

Séminaires et conférences

20 Mars Lyu Abe , Observatoire de la Cote d'Azur “ **Coronographe à masque de phase achromatique**”

27 Mars Salvador Cuevas Université de Mexico (UNAM) "La méthode de courbure pour le cophasage des télescopes segmentés et des interféromètres à pupilles diluées"

3 Avril Julien Dejonghe , Collège de France
"Problèmes et possibilités techniques pour la construction de grands hyper-télescopes au sol "

10 et 17 Avril: vacances, il n'y aura ni cours ni séminaire

24 Avril Prof. Colin R McInnes, Dept. of Aerospace Engineering, Université de Glasgow

" **Near-Term Mission Applications for Solar Sails**"

aussi: deux conférences par **Prof. Tobias Owen , Université d'Hawaii**

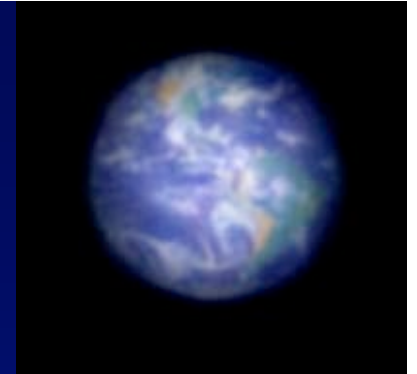
les Jeudi 26 Avril et 3 Mai , amphithéâtre Guillaume Budé à 17h

"**The origin of planetary atmospheres, the search for life in the Universe**"

aussi: deux conférences de biologie par **Prof. Alexander Rich , MIT**

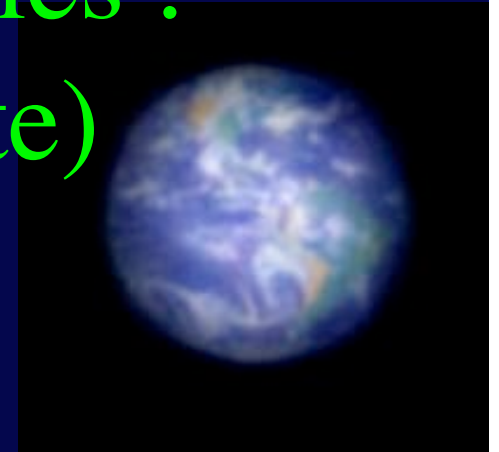
les Jeudi 26 Avril et 3 Mai , amphithéâtre Guillaume Budé à 15h30

"**Changing proteins by editing the genetic message, the role of left-handed DNA ribosomal frameshifting in the viral life cycle: structural and functional studies**"



cette année:

Exo-planètes, étoiles et galaxies : progrès de l'observation (suite)



- Les mardis jusqu 'au 24 Avril
- Sauf les 27 Février, 10 Avril, 17 Avril (vacances)
- Pages web en préparation sur www.college-de-France.fr
- Contiendront les fichiers des présentations

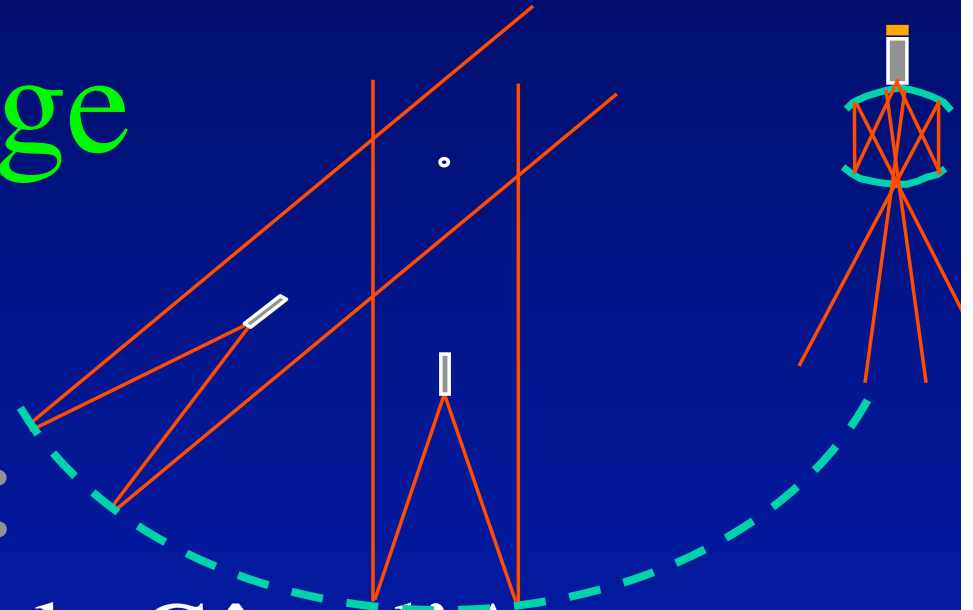
Aujourd'hui:

Version hypertélescope proposée pour le
"Terrestrial Planet Finder" de la NASA:
visible et infra-rouge

Séminaire à 15h15:

Lyu Abe, Observatoire de la Côte d'Azur

Imagerie Astronomique à Haute Dynamique: Introduction à
la Coronographie Stellaire



- Coronographe pré-combinez pour le visible (suite)
- Extraits de la présentation d 'étude faite à la NASA

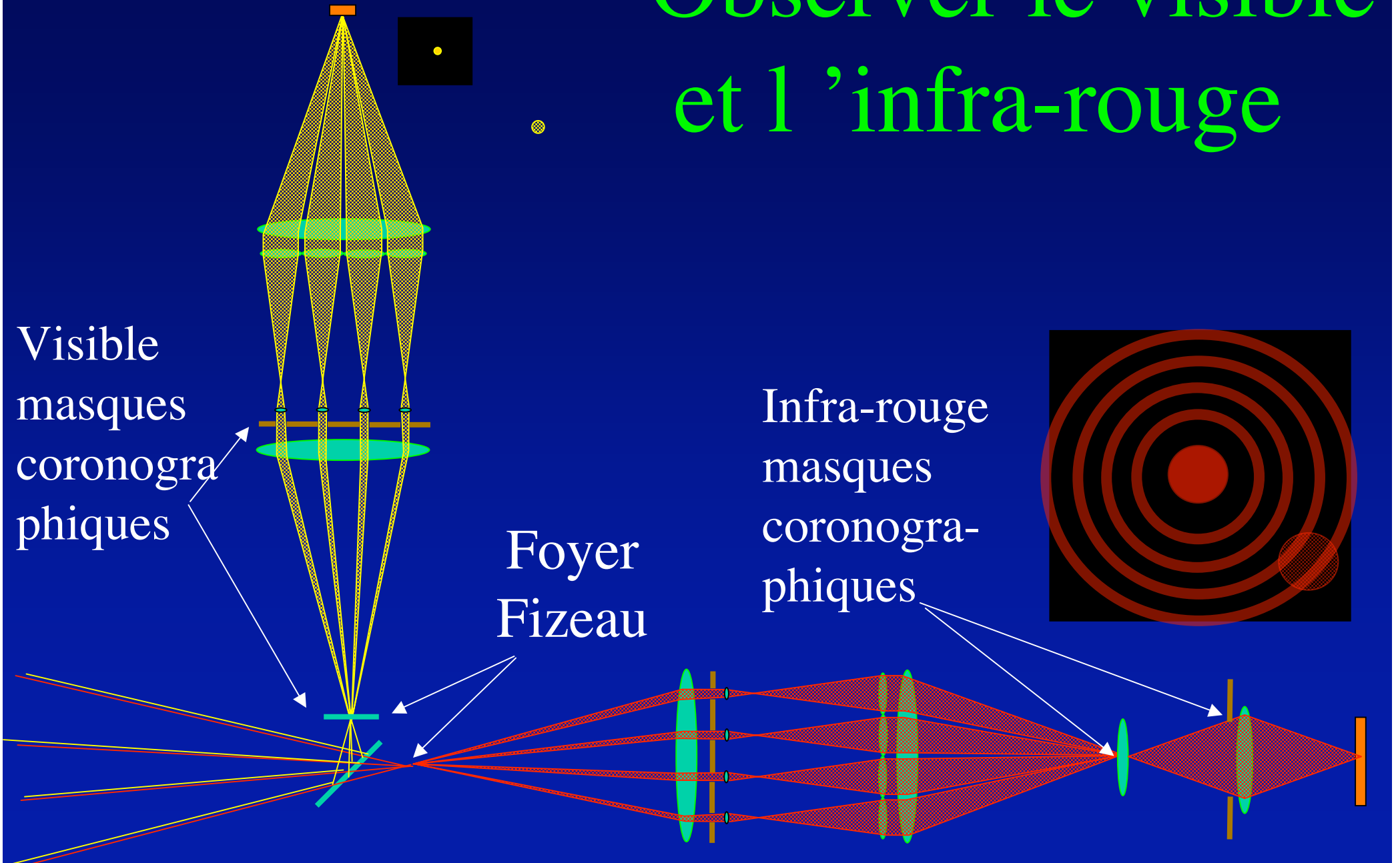
concept d'hypertélescope

proposé par les chercheurs de LISE (étude NASA en cours)

