Frame Rate and Human Vision

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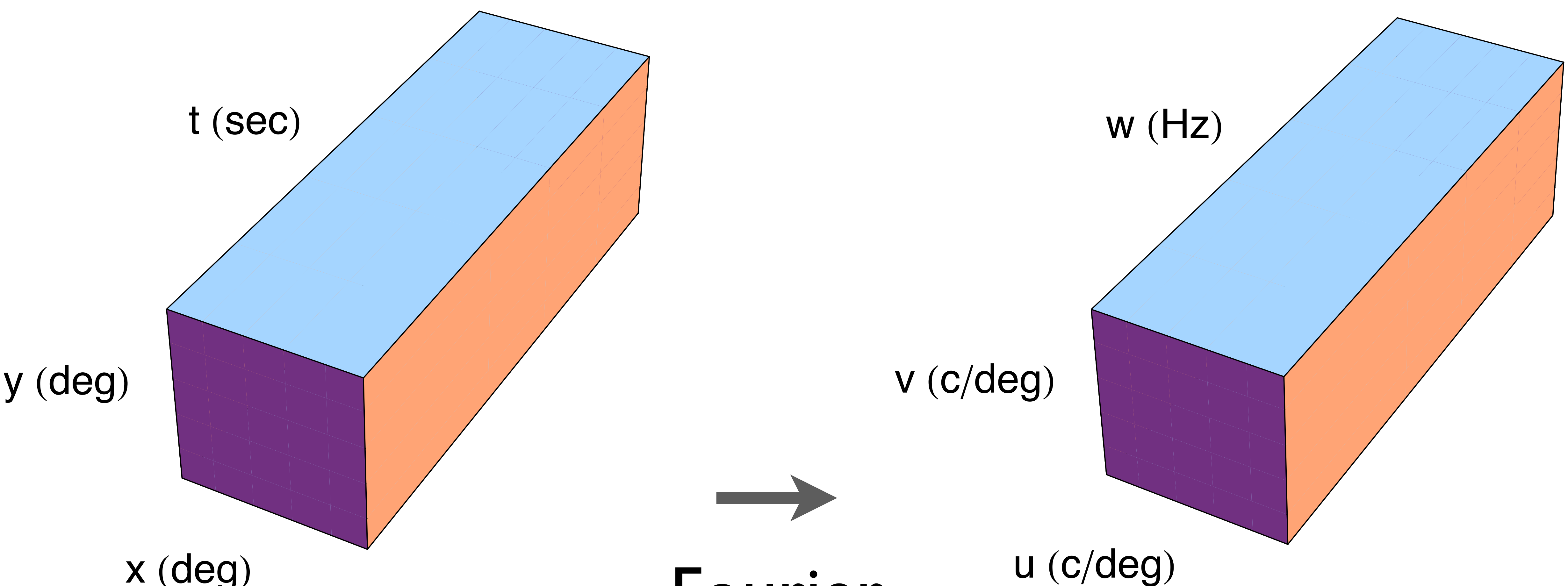
Stroboscopic Displays

