Refractive error sensing in natural multifocal eyes

Rafael Navarro

icma / Instituto de Ciencia de Materiales de Aragón /
CSIC Consejo Superior de Investigaciones Científicas
Universidad Zaragoza

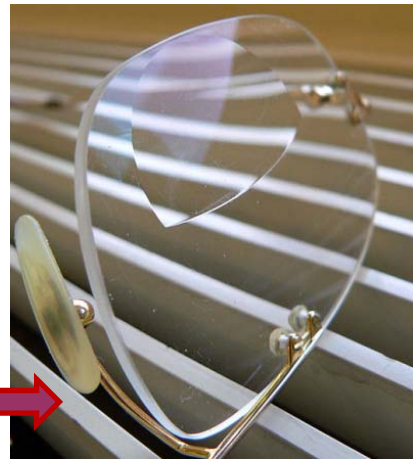
Universidad de Murcia

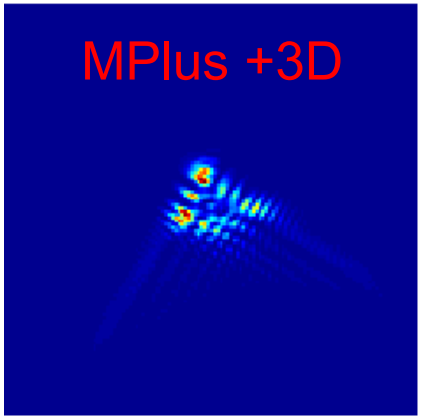
Vicente Fernández-Sánchez
& Norberto López-Gil

Introduction

Bifocal designs:

- Spherical aberration
  (aspherical, axicons, etc.)
- Coma
- Combinations of HOA





Bifocal eyes? Progressive?

Refraction changes across pupil

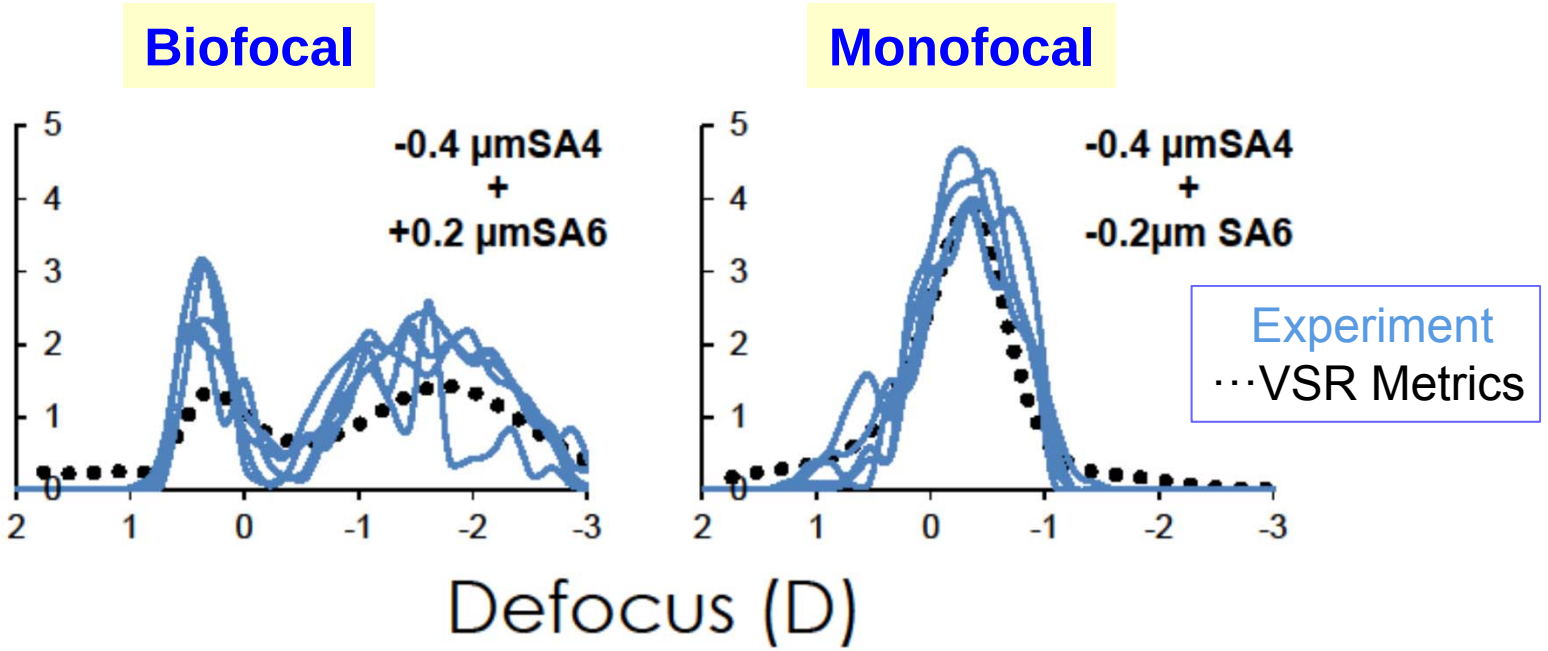
- Koomen et al., 1949; Ivanoff, 1953
- Charman & Walsh, 1989
- Legras & Bernard, 2011; Legras et al. 2012