vue d'artiste par Boeing /SVS

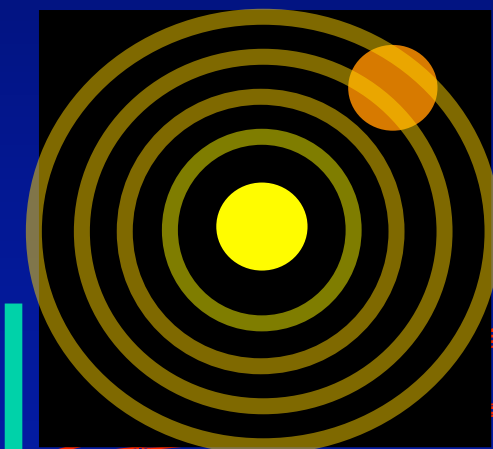
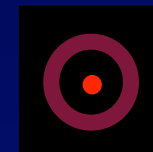
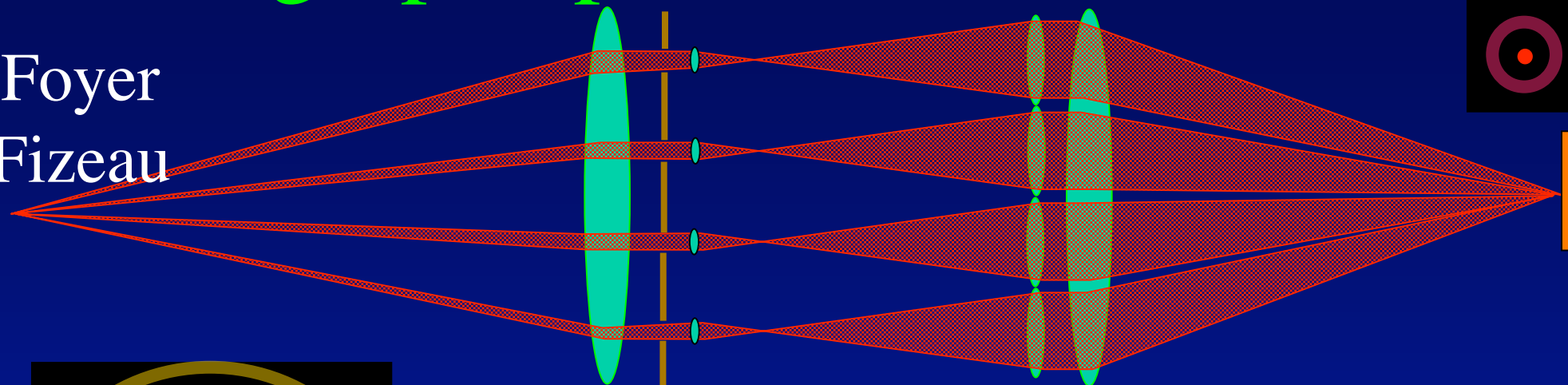


Observer le visible et l'infra-rouge

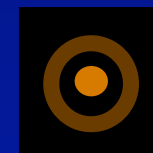
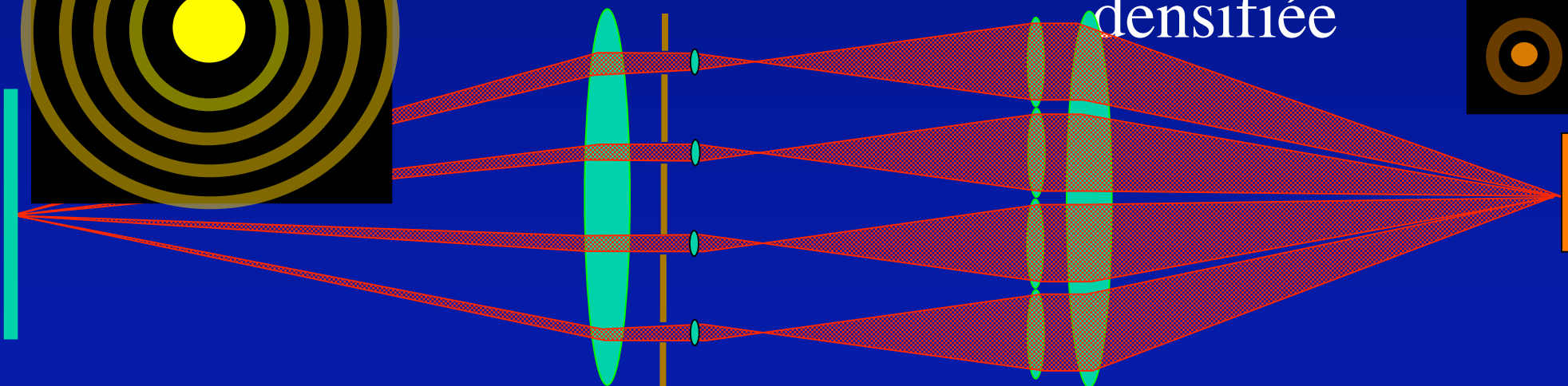


