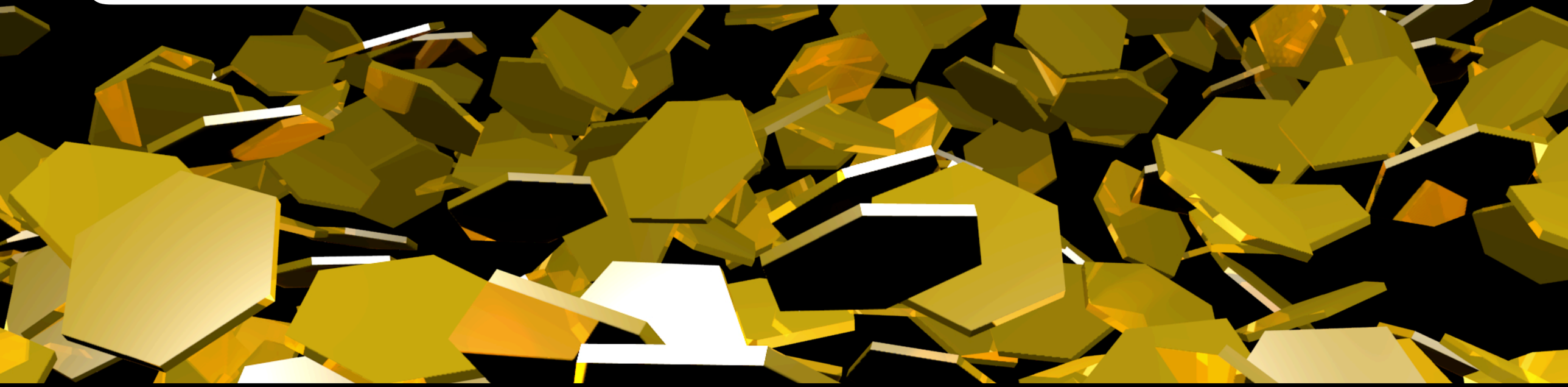
FINE COPHASING OF SEGMENTED APERTURE TELESCOPES - THE STORY OF A PHD QUEST

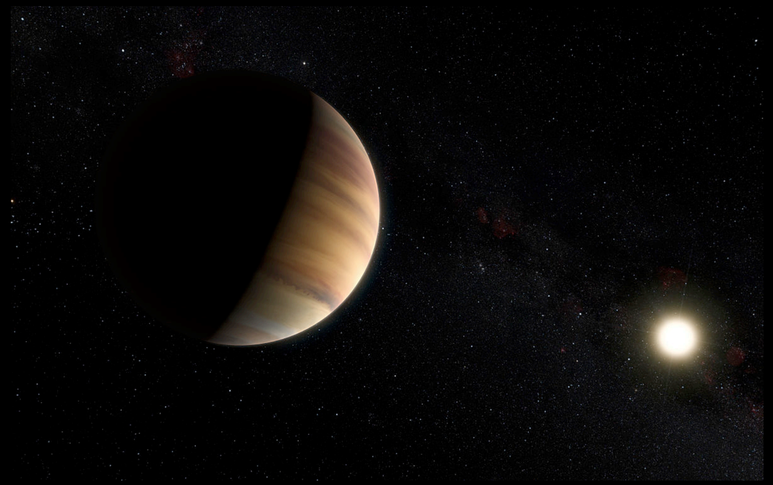
by P. Janin-Potiron



GRD seminar - 22nd of March 2018

Scientific & Instrumental context

Scientific & Instrumental context - which objectives ?



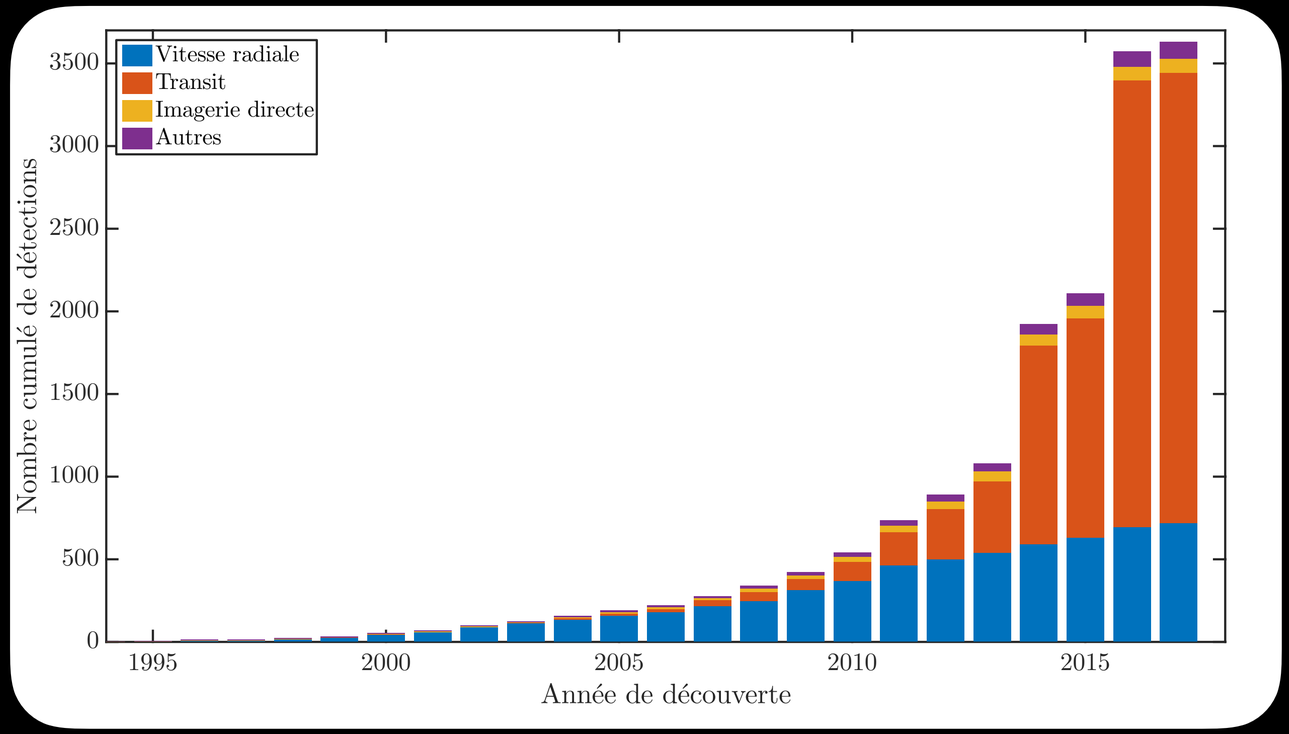
« There is an infinite number of worlds like ours and an infinite number of different that are different. »

Epicure, Lettre à Hérodote

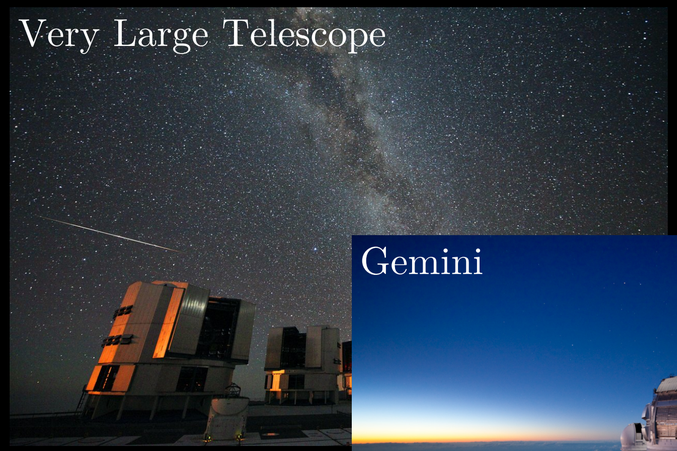
- In 1995, the discovery of a planet around 51 Pegasi opens a new era for astronomy