Introduction

Human Eyes:

Trough focus visual quality

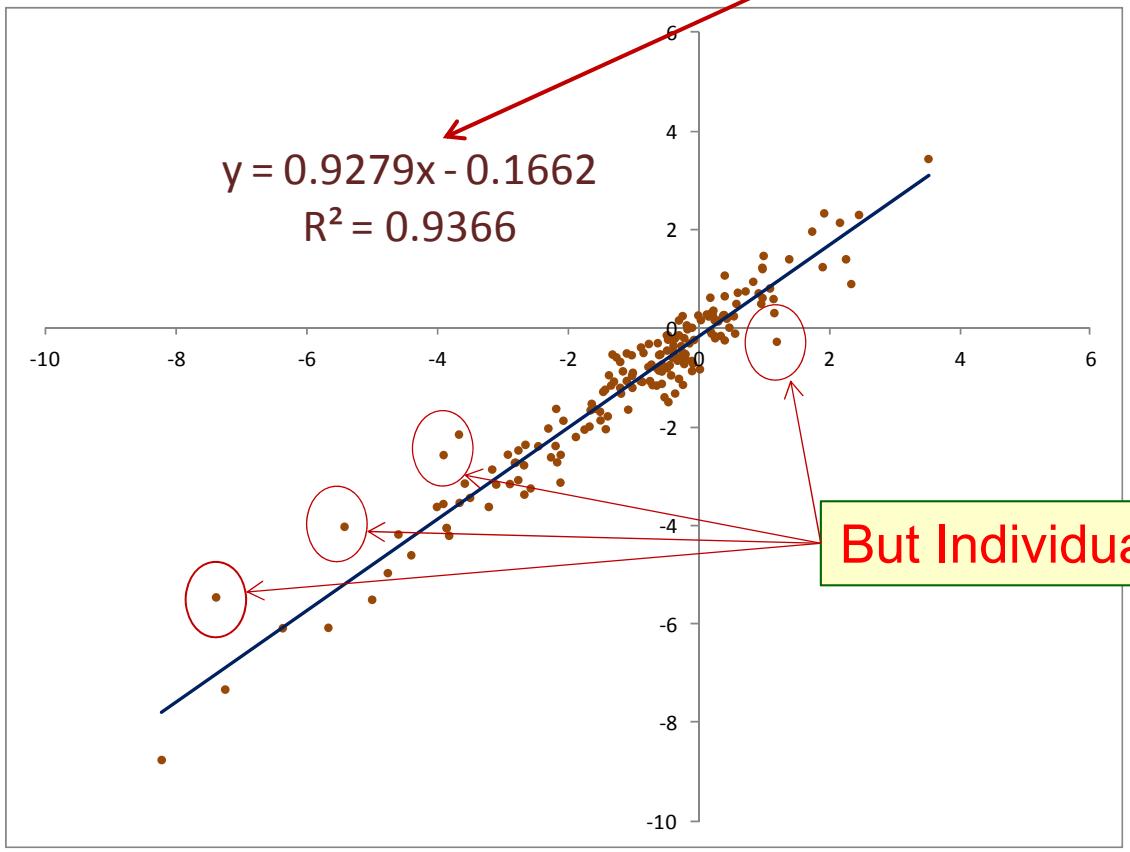
(SA4 ± SA6 induced by adaptive optics)



(Legras & Bernard, ARVO2011)

Introduction

RMS metric versus subjective (clinical) refraction



(López-Gil et al. 2009)

Problem: Individual discrepancies

Discrepancies > 1 D are frequent; in a few cases > 2.5 D

Explanations?

