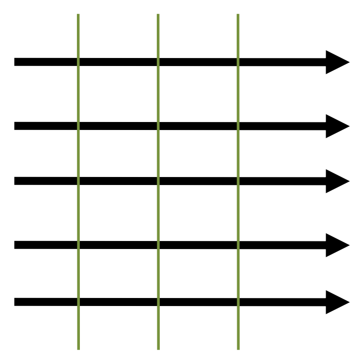


converging spherical wave



point
image

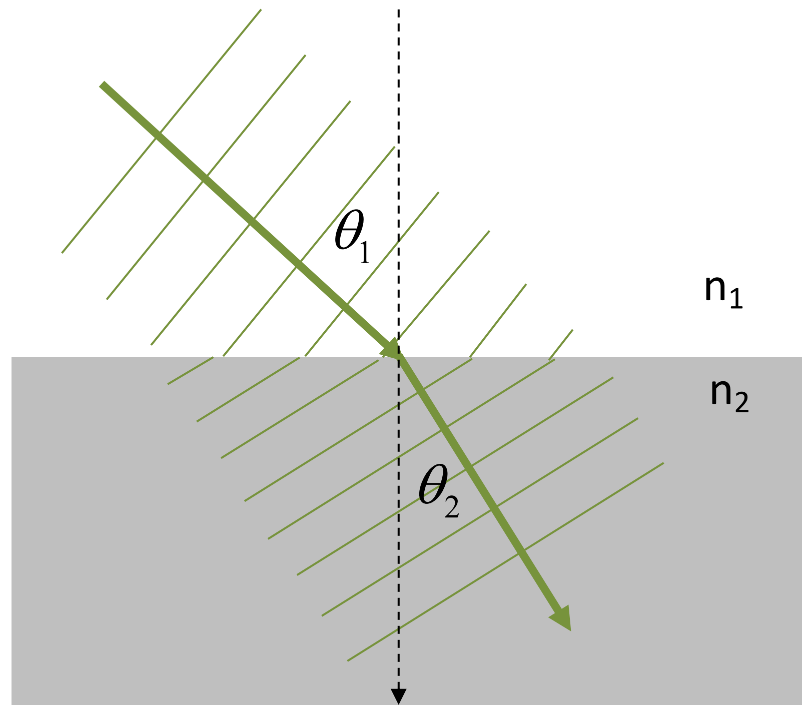
Remember: wave-fronts ⊥ to rays
Rays travel left→right