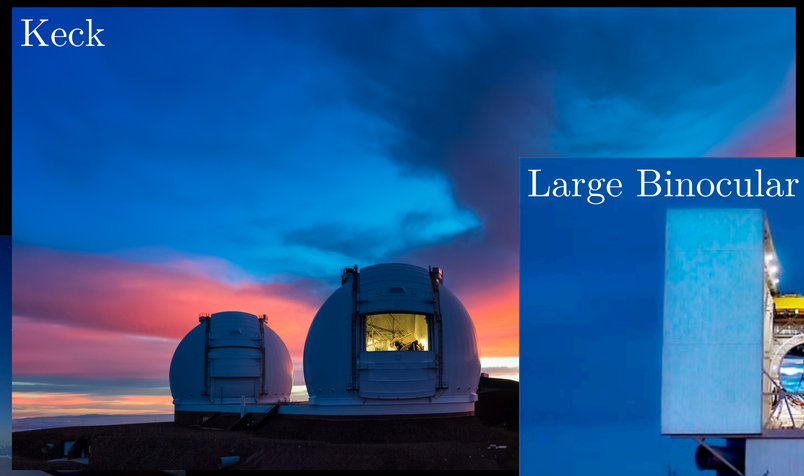
- There are different ways of detecting exoplanets like transit or radial velocity methods

- Direct imaging allows to characterize the spectrum of the planet, i.e. to look for signs of life



Scientific & Instrumental context - which means ?





Two major axis to develop to increase the performances

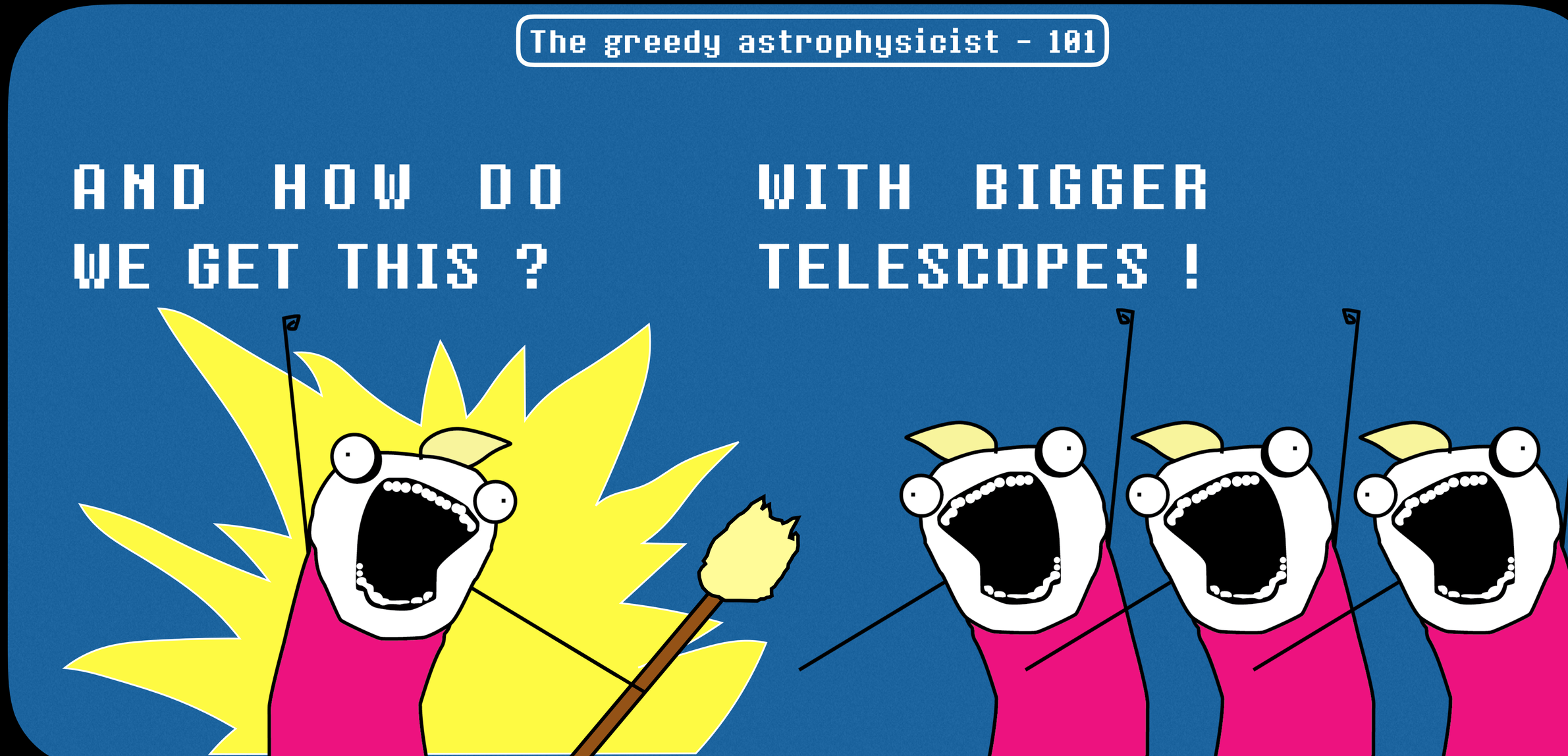
Increase the **ANGULAR RESOLUTION** of these telescopes

Increase the **HIGH CONTRAST IMAGING** capabilities

Also increase the **NUMBER OF PHOTONS**

The segmented telescope era


The greedy astrophysicist - 101
WHAT DO WE WANT ?!
More photons and greater spatial resolution !!!


The greedy astrophysicist - 101
AND HOW DO WE GET THIS ?
WITH BIGGER TELESCOPES !

The segmented telescopes era - Future instrumental projects

« An obvious solution to these and other problems is to compose the primary mirror from smaller segments, rather than a single large mirror. »

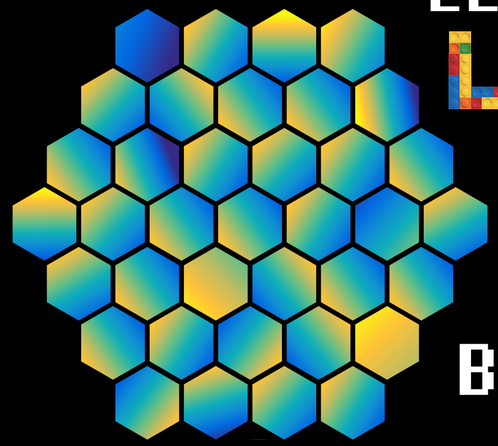
J. Nelson, Segmented Mirror Telescopes

LEGO STYLE IS GOOD

BUT IF NOT PHASED … BAD THINGS HAPPEN !

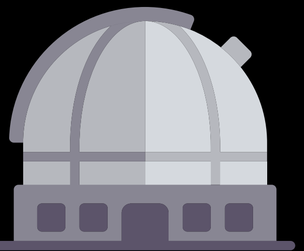
LETS TRY TO DO IT

LEGOSTYLE



NO MONOLITHIC SOLUTION FOR LARGE DIAMETER

BIGGER MIRRORS



BIGGER TELESCOPES

The segmented telescopes era - Future instrumental projects

« Although, there are a number of unique issues, concerns, and problems that arise with segments, and must be understood and dealt with [...] »

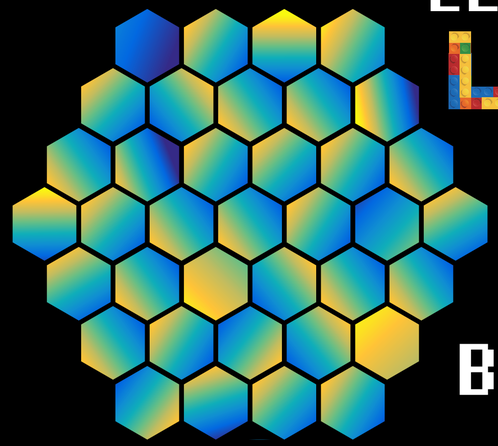
J. Nelson, Segmented Mirror Telescopes

LEGO STYLE IS GOOD

BUT IF NOT PHASED ... BAD THINGS HAPPEN !