Coronographe pré-combinateur

Foyer
Fizeau

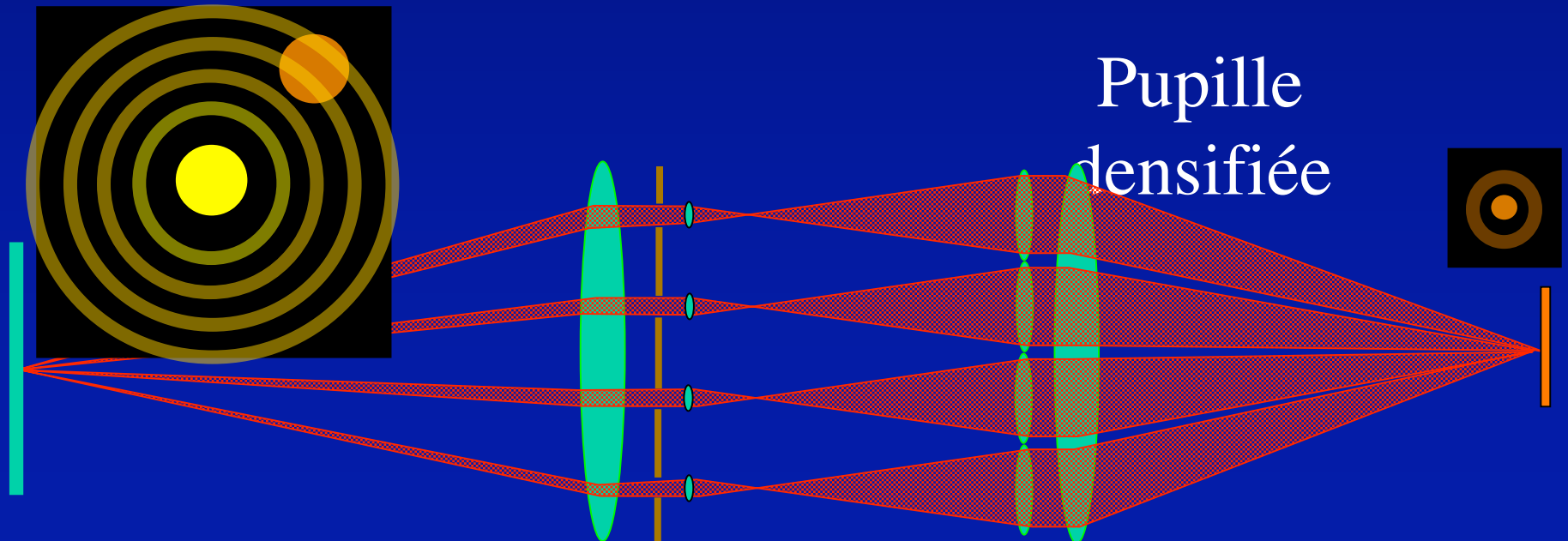


Pupille
densifiée

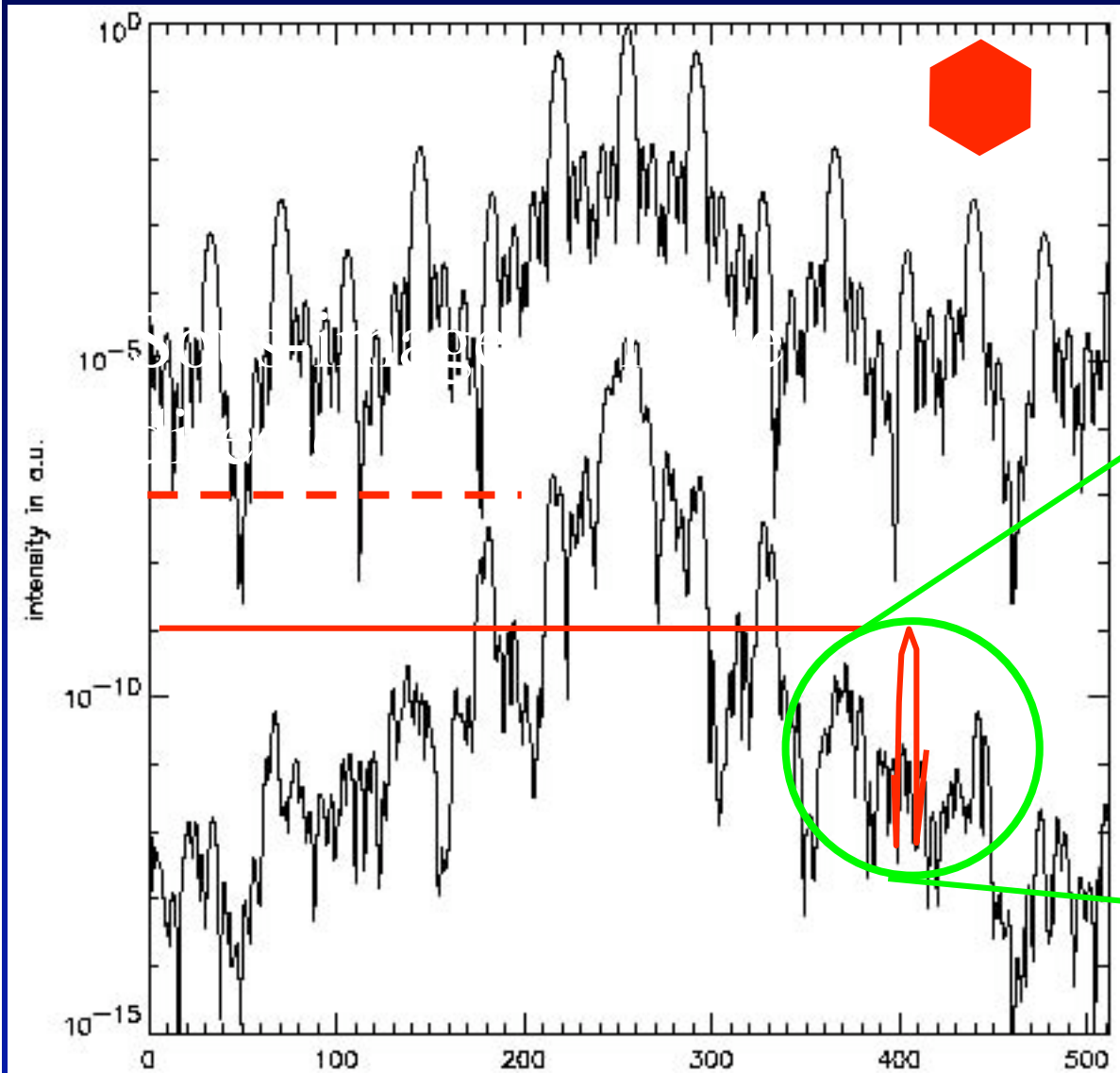


Coronographe pré-combinateur: dilution du résidu stellaire

- Visible: étoile/planète séparée par les sous-ouvertures
- Etoile masquable au foyer Fizeau
- « Lyot stops » dans les sous-pupilles
- « coronographes croisés », pré-combinateur



Coronographe pré-combinez



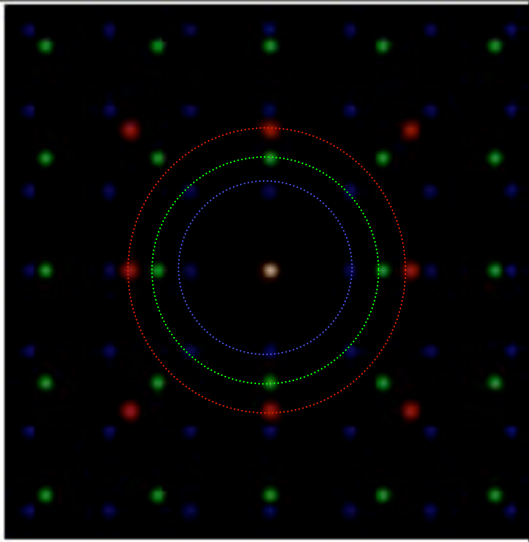
Profils calculés par P.Riaud pour un coronographe à 4 quadrants

Coronographe pré-combinezur: dilution du résidu stellaire

**Un peu
pessimiste...**

- Un speckle basse-résolution du résidu stellaire remplit 1 'image haute résolution
- Dilution: gain $\times \pi N$ (100 pour 36 éléments)

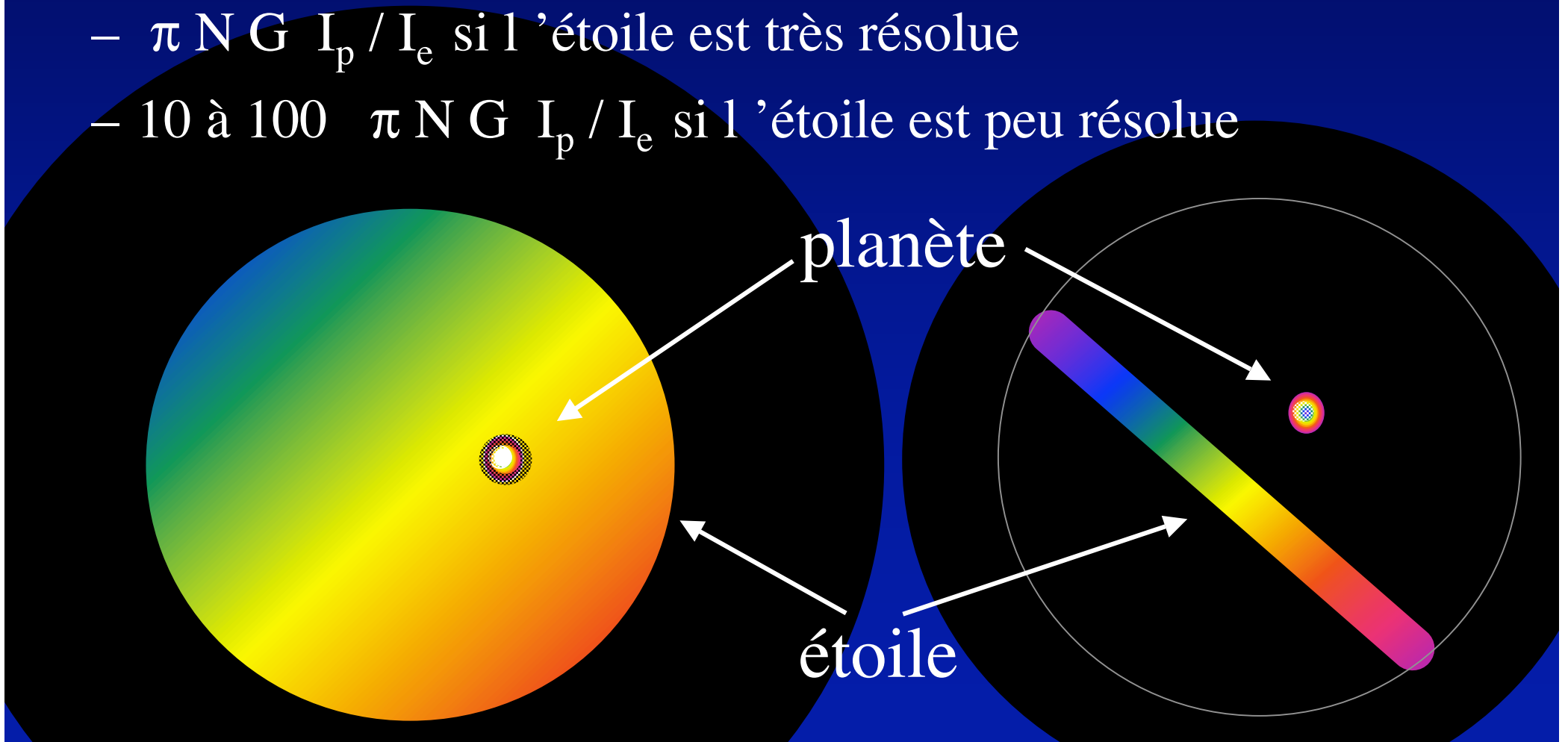
Champ « replié », pour une ouverture périodique



- Convolution de la fonction d'interférence
- Fenêtrage par l'enveloppe diffractive
- Les étoiles extérieures apparaissent par leur pics d'ordre supérieur
- Leur dispersion est correctible (spectro-imageur....)

Visible: contraste planète/étoile

- dans les sous-images: $= G I_p / I_e$
- dans l'image :
 - $\pi N G I_p / I_e$ si l'étoile est très résolue
 - $10 \text{ à } 100 \pi N G I_p / I_e$ si l'étoile est peu résolue