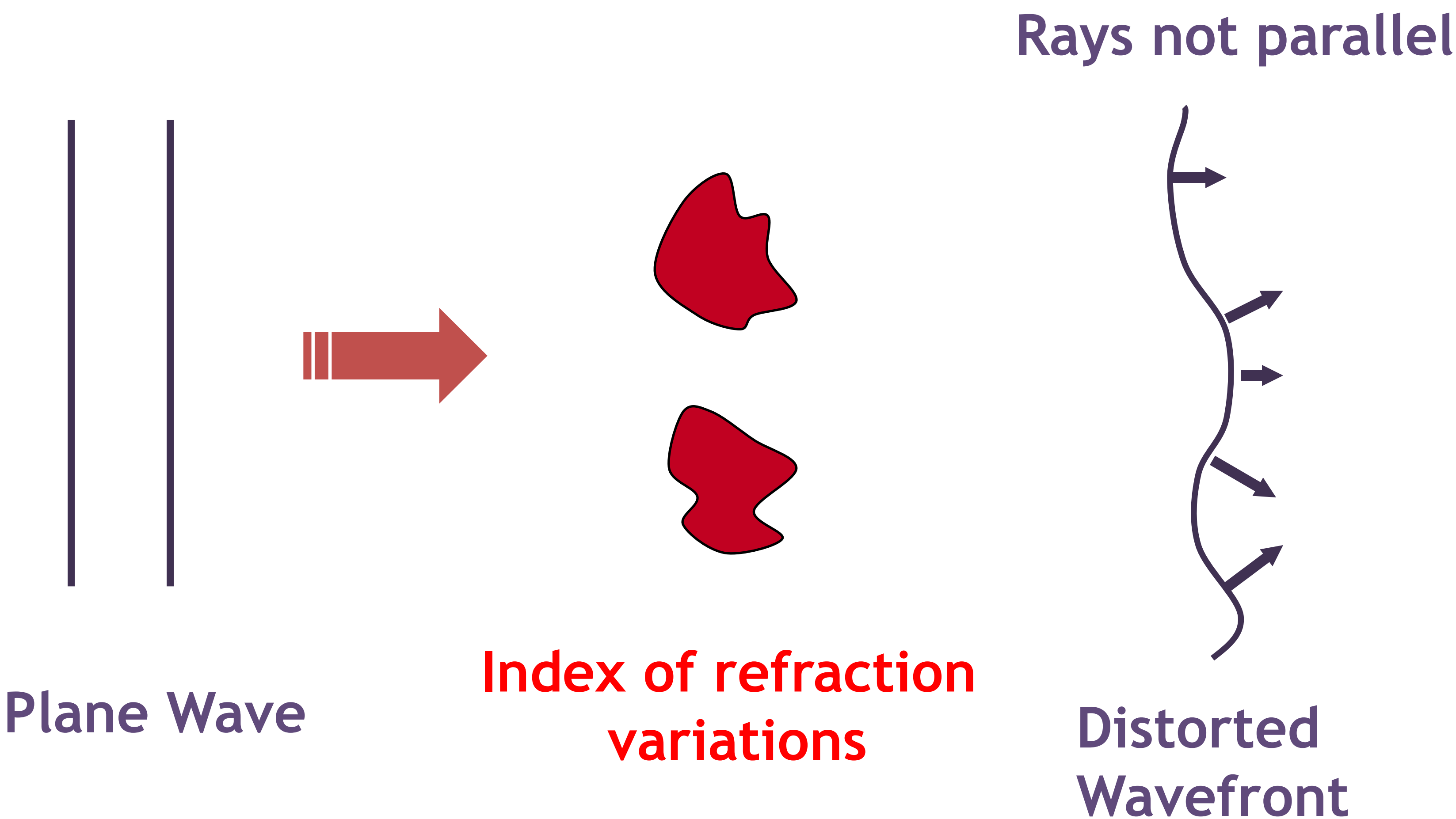
plane wave

Rays of light bend when index of refraction Wavefront is also bent accordingly

- » Light travels slower in more optically dense (higher index of refraction *n*) materials
- » Causes rays to bend at the interface of two materials