- All cinema and video is stroboscopic
- A sequence of still images

Lumière Cinématographe, 1896

Movies in the Frequency Domain



Fourier Transform

Spatio–temporal frequencies

Frequency (cy/deg) = 4.00

Orientation (°) = 0.00

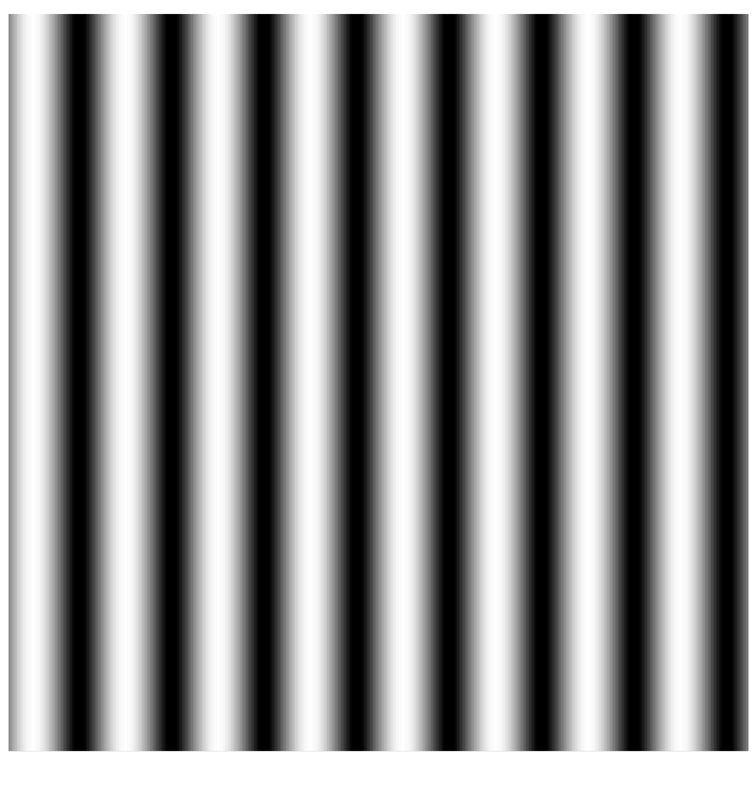
