

HOLOGRAPHIC TIMING

MARK WALKER

(MANLY ASTROPHYSICS)

OVERVIEW

- * THE HORRIBLE ISM
- * TIME DOMAIN VS. FREQUENCY DOMAIN
- * YOU NEED CYCLIC SPECTROSCOPY
- * B1937+21 CASE STUDY
- * I NEED AN ENORMOUS COMPUTER

THE HORRIBLE ISM

The background is a deep blue with a mottled, nebula-like texture. Several bright orange lines of varying lengths and slopes are scattered across the frame, some appearing to converge towards a large brown circle on the right. There are three brown circles: a large one on the right, a medium one at the top center, and a small one at the bottom center. The text 'THE HORRIBLE ISM' is written in a white, serif font at the top.

THE HORRIBLE ISM MEANS ...

- * IMPULSE RESPONSE FUNCTION IS COMPLICATED
- * IRF WIDTH (“SCATTERING TIME”) IS AN INADEQUATE REPRESENTATION OF THIS FUNCTION
 - * MAY HAVE SIGNIFICANT FLUX AT MUCH LARGER DELAYS
- * IRF SPECTRAL VARIATION IS UNPREDICTABLE
- * IRF TEMPORAL EVOLUTION IS UNPREDICTABLE AND RAPID
 - * ESPECIALLY SO AT HIGH FREQUENCIES
- * MUCH LARGER EFFECT THAN ANTICIPATED GW SIGNAL
- * **NEED TO CHARACTERISE FOR EVERY T.O.A.**

TIME- OR FREQUENCY-DOMAIN ?

$$\Delta T \sim W \times \Delta F / F \leq 10 \text{ ns}$$

$$\Delta F / F \leq 0.0001 \quad !!!$$

NOT JUST A S/N PROBLEM:
NEED DECONVOLUTION OF PULSE PROFILE
TO THIS LEVEL OF DETAIL

MUCH EASIER TO WORK IN FREQUENCY DOMAIN:

DECONVOLUTION \rightarrow DIVISION

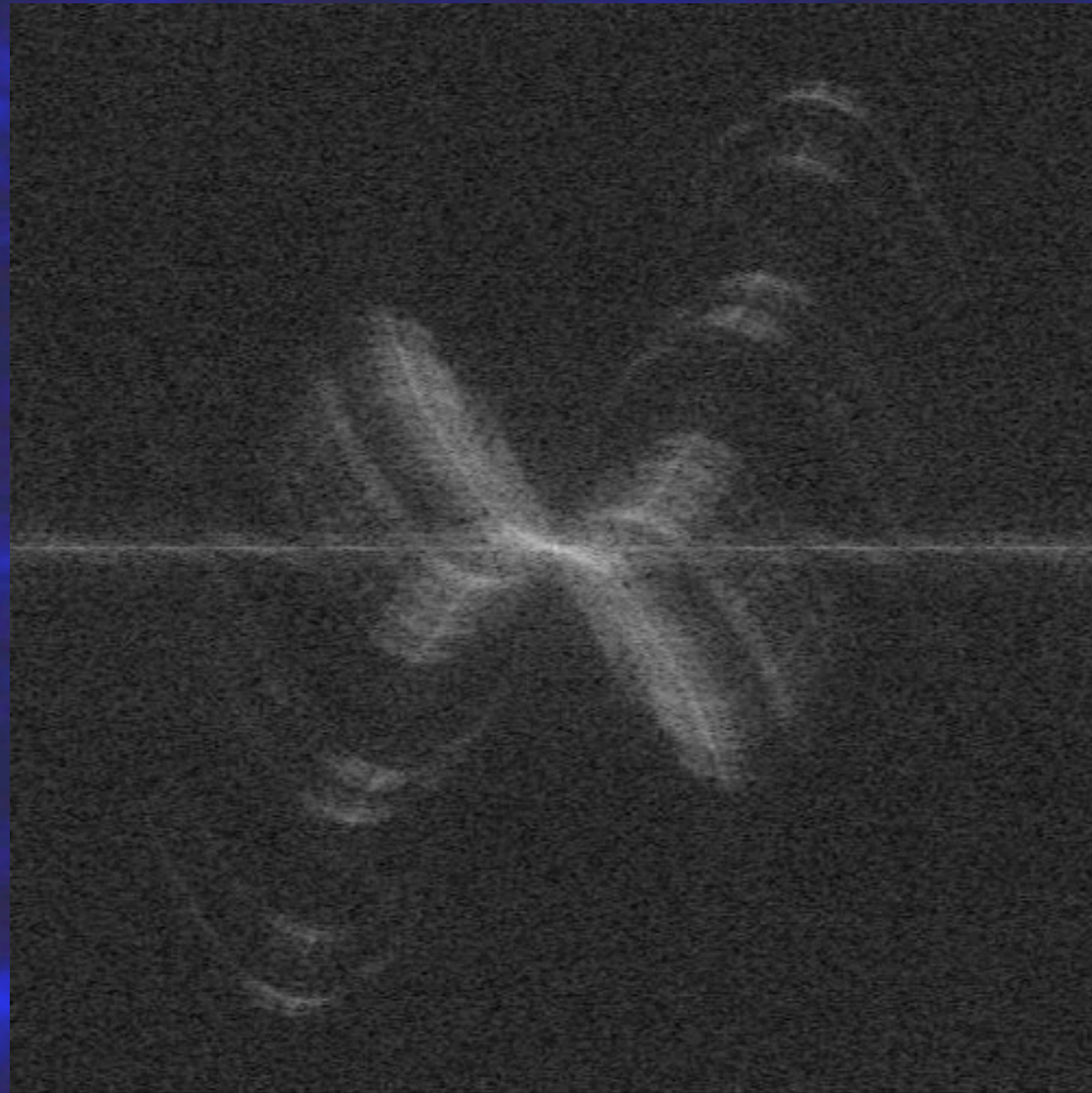
$1 \mu\text{s}$ \rightarrow 1 MHz