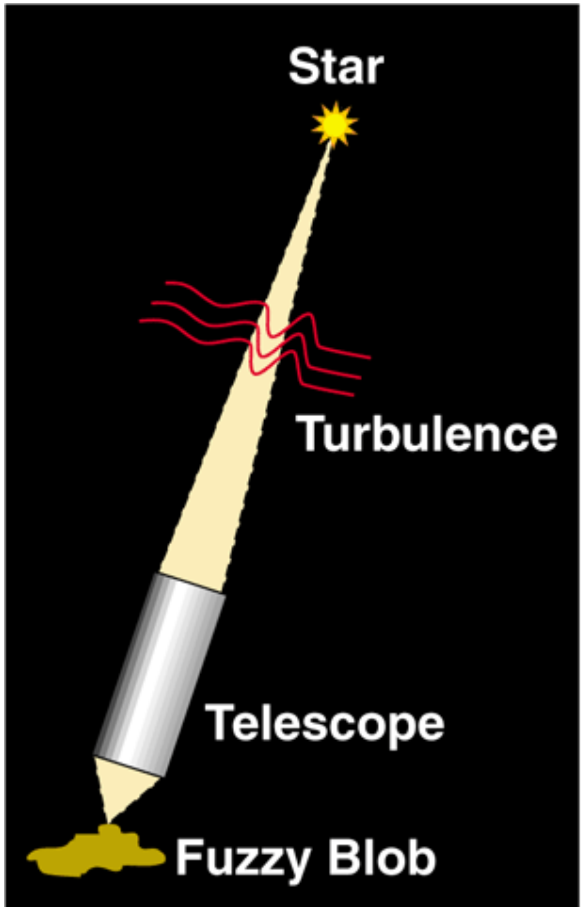


Atmospheric perturbations cause distorted wavefronts



https://www.ucolick.org/~max/289/

Turbulence leads to fuzzy images

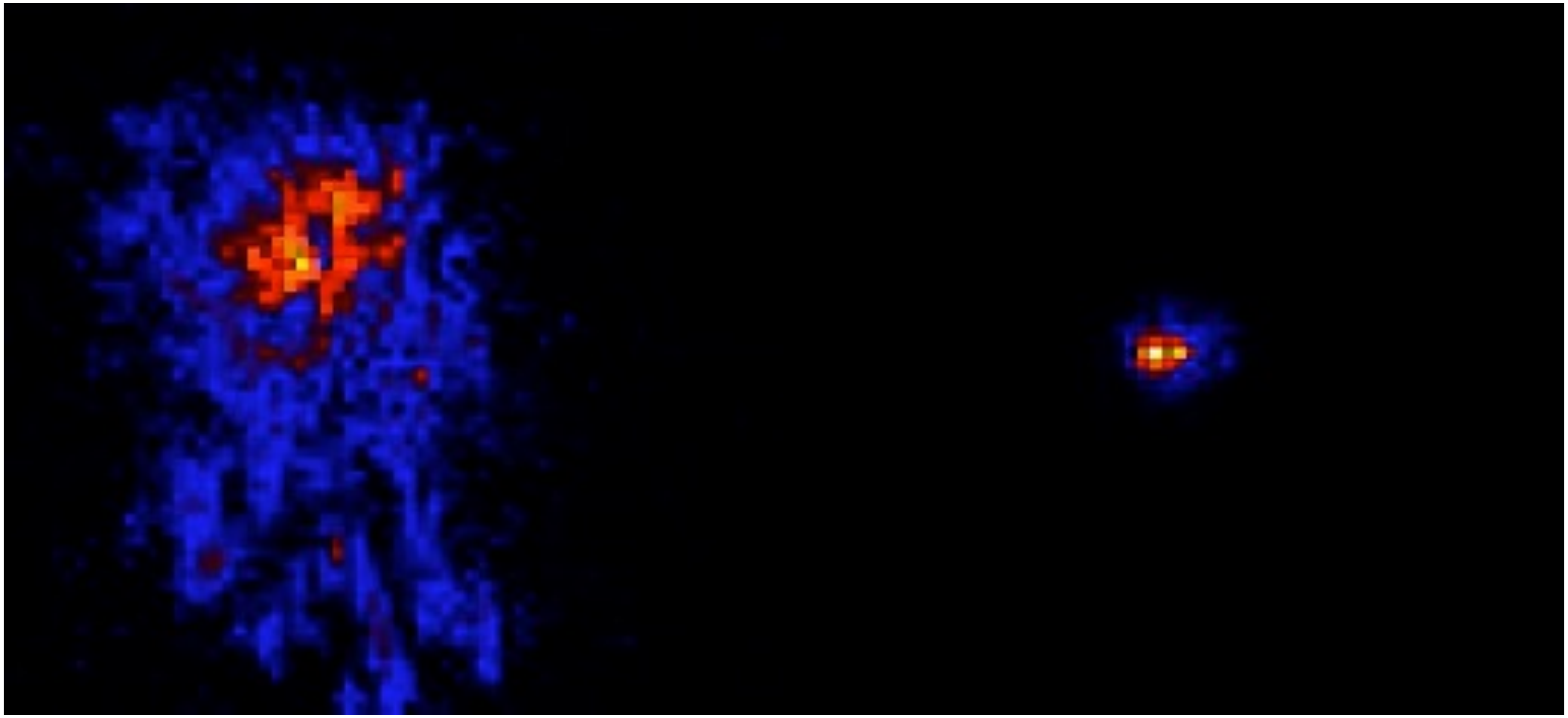


Turbulence in earth's atmosphere makes stars twinkle

More importantly, turbulence spreads out light; makes it a blob rather than a point