Contrast = 1.00

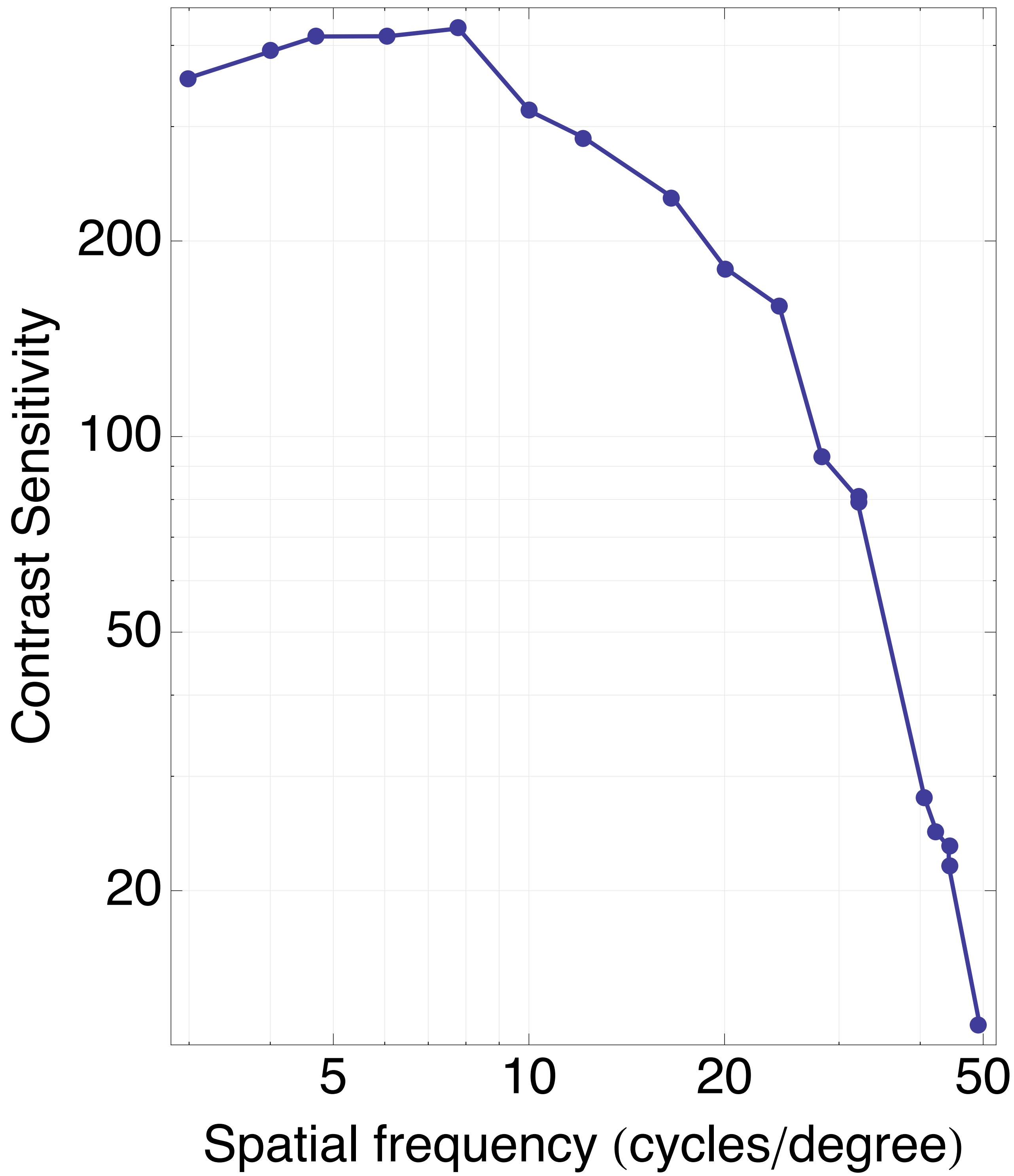
color G R/G B/Y

k

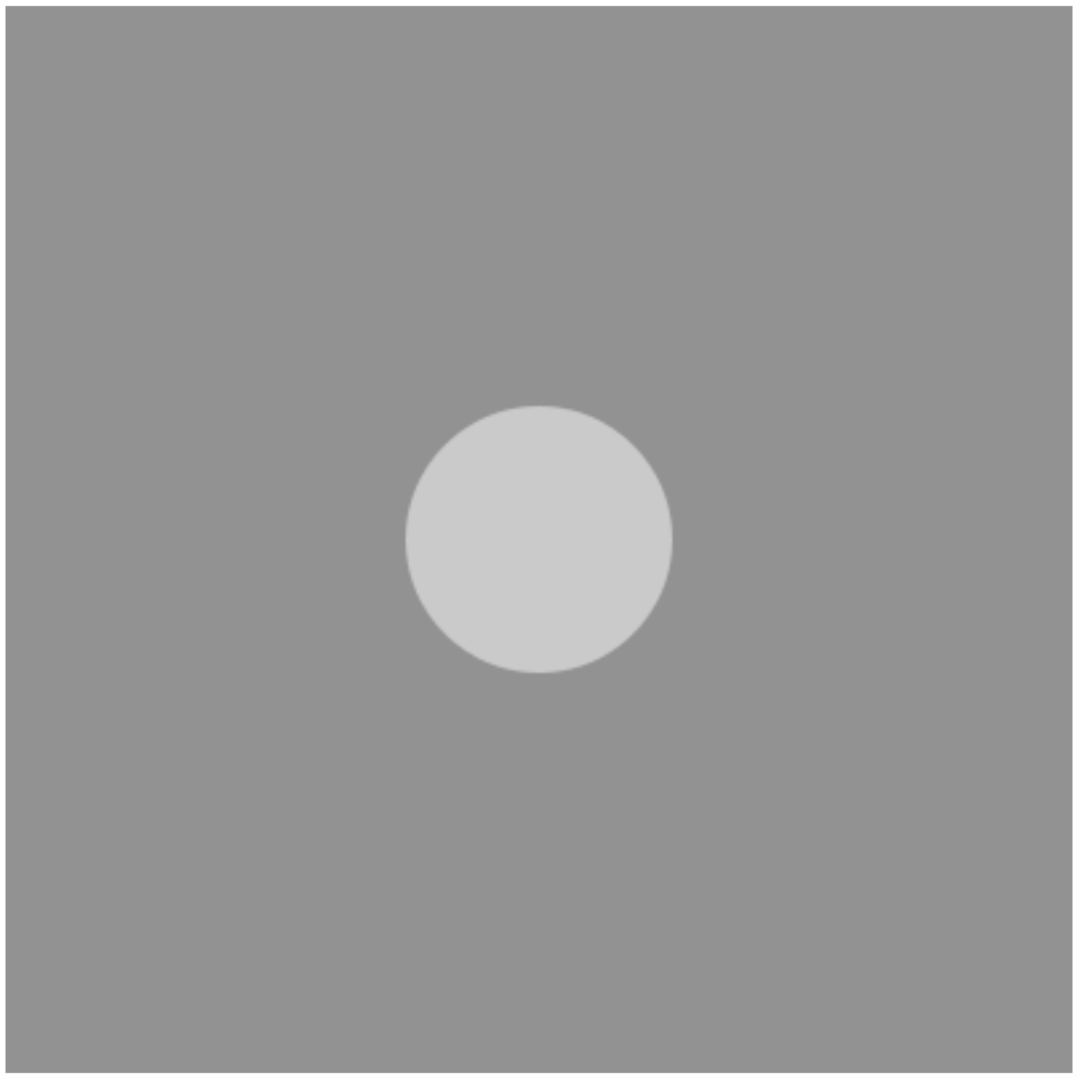
Spatial CSF

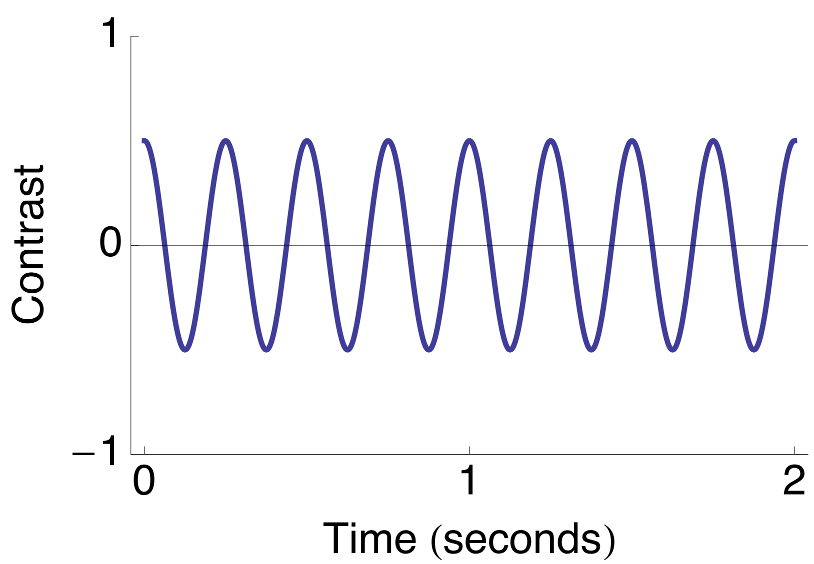
8 cycles/degree

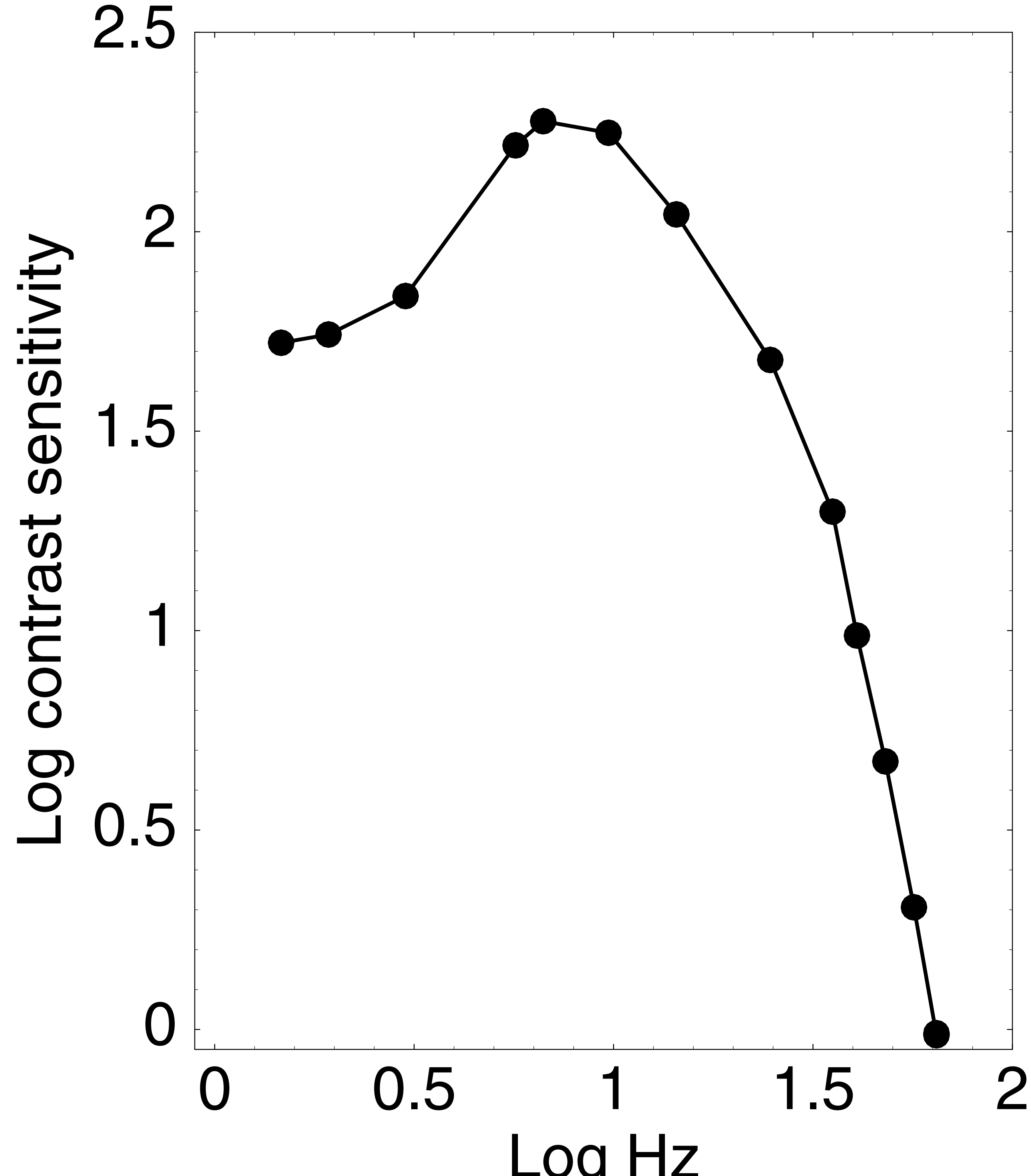




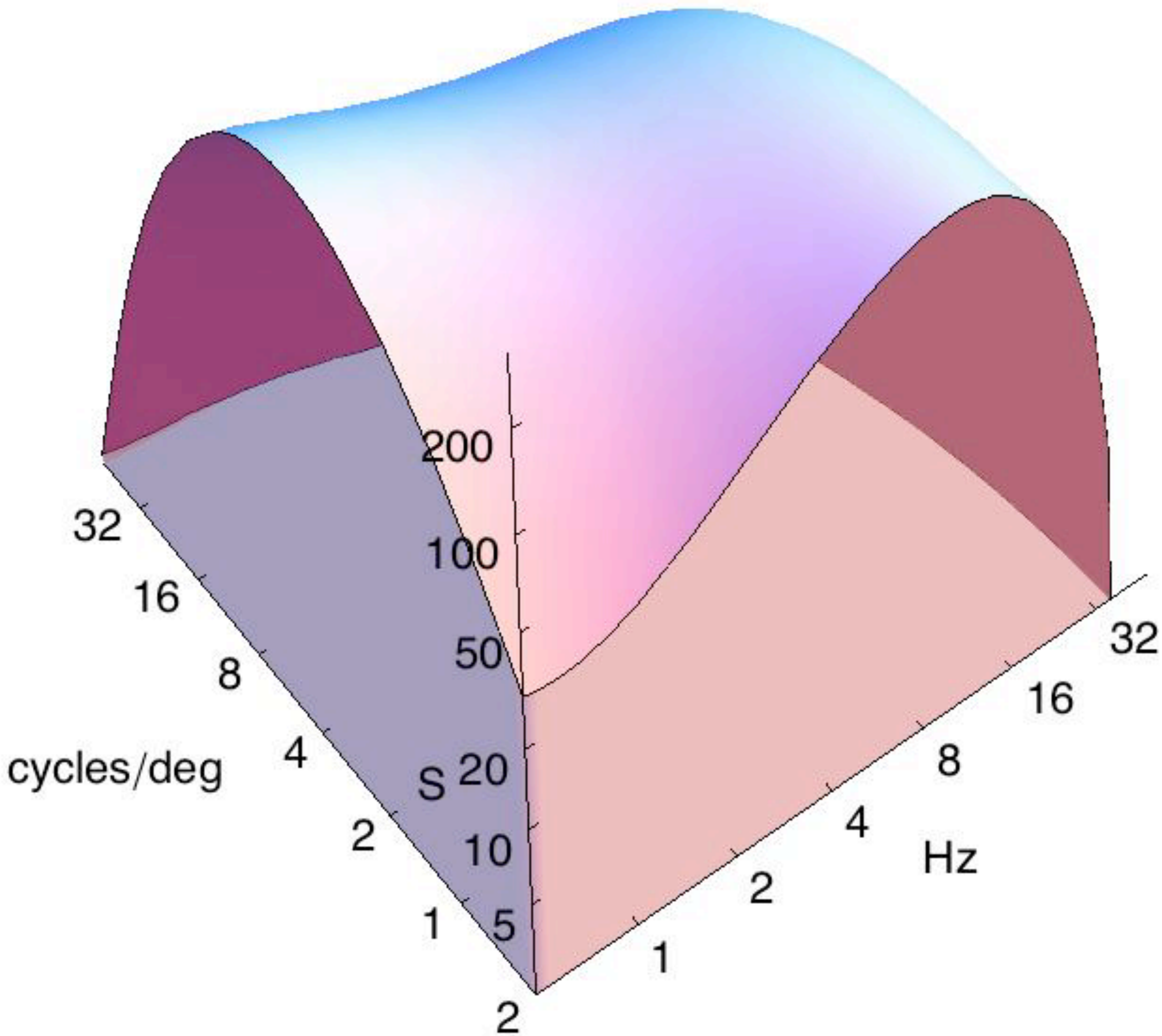
