

# Bayesian Data Analysis

PHY / CSI / INF 451 / 551

Fall 2022

# Prof. Kevin H. Knuth



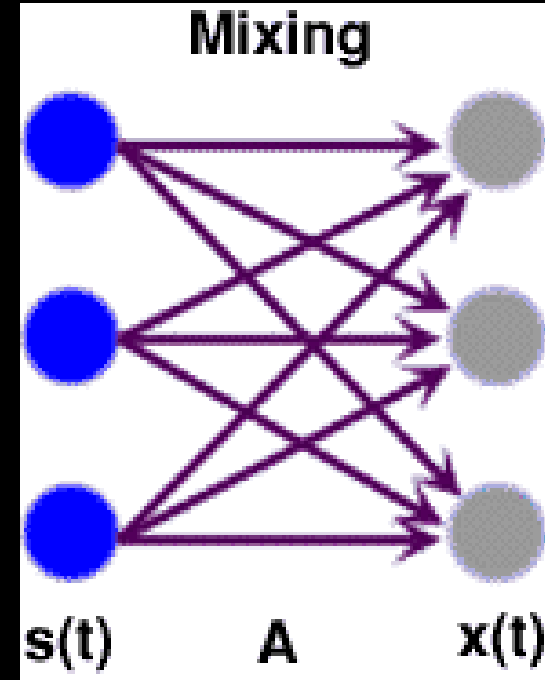
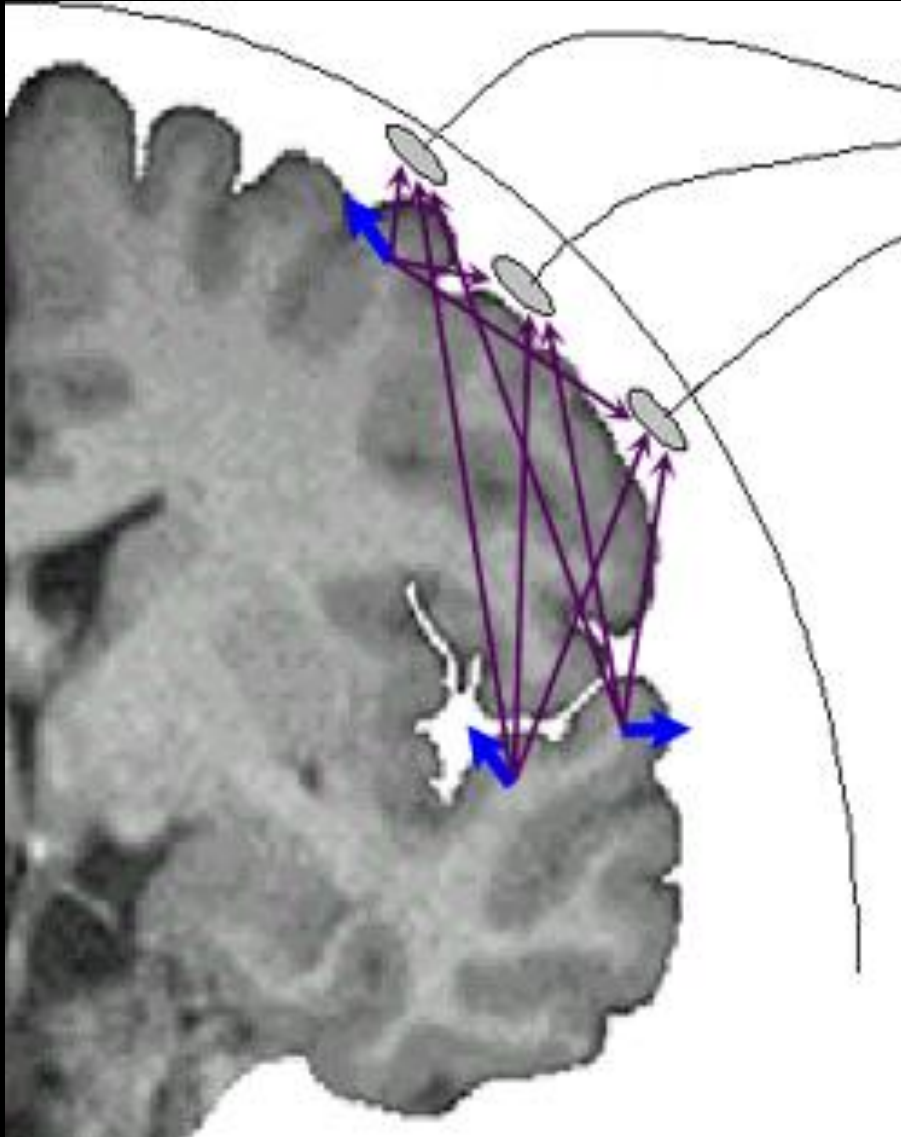