https://www.ucolick.org/~max/289/

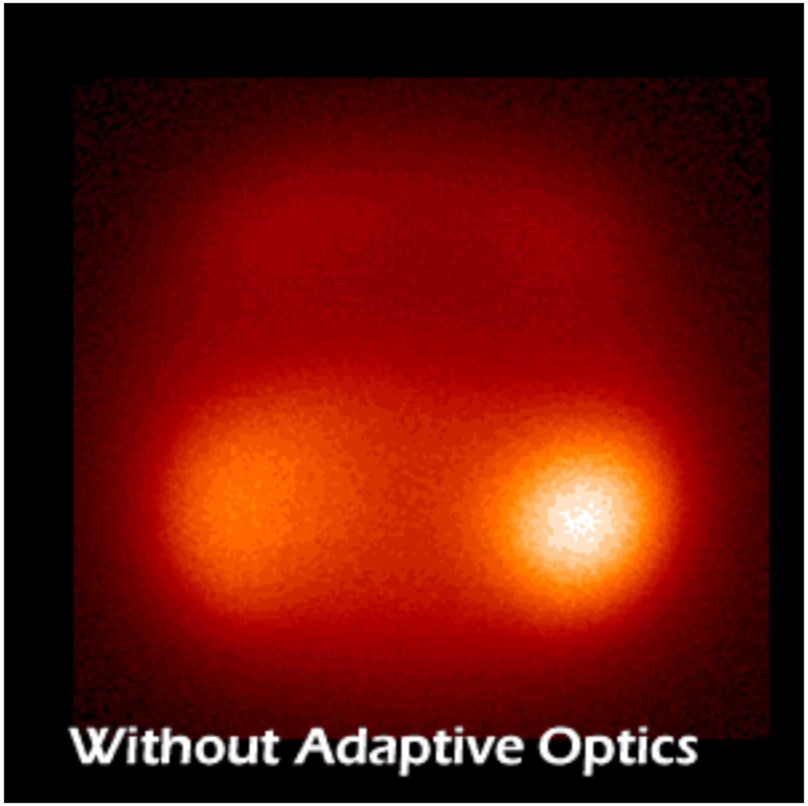
Solution? → Adaptive Optics



Infra-red images of a star, from Lick Observatory adaptive optics system

https://www.ucolick.org/~max/289/

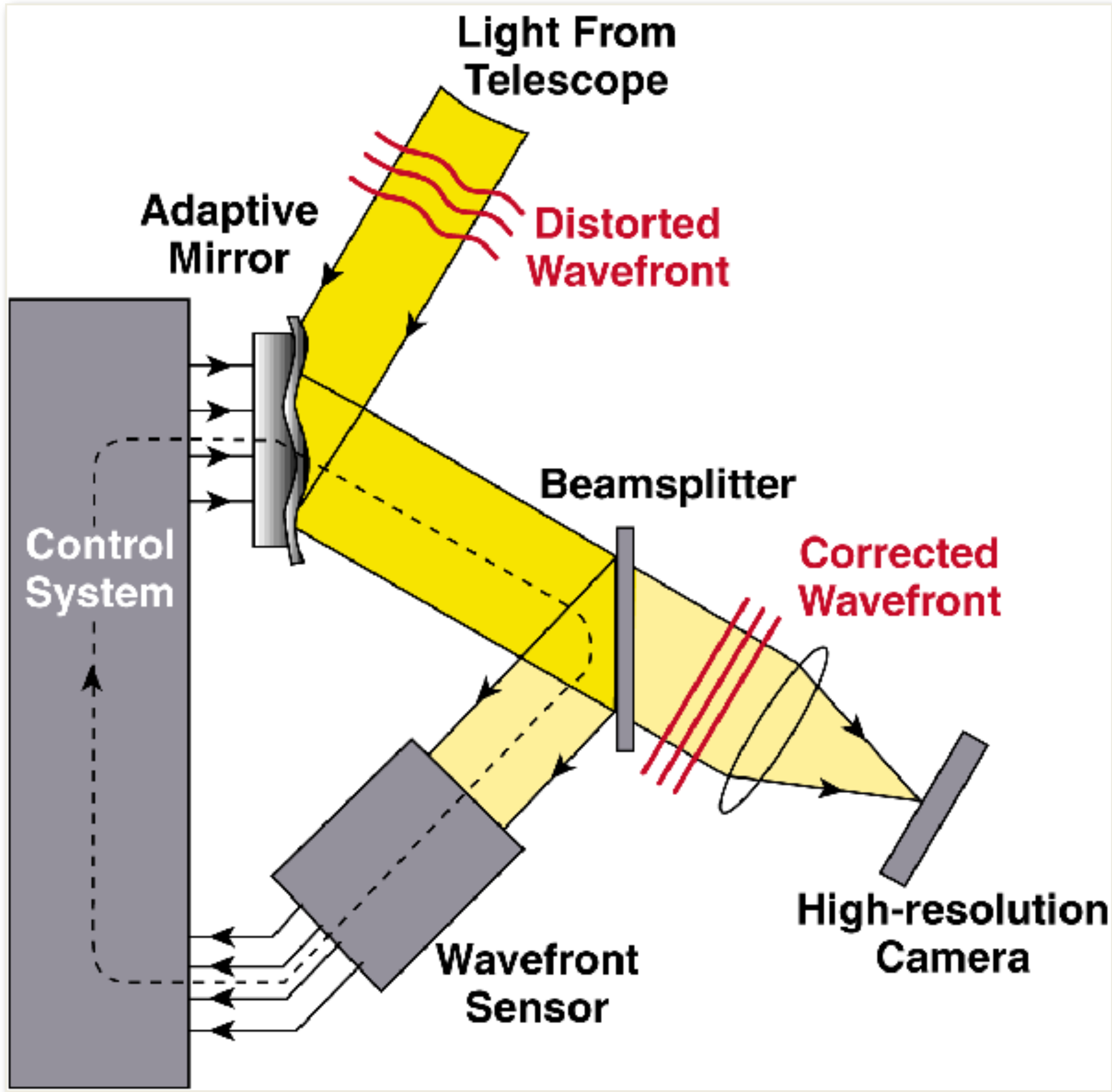
Solution? → Adaptive Optics



https://www.ucolick.org/~max/289/

How Adaptive Optics works?