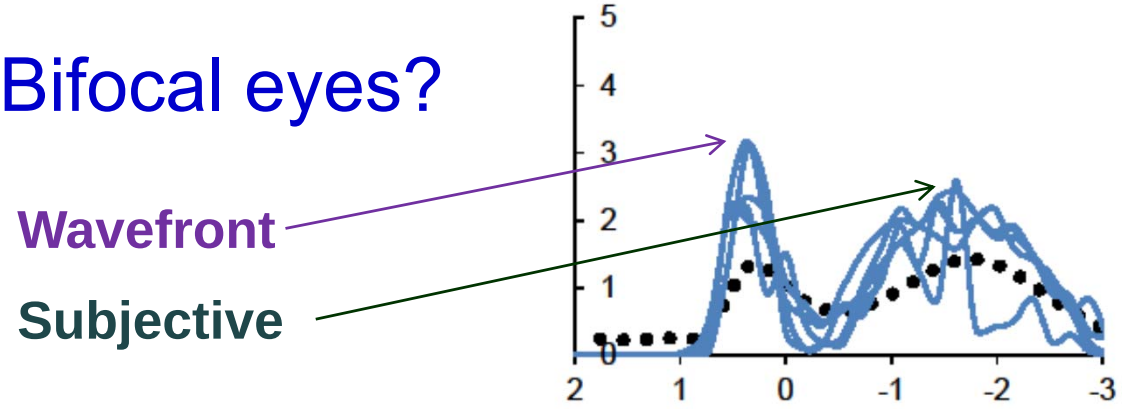
- Wrong aberrometric Metric? But Most metrics give similar results
- Bad subjective refraction? But all methods give consistent values
- Different conditions? Illumination, pupil, individual neural response,…

Cannot explain large discrepancies

Unsatisfactory!

Cue: High discrepancy ↔ High HOA (coma, SA)

Hypothesis: Bifocal eyes?



Methods

1.- Data: from 178 normal eyes taken from previous study (*López-Gil et al., 2009*)

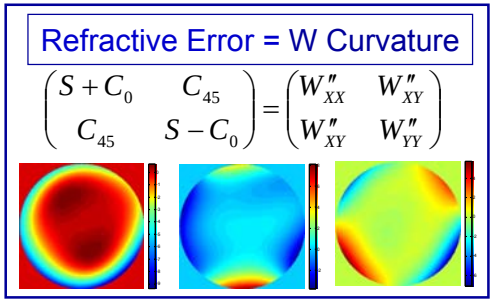
Objective refraction: retinoscopy & autorefractometer (Canon T1000)

Subjective refraction: Standard & custom Badal system

Aberrometry: (**irx3**, Imagine Eyes)

2.- Refractive Error Sensing (RES):