ΔF $\rightarrow \sqrt{(F \Delta F)}$



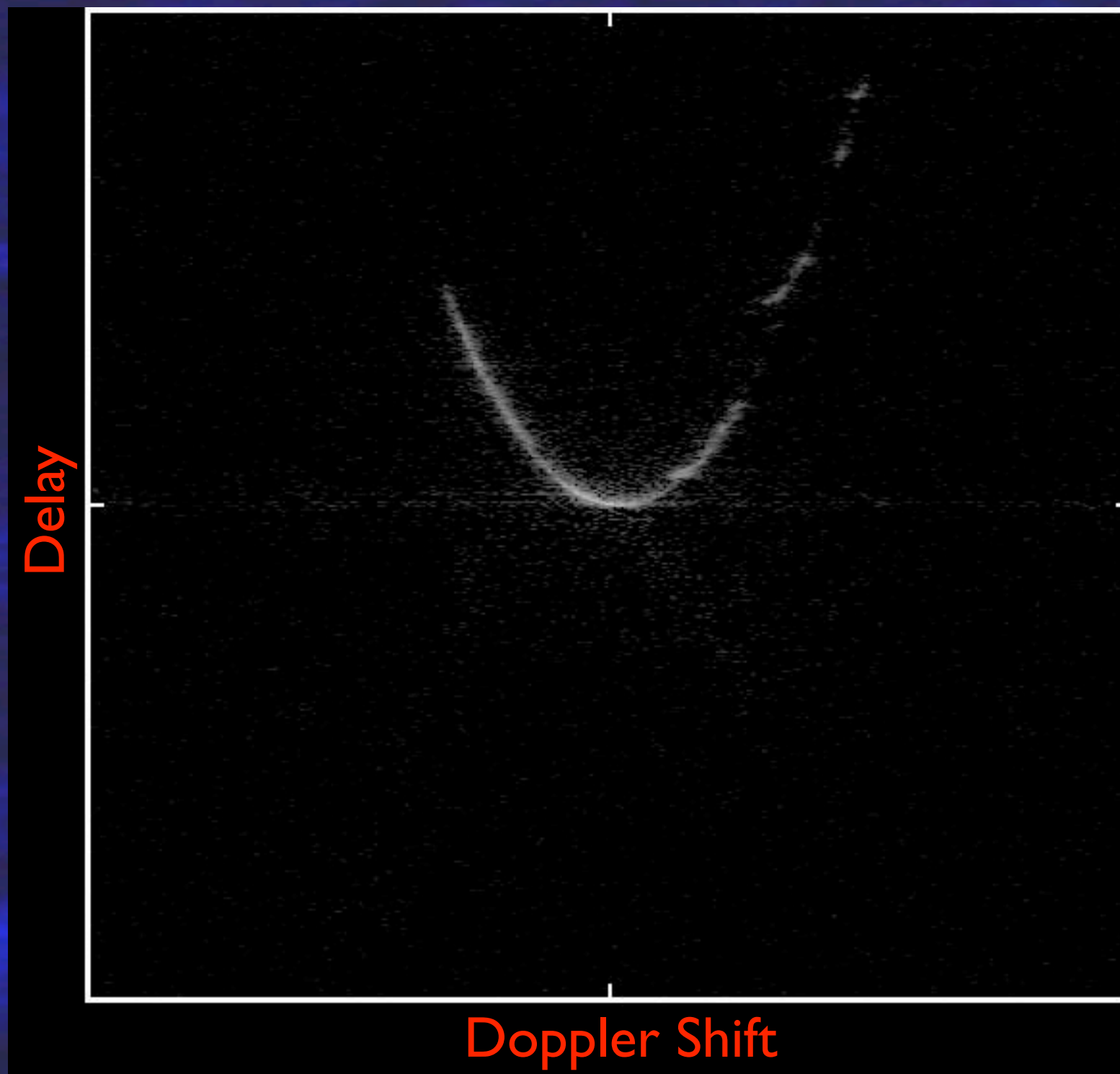
Ye Olde Interstelare Holografie

(DAN, LEON, WILLEM)