Feedback loop: next cycle corrects the (small) errors of the last cycle



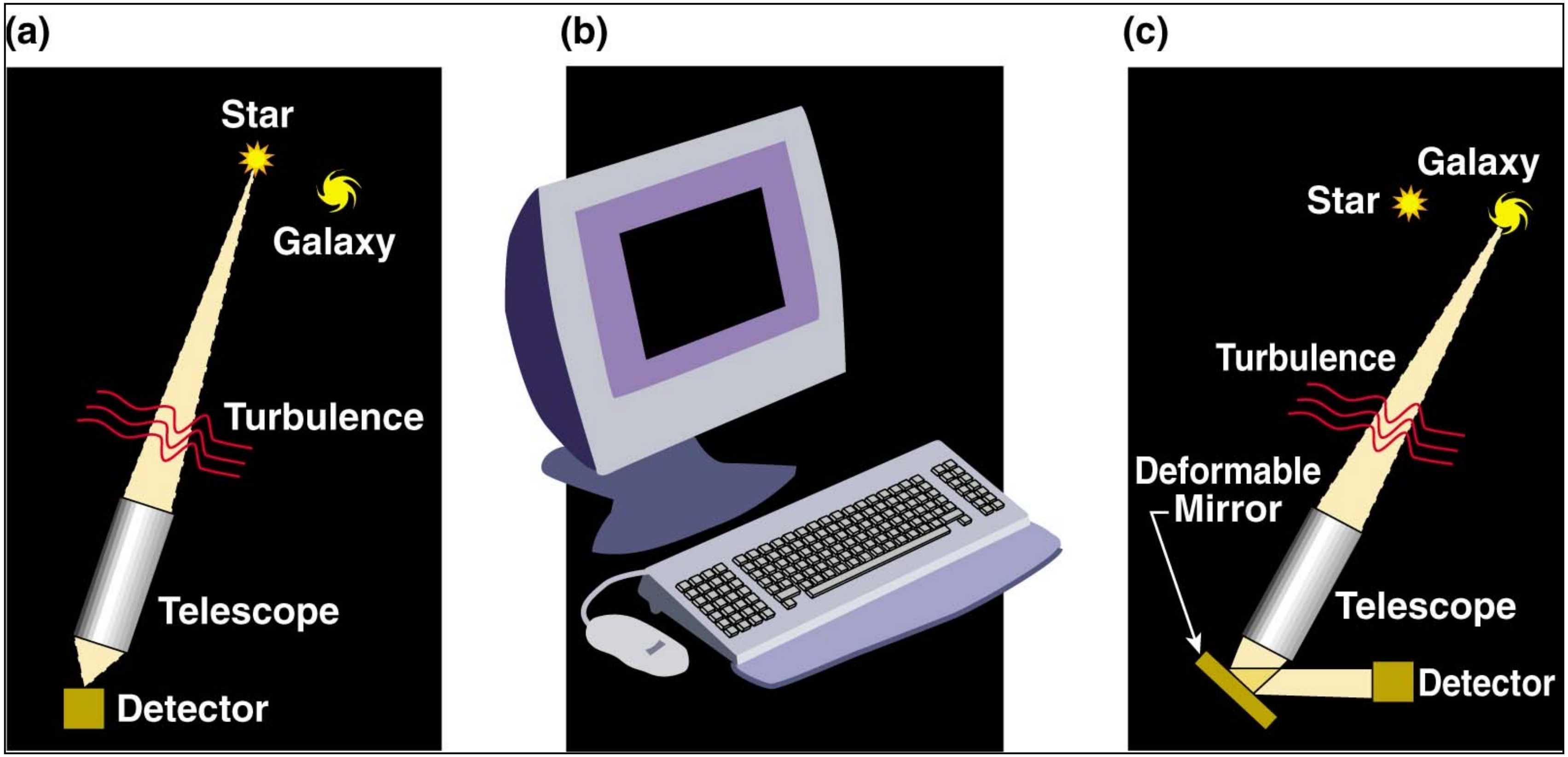
https://www.ucolick.org/~max/289/

How Adaptive Optics works?

Measure details of blurring from "guide star" near the object you want to observe

Calculate (on a computer) the shape to apply to deformable mirror to correct blurring