Refractive error from aberrometry



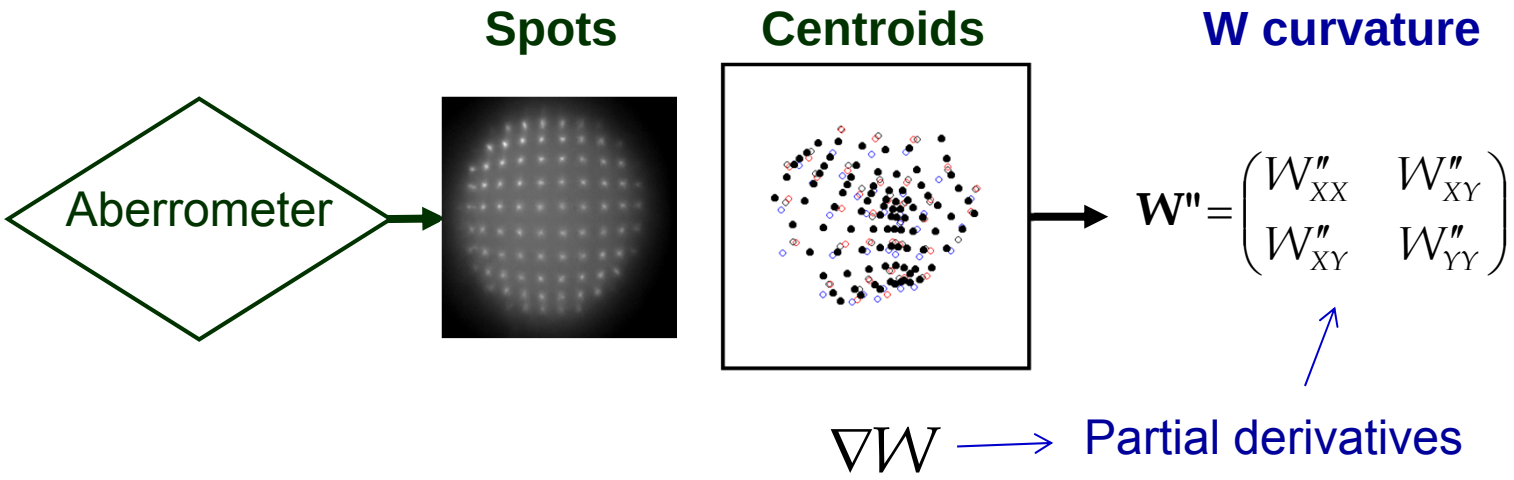
(*Navarro, 2010*)

3.- Identify bifocals > 1 D: 8/178

4.- Analysis:

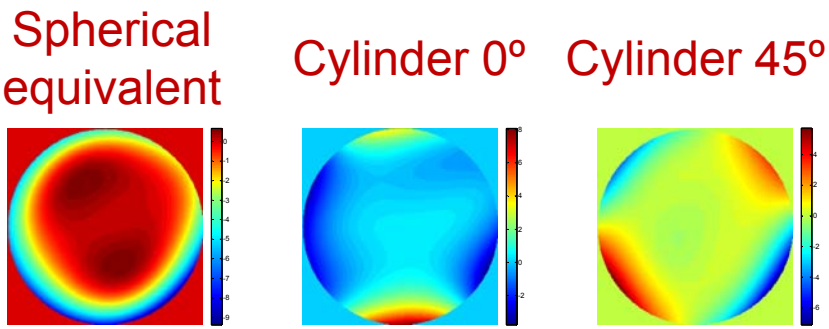
Generalized RES for inhomogeneous/irregular pupils

Standard RE sensing
in monofocal eyes



Refractive Error = W Curvature

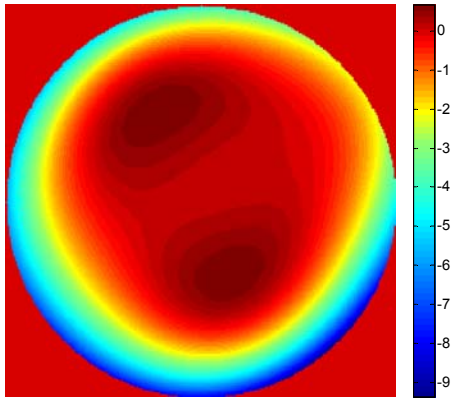
$$\begin{pmatrix} S+C_0 & C_{45} \\ C_{45} & S-C_0 \end{pmatrix} = \begin{pmatrix} W''_{XX} & W''_{XY} \\ W''_{XY} & W''_{YY} \end{pmatrix}$$