# NASA Ames Research Center 2001 – 2005

## UAlbany 2005 - present



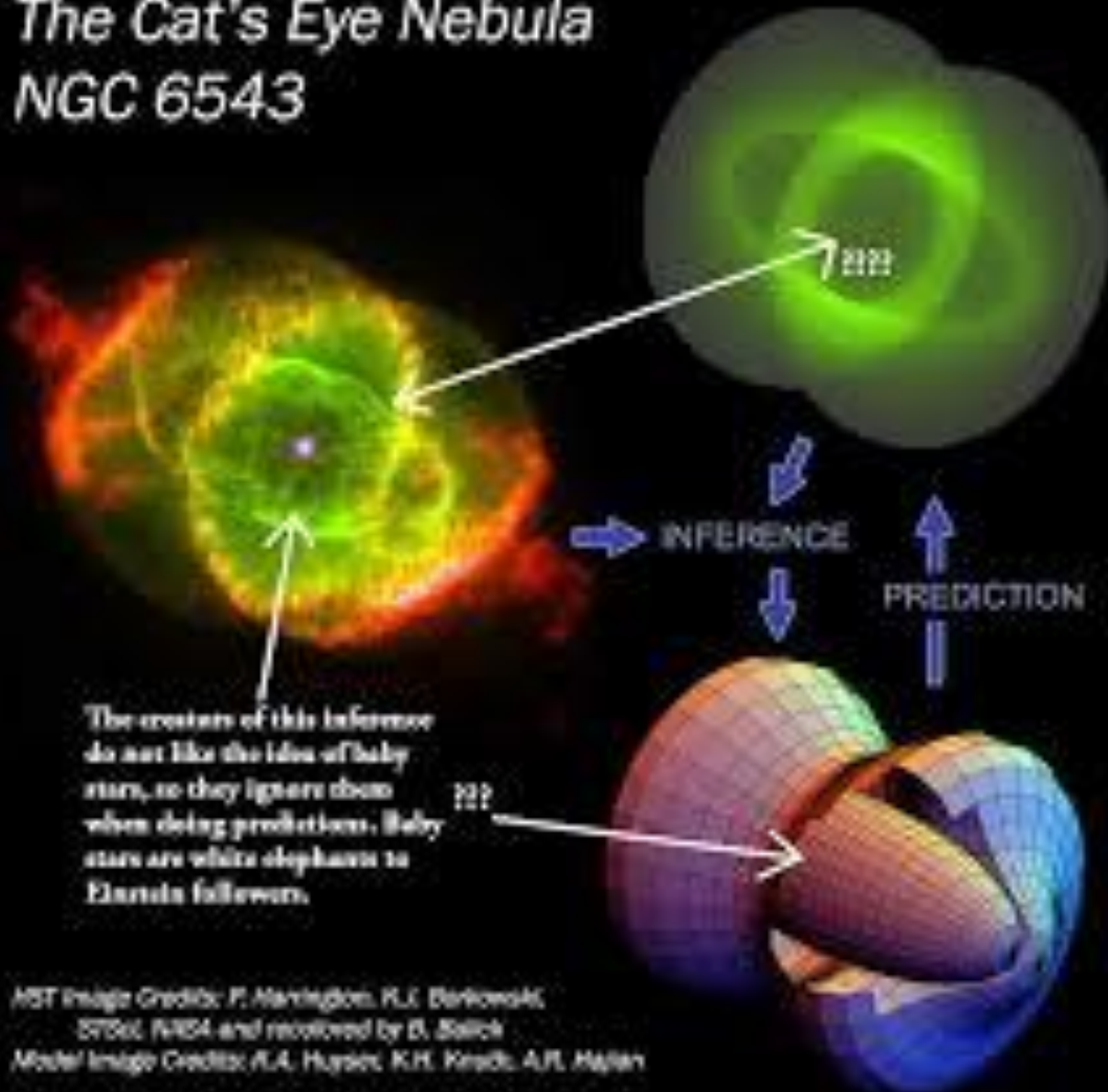
# Bayesian Separation of EEG Signals



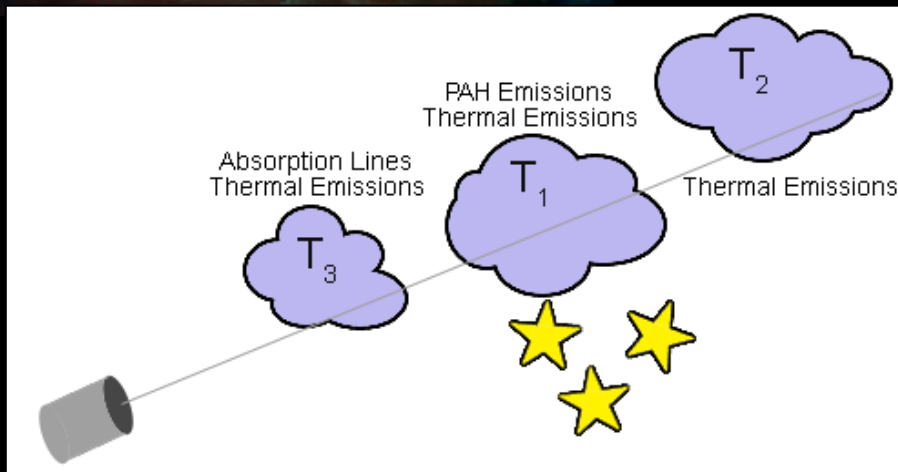
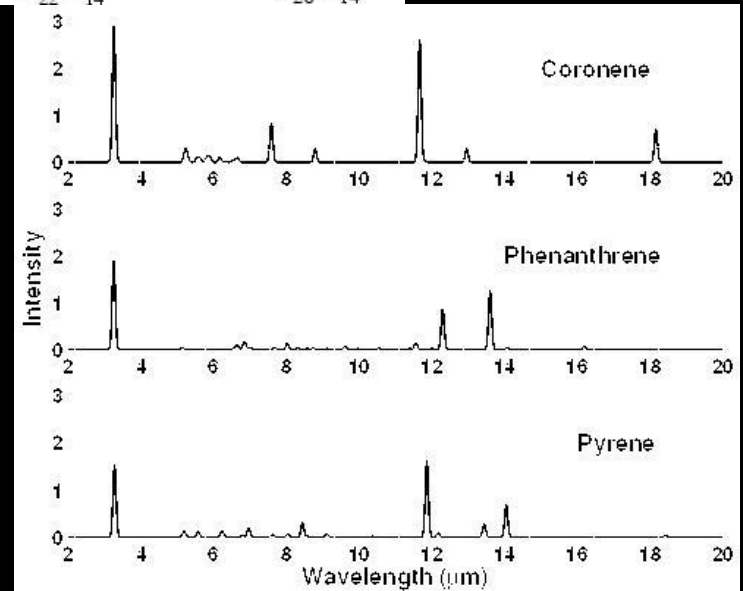
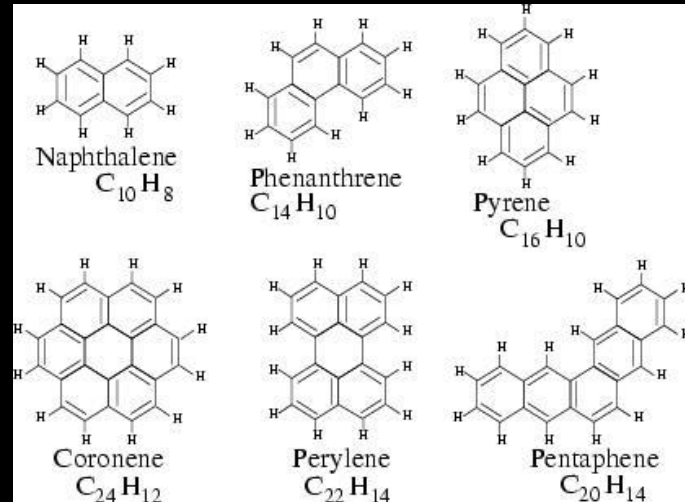


# Planetary Nebula Modeling

## The Cat's Eye Nebula NGC 6543



# Interstellar Organic Molecules



# Bayesian Vision-Based Navigation

Calibrate  
Accelerometer  
and Gyro signals

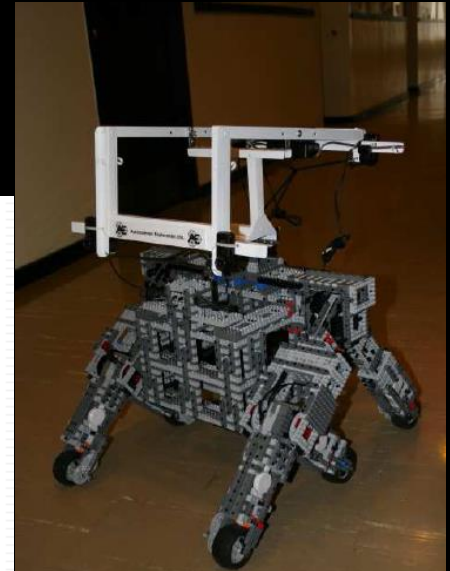
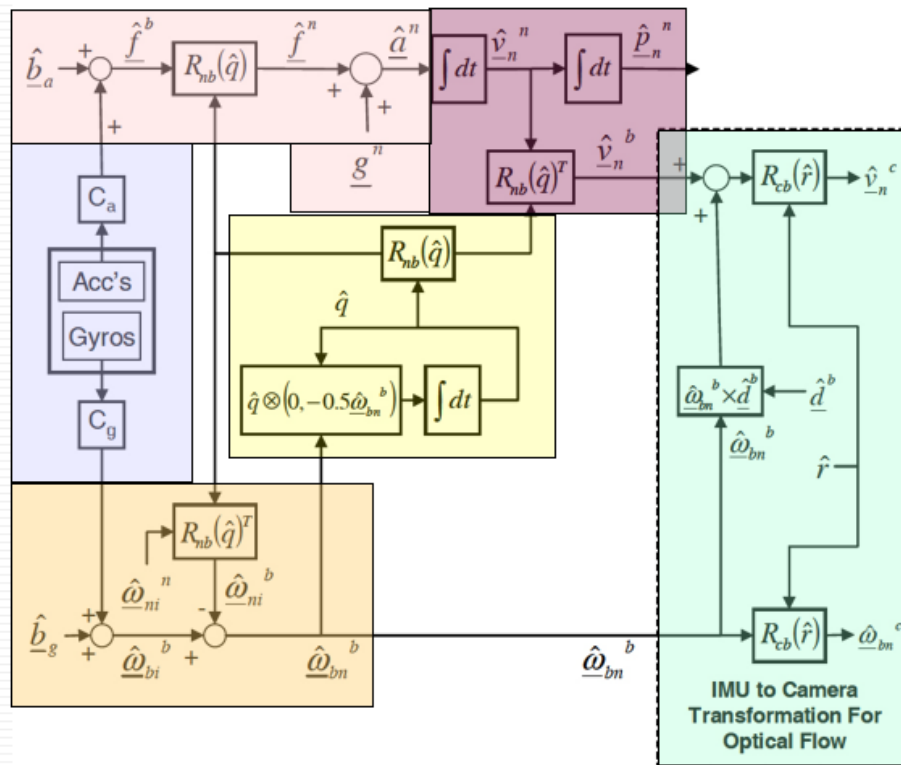
$F = ma$   
with flat earth

Obtain angular  
velocities

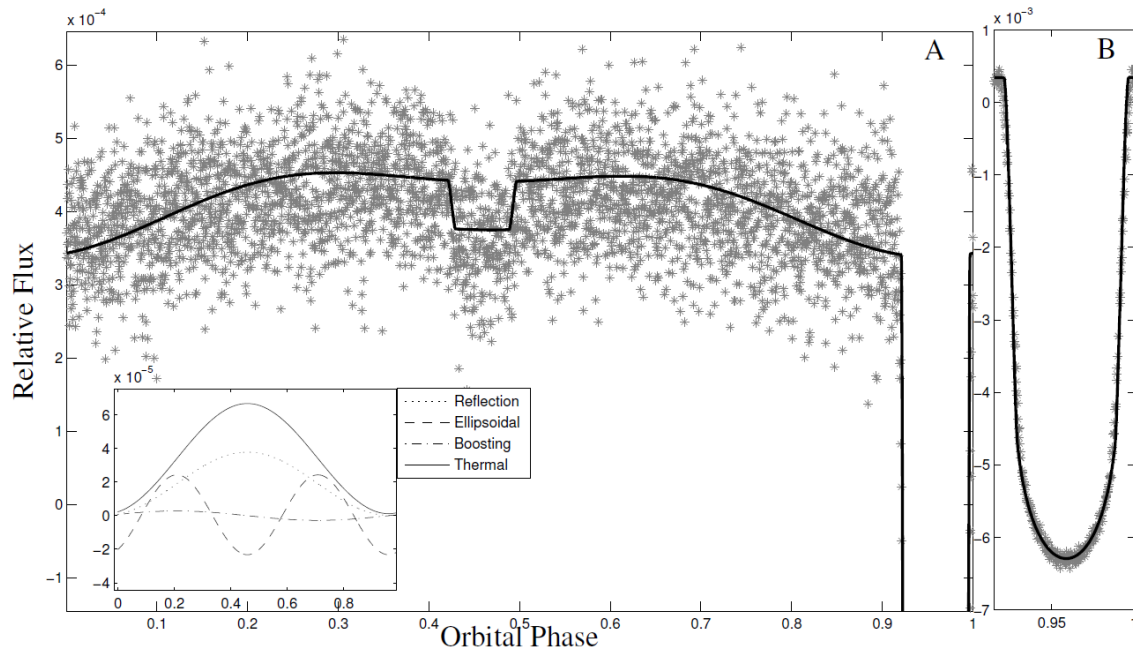
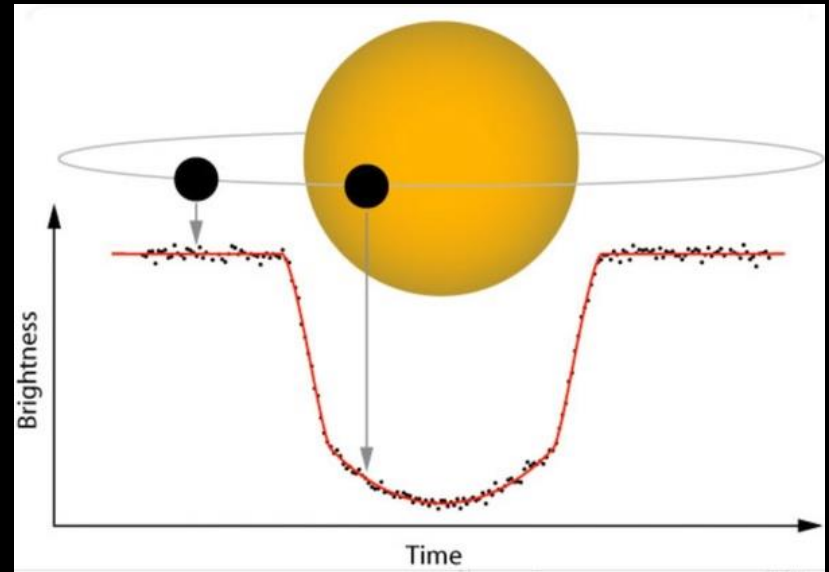
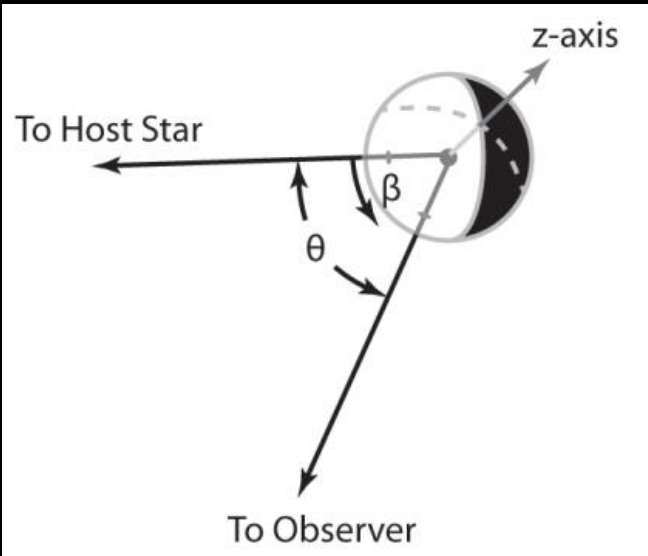
Quaternion  
orientation update