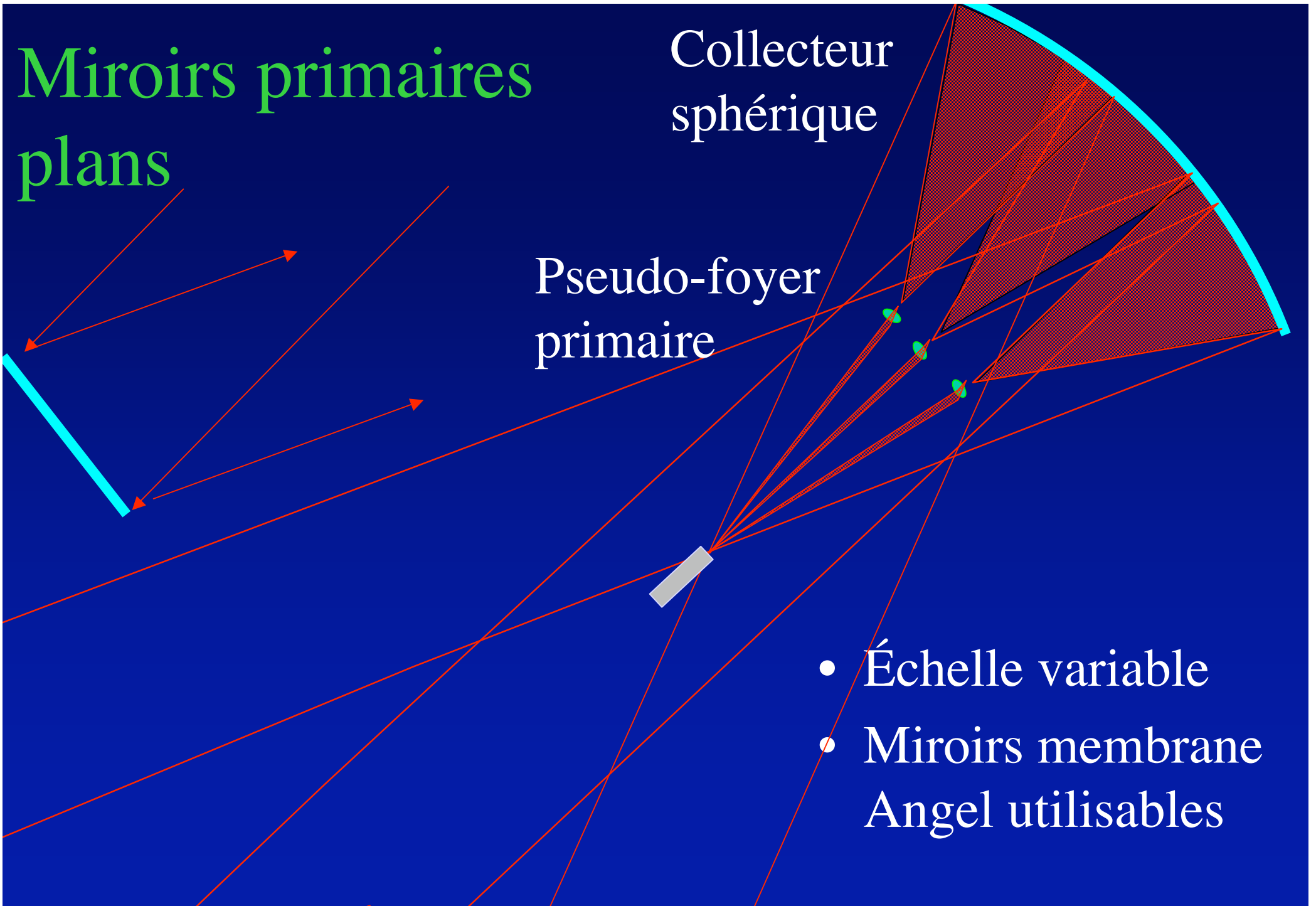


Miroirs primaires
plans

Collecteur
sphérique

Pseudo-foyer
primaire

- Échelle variable
- Miroirs membrane
Angel utilisables



TPF Preliminary Architecture Review

12-14 Dec. 2000

San Diego, CA

Boeing-SVS, Inc.

4411 The25 Way, NE Suite 350

Albuquerque, NM 87109

Boeing-SVS, Inc. **Raytheon** *Orbital* **BOEING**  Foster-Miller



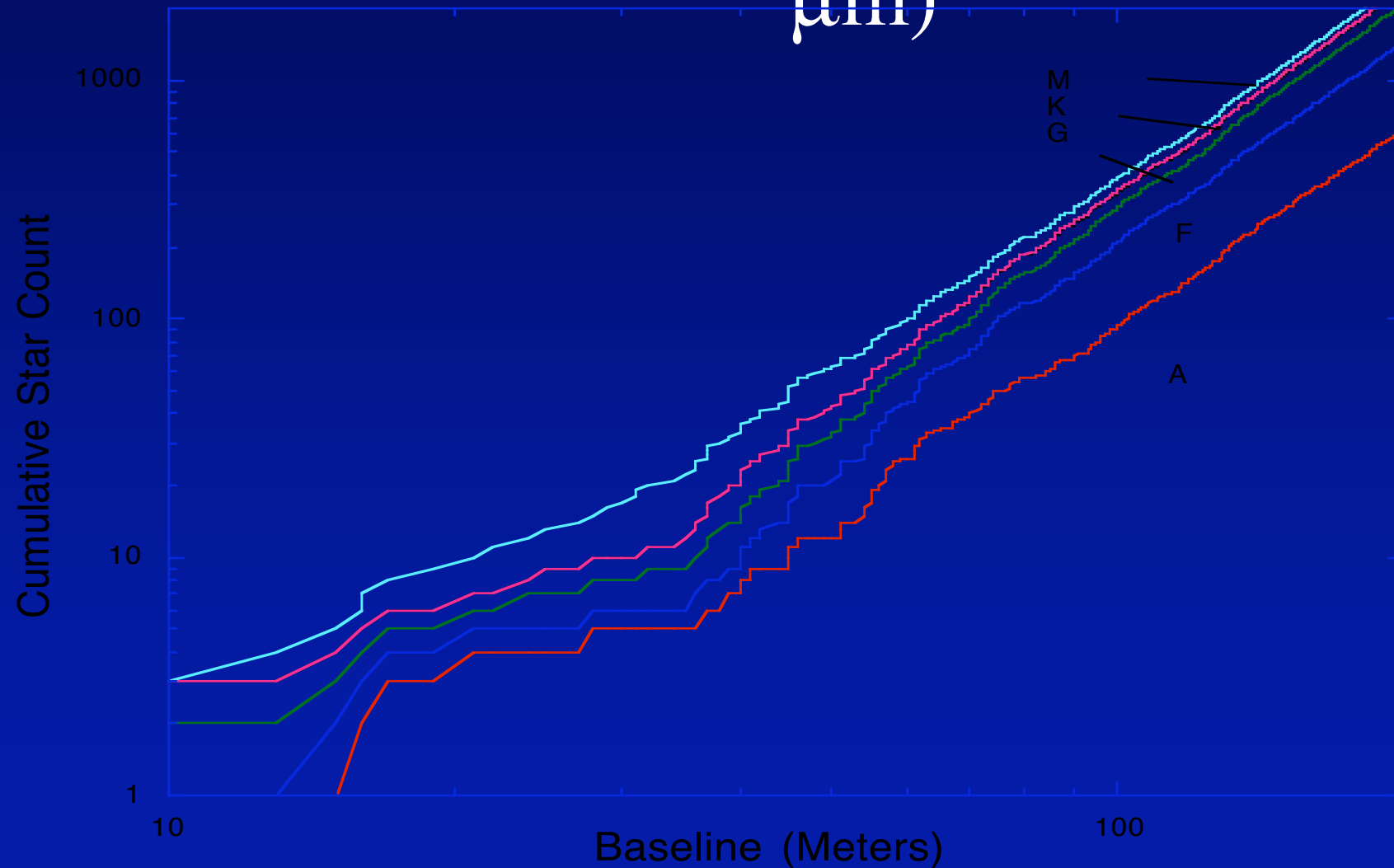
First Science Team Meeting, in Annapolis, MD



TPF Team at Pre-PAR Review @ OHP, France



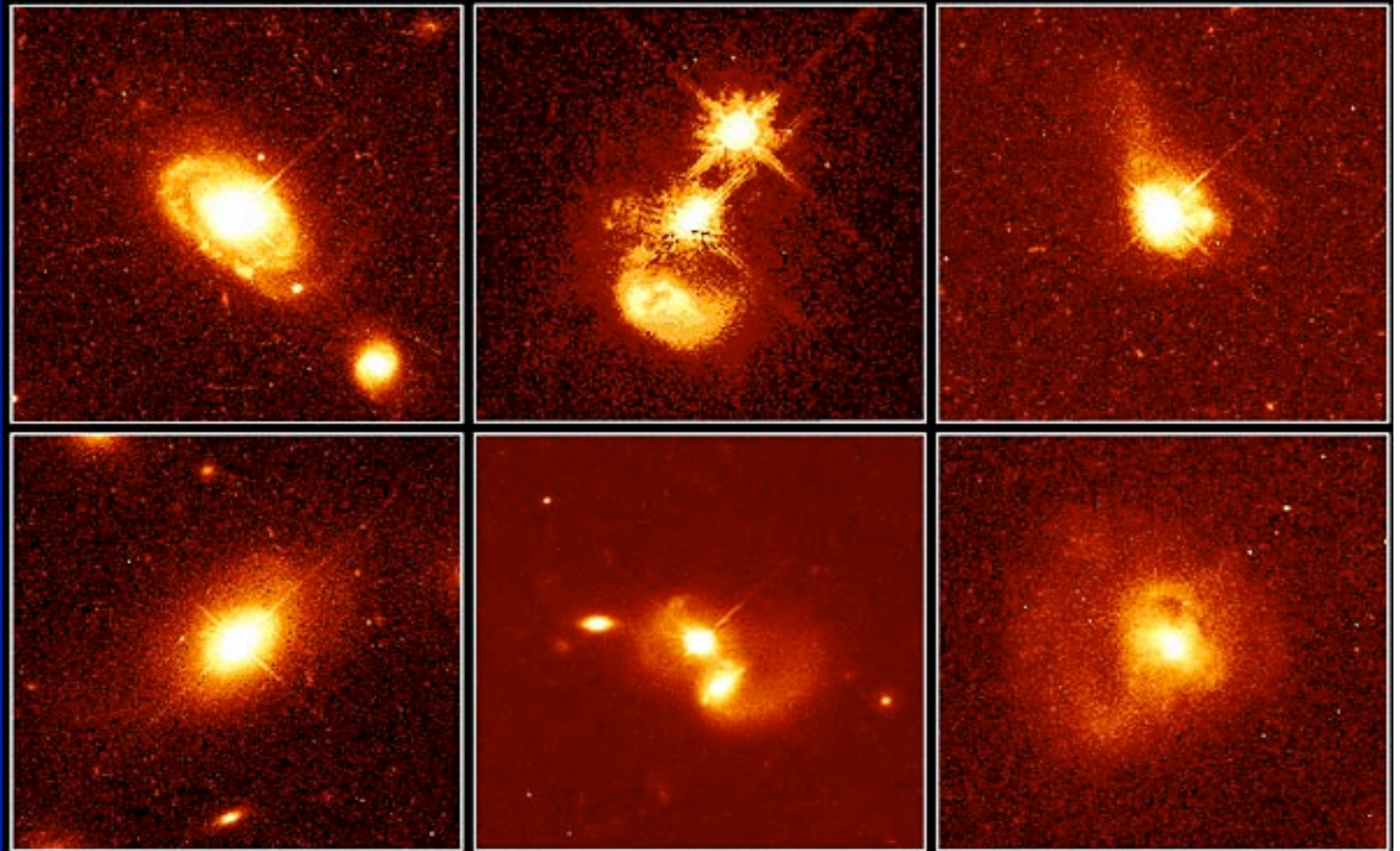
Accessible Candidate Stars vs Baseline (1AU resolved at 14 μm)