LETS TRY TO DO IT

LEGOSTYLE



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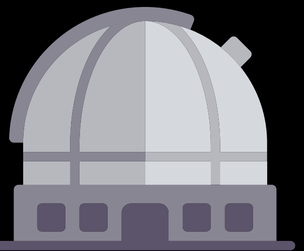
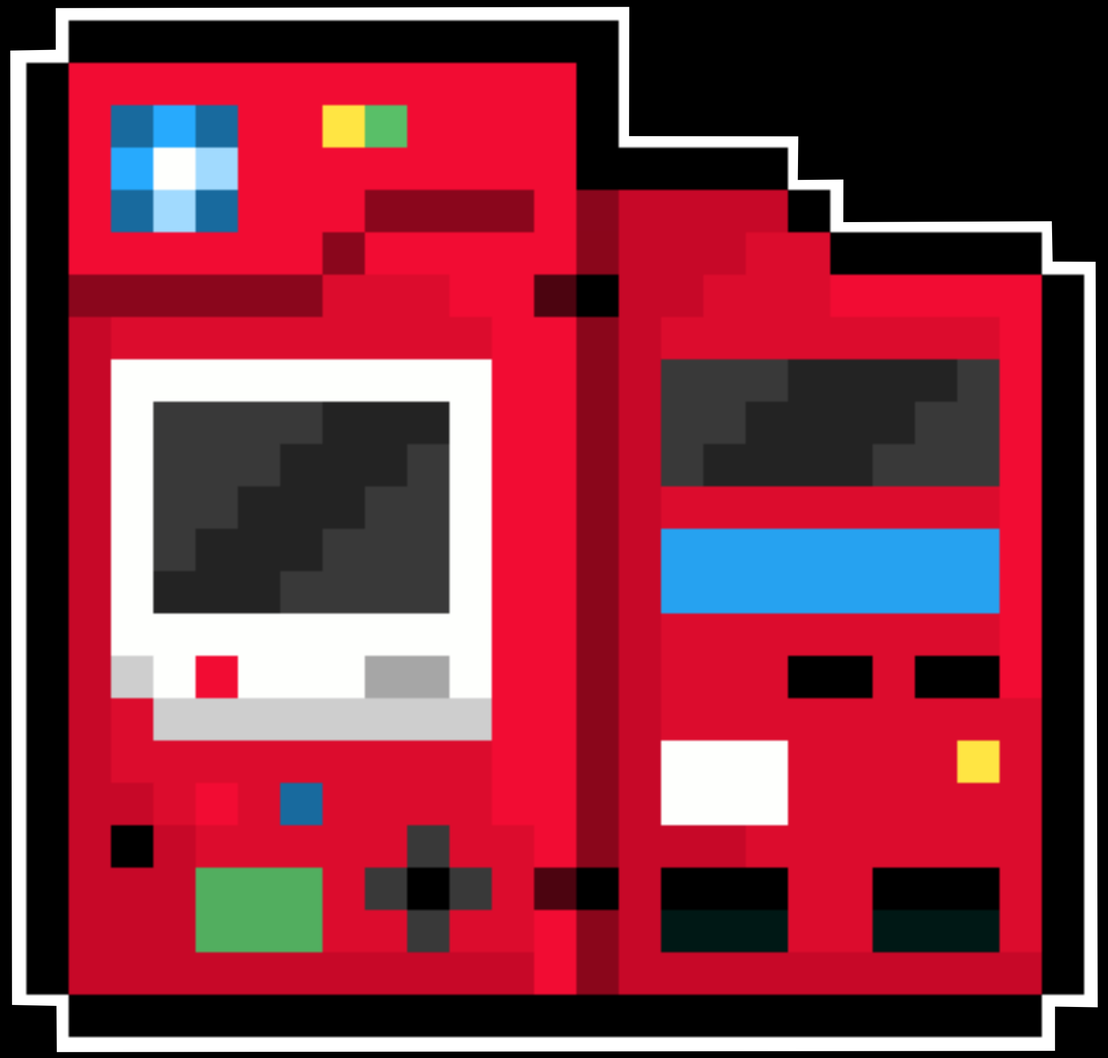
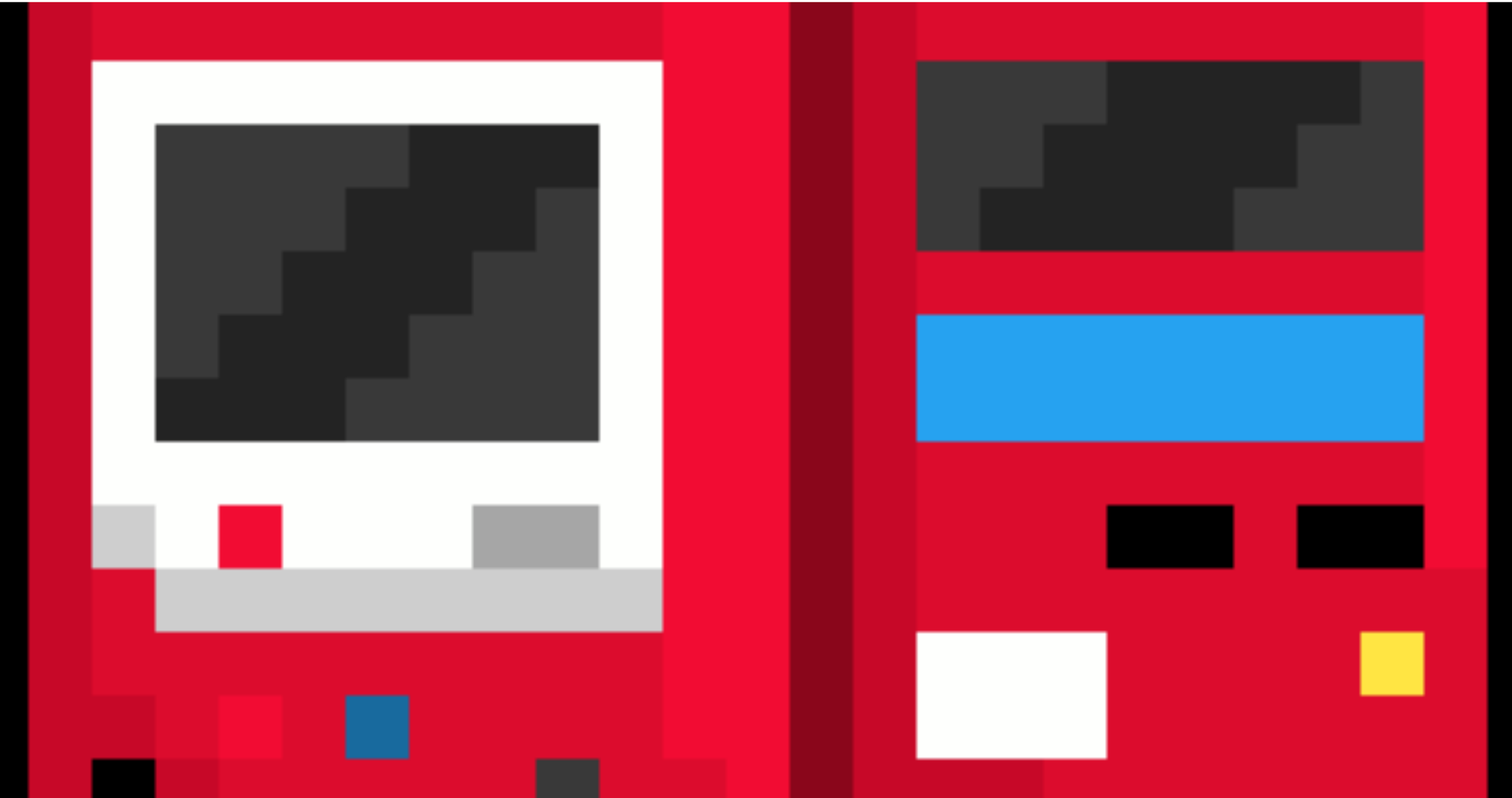