Light from both guide star and astronomical object is reflected from deformable mirror; distortions are removed

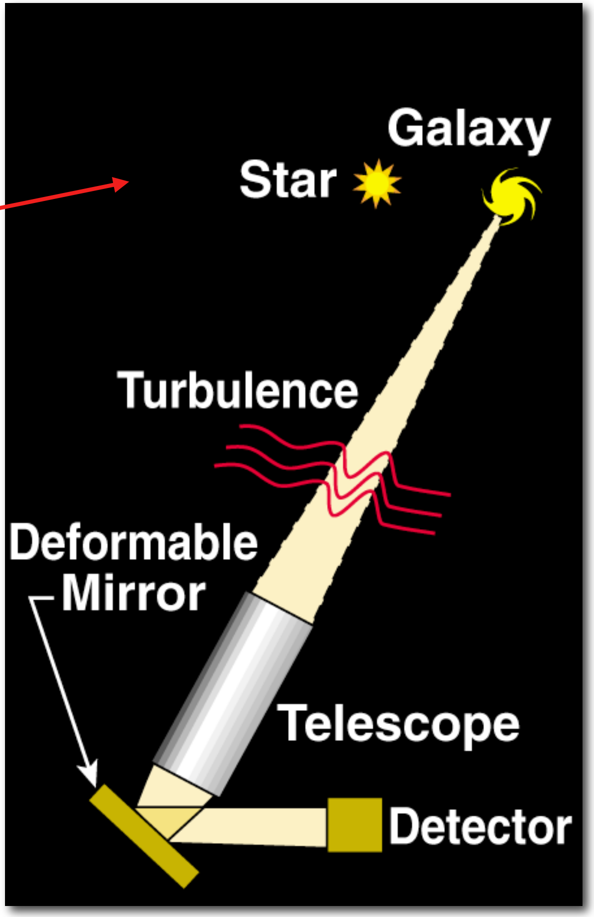


https://www.ucolick.org/~max/289/

How Adaptive Optics works? Need for "guide star"

If there's no close-by "real" star, create one with a laser

- Use a laser beam to create artificial "star" at altitude of 100 km in atmosphere