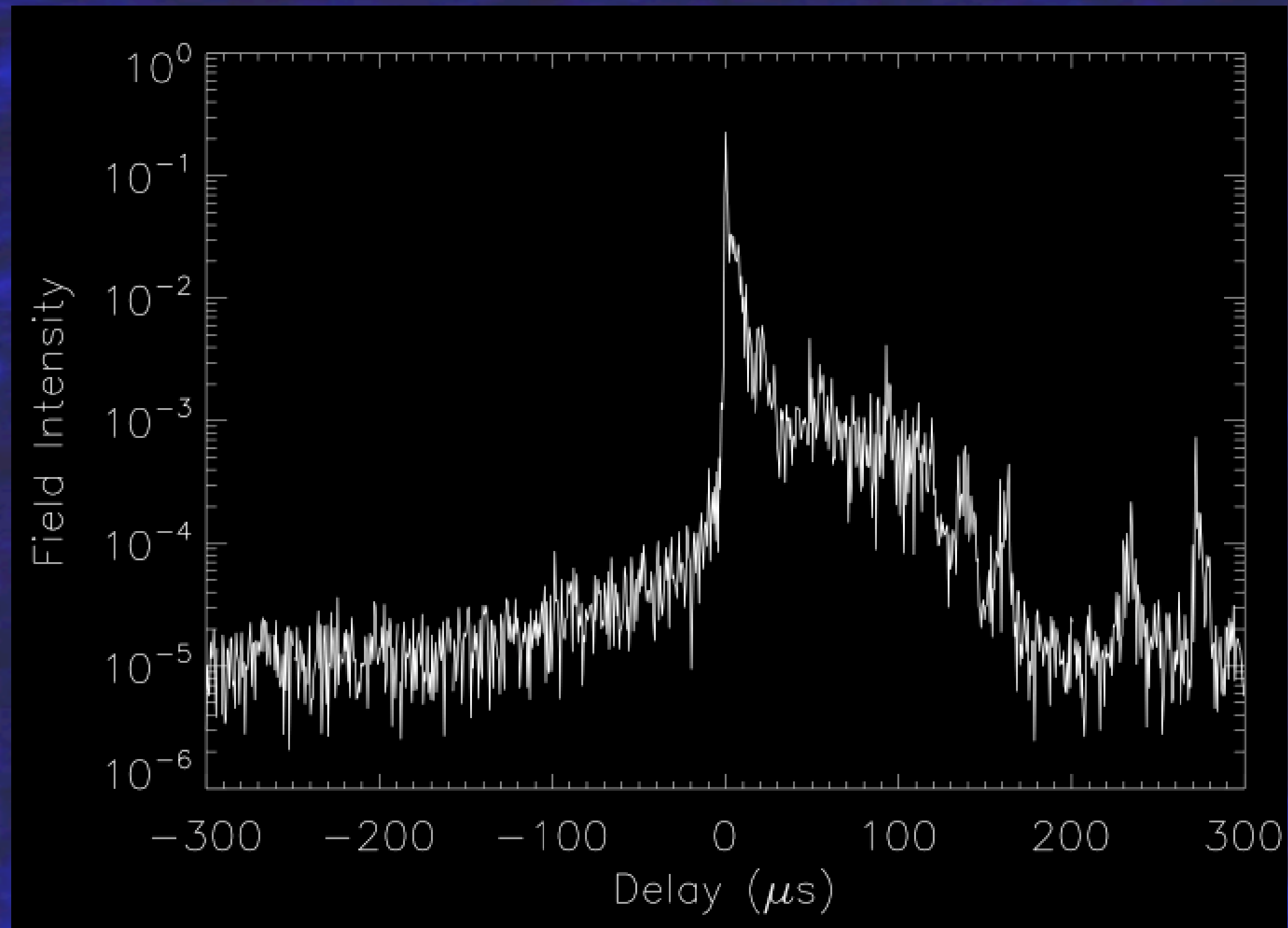
Ye Olde Interstellare Holografie

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