BIGGER TELESCOPES

The segmented telescopes era - Basic algorithmic lexical



The segmented telescopes era - Basic algorithmic lexical



The segmented telescopes era - Basic algorithmic lexical

SEGMENT

The segmented telescopes era - Basic algorithmic lexical

SEGMENT

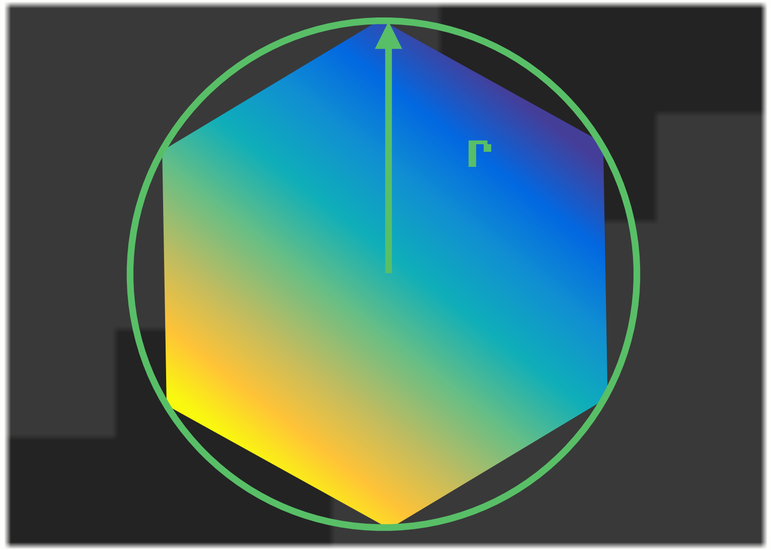
Elementary component of the segmented pupil

The segmented telescopes era - Basic algorithmic lexical

SEGMENT

With HEXAGONAL shape

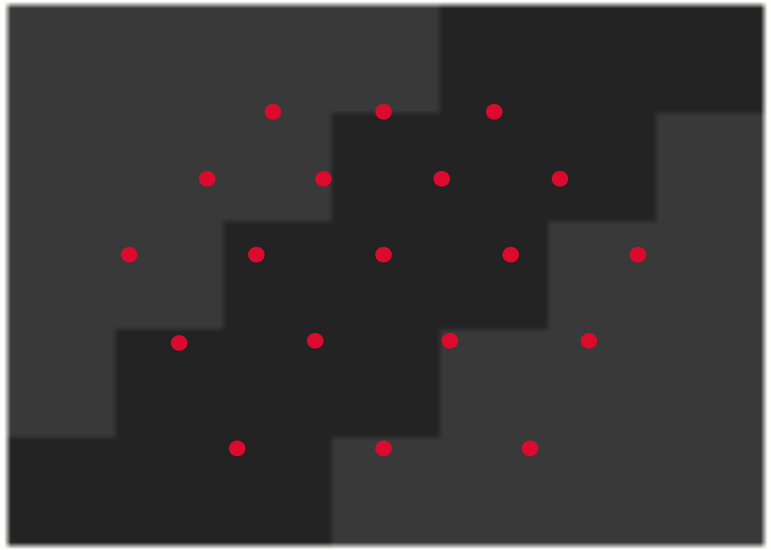
The segmented telescopes era - Basic algorithmic lexical



SEGMENT

Only defined by its radius r

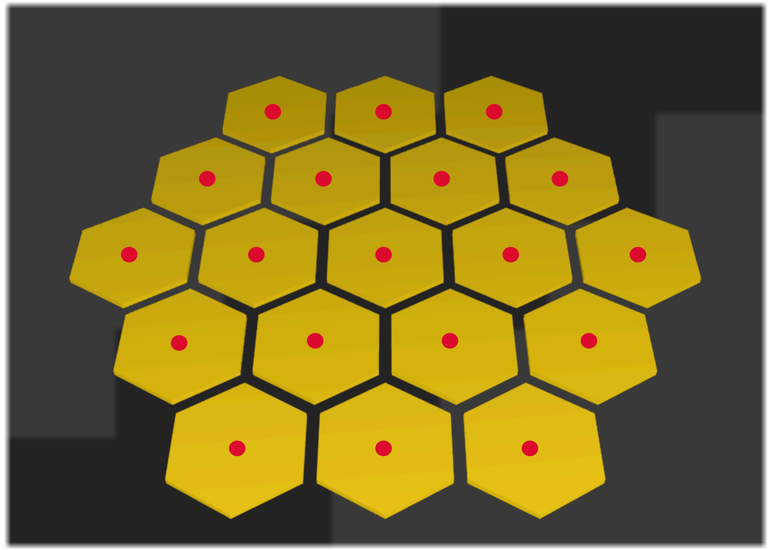
The segmented telescopes era - Basic algorithmic lexical



GRID

Grid with hexagonal lattices

The segmented telescopes era - Basic algorithmic lexical



PUPIL

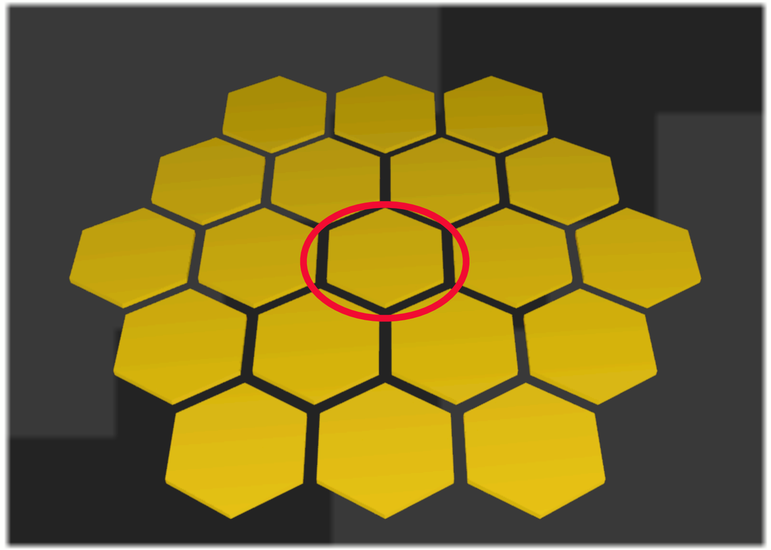
One segment at each node of the hexagonal grid