Integrate to get  
velocity & position

Resolve into  
camera frame



# Exoplanet Detection and Characterization





LegalShield® Personal Plans

Get legal guidance for common issues, like demand letters or trial defense. LegalShield

OPEN

PostEverything • Perspective

# UFOs exist and everyone needs to adjust to that fact

UFOs are not the start thinking a

CNN politics

45 CONGRESS SUPREME COURT FACTS FIRST 2020 ELECTION

## Senators receive classified briefing on UFO sightings

By Veronica Stracqualursi and Zachary Cohen, CNN  
Updated 2014 GMT (0414 HKT) June 20, 2019

Original Articles

# Flying saucers are real! The US Navy, unidentified flying objects, and INDEPENDENT

Robert P. Horstemeier

Pages 187-216 | Published online: 20 Sep 2010

Download citation <https://doi.org/10.1007/s11267-010-9510-1>

NEWS POLITICS VOICES FINAL SAY SPORT CULTURE VIDEO INDY LIFE HAPPY LIST INDY BEST LONG READS INDY 500 VOUCHERS MINDS

SUBSCRIBE NOW

**SIGNIFICANT NUMBER OF UFO SPOTTED OVER US AIRSPACE BY NAVY PILOTS**

Reports of strange aircraft that fly in apparently impossible ways have been growing in recent years

Andrew Griffin | Tuesday 28 May 2019 10:04 |

Click to follow The Independent Tech

US

## Pentagon Confirms It Does In Fact Investigate Reports Of UFOs

U.S. MILITARY

THE DRIVE THE WAR ZONE

## US Navy introducing guidelines report UFO sightings

By Barbara Starr, CNN Pentagon Correspondent  
Updated 1834 GMT (0234 HKT) April 24, 2019

THE WARZONE

## Recent UFO Encounters With Navy Pilots Occurred Constantly Across Multiple Squadrons

exclusive details about the incidents off the east coast in 2014 and 2015, including that the

UFOS · Published May 27

# Multiple pilots have reported encounters with UFOs, Navy says

The Philadelphia Inquirer

Unlimited Access

Log In

POLITICS ENTERTAINMENT LIFE FOOD HEALTH REAL ESTATE OBITUARIES JOBS

Search icon

## Frustrated pilots got Navy to stop dismissing UFO sightings

by Deanna Paul, Washington Post, Updated: April 24, 2019

LegalShield® Personal Plans  
Get legal guidance for nonbusiness issues, like demand letters or mail defense. LegalShield

OPEN

Original Articles

Flying saucers are real! The US Navy, unidentified flying objects, an INDEPENDENT

SUBSCRIBE NOW

# THE HILL

News

Policy

Opinion

Events

Jobs

Newsletters

THE HILL TV

Changing America

## Just In...

Newsom vetoes safe-injection site pilot program in California

HEALTHCARE - 3H 48M AGO

Trump held more than 300 classified documents after leaving White House: report

NATIONAL SECURITY - 4H 36M AGO

## OPINION

# Congress implies UFOs have non-human origins

BY MARIK VON RENNENKAMPFF, OPINION CONTRIBUTOR - 08/22/22 1:00 PM ET

THE VIEWS EXPRESSED BY CONTRIBUTORS ARE THEIR OWN AND NOT THE VIEW OF THE HILL



UFOs · Published May 27

## Multiple pilots have reported encounters with UFOs, Navy says

## Multiple Squadrons

exclusive details about the incidents off the east coast in 2014 and 2015, including that the

The Philadelphia Inquirer

Unlimited Access

Log In

ON POLITICS ENTERTAINMENT LIFE FOOD HEALTH REAL ESTATE OBITUARIES JOBS



## Frustrated pilots got Navy to stop dismissing UFO sightings

by Deanna Paul, Washington Post. Updated: April 24, 2019

A film that asks, are we alone?

## A Tear in the Sky

7 p.m. Friday, August 26, 2022

Page Hall, University at Albany downtown campus  
135 Western Avenue, Albany 12203

[View map](#)

Free and open to the public.

(United States, 2022, 88 minutes, color) Directed by Caroline Cory.

A Tear in "the Sky" explores the field of Unidentified Aerial Phenomena (known formerly as UFOs)— a subject that is generating considerable mainstream interest since the release of previously classified U.S. government videos, and the creation by the Pentagon of a UAP Task Force in August 2020.

Starring William Shatner of Star Trek and celebrity physicist Michio Kaku, the film follows a team of military personnel and scientists— including two University at Albany physics professors, Kevin Knuth and Matthew Szydagis— as they attempt to re-capture, in real time, evidence of UFOs and other space anomalies, using state-of-the-art, military-grade equipment and technology.





Go Fast USAF Footage

# 2004 Nimitz USAF Footage



“I have no idea what I saw.

It had no plumes, wings or rotors and outran our F-18s.

But I want to fly one.”

— *Cdr. David Fravor*



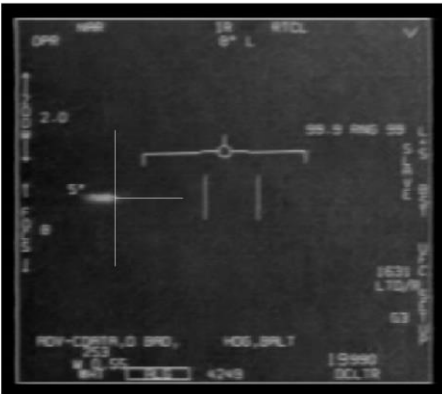
Nimitz Encounter (USS  
Princeton/Nimitz 2004)  
Nov 2004  
off Southern California USA

Tracking the Object

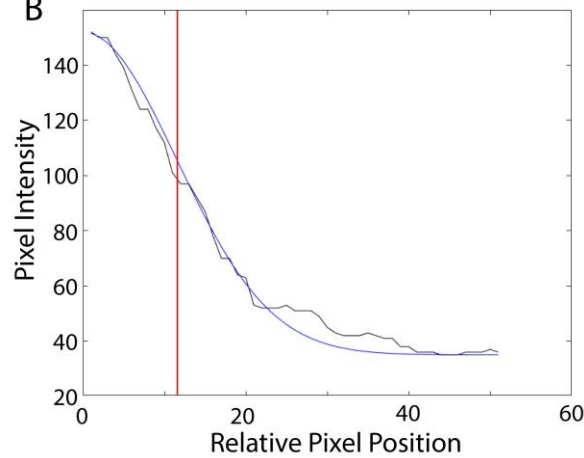
A Gaussian is fit to the right-edge  
intensity profile.