Astrophysics - Host Galaxies

- What fuels quasars?
- Did most galaxies contain quasars at one time?
- Are quasars born in mergers?

for Quasars



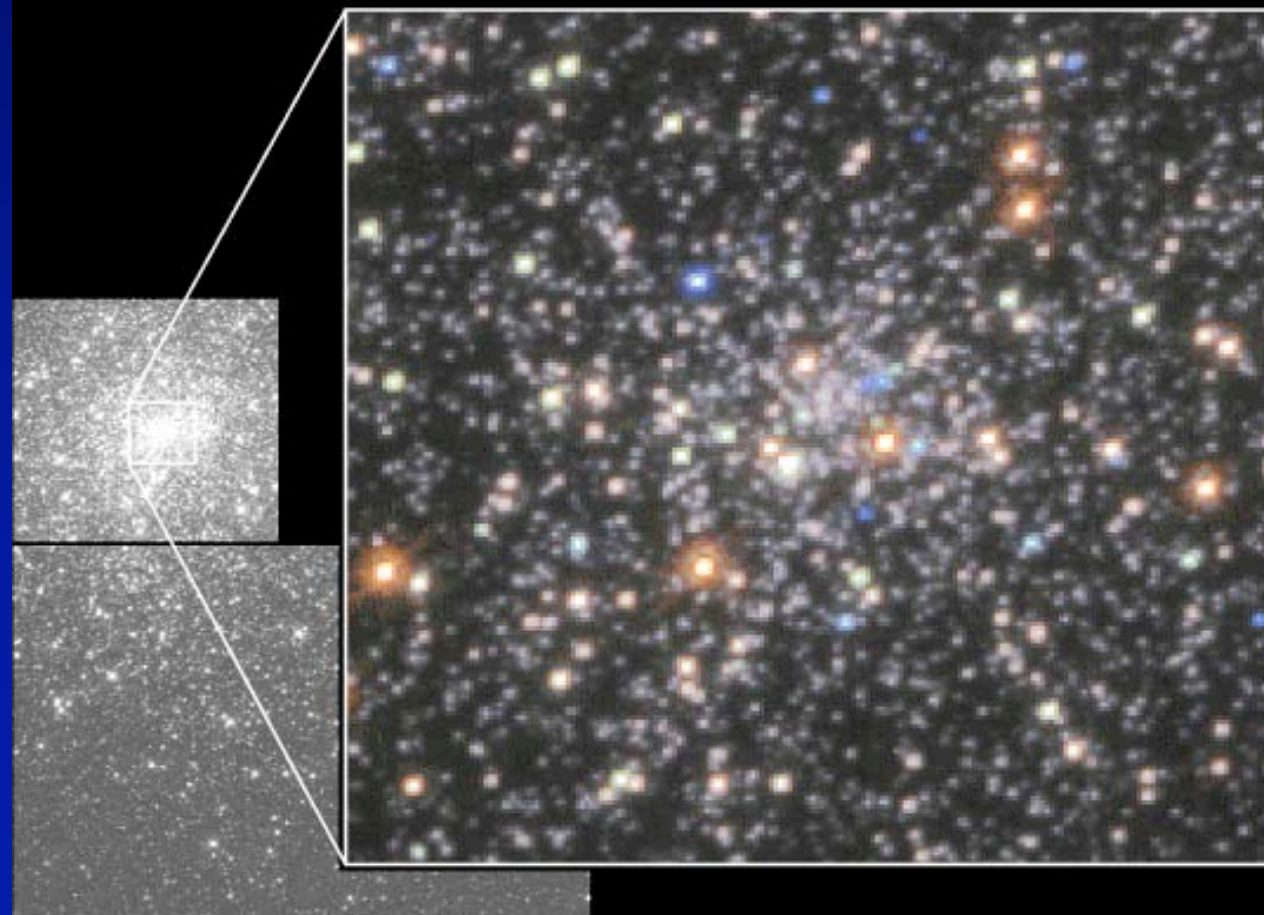
Astrophysics - Nebulosity around Quasars, Blazars, AGN's

- Image foreground lensing galaxies.
- Determine intrinsic nebulosity.
- Are they powered by interstellar matter?



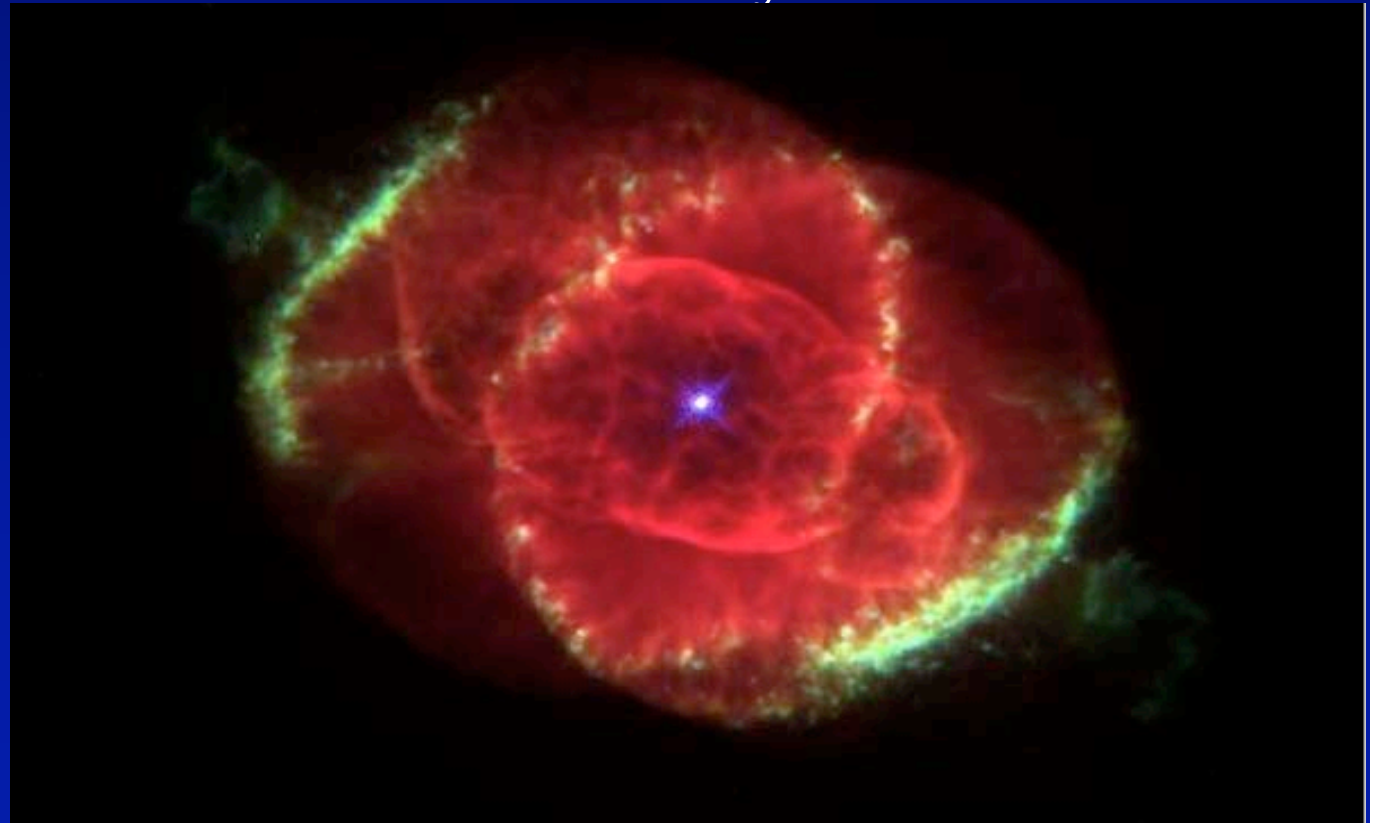
Astrophysics - Globular Cluster Cores

- Stars interact - binaries stripped.
- Physical collisions and tidal interactions may produce a new range of unfamiliar stellar phenomena.

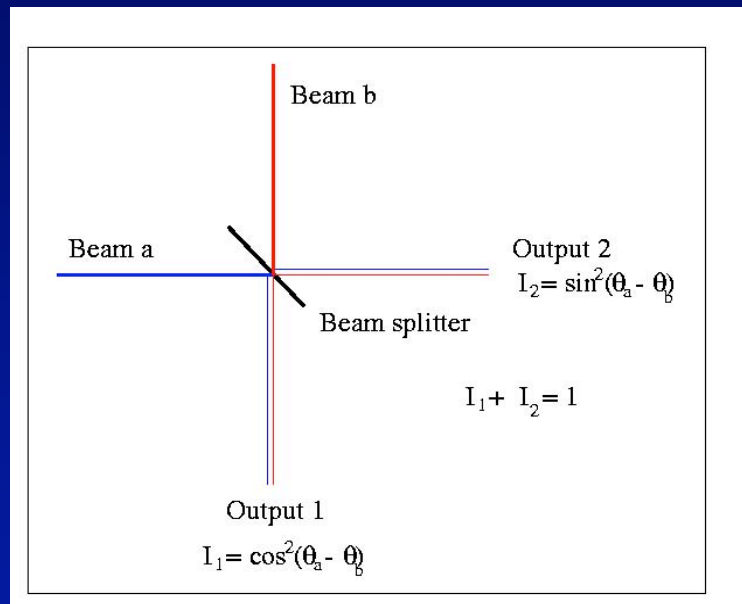


Mass Loss from Evolved Stars

- Complex structure of circumstellar shell records variations of stellar internal structure.
- TPF suppresses central star - time variability dissects mass-loss outflow and abundance history.