Temporal CSF



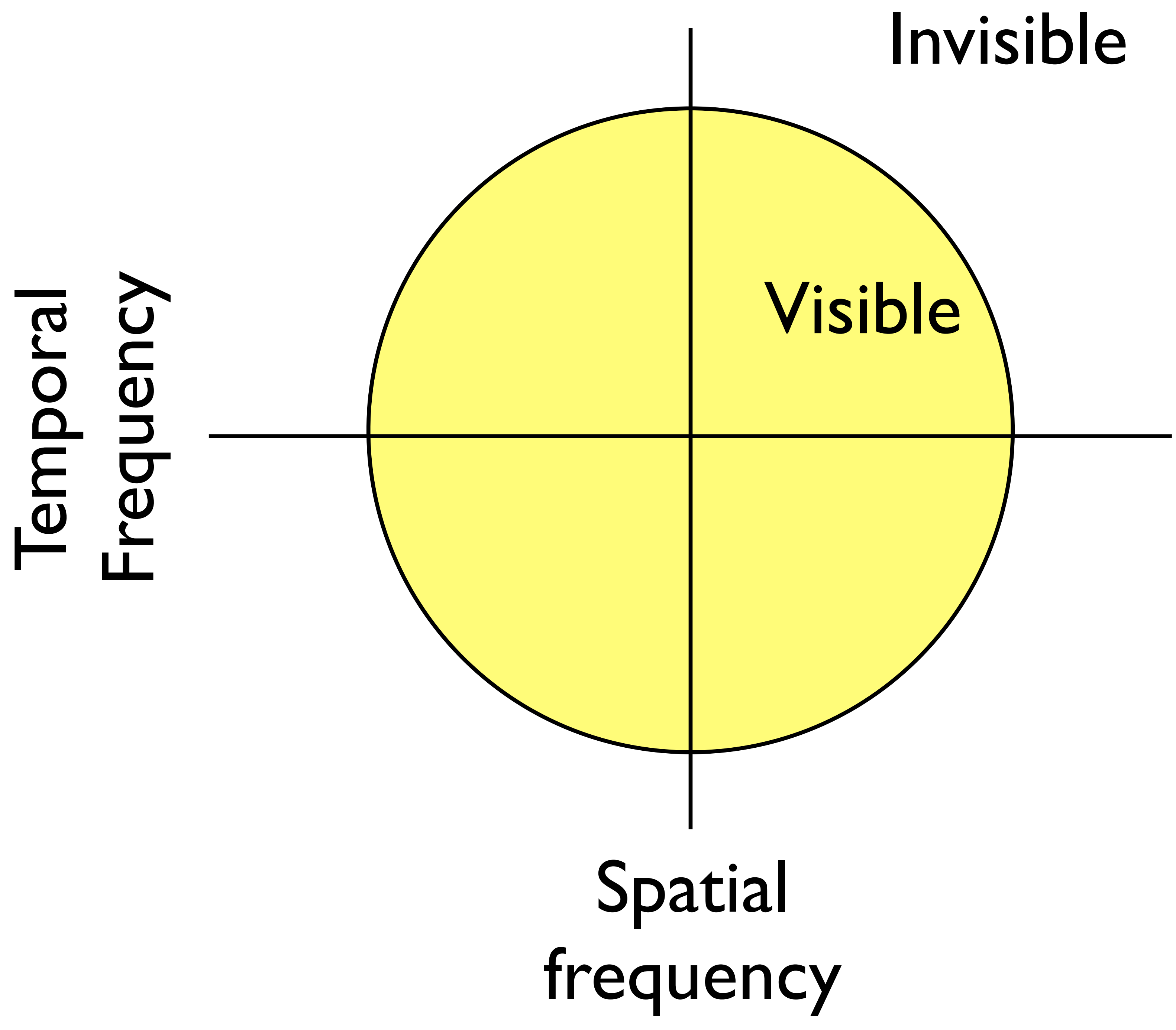




Spatio-Temporal CSF

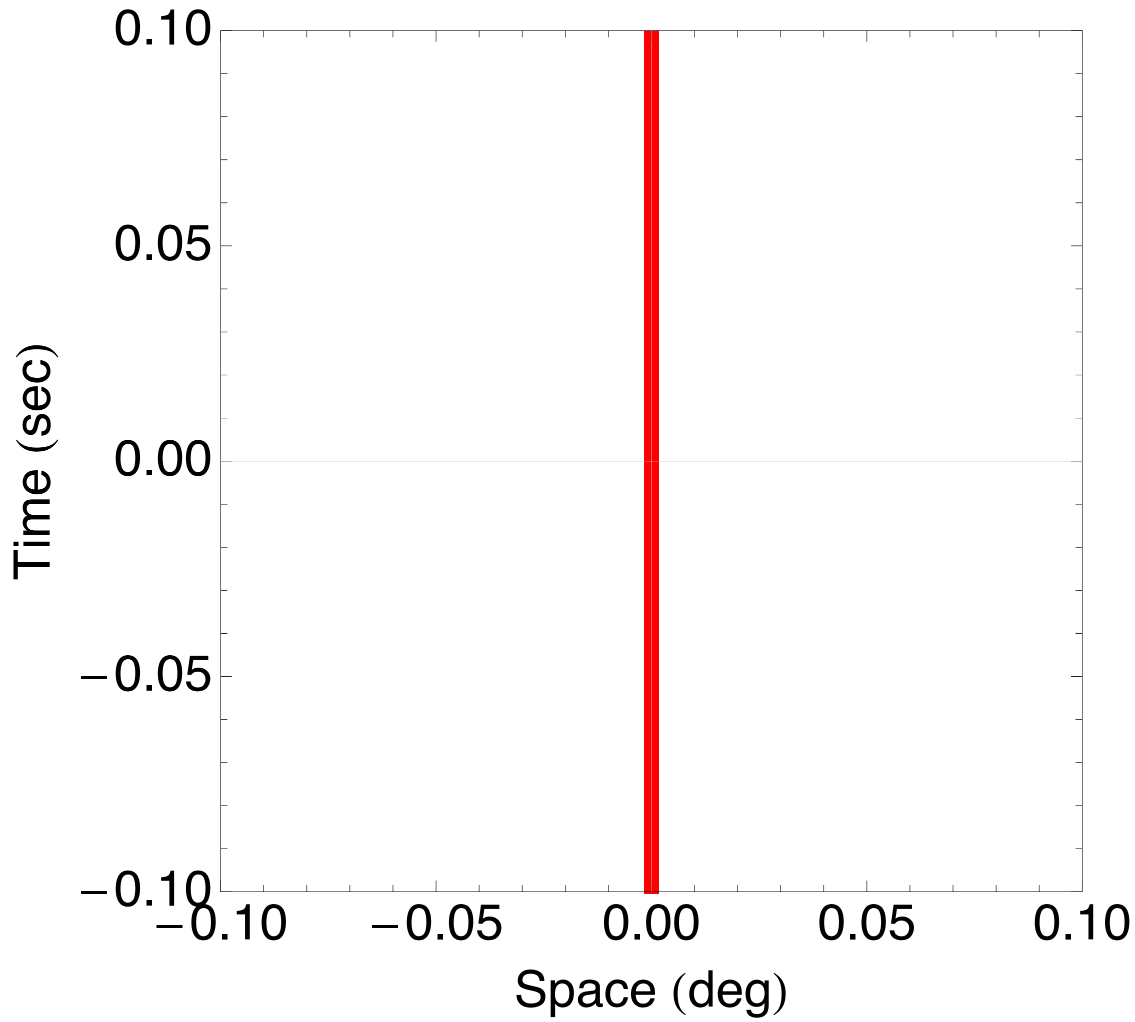


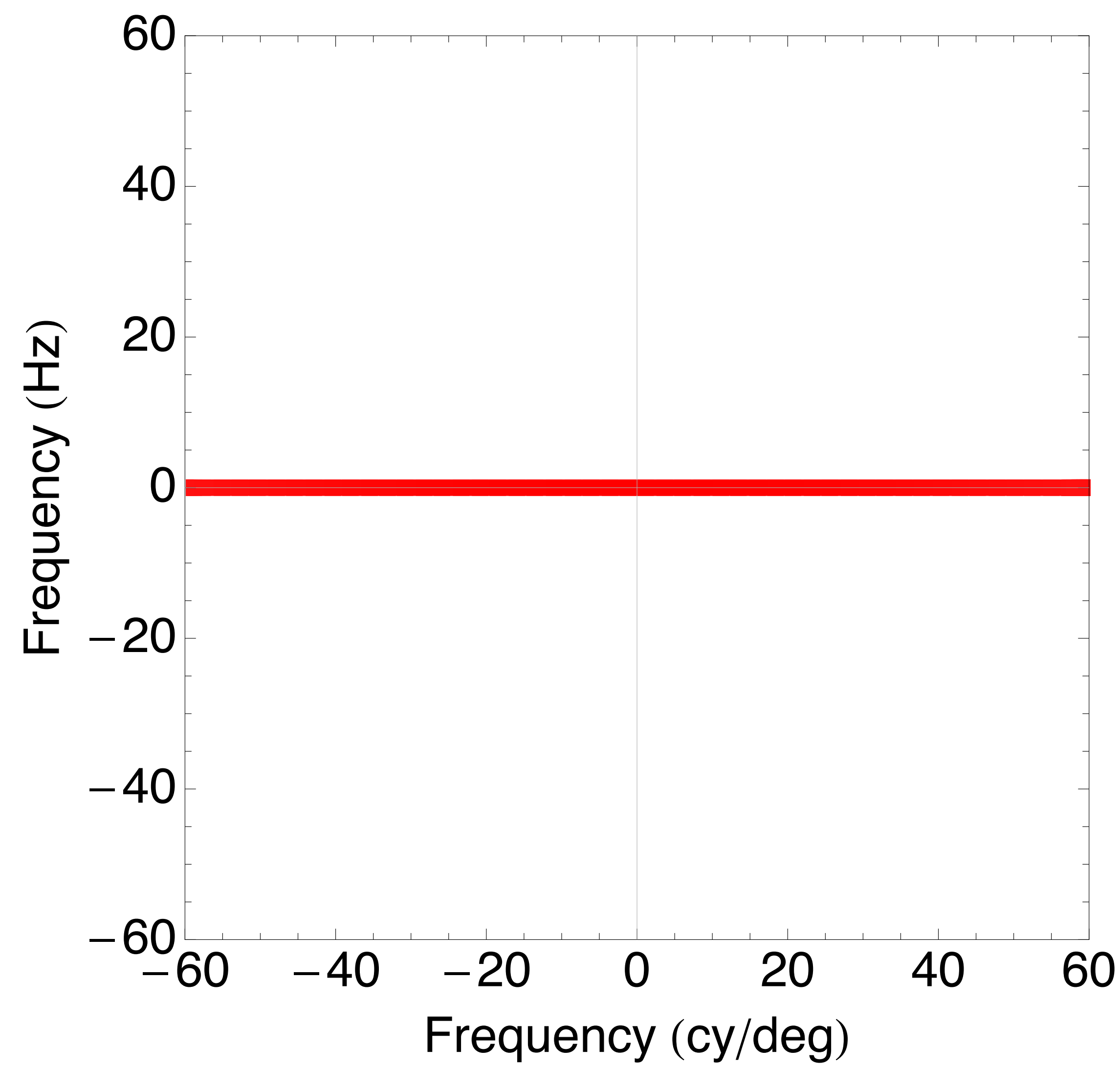
Window of Visibility



Moving line

Window of Visibility





Speed (deg/sec) = 0.00

Frame rate (Hz) = 240.