Distributions of refractive error

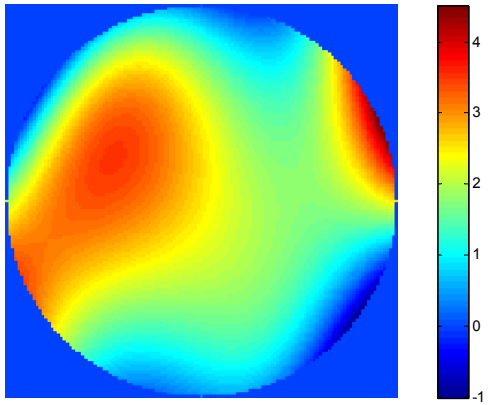
Spherical Equivalent

Monofocal



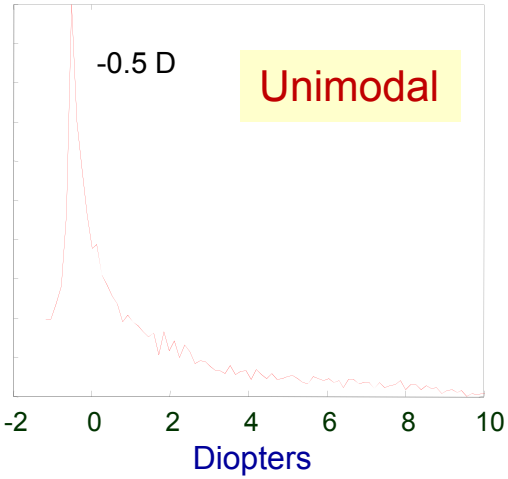
Diopters

Bifocal

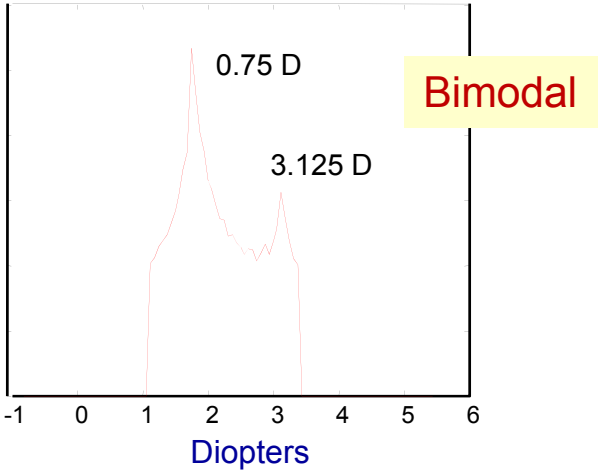


Diopters

Spatial (pupil) distribution

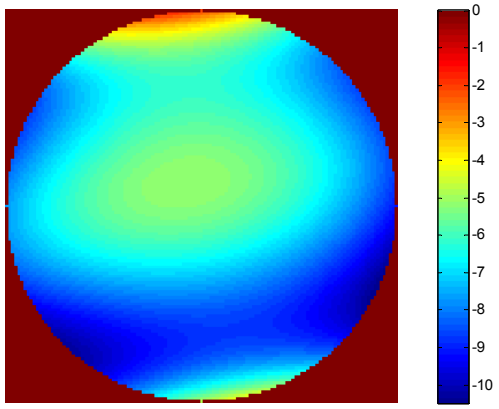


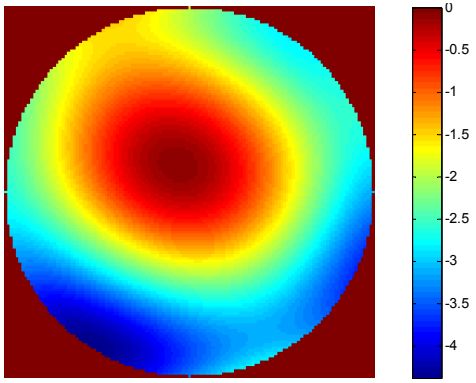
Probability density distribution (histogram)

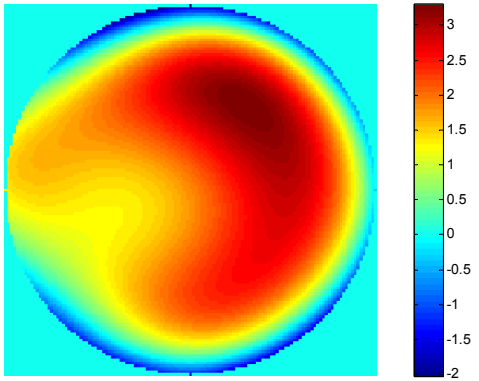


Multifocals

(examples)