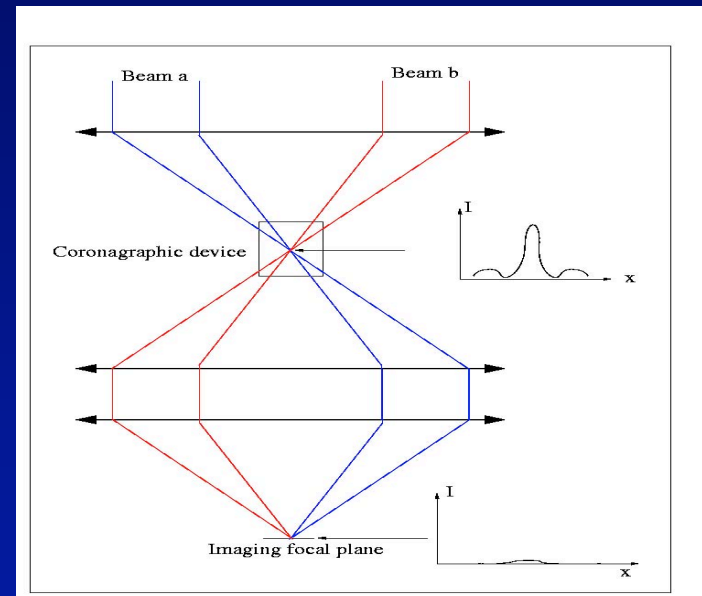


Nulling : Imaging coronagraphy vs. "classical" nulling



- Beams (one per aperture) are coherent
- One phase shift per beam
- One of the outputs is set to $I=0$ for an on-axis point source
- The star light is found in the other outputs
- Number of outputs = number of input beams

_ Imaging coronagraphy

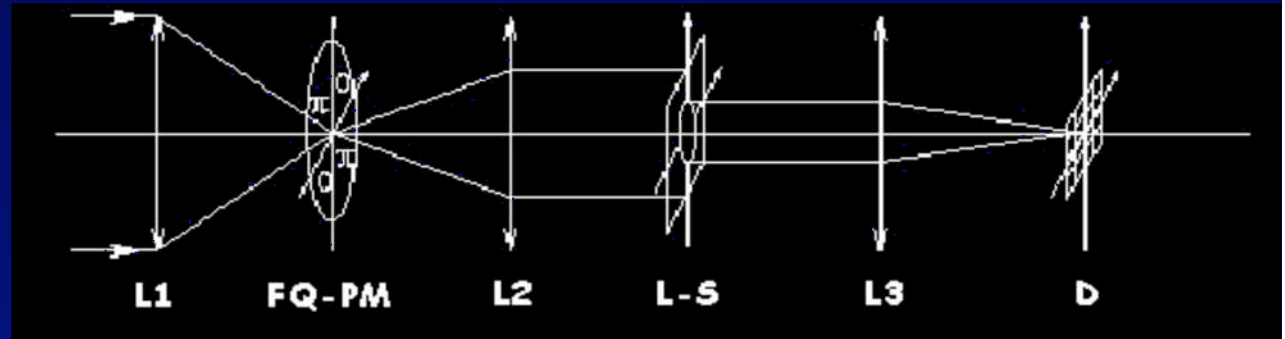


- Beams (one per aperture) are not coherent
- Without coronagraphy, no significant fraction of the field is usable (very small ring in the dark rings of the PSF)
- 2-step process : coronagraphy and then imaging
- Number of pixels in densified pupil mode = number of input beams

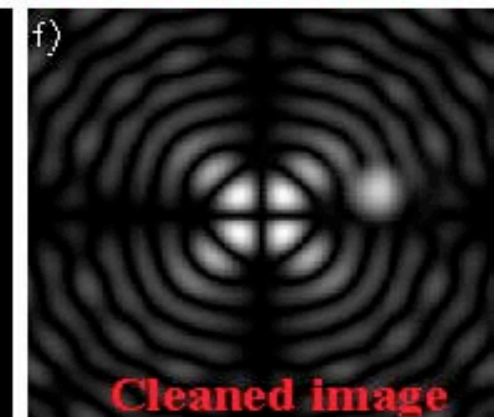
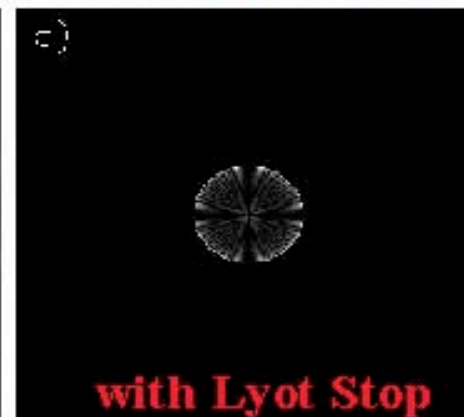
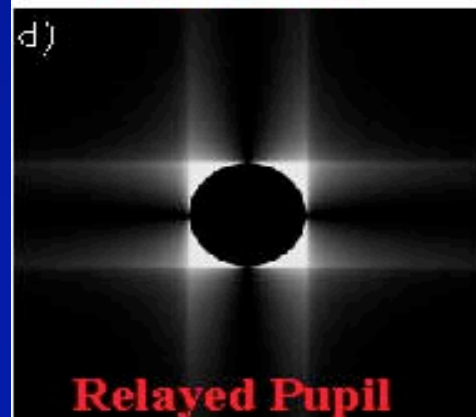
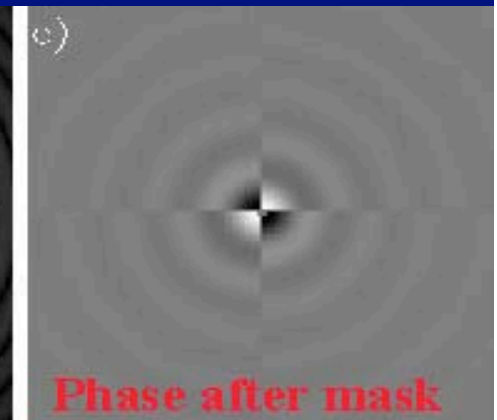
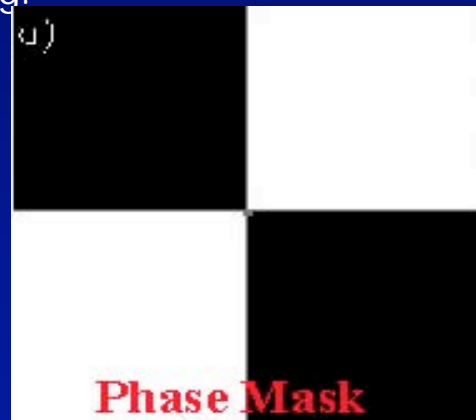
Four Quadrant Coronagraph

(*Rouan et al., 2000, Riaud et al, in preparation*)

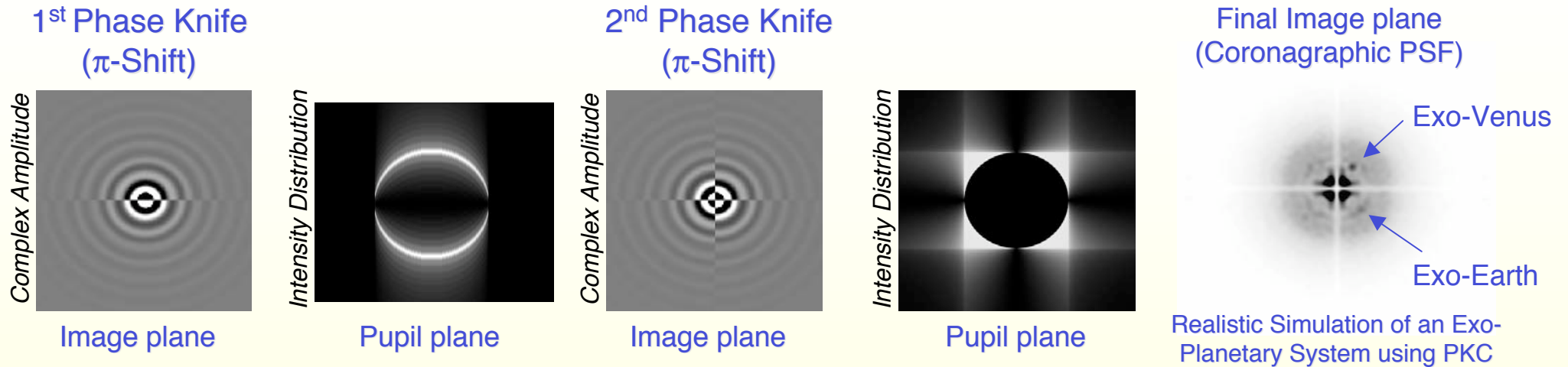
Optical layout



- Four quadrant phase-mask in the focal plane (Rouan 2000)
- High dynamic range \Rightarrow 20mag. (with perfect optics)
- Resolution unaffected
- Broad-band operation with achromated phase mask
- requires a circularized pupil
- affected by guiding errors (null width $\propto \theta^2$)
- Pupil obscuration up to 10% tolerable