The segmented telescopes era - Basic algorithmic lexical

PUPIL

Variable number of segments N organized in rings around the center

The segmented telescopes era - Basic algorithmic lexical



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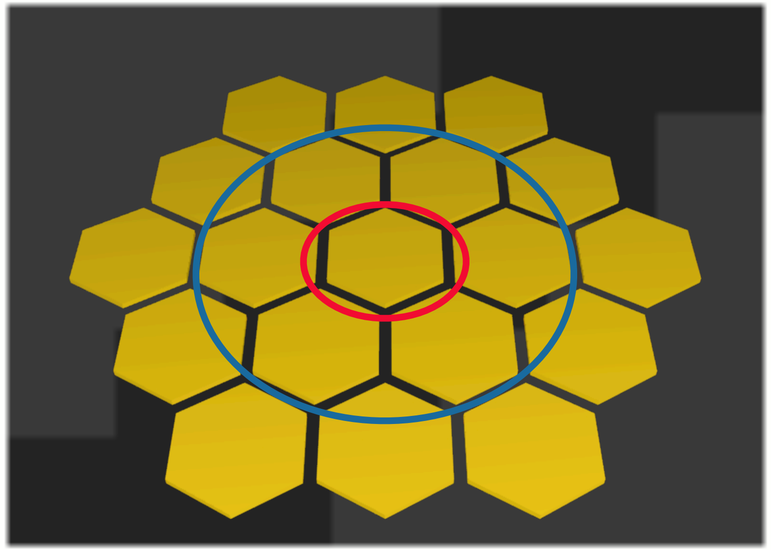
The segmented telescopes era - Basic algorithmic lexical



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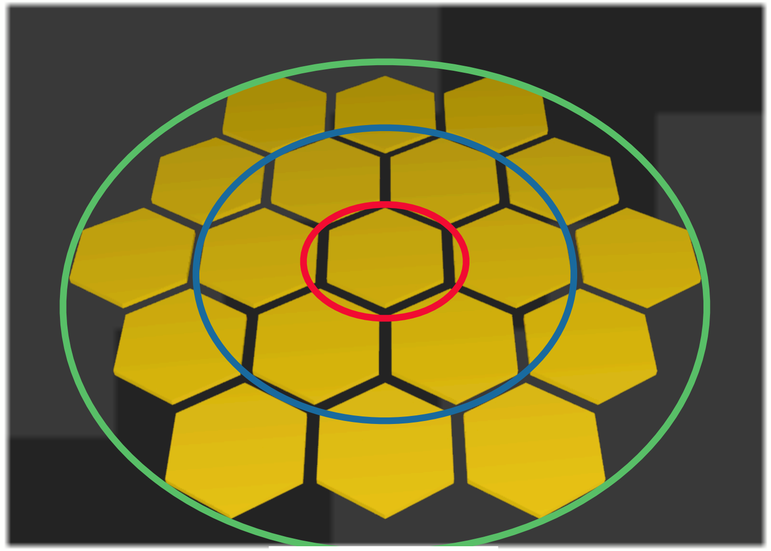
The segmented telescopes era - Basic algorithmic lexical



PUPIL

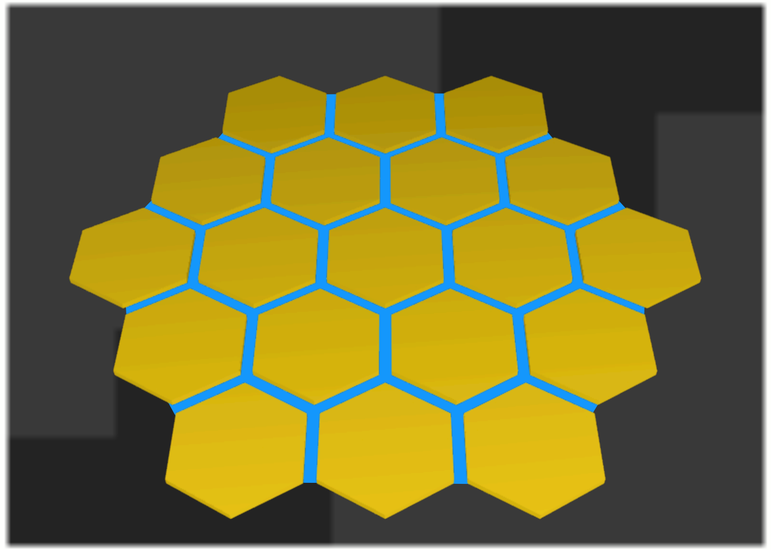
Variable number of segments N organized in rings around the center

The segmented telescopes era - Basic algorithmic lexical

PUPIL

Variable GAP size between each segment

The segmented telescopes era - Basic algorithmic lexical



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Variable GAP size between each segment

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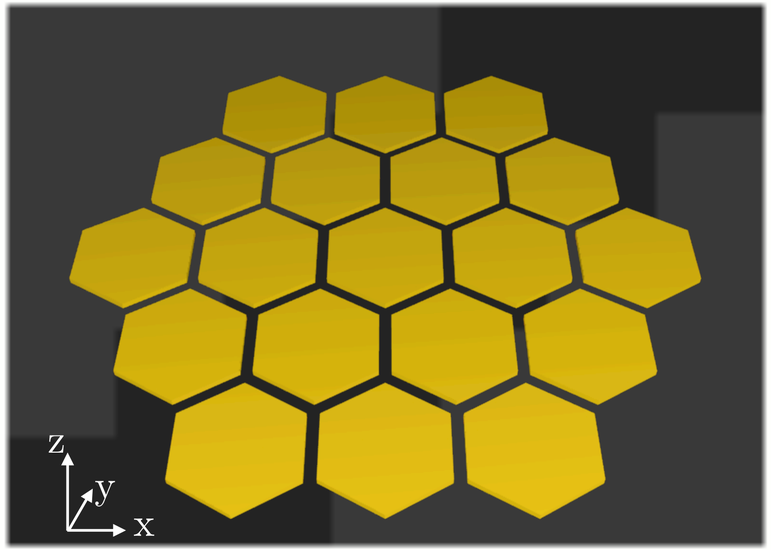
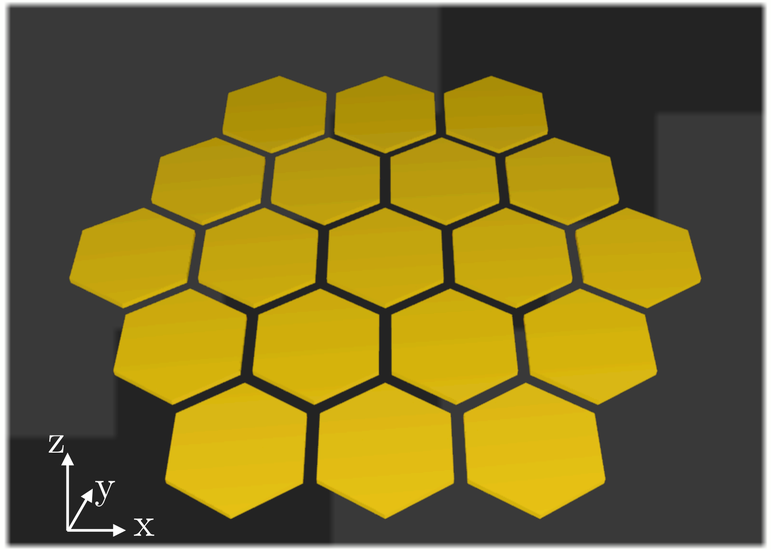