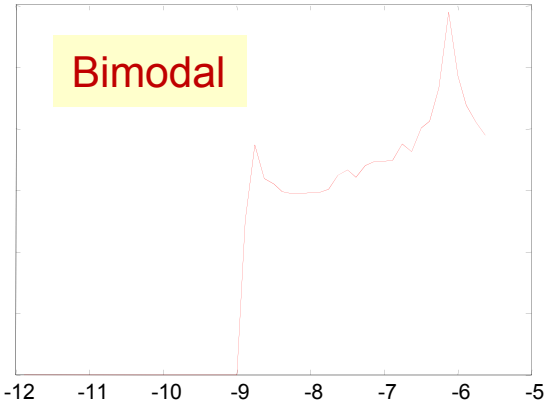




$\Delta D \approx 2.75D$

$\Delta D \approx 2D$

$\Delta D \approx 1.5D$



Discussion. Part 1

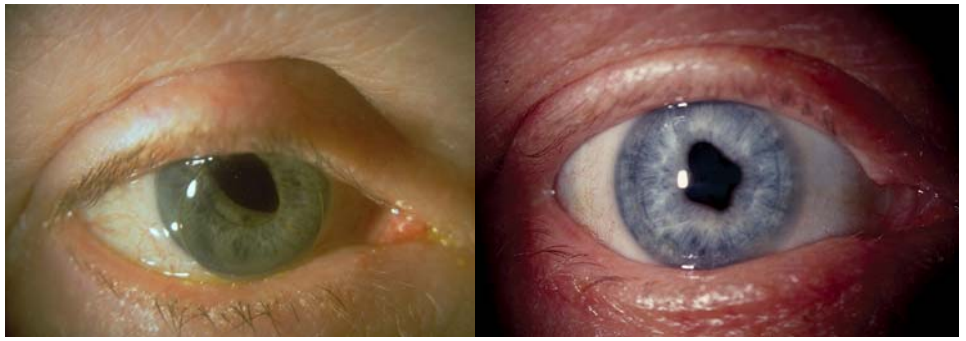
- ✓ A small but significant number (5%) of eyes show bifocal or even multifocal properties
- ✓ They show large amounts of HOA: Poor image quality
- ✓ Highest discrepancies aberrometric/standard refraction

Questions:

- ➢ Strategies of the HVS to improve visual quality?
- ➢ Role of SCE? neural response?
- ➢ Generalization of RE Sensing to account for that?

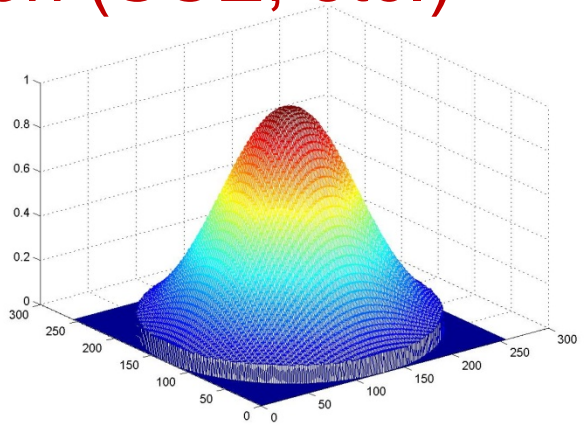
Generalized RE sensing

✓ Irregular pupil shape



✓ Inhomogeneous pupil transmission (SCE, etc.)

Probability(RE) = { 0 outside real pupil
Effective transmission



Analysis of Eye #43

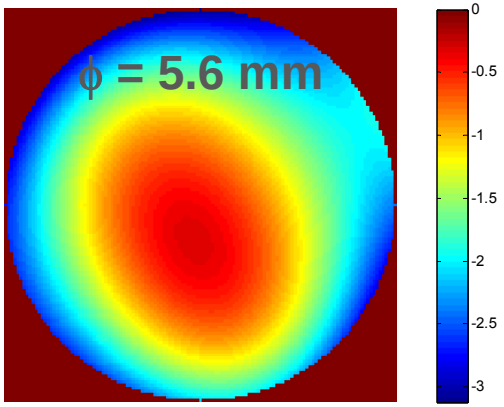
Refraction (SE)