Phase Knife Coronagraph: Principles



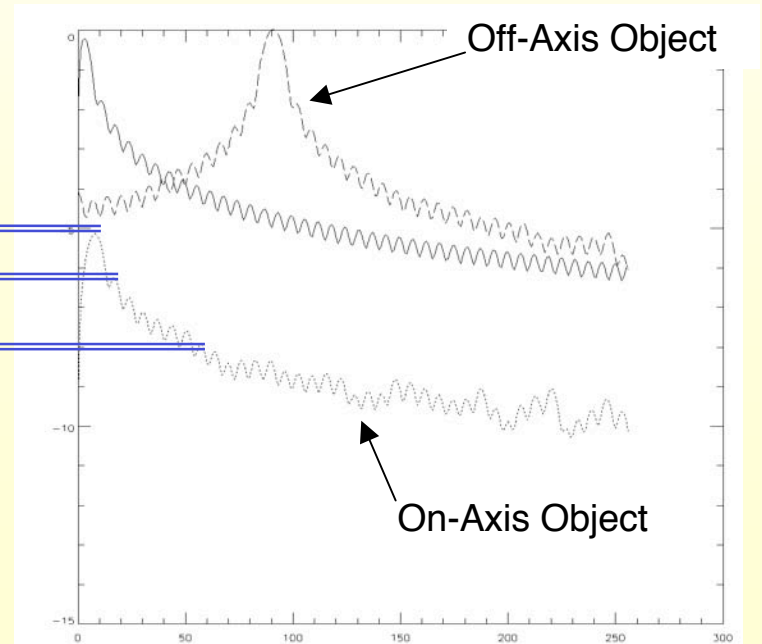
Extinction Performance:

10^{-6} at First Airy Ring

10^{-5} Peak to Peak

10^{-8}

**π -Shifts are Wavelength Dependent,
i.e. Chromatic**

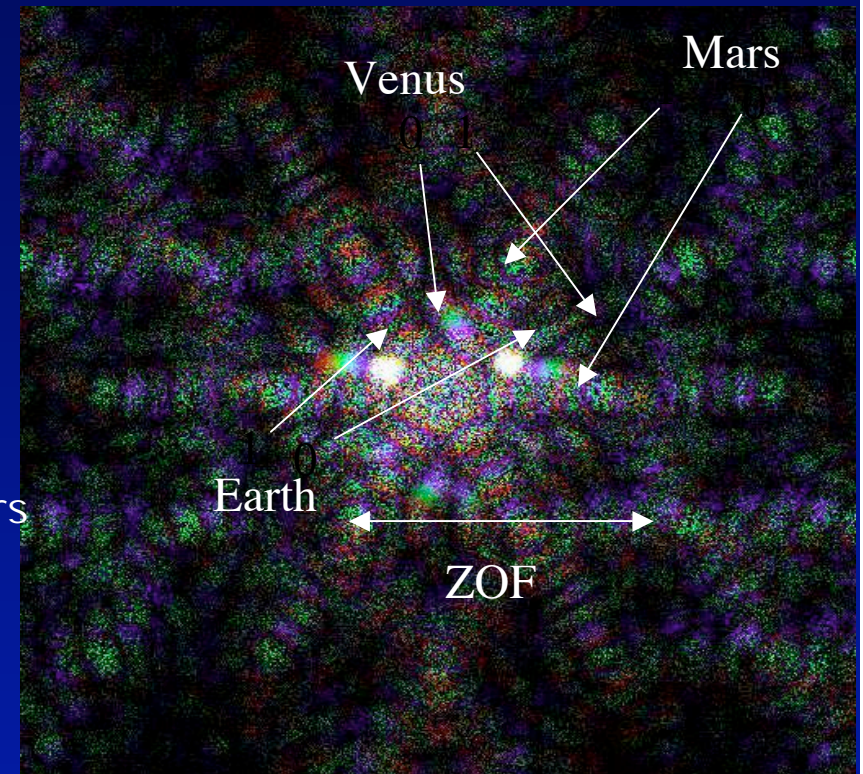
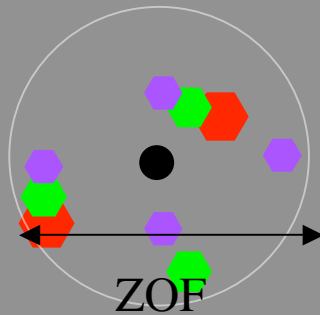


Imaging beyond the Zero-Order Field:

Zero-Order Field

$$\text{ZOF} = \lambda / s$$

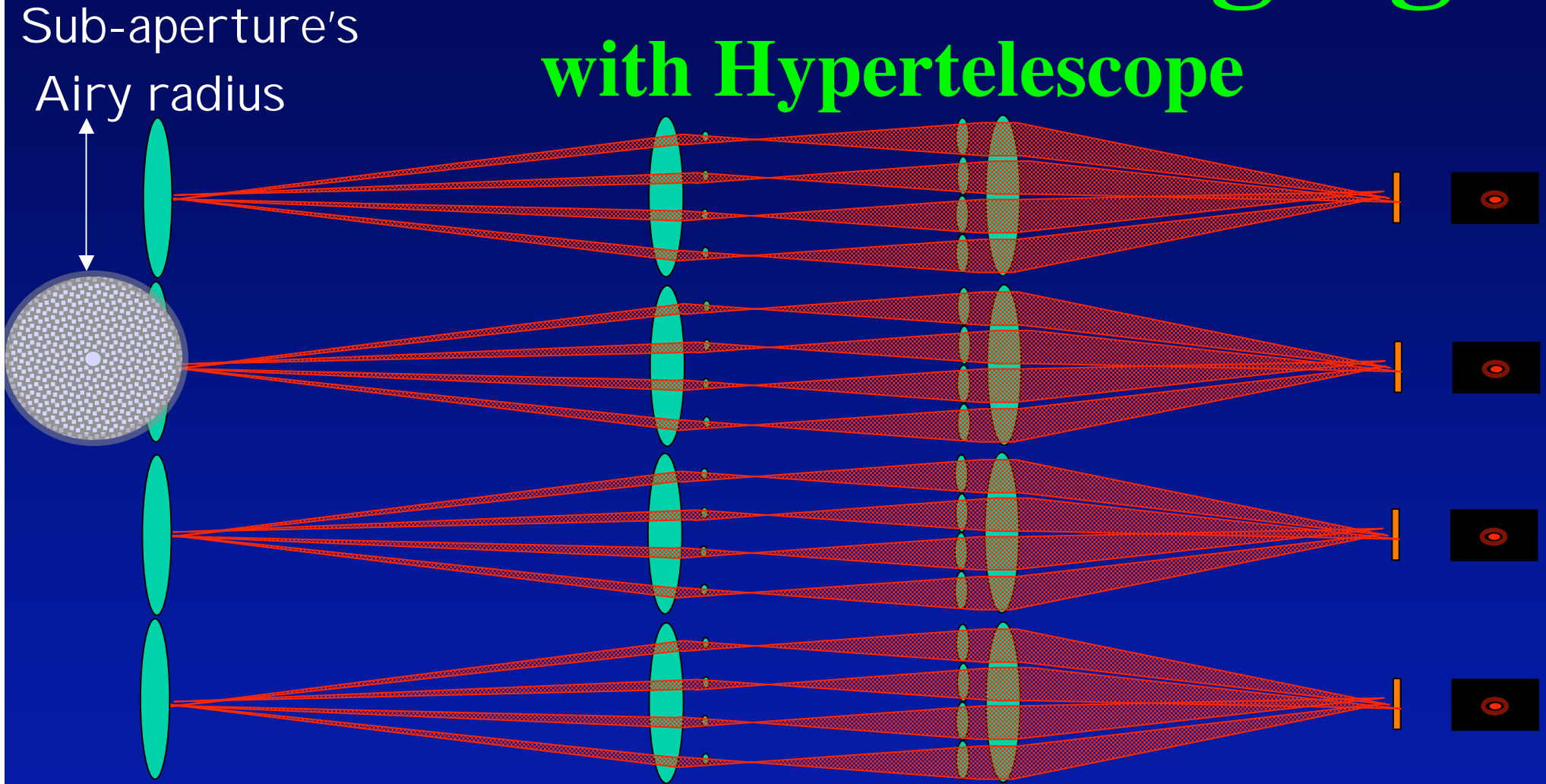
Sun (nulled) with Earth, Venus, Mars image simulation (Boccaletti et al., 2000, Icarus)



- Planets outside ZOF have a dispersed image in ZOF
- Extended image can be reconstructed if:
 - fewer than pN active pixels in object (OK for exo-planets)
 - multi- λ camera (ex: STJ, ... Courtès optics)