PUPIL

Each segment is actionable in PISTON

The segmented telescopes era - Basic algorithmic lexical



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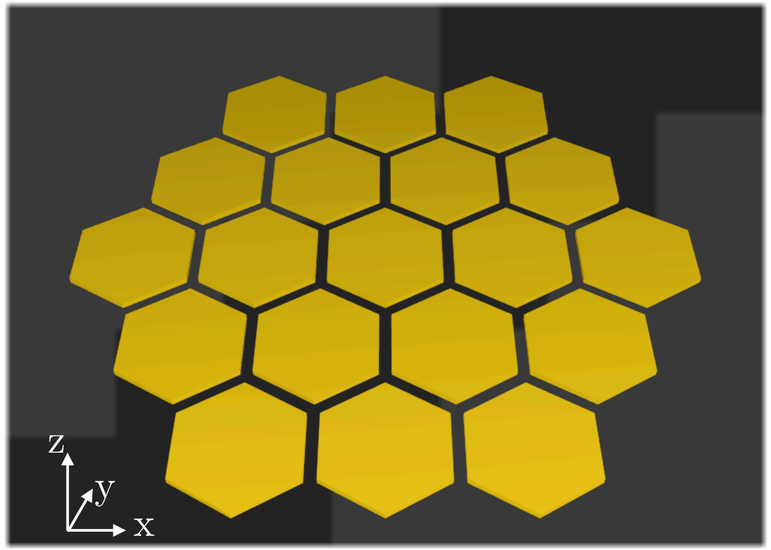
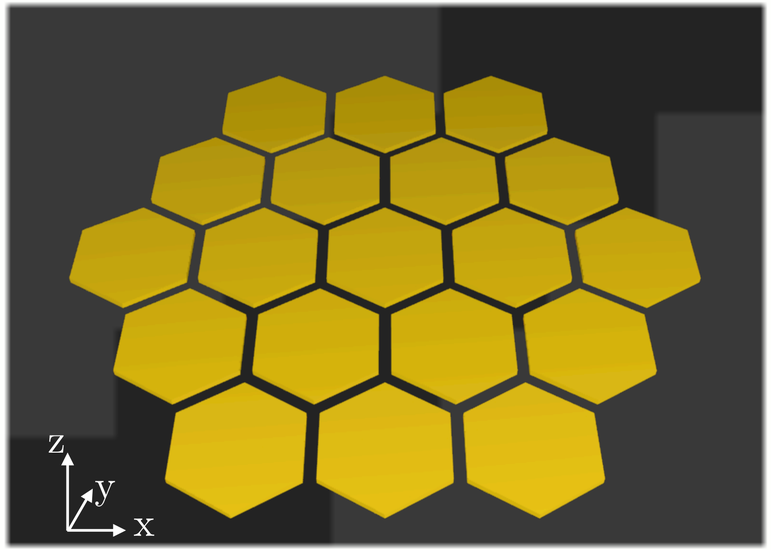
The segmented telescopes era - Basic algorithmic lexical



PUPIL

Each segment is actionable in TIP-TILT

The segmented telescopes era - Basic algorithmic lexical



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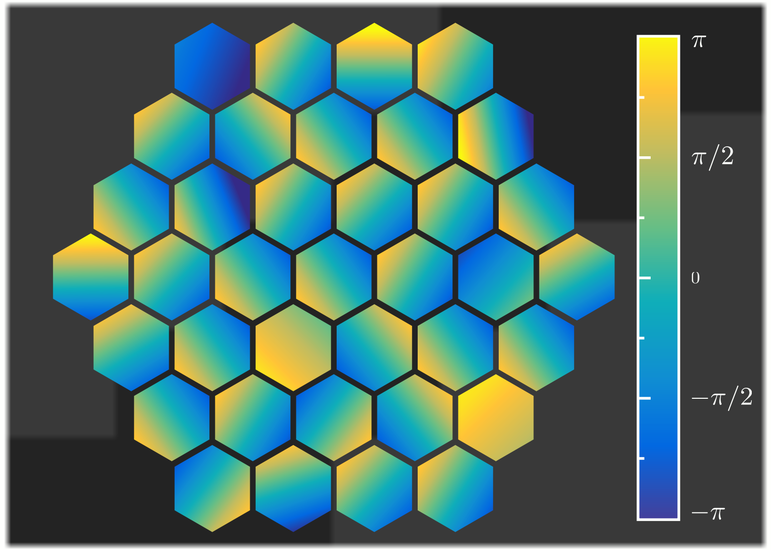
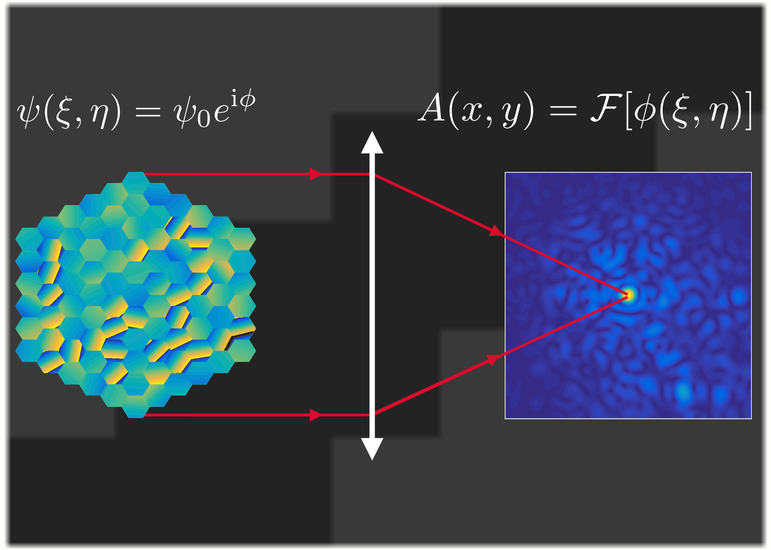


OPTICAL PROPAGATION

Position errors of piston, tip and tilt translated to phase errors ($\phi = 2\pi\Delta p/\lambda$)

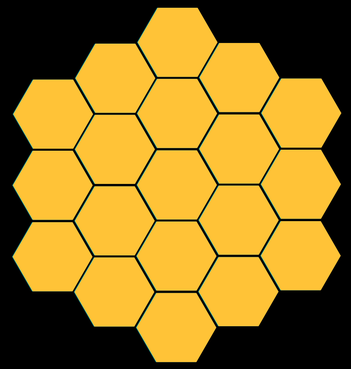


OPTICAL PROPAGATION

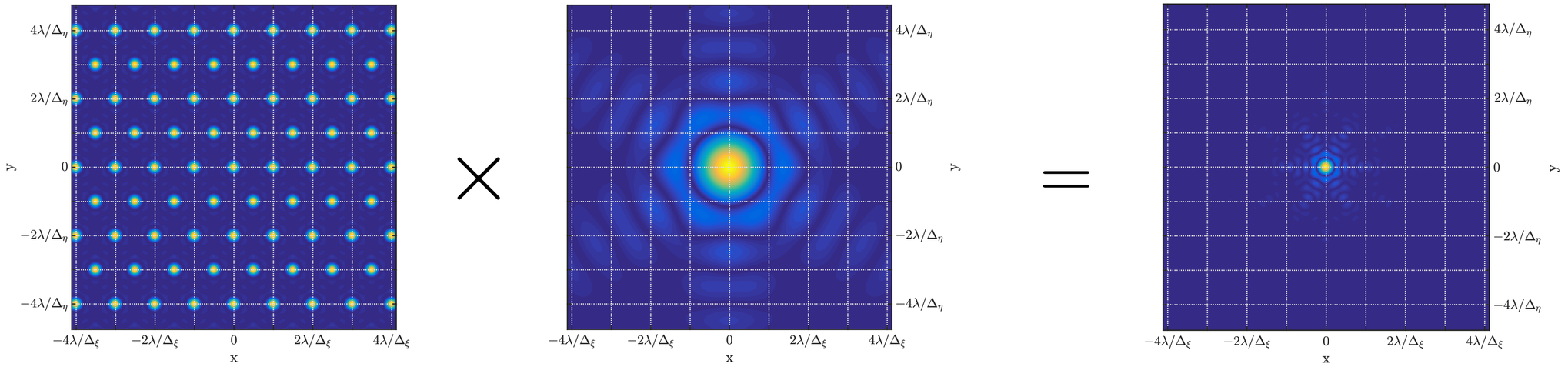
Optical propagation from PUPIL PLANE to FOCAL PLANE by Fast Fourier Transform