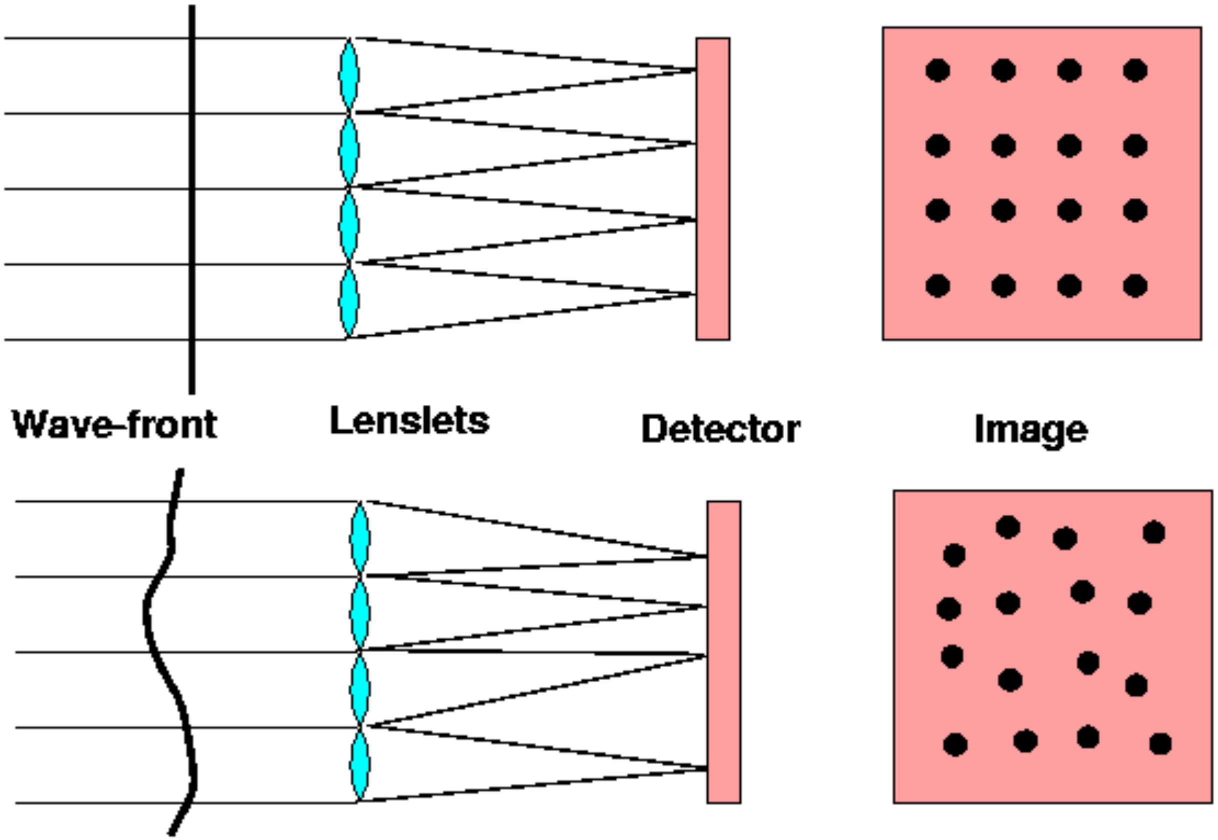
https://www.ucolick.org/~max/289/

How Adaptive Optics works?
Need for "guide star"

Four lasers on Mauna Kea: Keck 1 and 2, Gemini, Subaru telescopes

https://www.ucolick.org/~max/289/

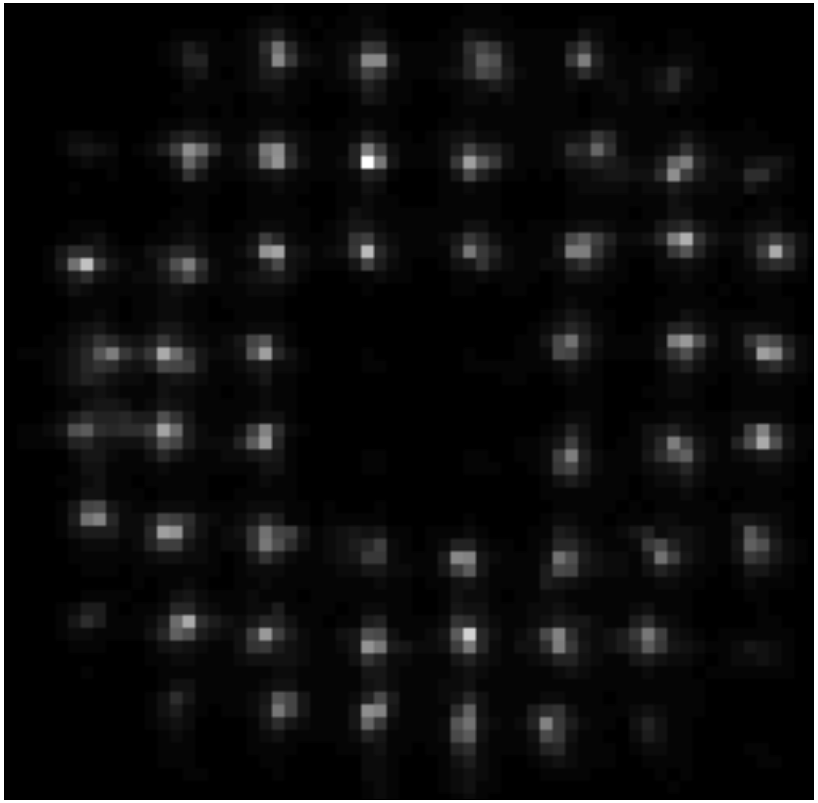
How Adaptive Optics works?
How to measure the wavefront?
→ wavefront sensing