- Retinoscopy: -0.5D
- Subjective (Badal): -0.4D

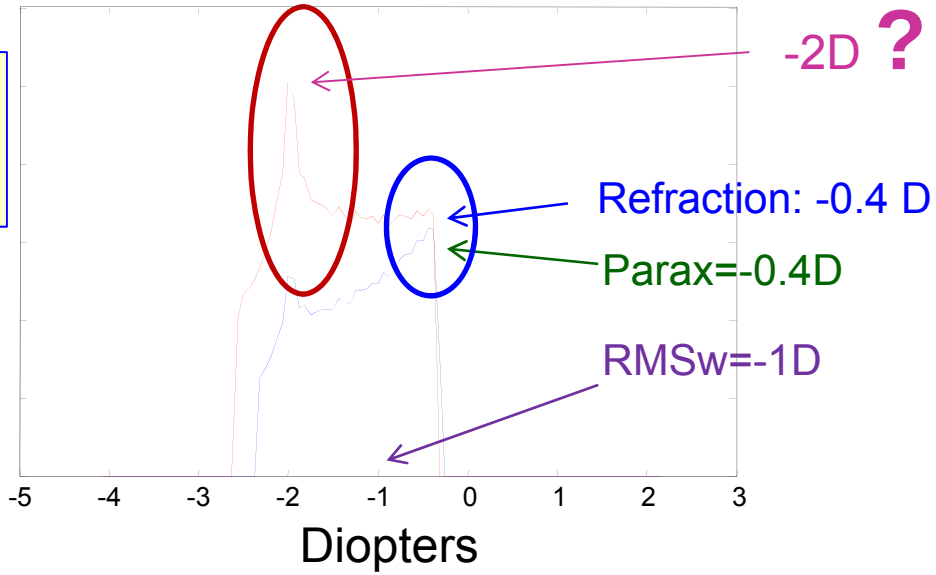
HOA:

- Coma: 0.125 μm
- Spherical A.: 0.16 μm
- RMS HOA: 0.29 μm

Spherical equivalent



SE histogram



Stiles-Crawford effect

Analysis of Eye #74

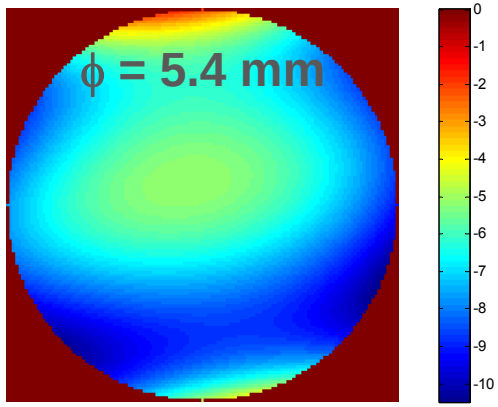
Refraction (SE)

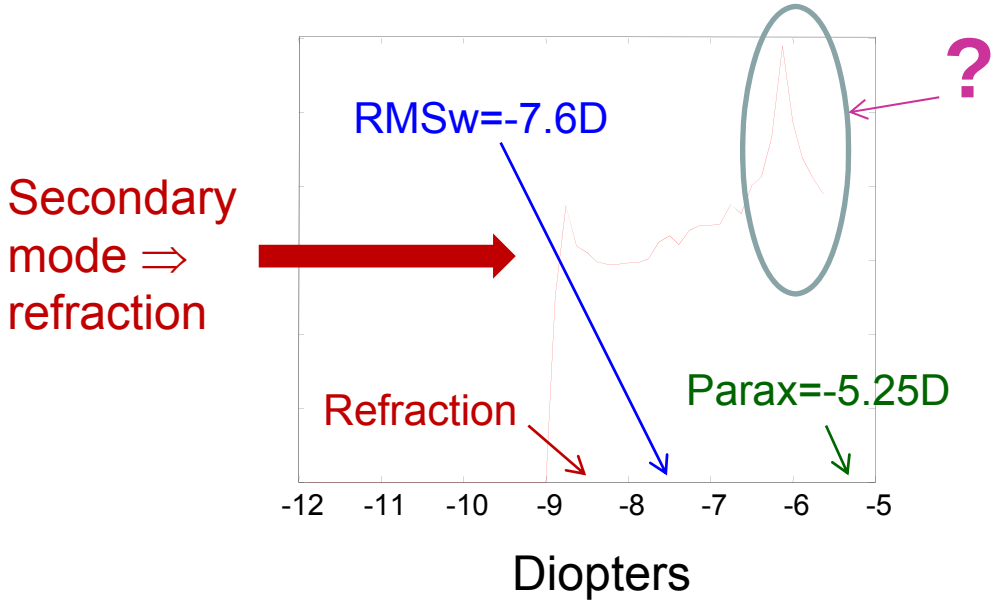
- Retinoscopy: -8.5D
- Subjective (Badal): -8.25D