A



B





Nimitz Encounter (USS Princeton/Nimitz 2004)

Nov 2004

off Southern California USA

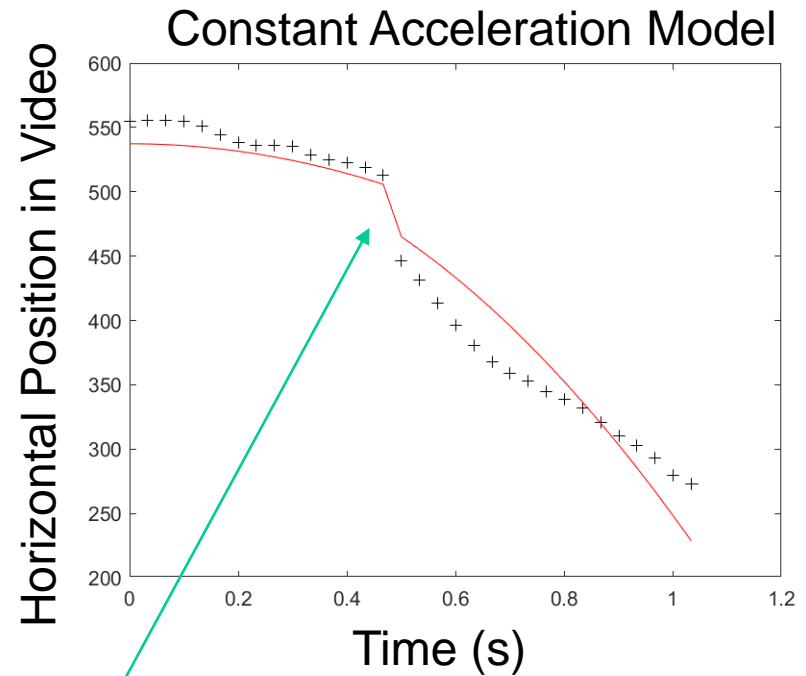
Constant Acceleration Model

$$x = \frac{1}{2} a_x t^2 + x_o$$

Nested Sampling

$$a_x = -33.7 g \pm 0.85 g$$

$$\log Z = -245000$$



The targeting computer changes its magnification

Nimitz Encounter (USS Princeton/Nimitz 2004)

Nov 2004

off Southern California USA

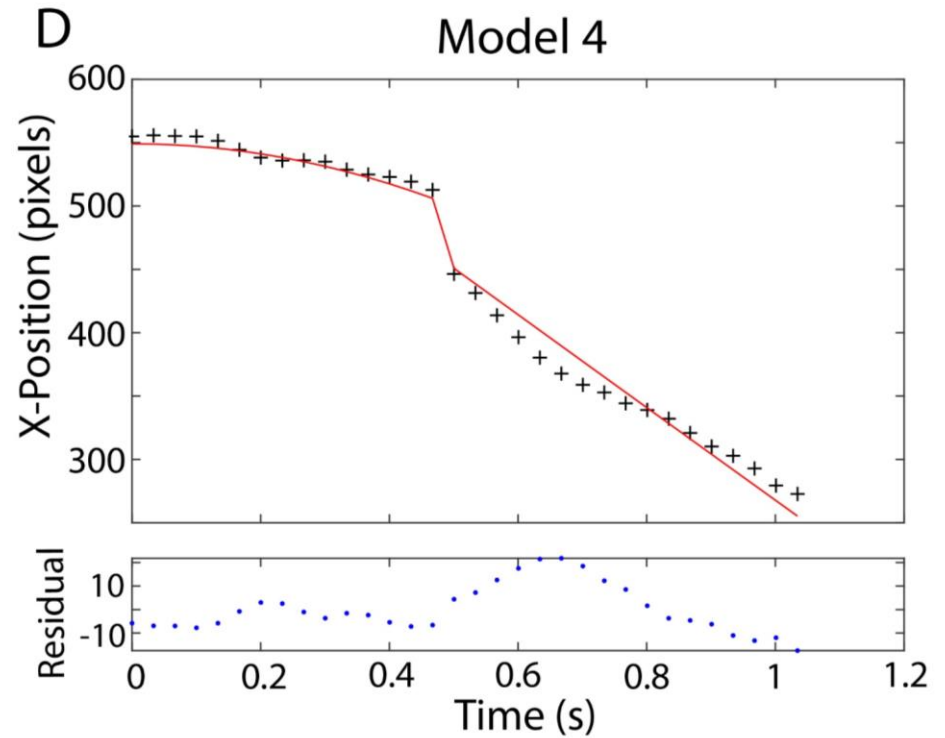
Constant Acceleration + Constant Speed Model

The UAV accelerates to the left and away from the F-18.

Nested Sampling

$$a_x = -79.5 g \pm 0.2 g$$

$$\log Z = -52084$$



We estimate accelerations ranging from 68 *g* to ~ 5300 *g*

An acceleration of 25*g* would kill most living things!

The F-35 fighter jet cannot withstand more than about 13.5 *g*

The Crotale NG VT1 Missile can withstand 50 *g*

and maintain maneuverability up to 35 *g*

These are indeed “impossible” accelerations.

Encounter	Dimensions	Acceleration
Bethune (1951) over Atlantic Ocean off Nova Scotia		
Bethune (1951)	300 ft	~1700 <i>g</i>
JAL 1648 (1986) over Alaska (40 min encounter!)		
JAL 1648 Linear Motion	1000 ft	68 ± 7 <i>g</i>
JAL 1648 Circular Motion	1000 ft	84 ± 8 <i>g</i>
Nimitz Carrier Strike Group (2004) off Southern CA		
Day (2004)		~5300 <i>g</i>
Fravor (2004)	40 – 50 ft	~ 150 <i>g</i>
Nimitz FLIR (2004)	40 – 50 ft	79.5 ± 0.2 <i>g</i>







I THINK IT IS  
**POSSIBLE** FOR  
**ORDINARY**  
PEOPLE TO  
**CHOOSE** TO BE  
**EXTRAORDINARY.**

ELON MUSK  
FEARLESSMOTIVATION.COM





Doing math homework when you don't know exactly how to do a problem:

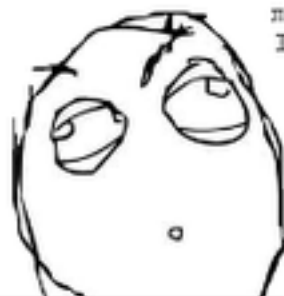
Elementary

Don't know how to do this, but I think I can figure it out...