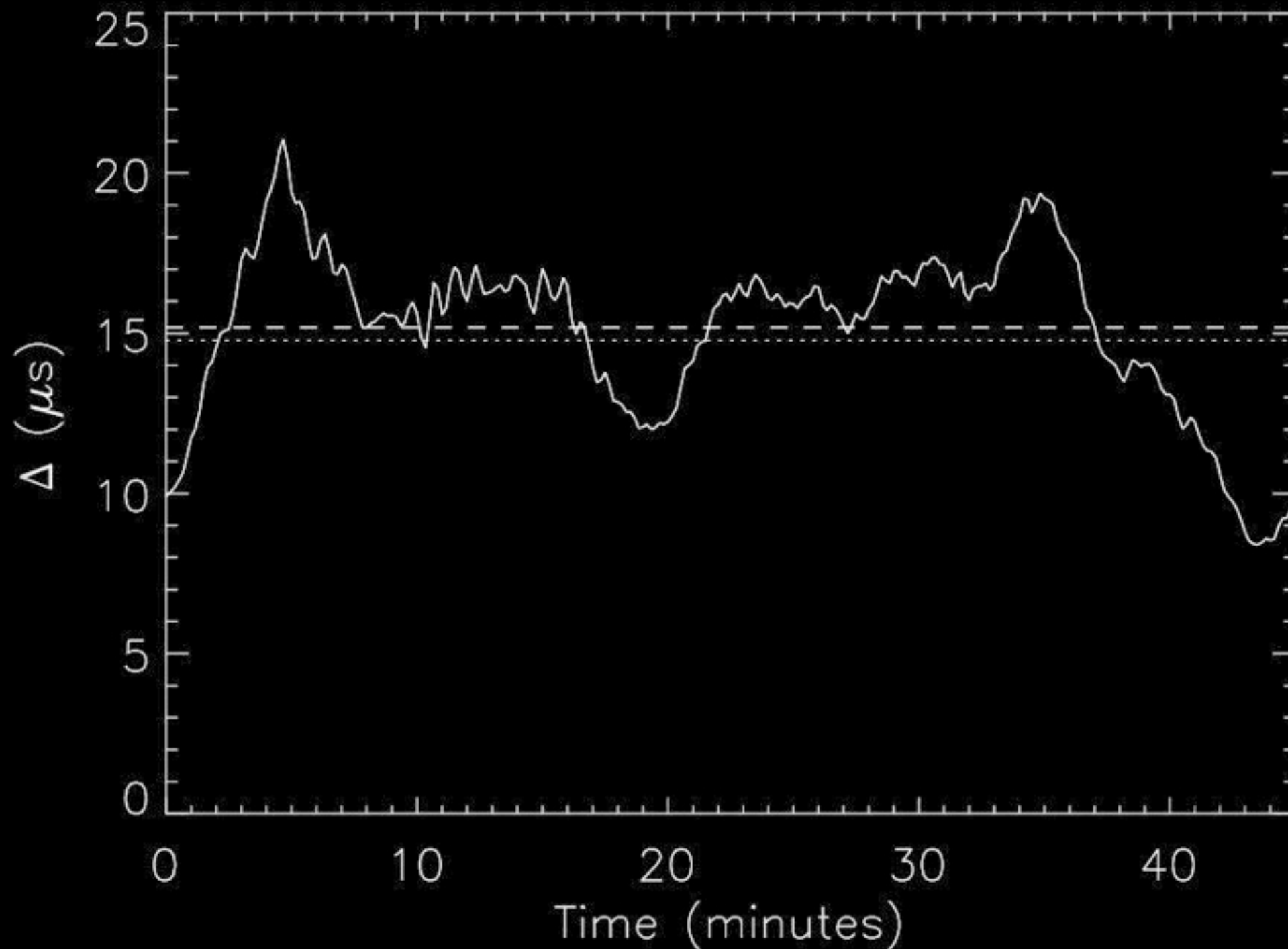
Ye Olde Interstelare Holografie

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INTERSTELLAR HOLOGRAPHY IN 2010