The cophasing needs

The cophasing needs - Piston errors



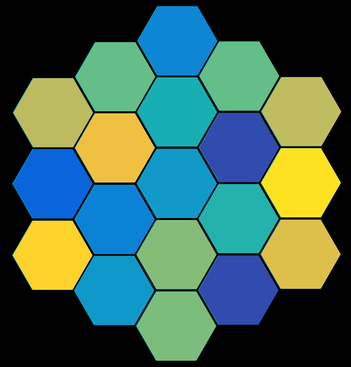
Perfectly cophased



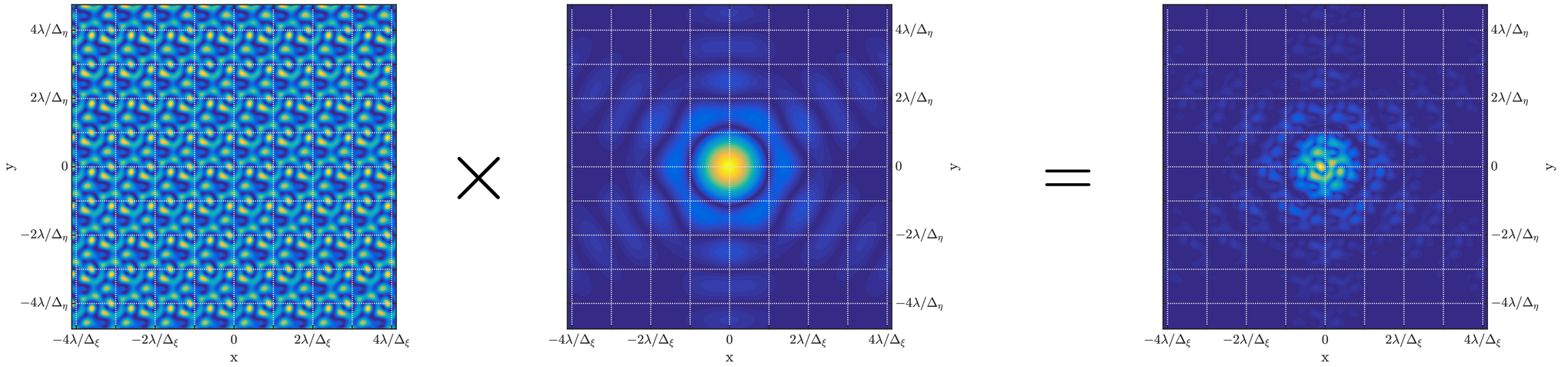
Fourier transform of the grid function

PSF of a single segment

Resultant PSF

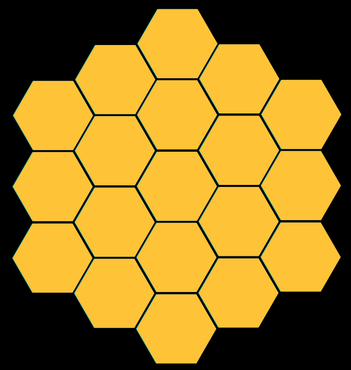


Random piston error



Chanan & Troy (1999) / Yaitskova & Dohlen (2002) / Yaitskova et al. (2003)

The cophasing needs - Tip and tilt errors



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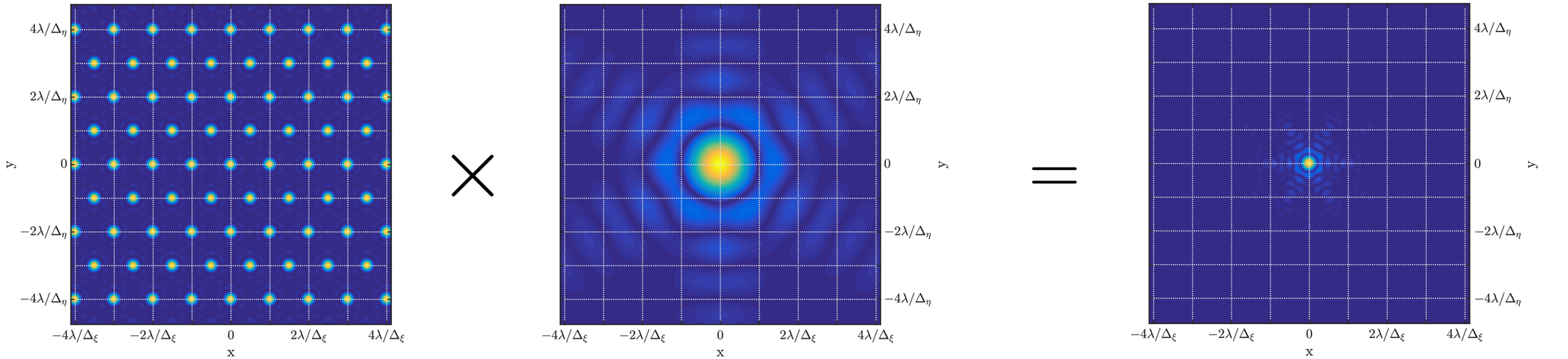
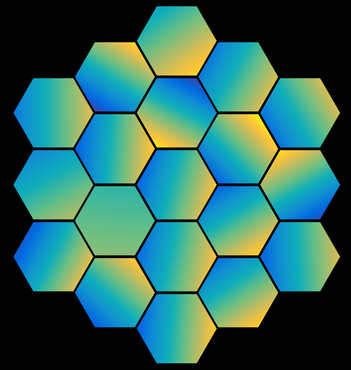