Algebra

hmm...this is hard...I might be able to do it if I ask a friend for help



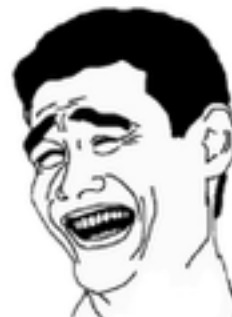
Trigonometry

Whatever I'll just ask the teacher in class tomorrow how to do it



Calculus

Fuck it! I'll just copy my friend's answers









I THINK IT IS  
**POSSIBLE** FOR  
**ORDINARY**  
PEOPLE TO  
**CHOOSE** TO BE  
**EXTRAORDINARY.**

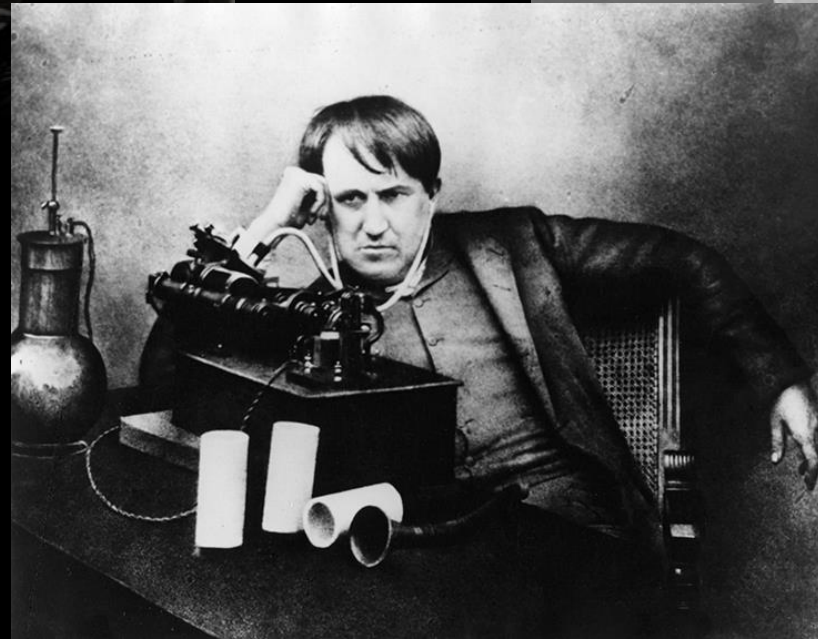
ELON MUSK  
FEARLESSMOTIVATION.COM

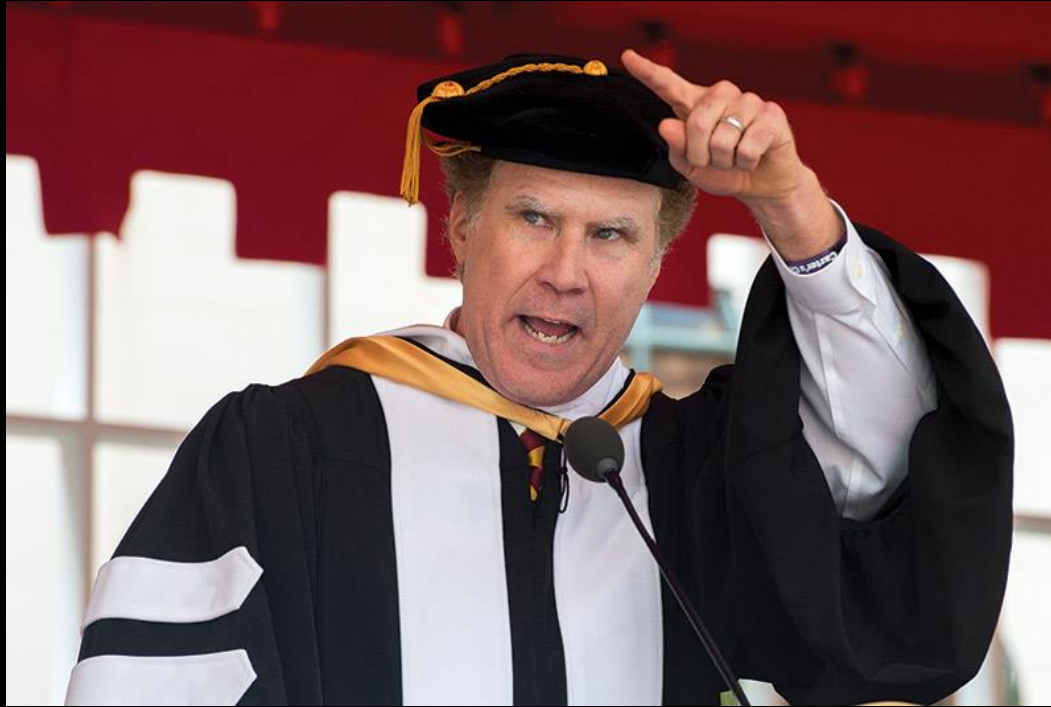


## **Arnold Schwarzenegger Motivation - 6 rules of success speech**

<https://www.youtube.com/watch?v=EyhOmBPtGNM>



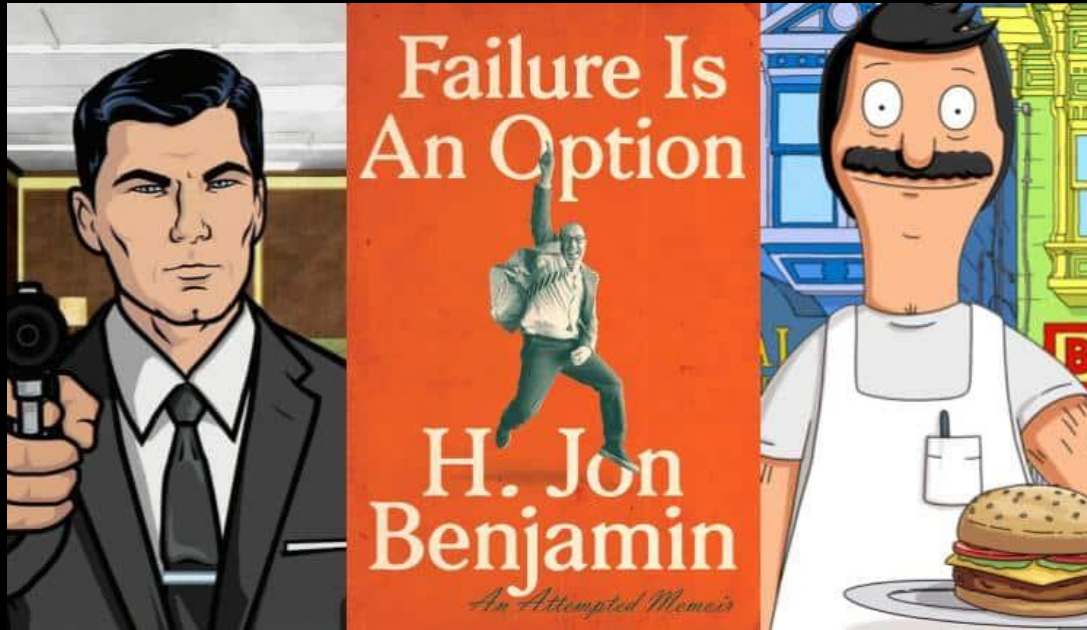




“You're never not afraid”

“My fear of failure never approached in magnitude my fear of ‘what if’: What if I never tried at all?”

- Will Farrell



I've never worked for a show or was on a show that I didn't have a lot of control creatively, but then again, I haven't worked on a lot of shows.

- H. Jon Benjamin






CHAPTER 22

---

**How I Failed at  
Differentiating My Two  
Characters of Bob and Archer**

**I** did the same voice. The end.

A photograph of Elon Musk speaking at a Tesla event. He is smiling and looking to the right. The Tesla logo is visible in the background. The image has a semi-transparent dark overlay.

**"Failure is an option here. If things are not failing, you are not innovating enough."**

**Elon Musk**

We learn from our mistakes

We learn from our mistakes

“The job of a theoretical physicist is to make mistakes as fast as possible”

- John Archibald Wheeler









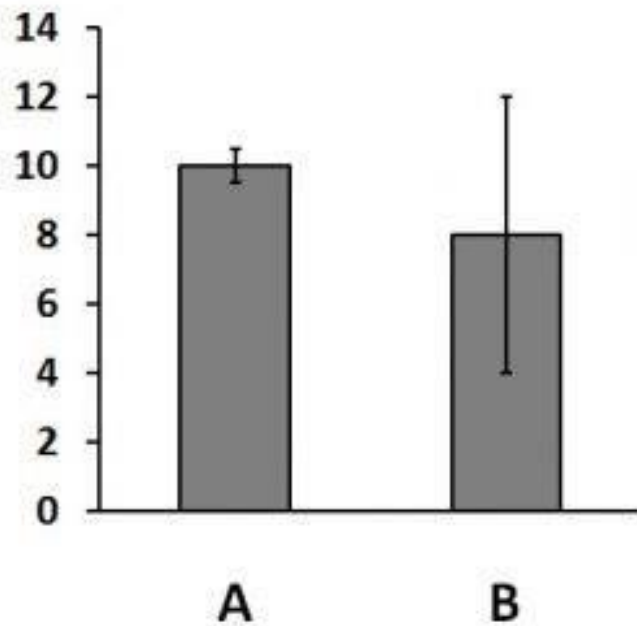
1000 ml. ( $\pm 15$ ) DEF  
Ayran; özel üretim tekniği sayesinde yoğun kıvama  
kalmırlı ve tuz kabı olarak üretilmiştir. 4-6°C'de m  
edir. Son kullanma tarihinden önce tüketiniz.  
11-00001-3 sayılı izn

1000 ml. ( $\pm 15$ ) DE  
ZİTOSUZ TS. 3810

Quantifying Uncertainty Is Critical

# MR T TEST

*"THAT AIN'T SIGNIFICANT, FOOL!"*



Non-Invertible Transformations  
Destroy Information!

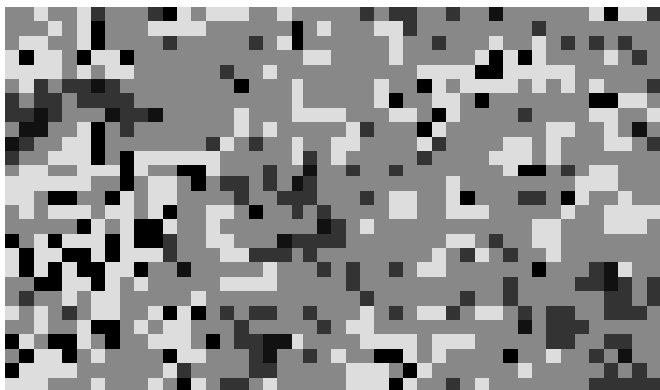
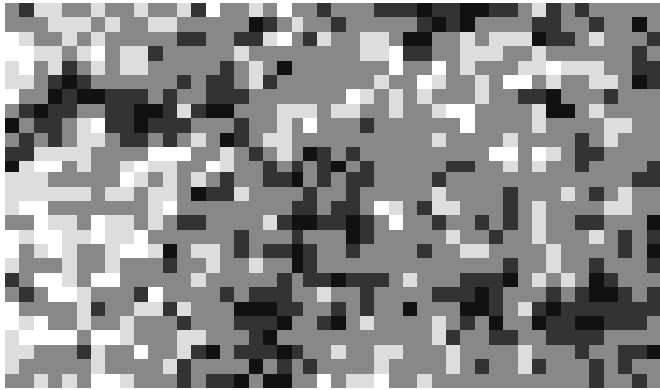