Shack-Hartmann wavefront sensor

https://www.ucolick.org/~max/289/

How Adaptive Optics works?
How to measure the wavefront?
→ wavefront sensing

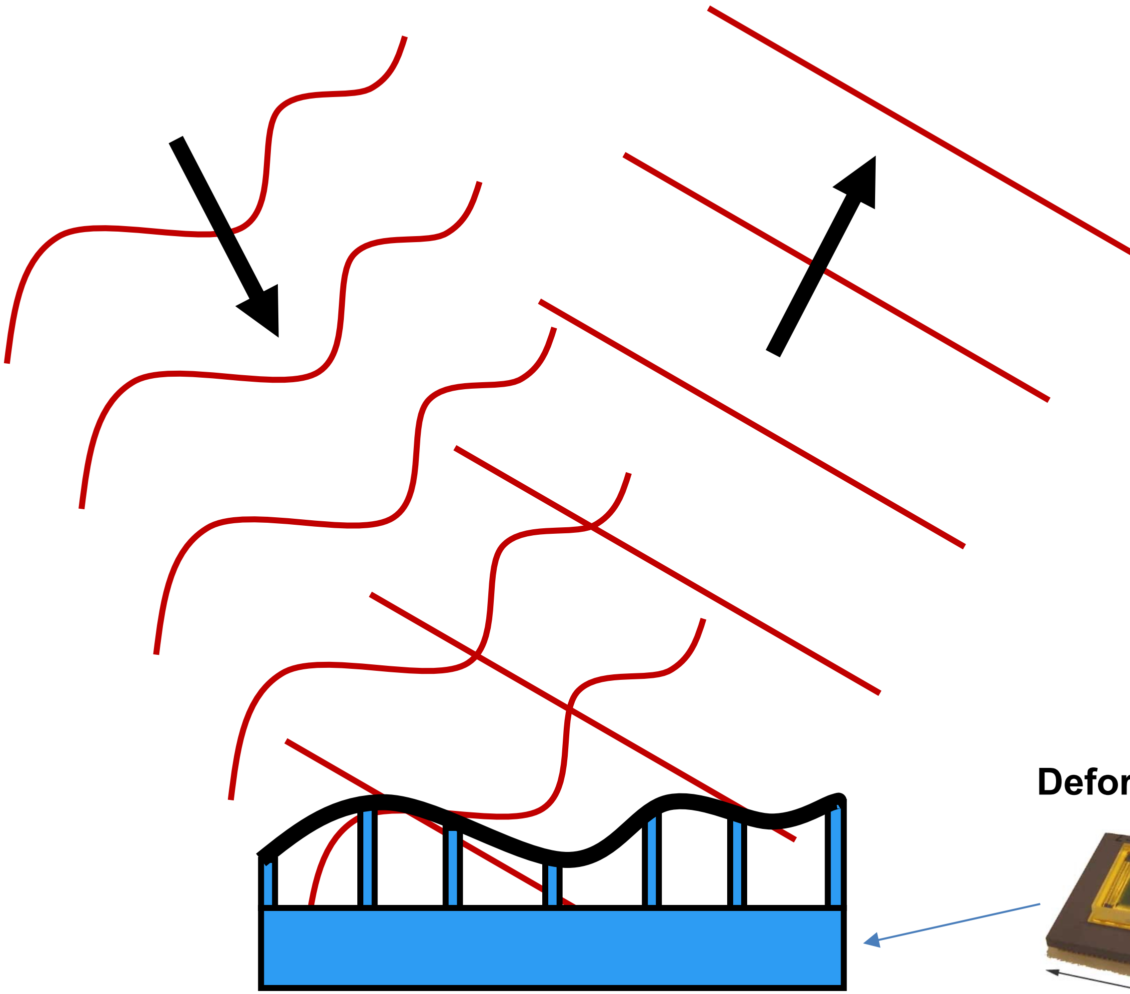


Shack-Hartmann wavefront sensor

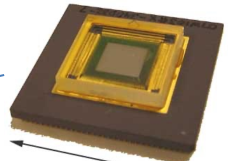
https://www.ucolick.org/~max/289/

How Adaptive Optics works?

How to **physically** correct for the wavefront?



Deformable mirror



Emerging idea: Computational Adaptive Optics