Shutter (frames) = 1.00

Blur (deg/60) = 0.20

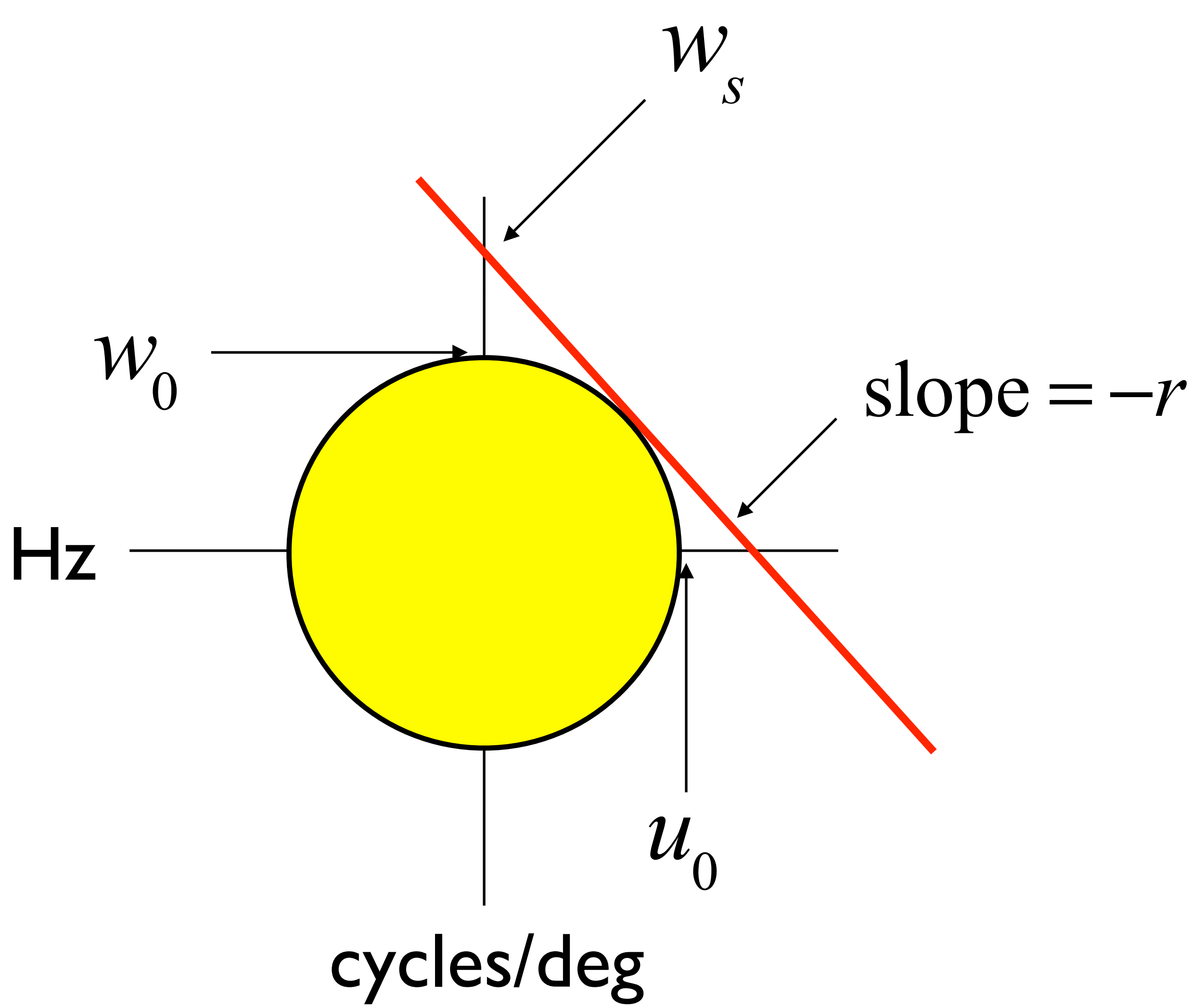
Hold (fields) = 1.00

Flicker (# fields) 1 2 3 4 5

Sampled

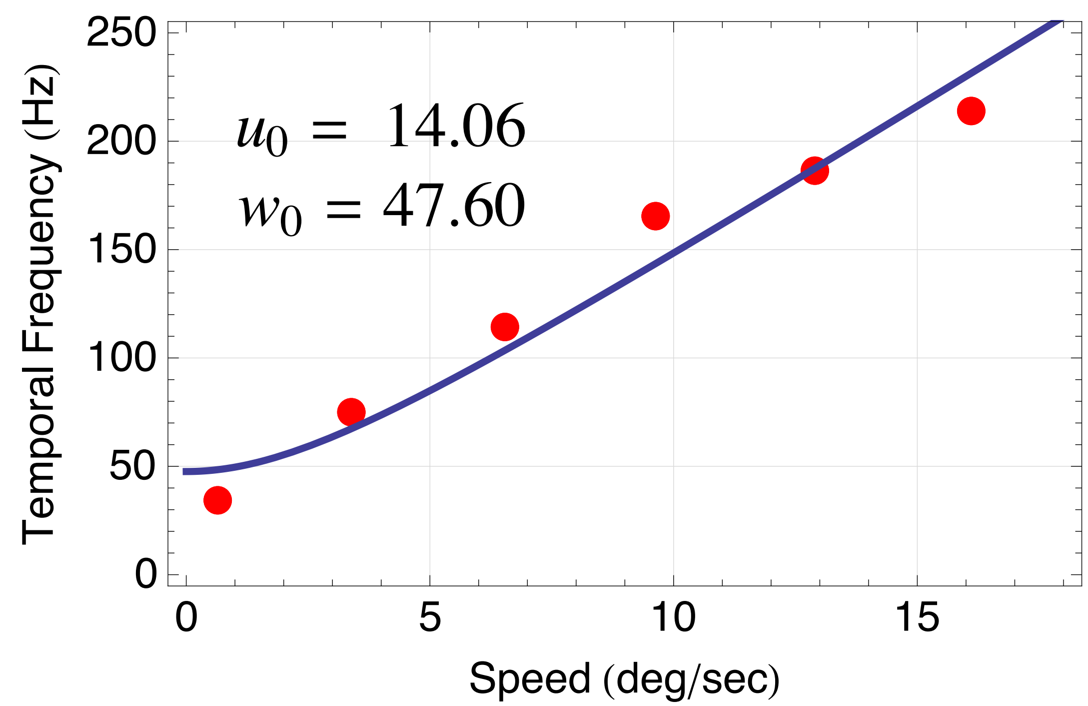
Critical Frame Rate

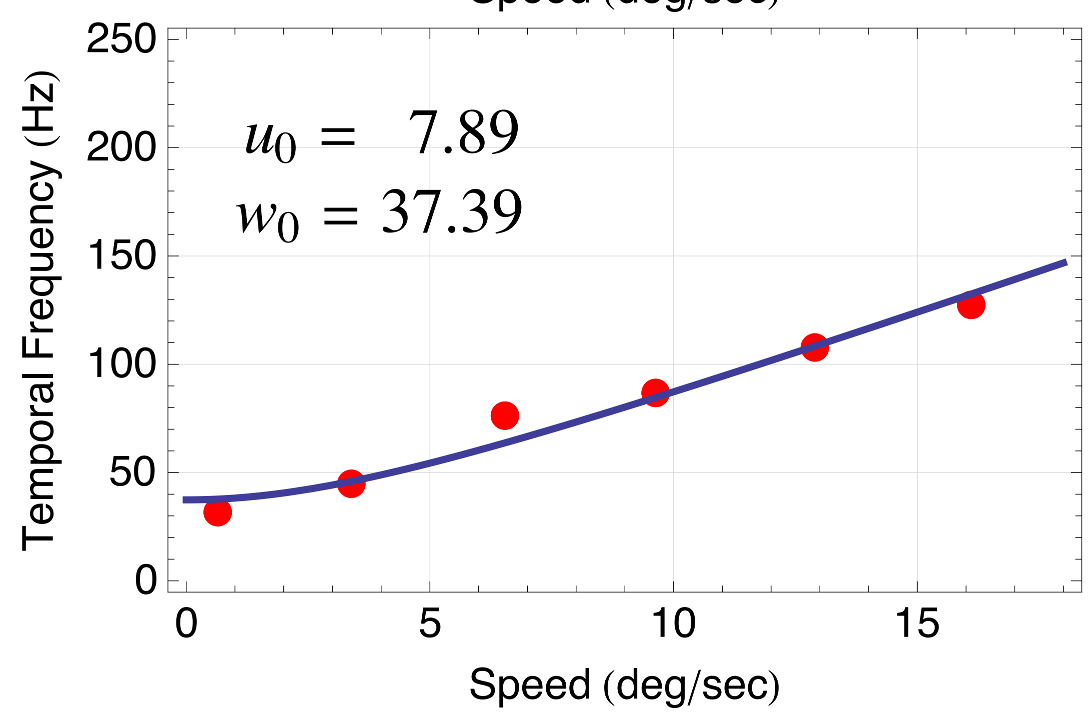
Theory



$$w_s = \sqrt{r^2 u_0^2 + w_0^2}$$

Data





Preliminary Summary

- Understanding the spatio-temporal frequency spectrum of the source,
- and the spatio-temporal frequency sensitivity of the human,
- allows you to predict the required frame rate.

Effects

- Object spectrum
- Camera blur
- Exposure duration
- Display hold
- Display flicker
- Brightness
- Color
- Eye movements

Math

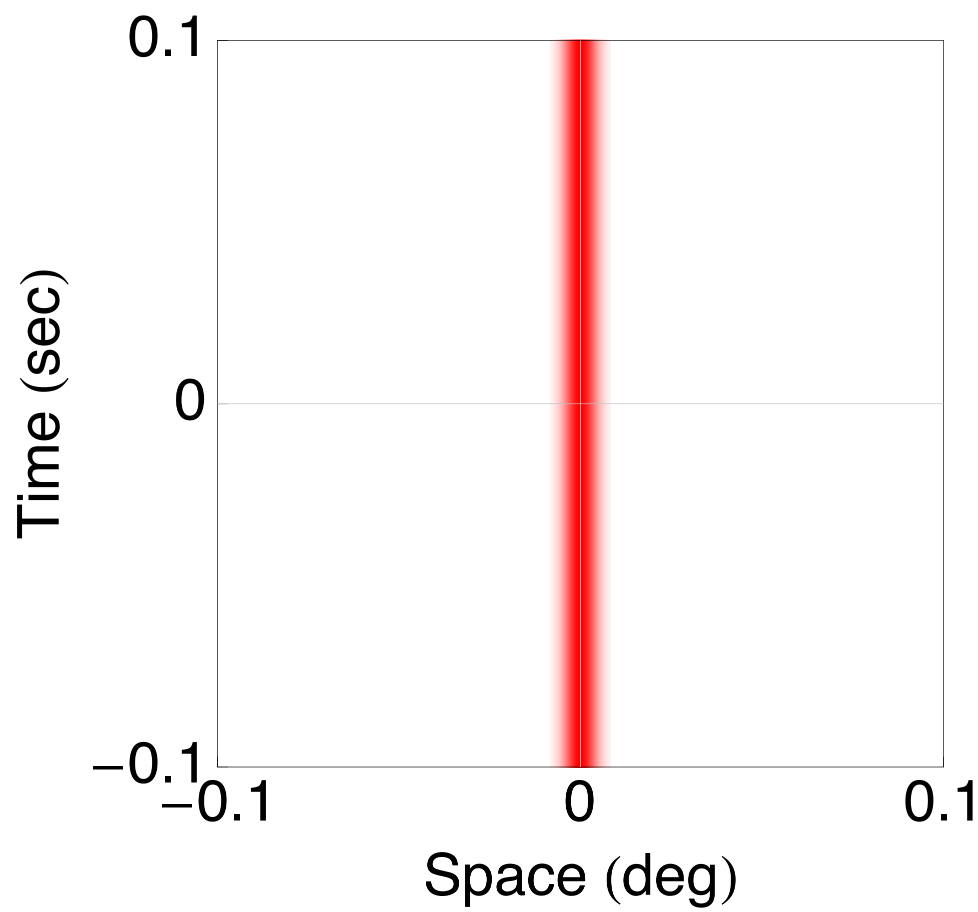
object motion exposure sampling flicker hold