# Super-Resolution Imaging

by Peter Cheeseman, Bob Kanefsky, Robin Hanson, and John Stutz

NASA Ames Research Center

## Sample Input Images

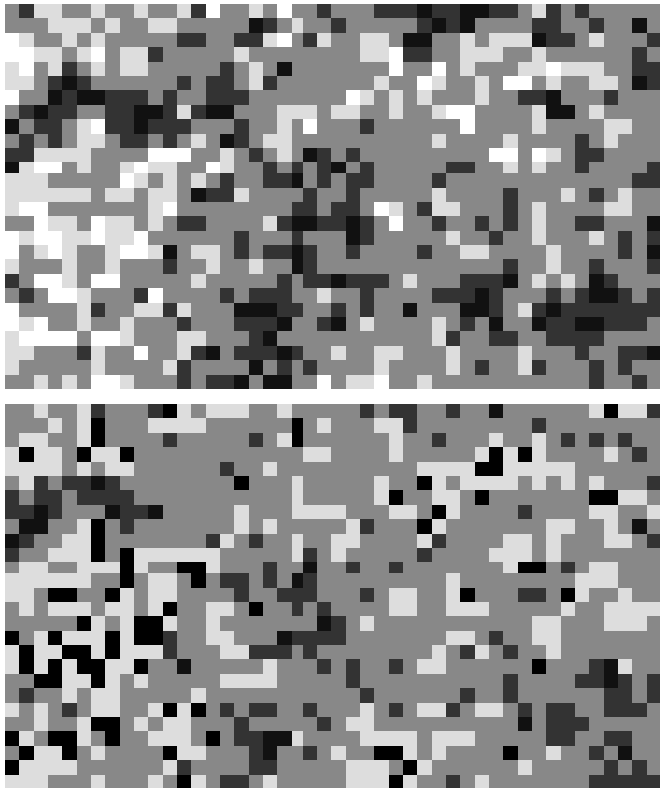


# Super-Resolution Imaging

by Peter Cheeseman, Bob Kanefsky, Robin Hanson, and John Stutz

NASA Ames Research Center

Sample Input Images



Average Image

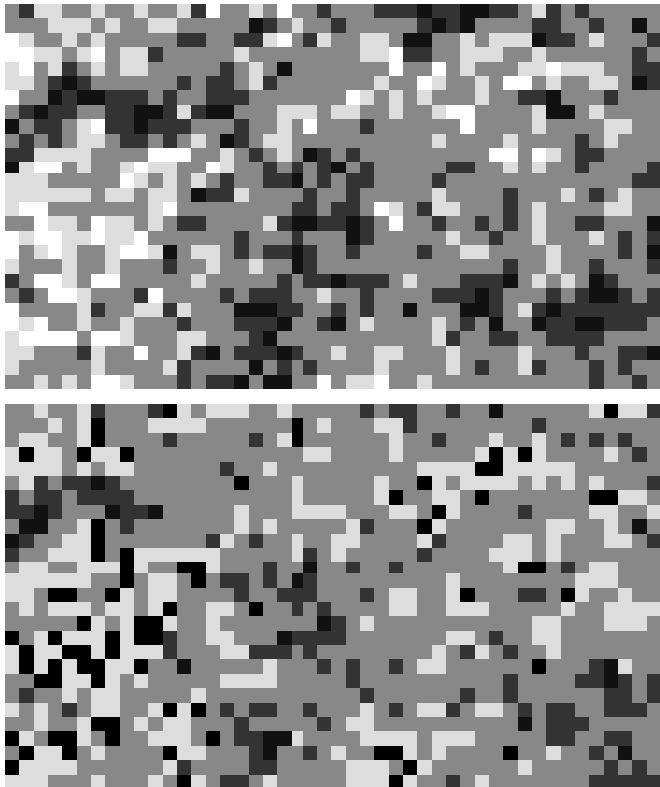


# Super-Resolution Imaging

by Peter Cheeseman, Bob Kanefsky, Robin Hanson, and John Stutz

NASA Ames Research Center

Sample Input Images



Average Image



Output Image

# Super-Resolution Imaging

by Peter Cheeseman, Bob Kanefsky, Robin Hanson, and John Stutz

NASA Ames Research Center

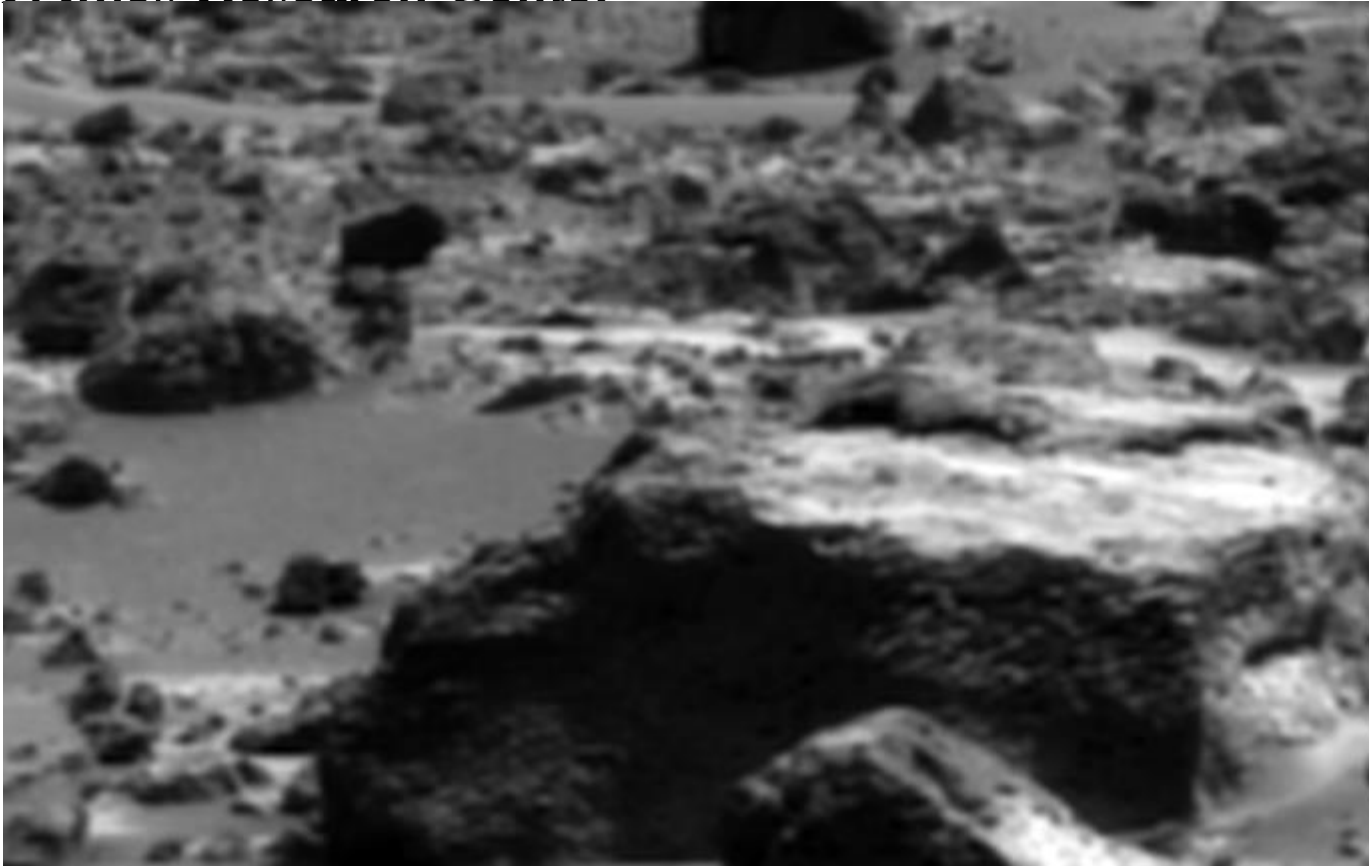


Sample Input Image

# Super-Resolution Imaging

by Peter Cheeseman, Bob Kanefsky, Robin Hanson, and John Stutz

NASA Ames Research Center



Output Image

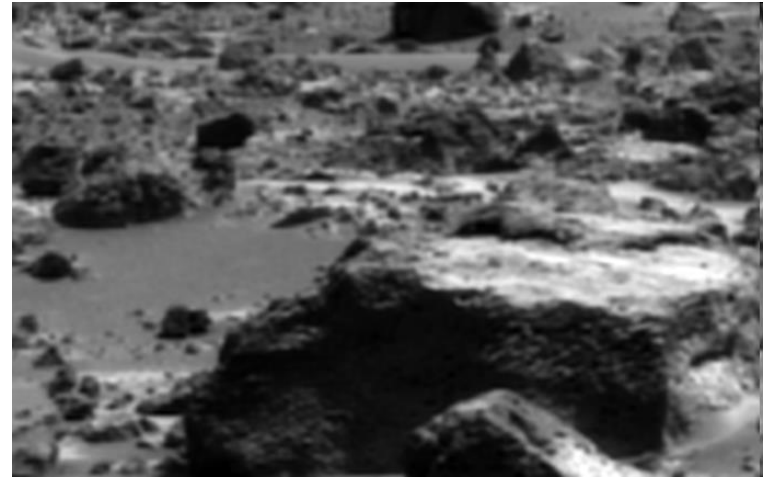
# Super-Resolution Imaging

by Peter Cheeseman, Bob Kanefsky, Robin Hanson, and John Stutz

NASA Ames Research Center



Sample Input Image



Output Image



# **Image and Depth from a Conventional Camera with a Coded Aperture**

**Anat Levin, Rob Fergus,  
Frédo Durand, William Freeman**

**MIT CSAIL**

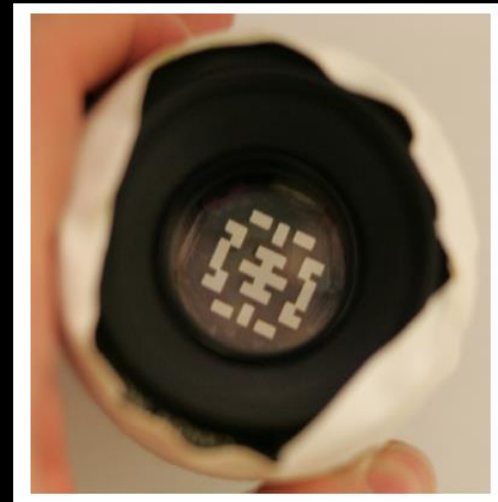
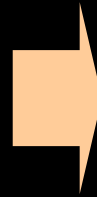
# Idea 2: Coded Aperture

---

- **Mask (code) in aperture plane**
  - make defocus patterns different from natural images and easier to discriminate



**Conventional  
aperture**



**Our coded  
aperture**

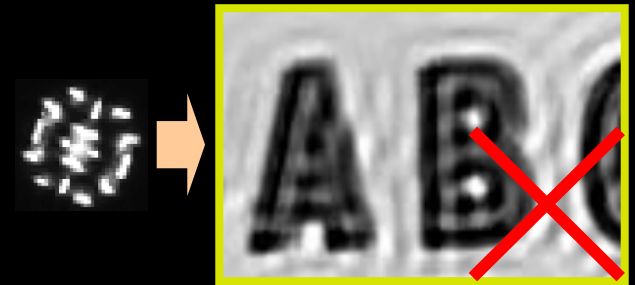
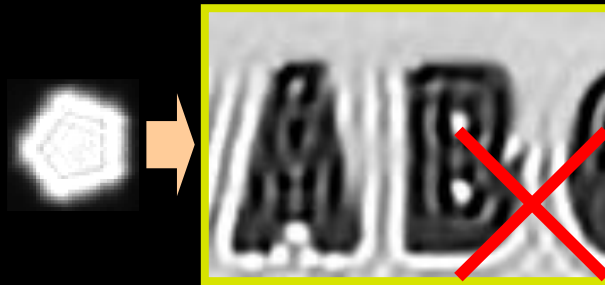
# Why coded?