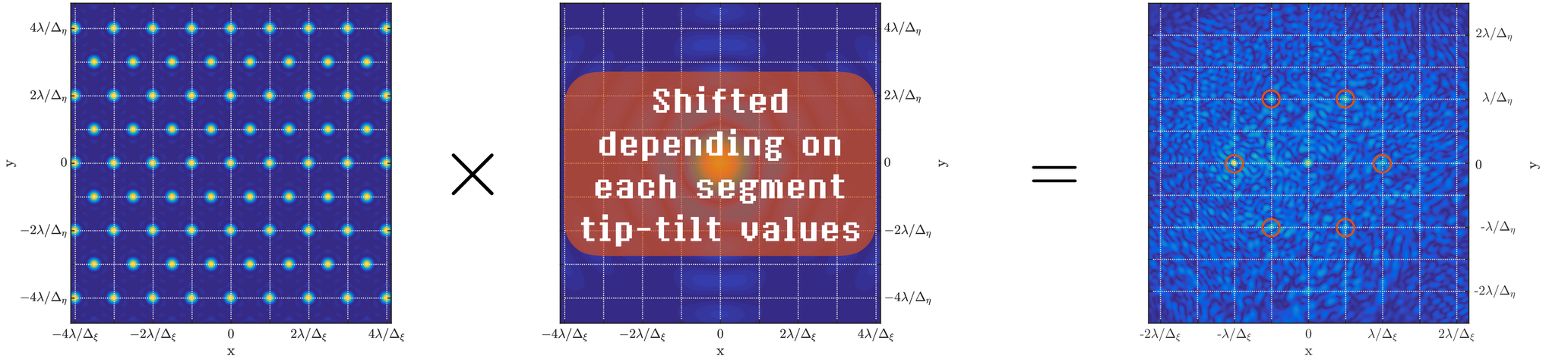
Fourier transform of the grid function

PSF of a single segment

Resultant PSF

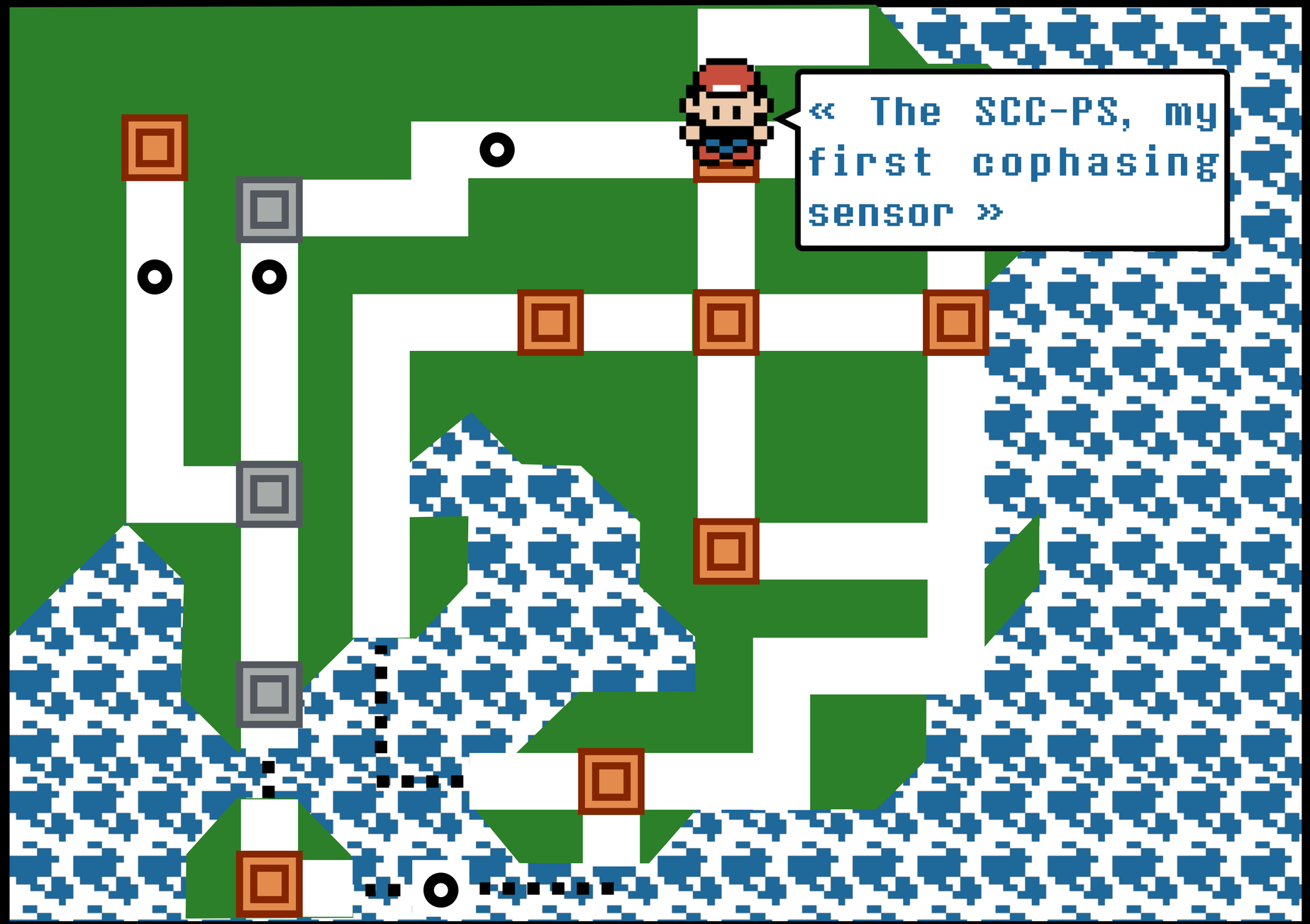


Random tip-tilt error

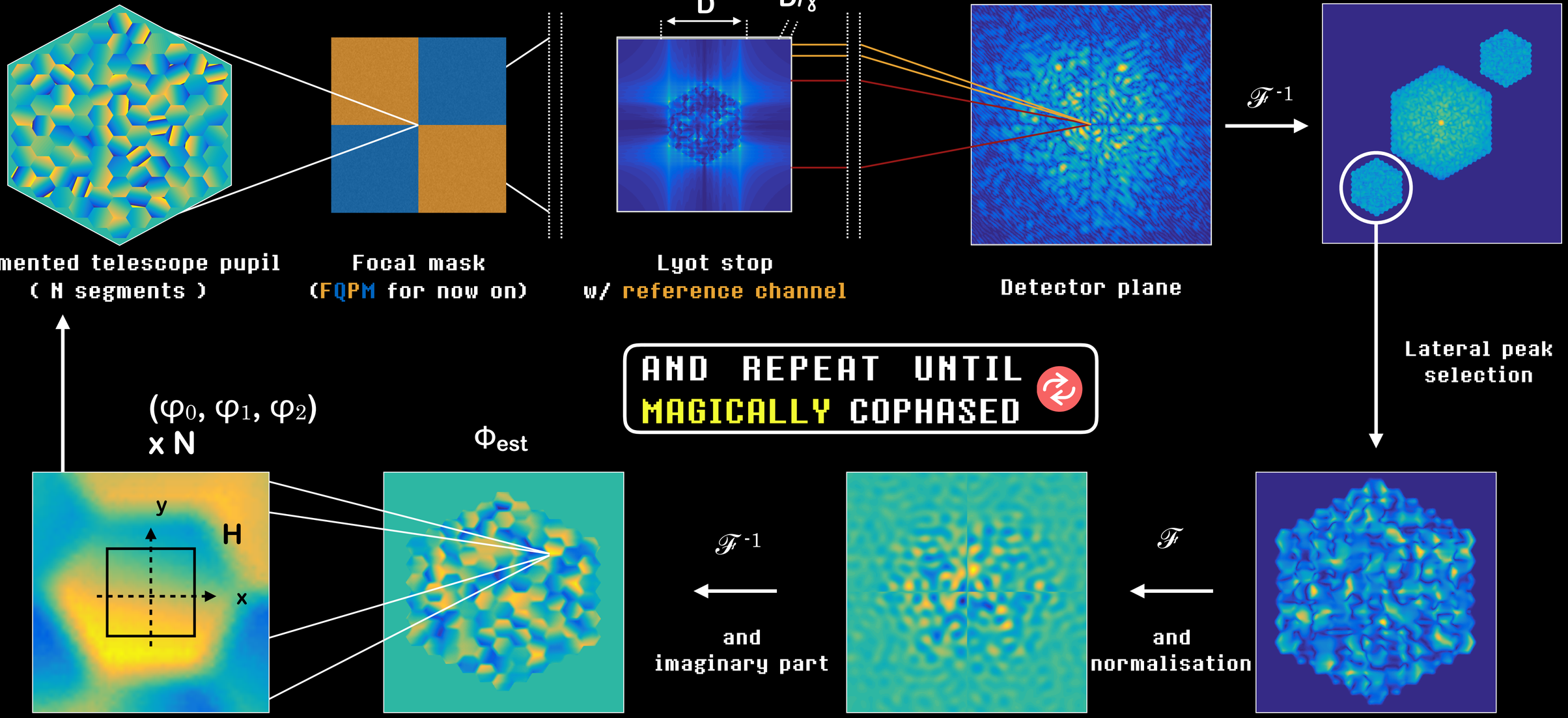


Chanan & Troy (1999) / Yaitskova & Dohlen (2002) / Yaitskova et al. (2003)

The Self-Coherent Camera - Phasing Sensor



The SCC-PS - How does it work ?



SCC-PS : Janin-Potiron et al. (2016)

SCC : Baudoz et al. (2006) ; Galicher et al. (2008)