$$S_z(f, \Omega) = H(f + \Omega/2) H^*(f - \Omega/2) S_0(\cancel{f}, \Omega)$$

CYCLIC SPECTRUM: MANIFESTS PHASES EXPLICITLY

-> GET $H(f)$ EVERY ~ 10 SECONDS

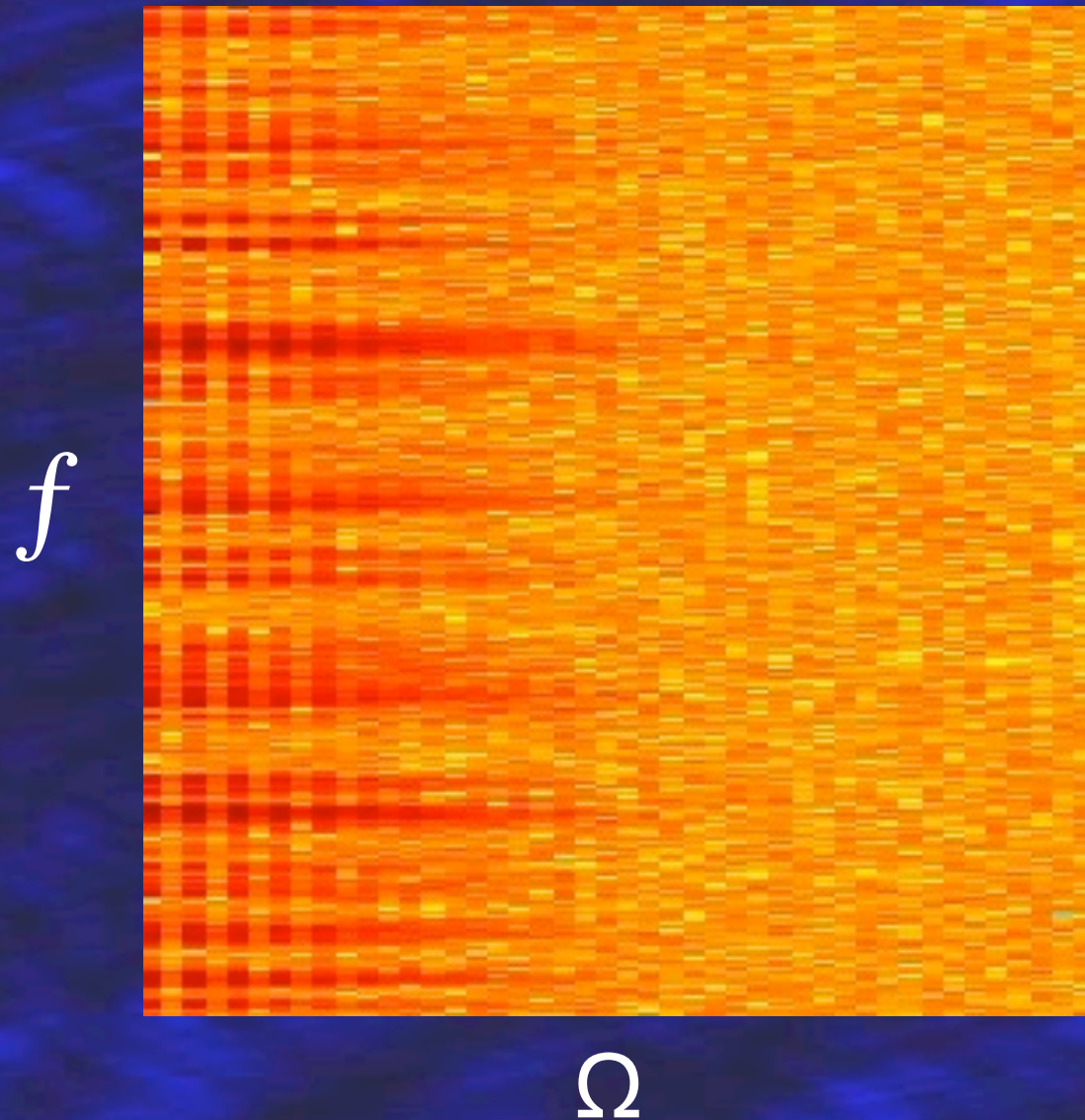
- + NO PHASE RETRIEVAL REQUIRED
- + MAXIMUM LAG NOT LIMITED BY PULSE WIDTH
- + GET INTRINSIC (UNSCATTERED) PULSE PROFILE
- + DELAYS ARE RELATIVE TO TEMPLATE PULSE PROFILE
- + RESIDUAL DM UNCERTAINTY CAPTURED IN $H(f)$

THANKS PAUL!

HOLOGRAPHY OF B1937+21

(PAUL, WILLEM)

$$S_z(f, \Omega) = H(f + \Omega/2) H^*(f - \Omega/2) S_0(\Omega)$$



BOOTSTRAP:

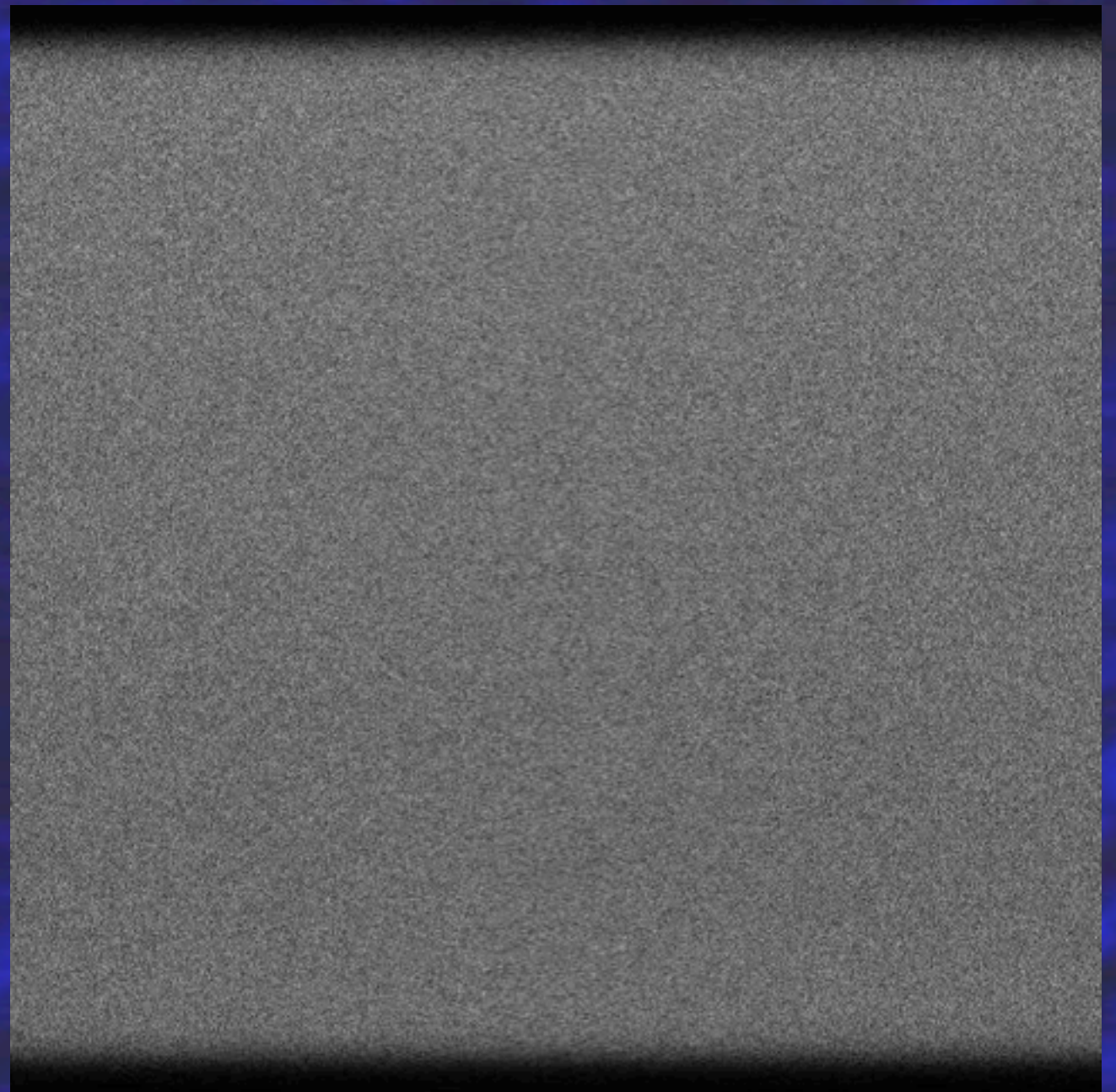
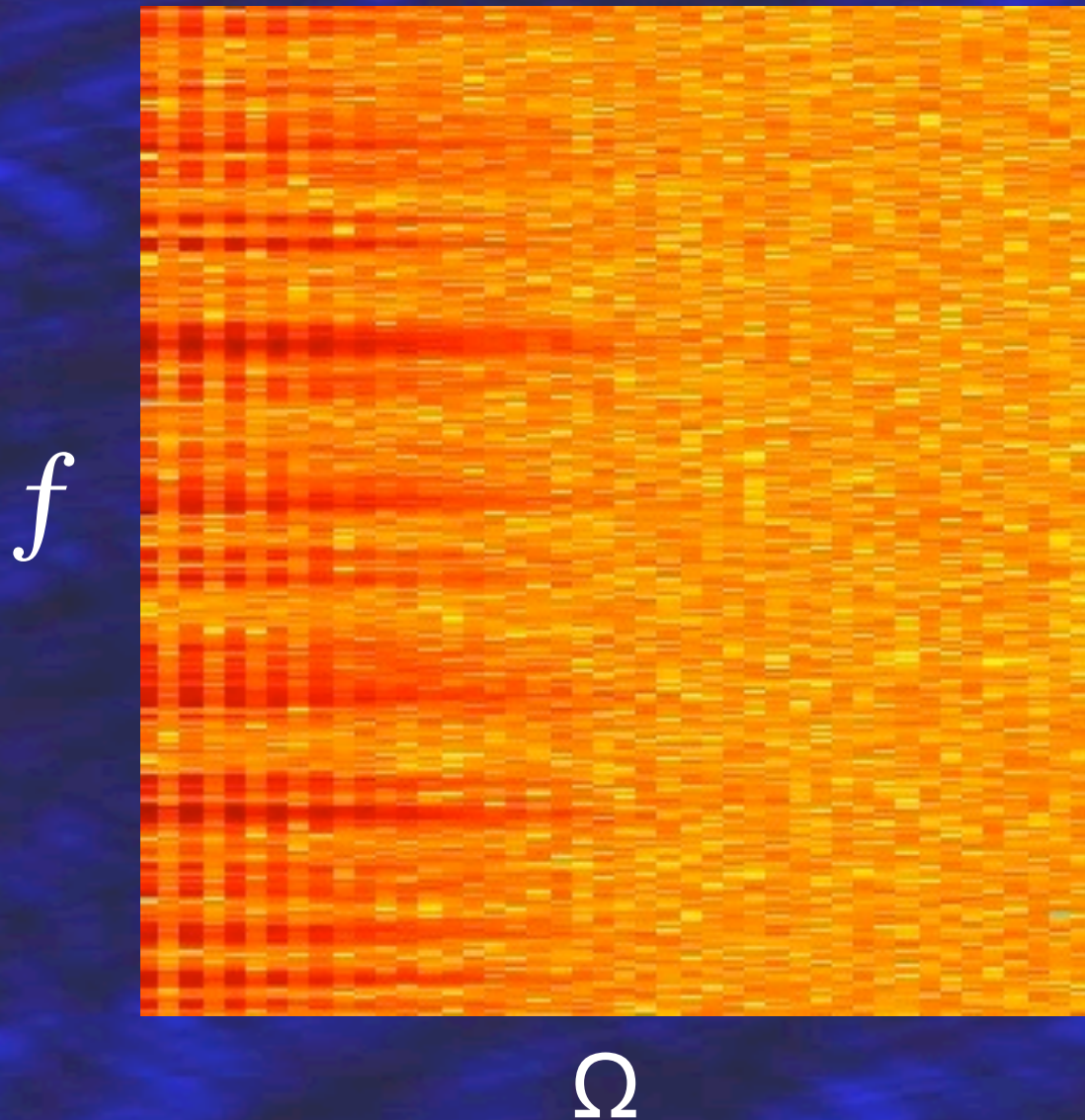
USE SCATTERED PROFILE FOR S_0
DETERMINE H