Coded aperture- reduce uncertainty in scale identification

Conventional

Coded

Larger scale



Correct scale

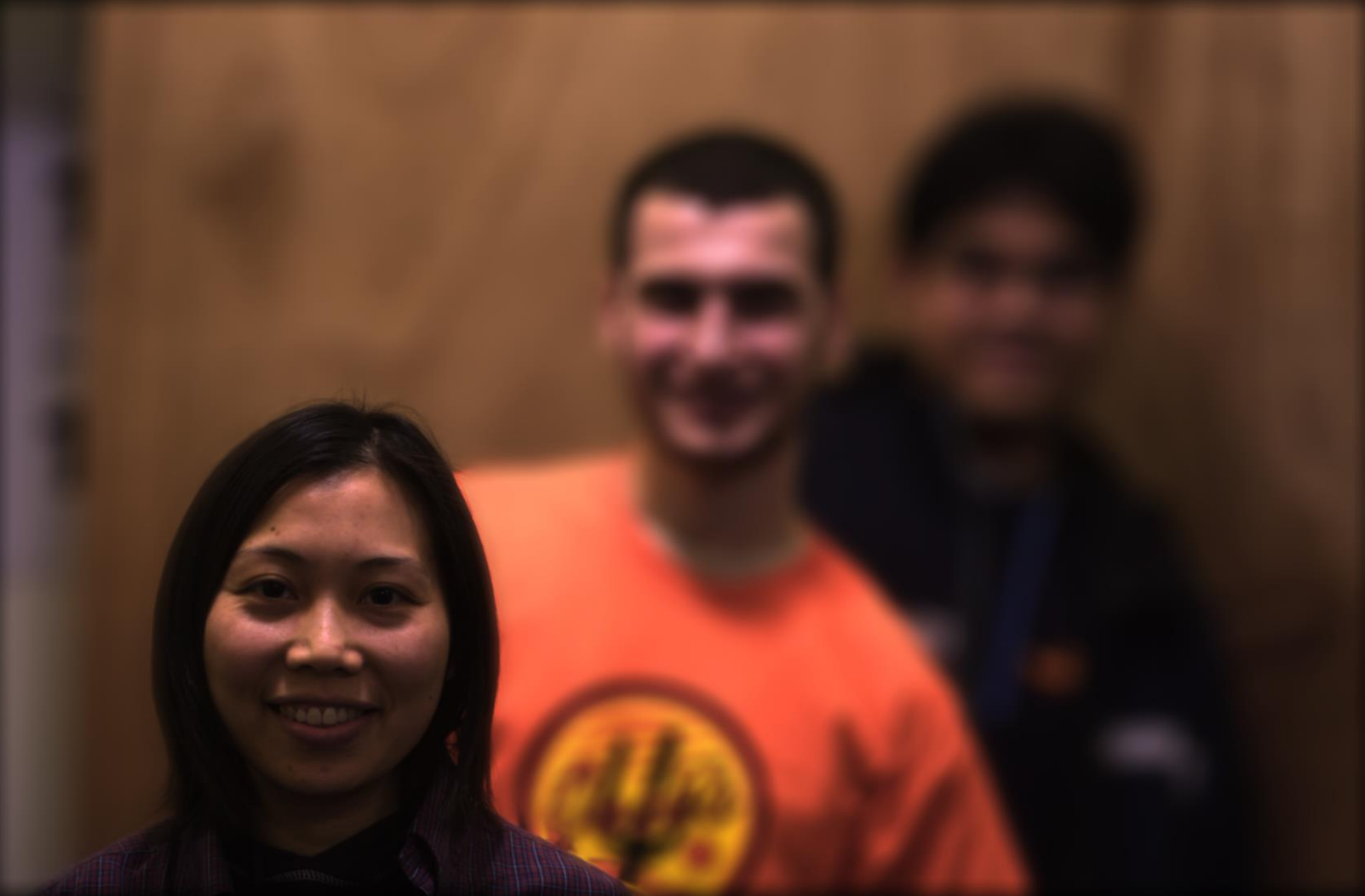


Smaller scale



# Application: Digital refocusing from a single image

---



# Application: Digital refocusing from a single image

---



# Application: Digital refocusing from a single image

---





# Application: Digital refocusing from a single image

---





How Do We Function?

# The Brain: The Living State of Matter

$10^{11}$ - $10^{12}$  Neurons

$10^4$ - $10^5$  Connections per Neuron

Maximum Firing Rate: 1 ms

1kHz massively parallel computer



The Virtual Hospital, Ch 5, Williams, Gluhbegovic, and Jew

Information Processed on order of 100s ms

**MUST use Prior Information**

# A Powerful Computer

Here is an excellent example of how your wonderful mind can read this text even though its all jumbled.

# Sounds and Prior Information

Listen to these sounds...



Sounds from Haskins Laboratories, Rubin, Remez, Pardo

# Sounds and Prior Information

Now listen to this one...



Sounds from Haskins Laboratories, Rubin, Remez, Pardo



# Sounds and Prior Information

And now go back to this one...



Sounds from Haskins Laboratories, Rubin, Remez, Pardo

# Sounds and Prior Information

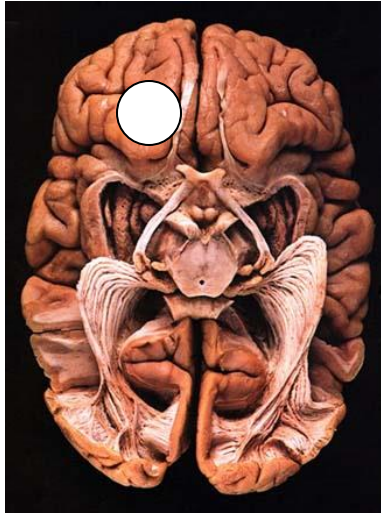
What about the rest?



Sounds from Haskins Laboratories, Rubin, Remez, Pardo

# Prior Information is Key

Only 10% of the inputs into primary visual cortex come from the retina via the lateral geniculate nucleus. The rest come from higher visual and frontal areas.



Human Brain: basal view (front at top)  
The Virtual Hospital, Ch 5, Williams, Gluhbegovic, and Jew

Perception can also be modified by attention.

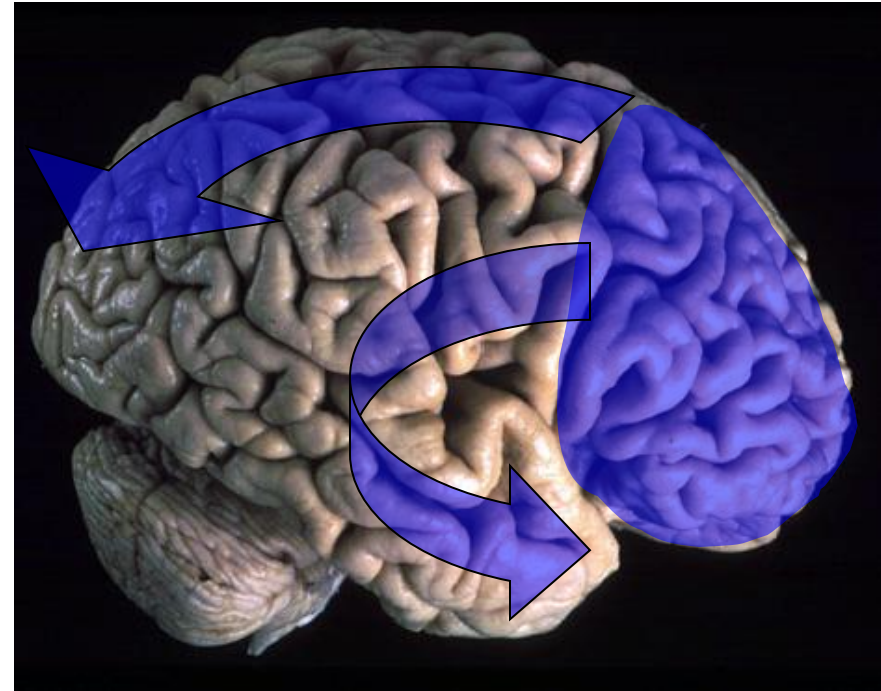
Thus the brain can actively focus on **relevant information**.

# The Brain Models its Environment

The frontal regions of the brain create models of the world based on prior experience. These models affect perception and attention.

In addition, the brain models itself.