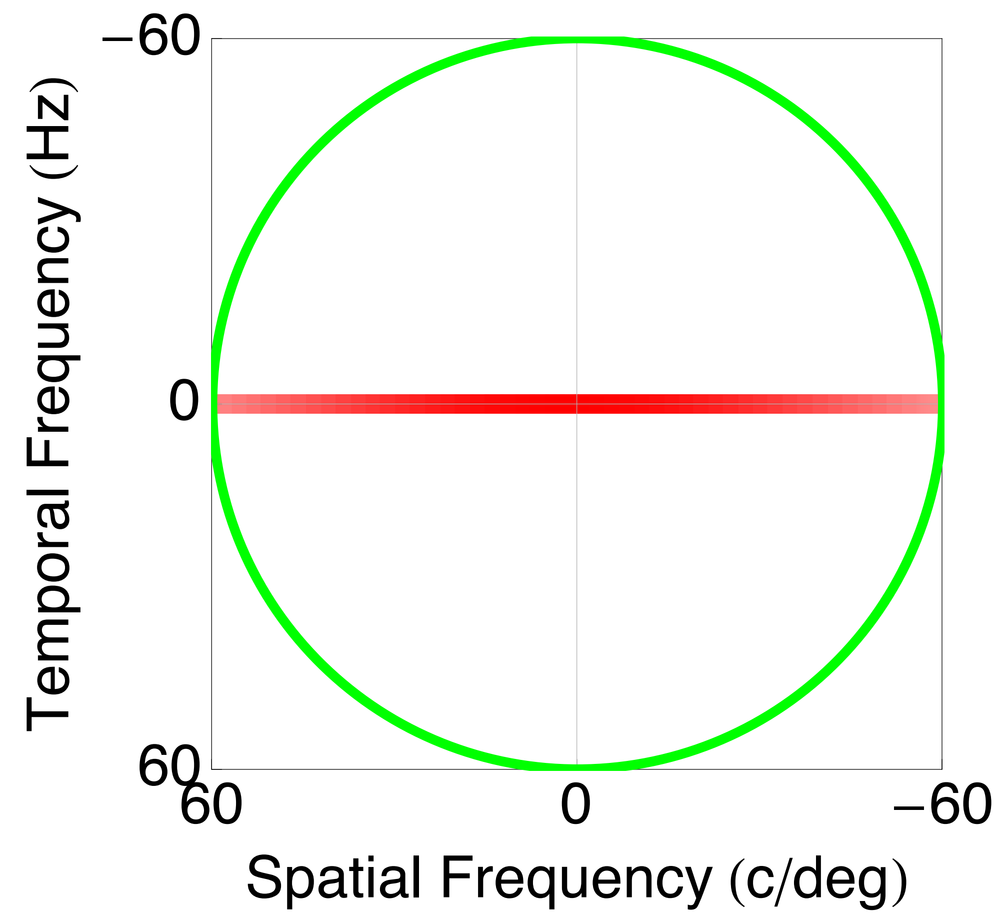
$$\left(\left(\left(o(x)*m(x,t)\right)*e(t)\right)s(t)\right)*f(t)*h(t)$$

$$\Big\updownarrow \text{ Fourier Transform}$$

$$\left(\left(O(u)\,M(u,w)\,E(w)\right)*S(w)\right)H(w)\,F(w)$$

Window of Visibility





Speed (deg/sec) = 0.00

Frame rate (Hz) = 240.

Shutter (Frames) = 0.10

Blur (deg/60) = 0.50

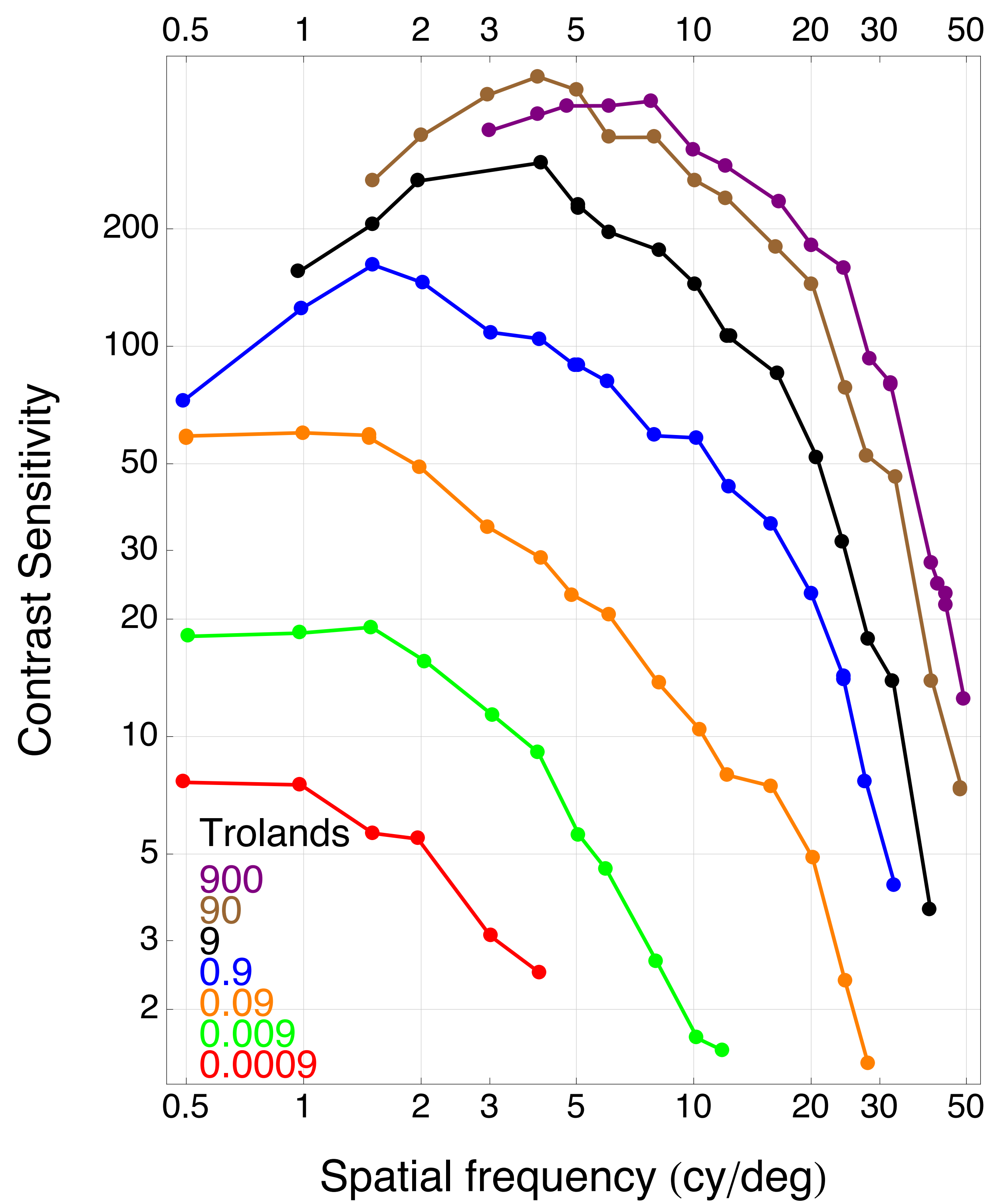
Hold (Fields) = 0.10

Flicker fields 1 2 3 4 5

Sampled

SCSF vs Illuminance

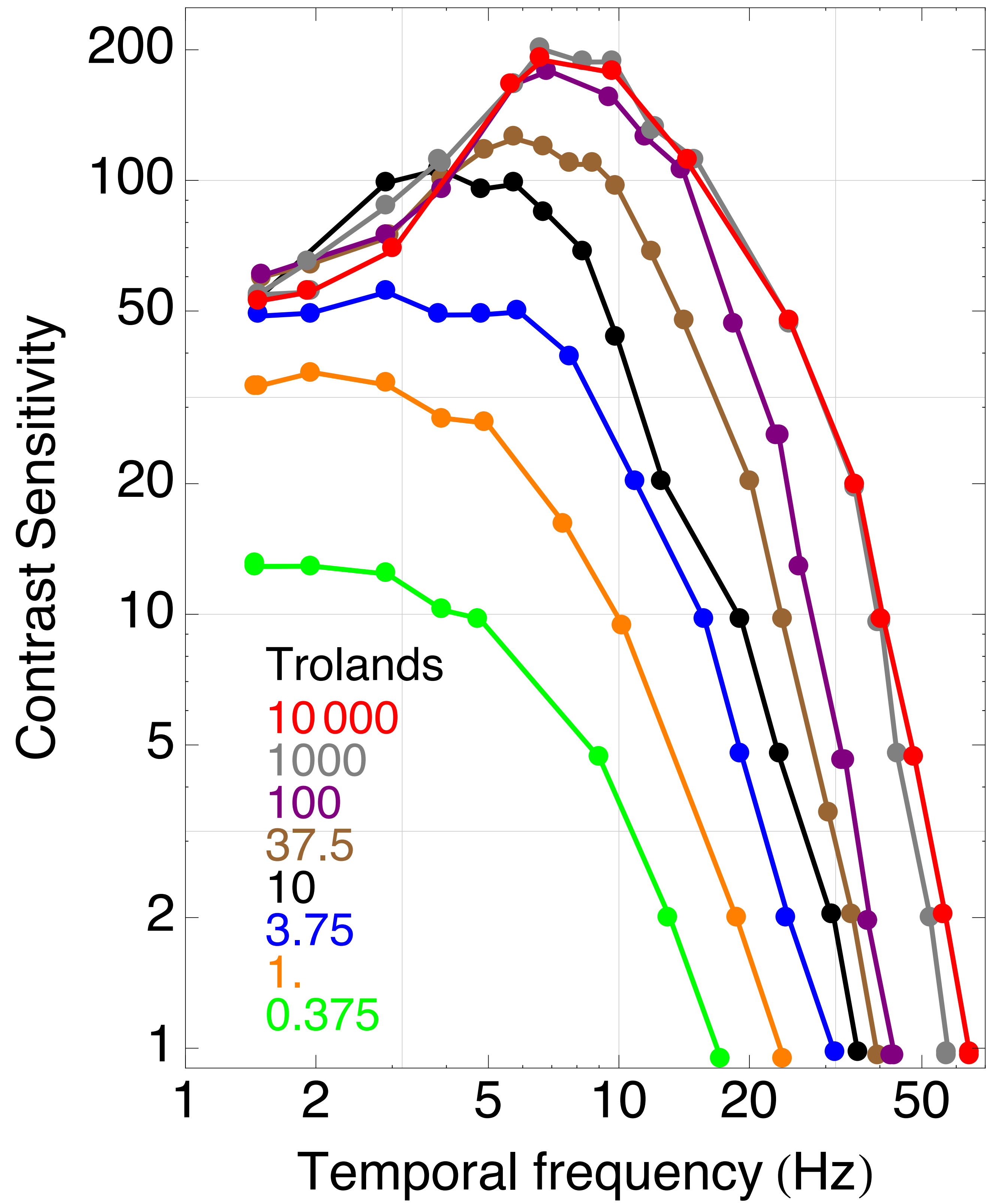
- Dimmer backgrounds
  - reduce sensitivity
  - decrease resolution
- Asymptotes at high brightness



