6 High contrast imaging

6.2 Coronagraphy (part 2)

Types of coronagraphs

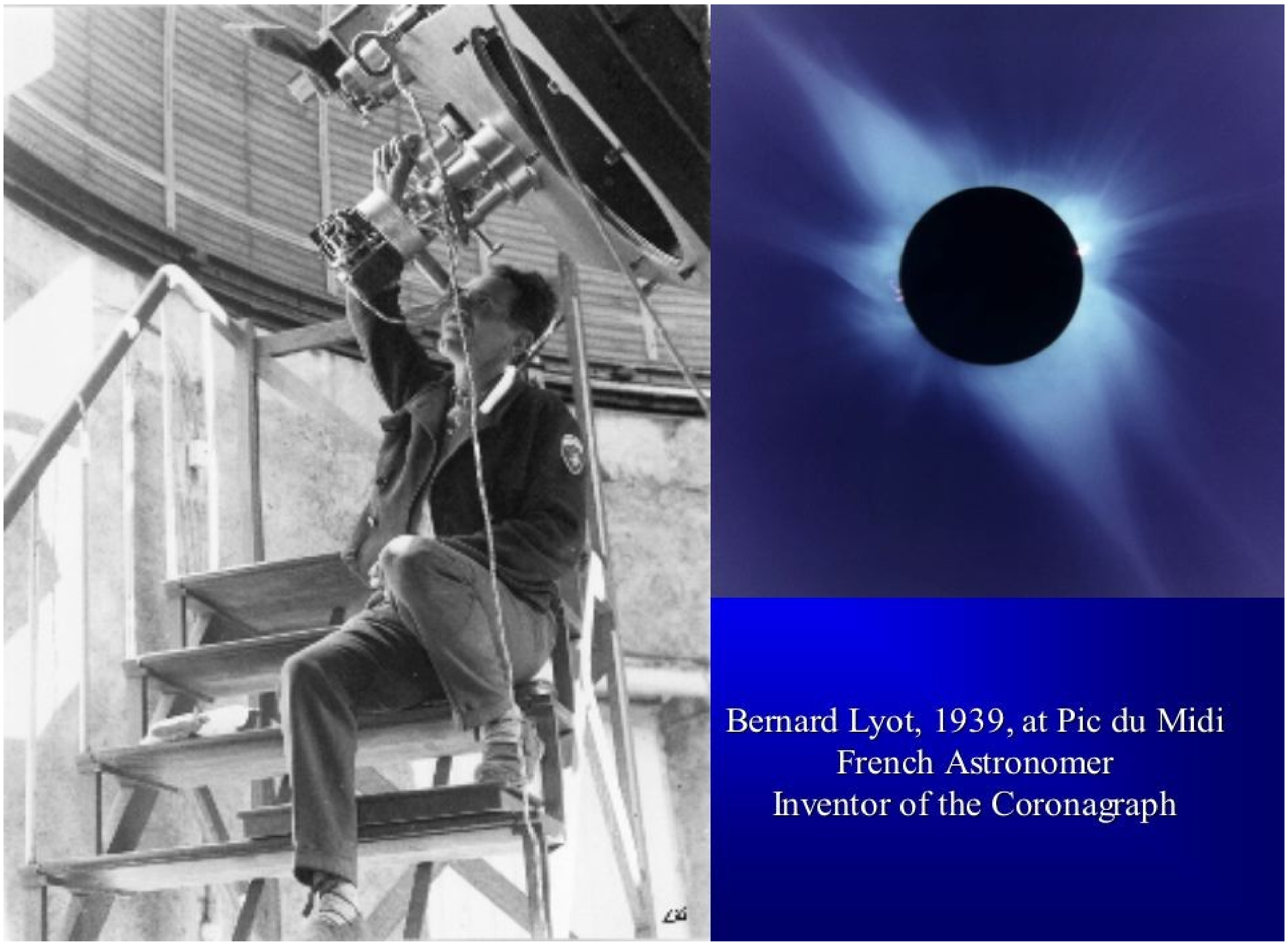
- Lyot coronagraph(s)

  Understanding Lyot coronagraphs with Fourier Transforms
  - Amplitude focal plane mask
  - Phase focal plane mask
  - Pupil apodization

- Pupil apodization
  - Conventional
  - PIAA
  - Pupil apodization and Lyot coronagraphs

Interferometric coronagraphs / nulling interferometers

Lyot Coronagraph was first developed to observe the solar corona



Lyot Coronagraph architecture

Relies on focal plane mask AND pupil mask (Lyot stop) to augment contrast

Why a Lyot pupil mask ?