Experiments in multi-sensory processing has shown that the information processing is consistent with Bayes Theorem



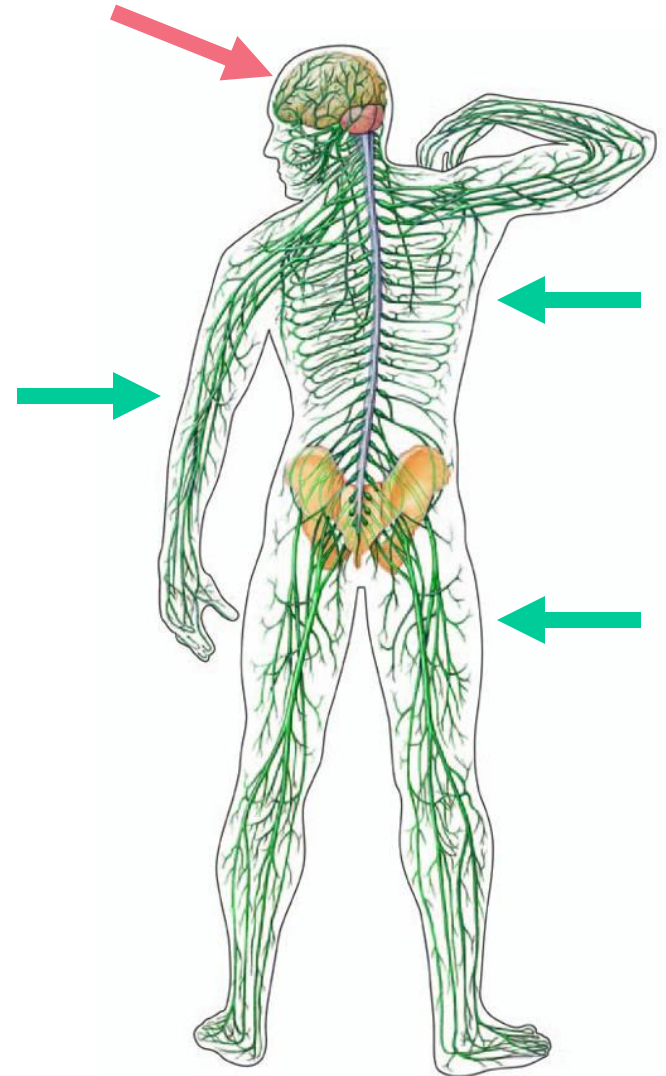
The Virtual Hospital, Ch 5, Williams, Gluhbegovic, and Jew

# Thinking Machines

Your **frontal lobes** carry a model of yourself that is continually updated from data received from a **dense sensor network**. This implements both 'Instrument Health Monitoring' and 'Calibration'

You **learn** from new data by updating your model of the world.

You actively seek new data by **asking relevant questions.**



# Body and Brain form a Symbiotic Unit



Bayesian Data Analysis

Perception  
and  
Relevant Questions





# Relevance and Perception



A. L. Yarbus, *Eye Movements and Vision*, Plenum, New York, 1967  
(Originally published in Russian 1962)

# Free Examination



**Three minute  
recording**

A. L. Yarbus, *Eye Movements and Vision*, Plenum, New York, 1967  
(Originally published in Russian 1962)

# Estimate Ages of the People



**Three minute  
recording**

A. L. Yarbus, *Eye Movements and Vision*, Plenum, New York, 1967  
(Originally published in Russian 1962)

# Remember their Clothes



**Three minute  
recording**

A. L. Yarbus, *Eye Movements and Vision*, Plenum, New York, 1967  
(Originally published in Russian 1962)

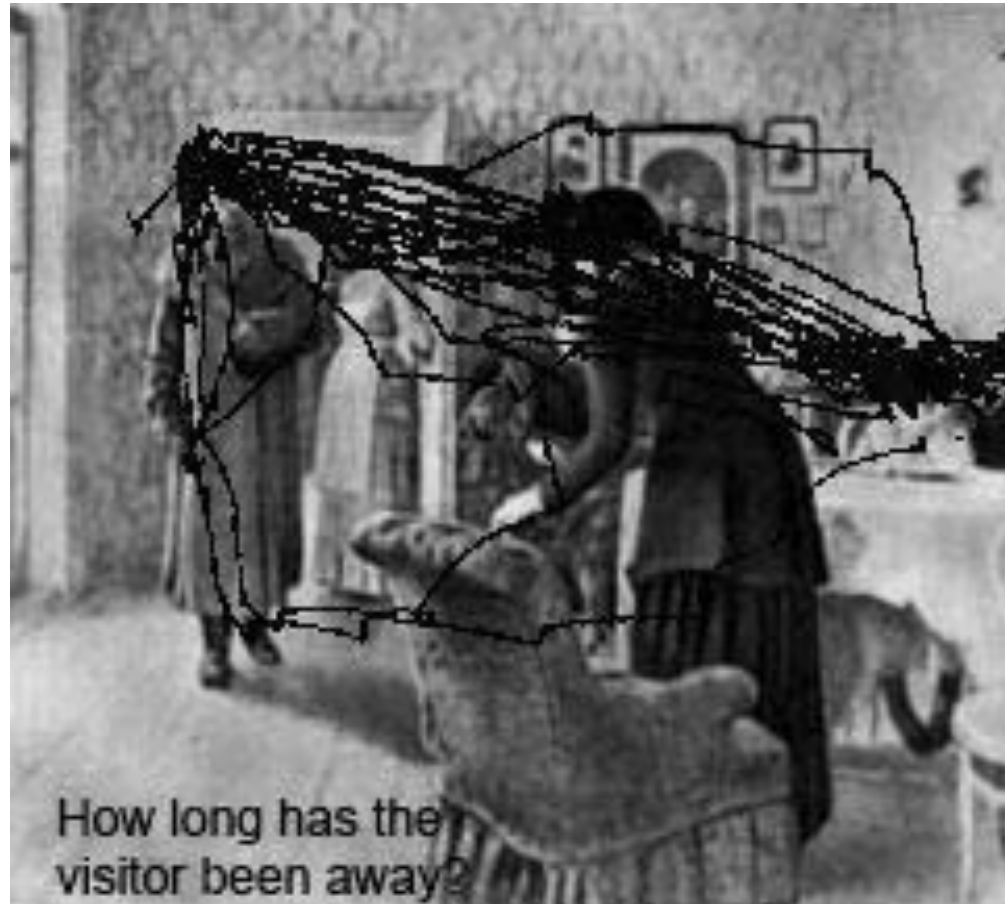
# Estimate Material Circumstances



**Three minute  
recording**

A. L. Yarbus, *Eye Movements and Vision*, Plenum, New York, 1967  
(Originally published in Russian 1962)

# How Long has the Visitor been away?

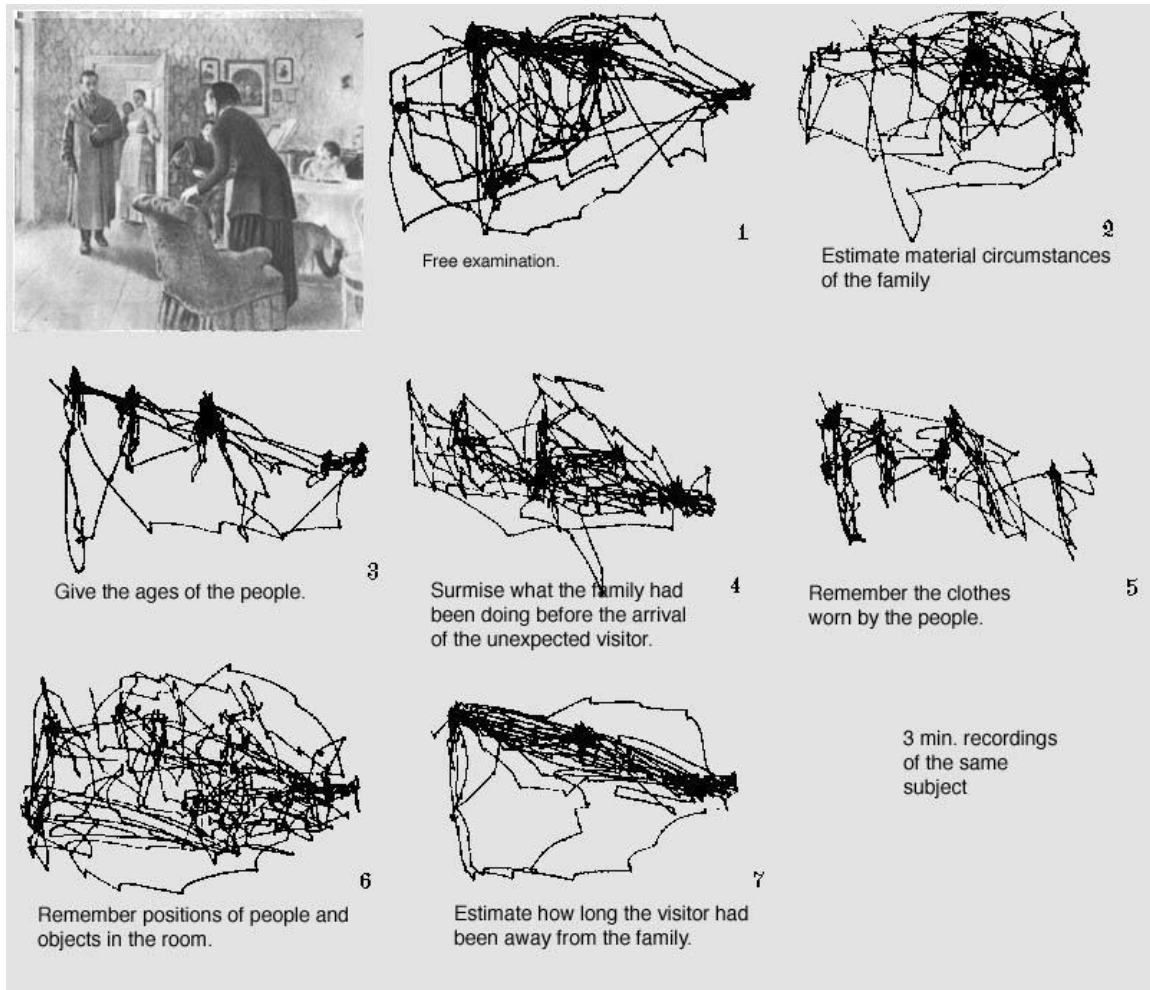


**Three minute  
recording**

A. L. Yarbus, *Eye Movements and Vision*, Plenum, New York, 1967  
(Originally published in Russian 1962)



# Relevance and Perception



A. L. Yarbus, *Eye Movements and Vision*, Plenum, New York, 1967  
(Originally published in Russian 1962)

Do We Analyze Everything?