Data from Van Nes & Bouman (1967)

TCSF vs Illuminance

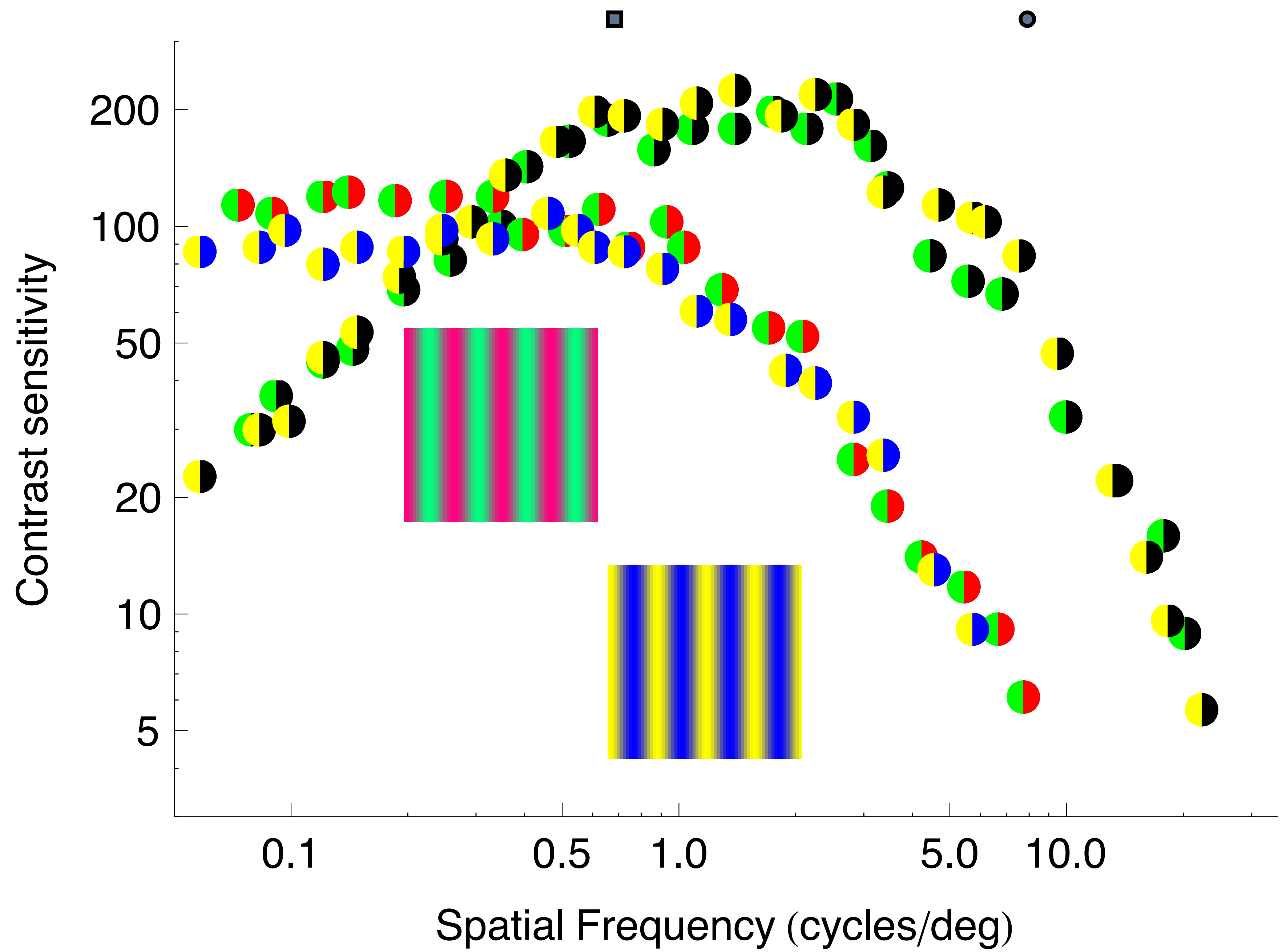
- Dimmer backgrounds
  - reduce sensitivity
  - decrease resolution
- Asymptotes at high brightness



Data from De Lange (1958)

SCSF vs Color

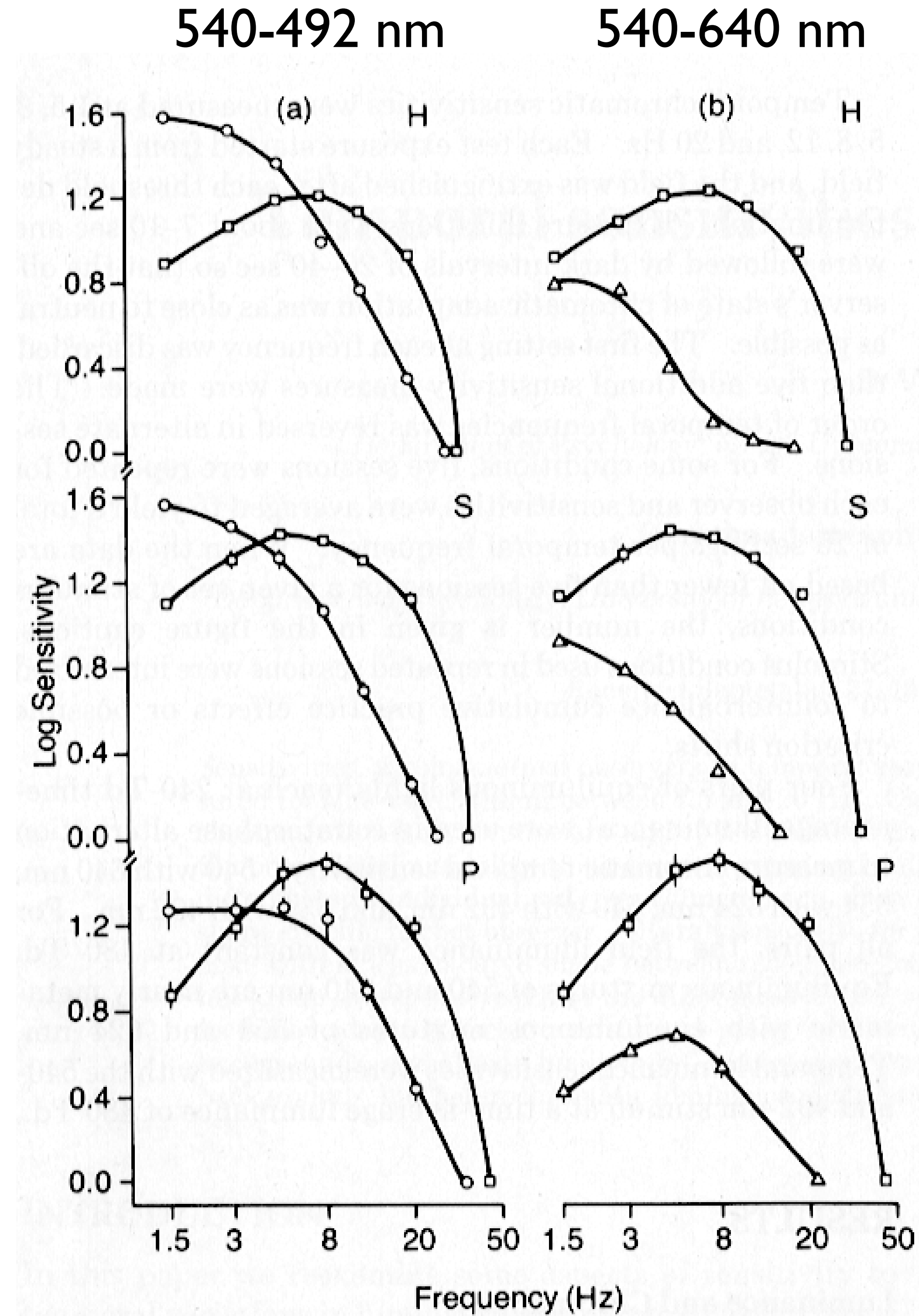
- Color modulation
  - lower sensitivity
  - lower resolution



Mullen, K. T. (1985). The contrast sensitivity of human color vision to red/green and blue/yellow chromatic gratings. *Journal of Physiology, Lond*. 359(381-400).