HOA:

- Coma: 0.56 μm
- Spherical A.: 0.37 μm
- RMS HOA: 0.76 μm

Spherical equivalent

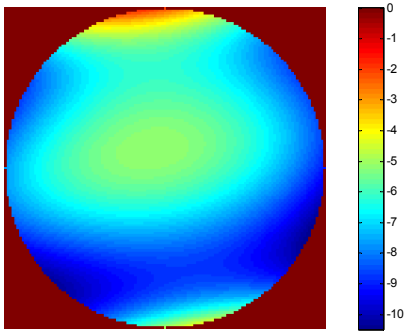


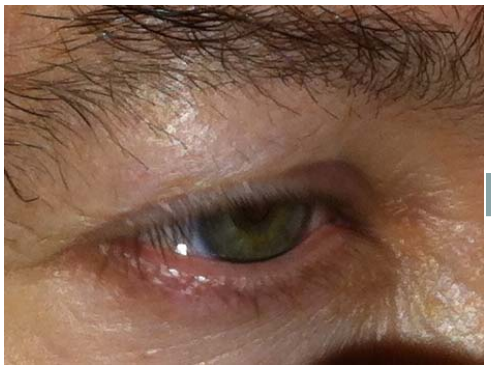


Strategies to improve vision?

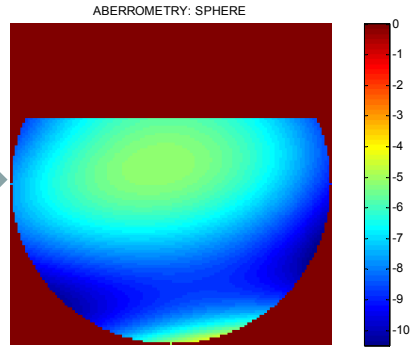
(huge amount of coma)

Full pupil

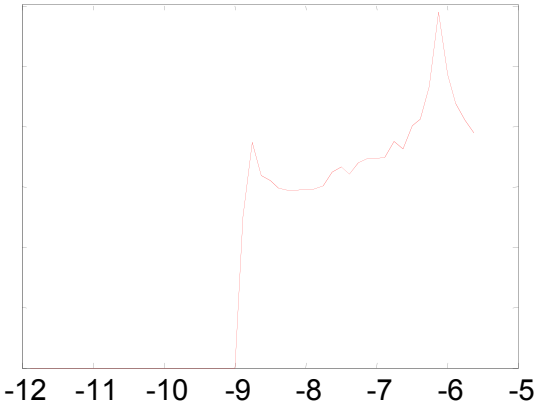


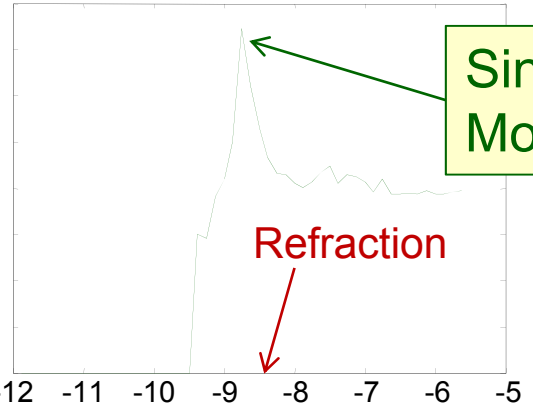


Eyelid Vignetting



His eyelid blocks the upper part of the pupil (both eyes)





Summary & Conclusions

✓ The eyes studied often show a complex distribution of RE. ~5% show bimodal or multimodal histograms with peak distances > 1D (multifocality.) These eyes show large amounts of HOA (poor image quality) and discrepancies between aberrometric and standard refraction.

✓ Generalized RE sensing seems well suited to analyze these cases, including irregular and/or inhomogeneous pupils.

✓ SCE or even eyelid vignetting may help to avoid bifocality & improve image quality.

Future work

- Implementation of complete & automatic histogram analysis

- Selection an deep study of potential multifocal eyes.


Thanks for
your attention
0
-1
-2
-3
-4
-5
-6
-7
-8
-9