Multi-field Imaging

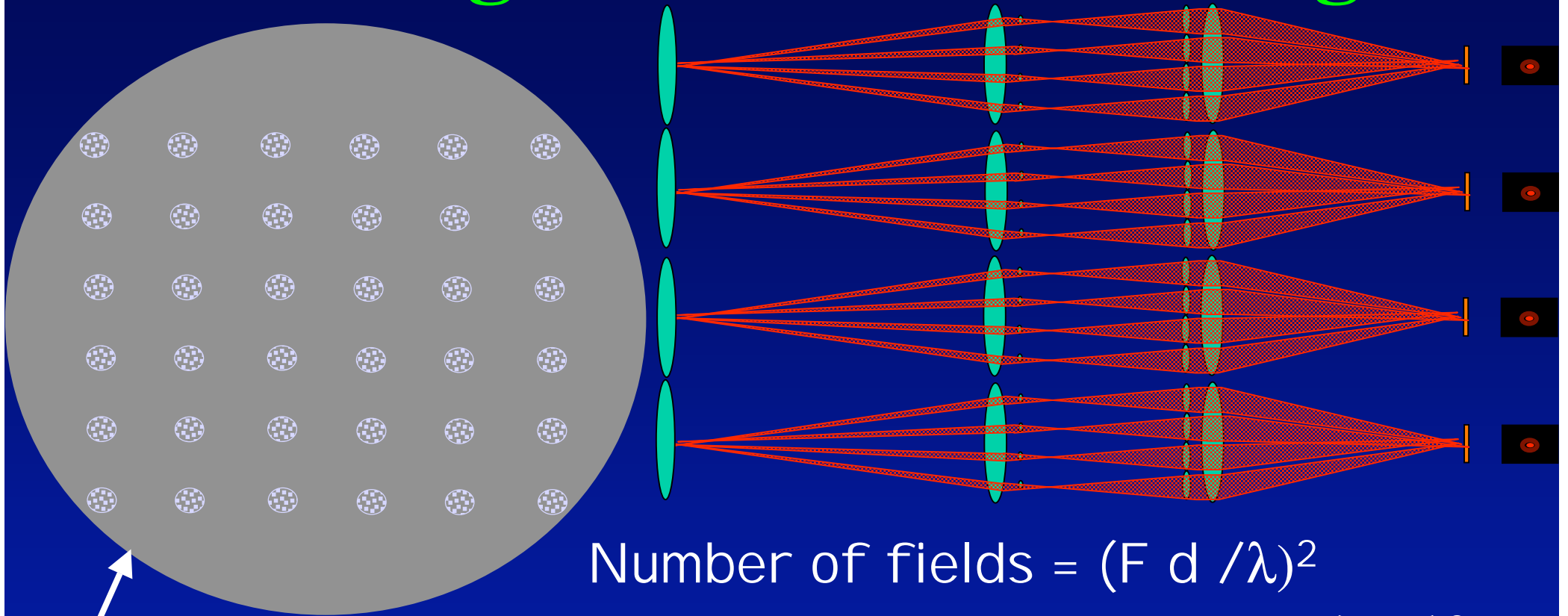
with Hypertelescope



Fizeau focus

Array of densifiers

Coverage of Multi-field Image

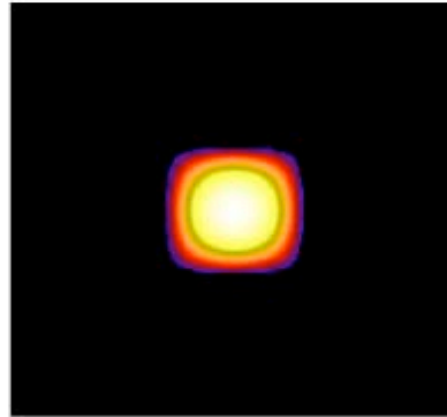


corrected Fizeau field
(size F on sky)

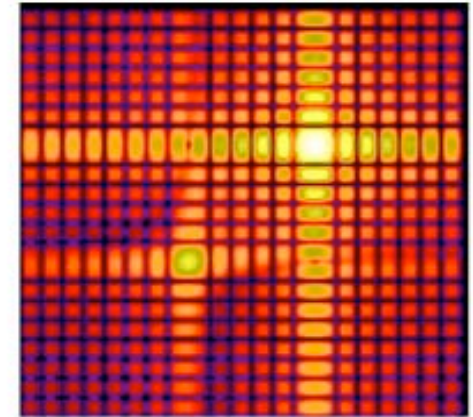
Number of fields = $(F d / \lambda)^2$
relative coverage of sky area = $N (d/D)^2$
Example: "exploded OWL"
 $N=10,000$; $d=1\text{m}$; $D=1\text{km}$
gives 10,000 fields and 1% coverage

A square aperture with and without apodization

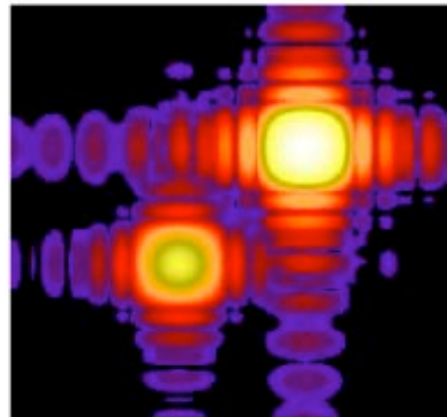
- Here is a square aperture with crossed Sonine apodization.
- Next to it is the two point image (100:1 contrast) with square aperture but no apodization.
- On the lower row, the 100:1 image with apodization and then $10^6:1$ ratio with apodization.
- Apodization narrows the aperture and degrades the resolution, with a *significant* increase in dynamic range.



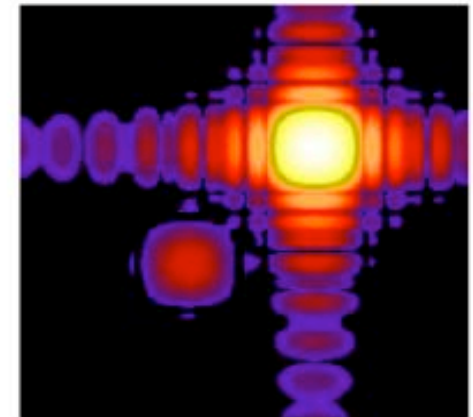
Apodized Square Aperture



100:1 Two Point Image with No Apodization



100:1 Two Point Image with Apodization



One Million:1 Two Point Image with Apodization

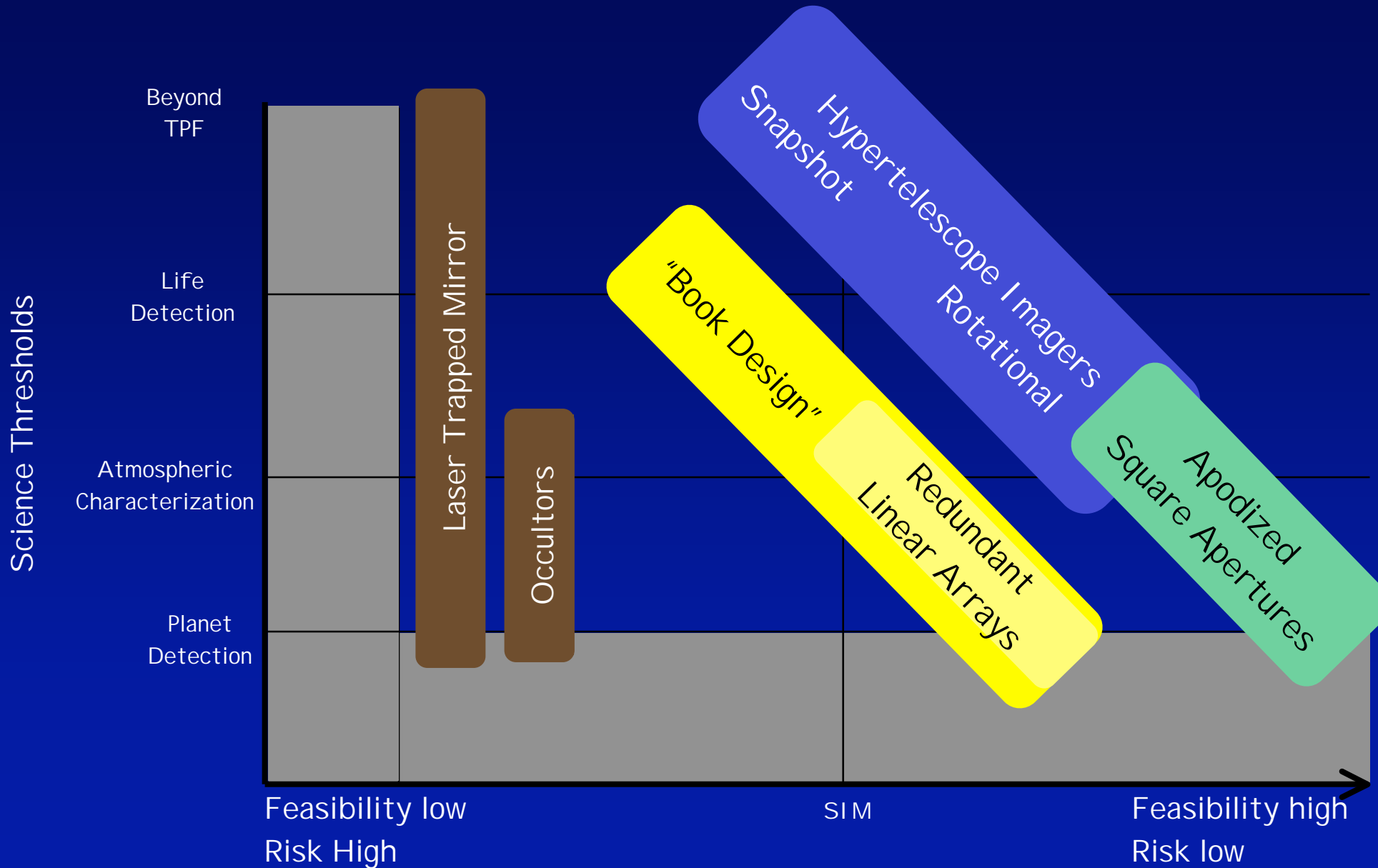
Apodization with Square Aperture

Science Scoring – Results

(Planetary sci: 75% Astrophys: 25%)

	Planetary Sci	Astrophys	Weighted total
Densified Pupil Hypertelescope	455/500	412/550	444
Laser Trapped Mirror	400/500	550/550	437
Book Design	365/500	371/550	366
Redundant Linear Array	300/500	287/550	297
ASA	300/500	340/550	310
Occulters	250/500	520/550	317

Comparison of Concepts



Conclusions and Recommendations

- Develop Apodized Square Aperture architecture on several possible scales - in visible and infrared - as potentially quickest, cheapest TPF realization.
- Develop Hypertelescope Imager architectures, as most promising for eventual very high resolution TPF realizations, scalable to Life Finder and Planet Imager.
- Define earth frequency through precursors.
- Develop mini-TPF options as TPF alternatives.
- Continue investigation of Laser Trapping as enabling technology for future ultra-large apertures.