- Focal plane occulter blocks central part of the image = low spatial frequencies in pupil plane
- What is left after focal plane mask are high spatial frequencies in pupil plane = light around edges
- This light can be masked by an undersized pupil plane stop

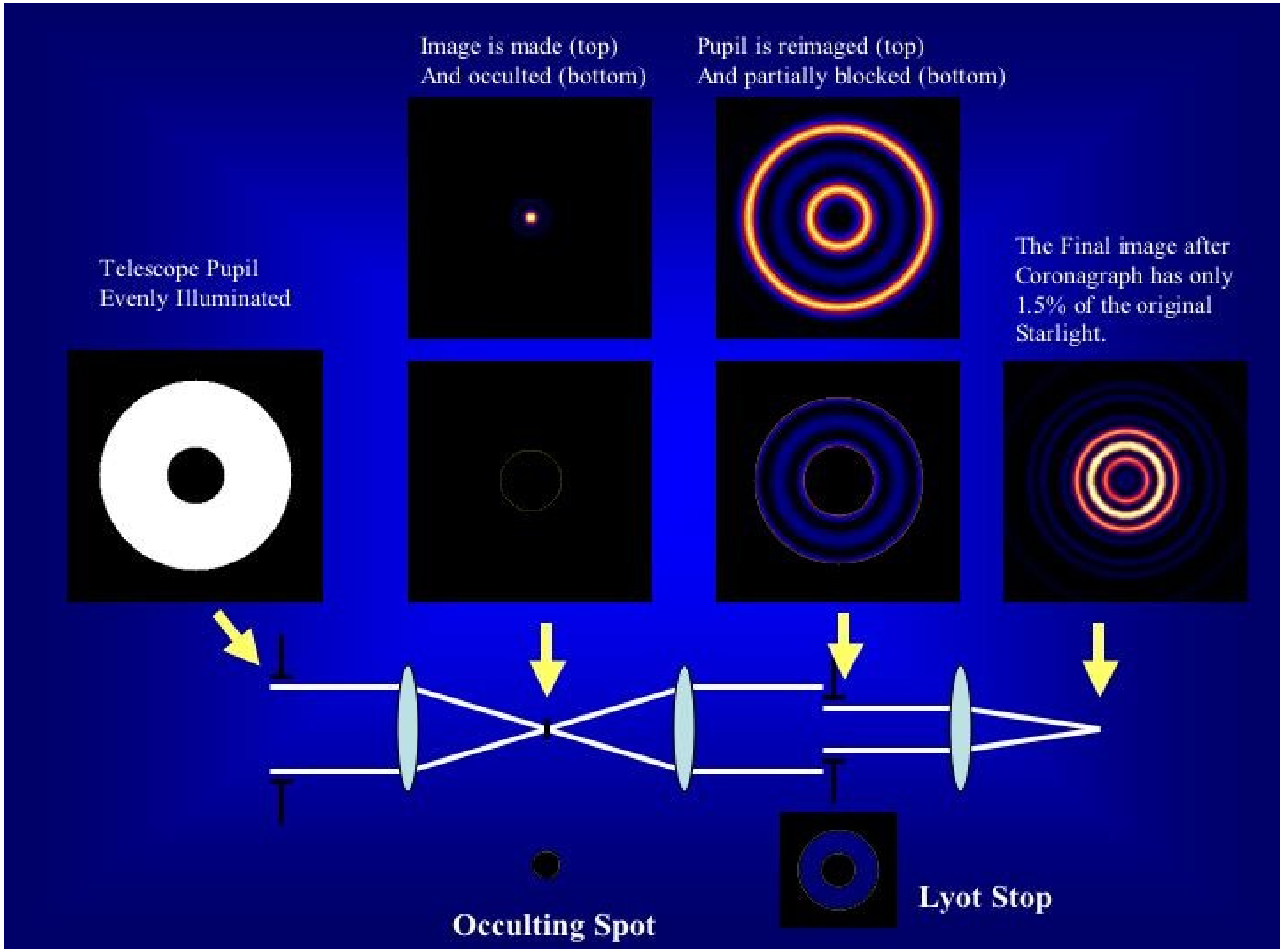


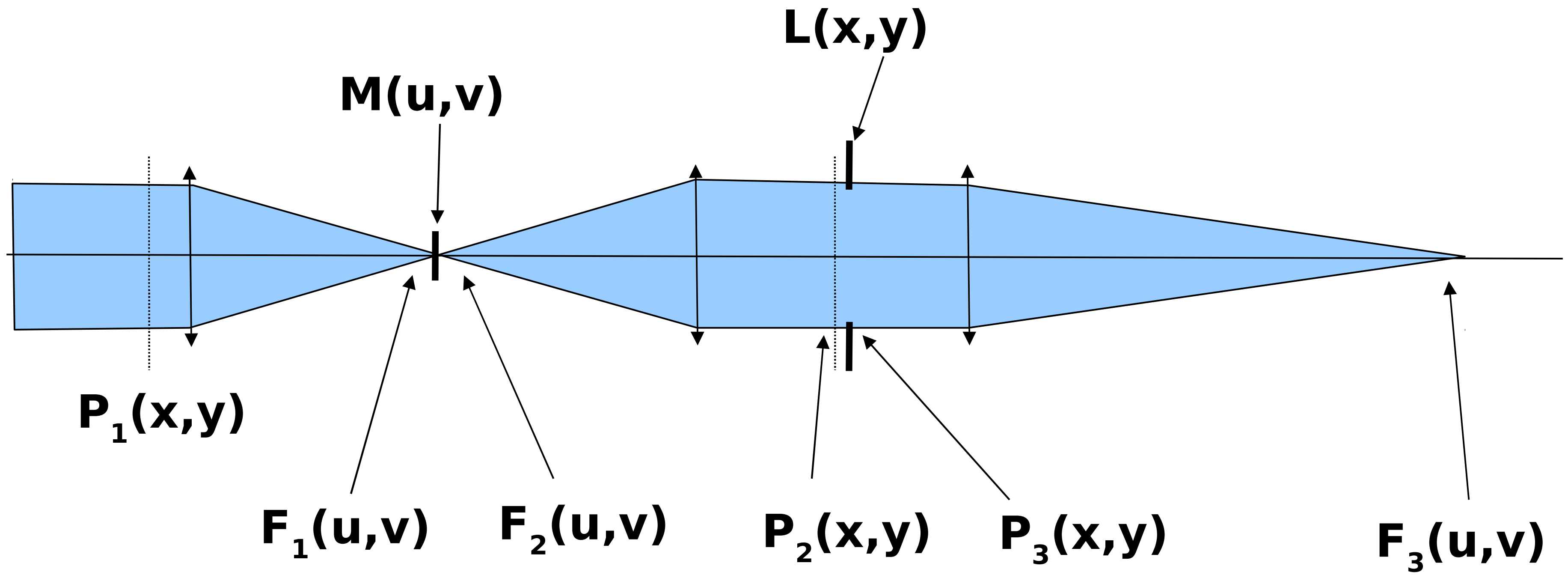
figure from Lyot project website

Lyot Coronagraph explained by Fourier transforms

Pupil plane complex amplitude ↔ focal plane complex amplitude

→ Fourier transform
← Inverse Fourier transform

Coordinates in pupil plane: x,y
Coordinates in focal plane : u,v
 * denoting convolution (product = convolution in Fourier transform)



Lyot Coronagraph explained by Fourier transforms

Entrance pupil of telescope: $P_1(x,y)$

Focal plane complex amplitude (before focal plane mask): $F_1(u,v)$

$F_1(u,v) = FT\ (\ P_1(x,y)\ )$

Focal plane mask complex amplitude transmission: $M(u,v)$

Focal plane complex amplifude (after focal plane mask): $F_2(u,v)$

$F_2(u,v) = F_1(u,v) \times M(u,v) = FT(P_1(x,y)) \times M(u,v)$

Exit pupil plane:

$P_2(x,y) = FT^{-1}(\ F_2(u,v)\ ) = FT^{-1}\ (\ FT(P_1(x,y) \times M(u,v)\ ) = P_1(x,y) * FT^{-1}(M(u,v))$

With * denoting convolution

$P_3(x,y) = L(x,y) \times P_2(x,y)$

$\mathbf{P_3(x,y) = L(x,y) \times (P_1(x,y) * FT^{-1}(M(u,v)))}$

$F_3(u,v) = FT(L(x,y)) * (F_1(u,v) \times M(u,v))$

Coronagraphy problem: minimize $P_3(x,y)$ for on-axis point source