TCSF vs Color

- Color modulation yields lower temporal resolution
- Luminance and Chromaticity sensitivities for two color directions and three observers.

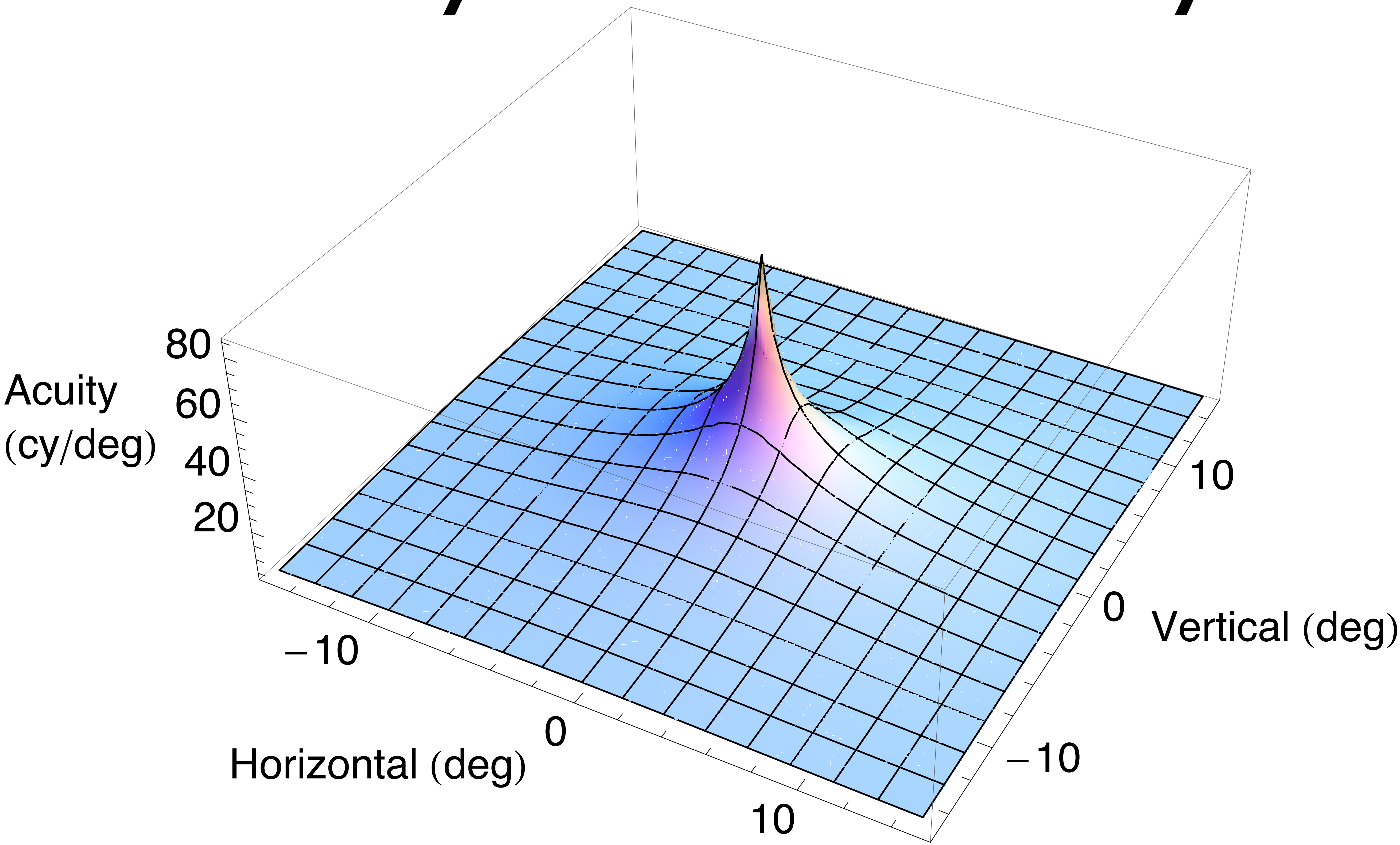


From Varner (1984)

Effects on Window Size

- Dimmer ➔ smaller
- Color ➔ smaller
- Periphery ➔ smaller
- Smaller window ➔ fewer visible artifacts

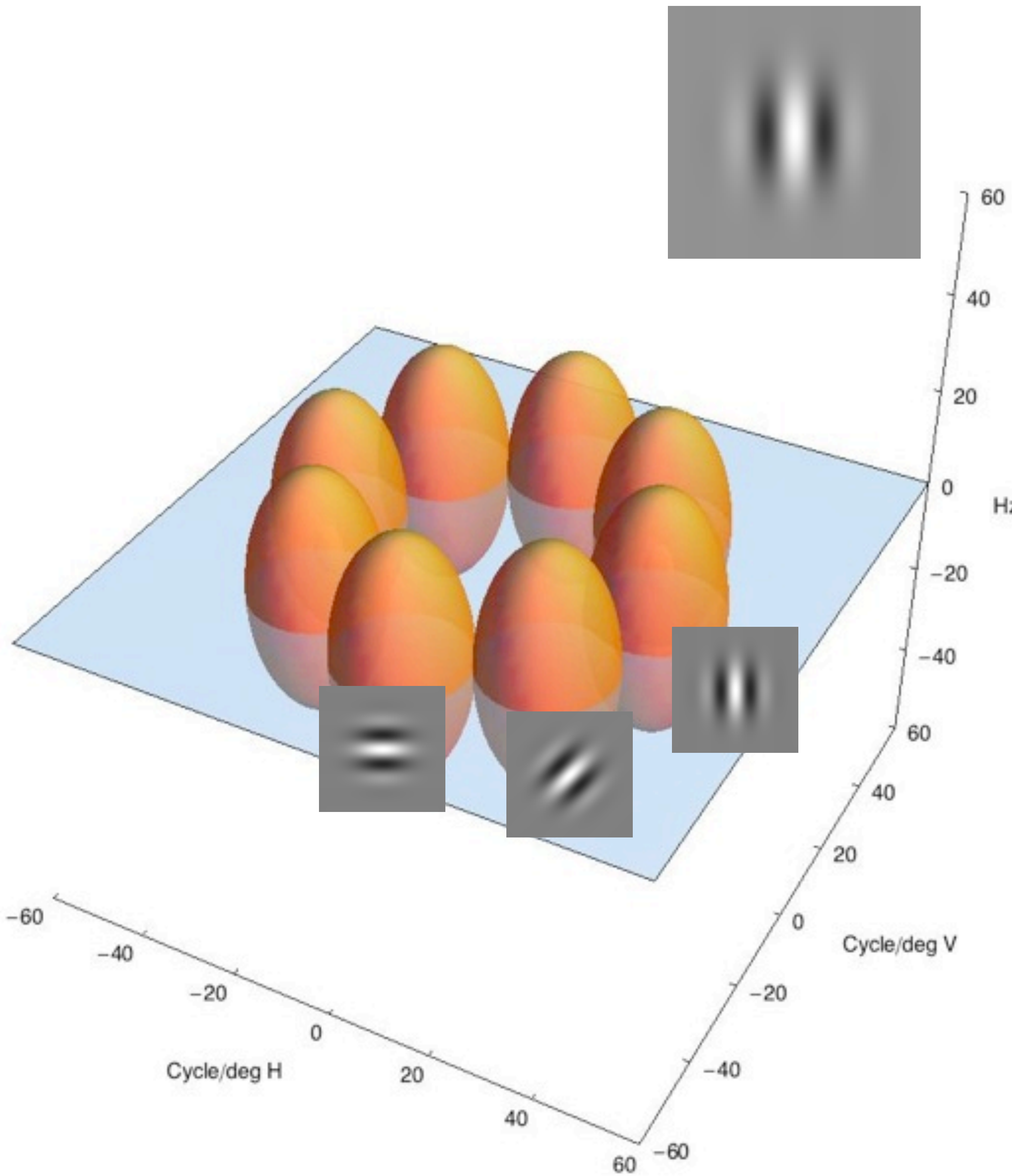
Acuity vs Eccentricity



Eye-movements

- Visual system responds to retinal image motion
- When the eye tracks an object, its retinal motion is reduced or eliminated
- Other objects are not tracked, but they lie in the low-resolution periphery

Channels


60
40
20
0
Hz
−20
−40
60
40
20
0
Cycle/deg V
−20
−40
−60
−60
−40
−20
0
Cycle/deg H
20
40
60

Summary

- Window of Visibility predicts frame rate effects
- Can incorporate effects of content, camera, display & observer
- Benefits may be greater in coding than in capture

References

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