IMPROVE ESTIMATE OF S_0
IMPROVE ESTIMATE OF H
... (REPEAT).

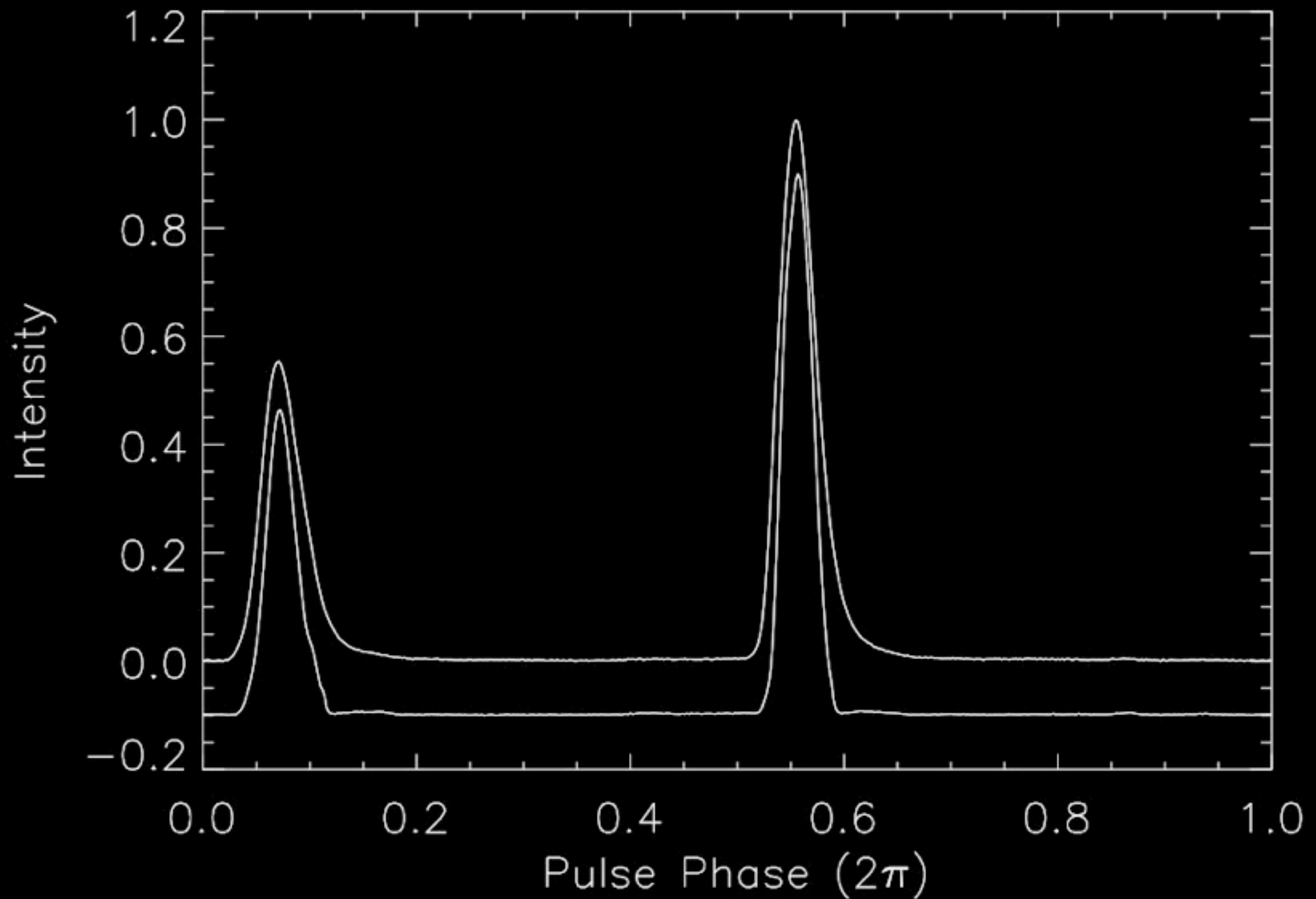
HOLOGRAPHY OF B1937+21

(PAUL, WILLEM)

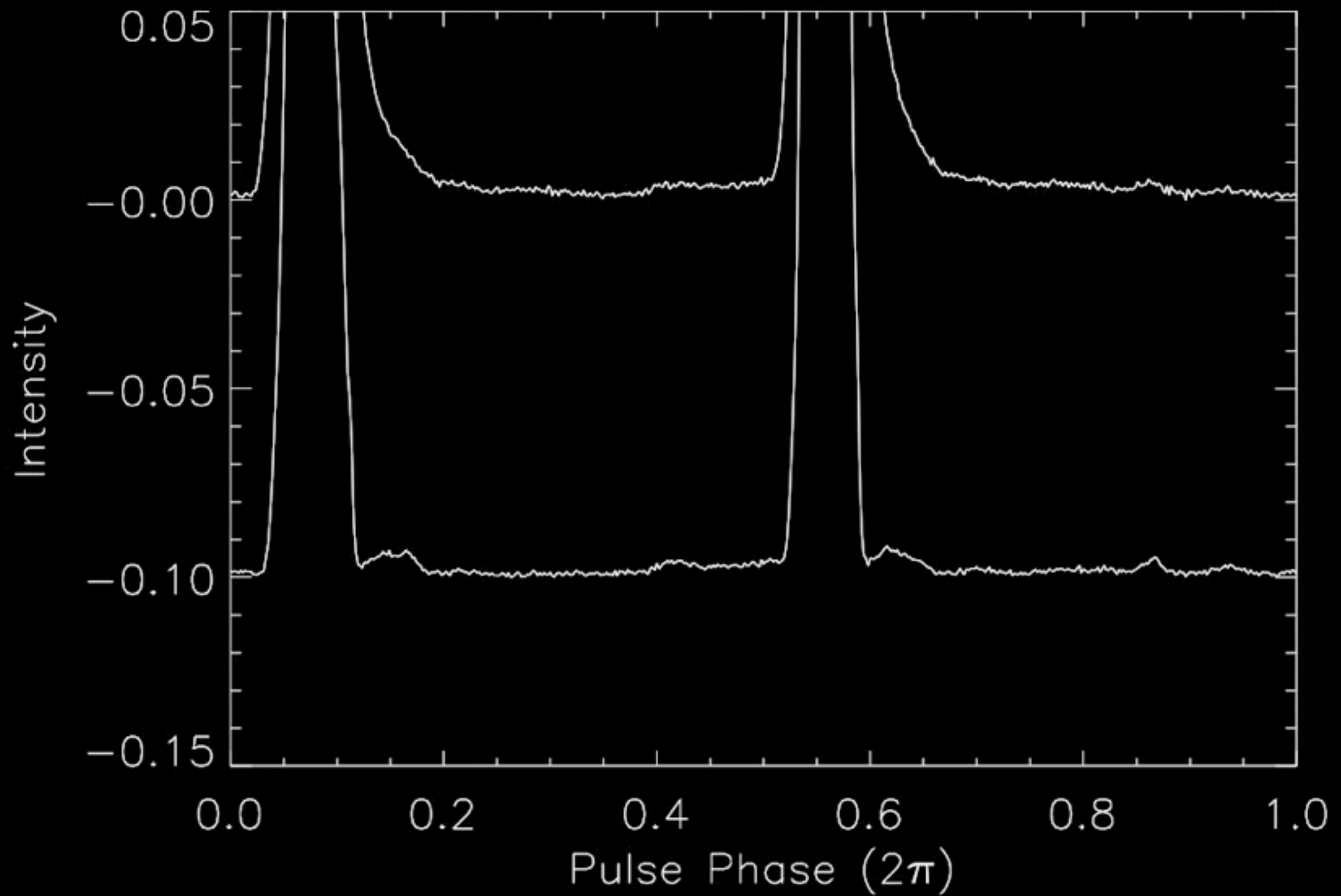
$$S_z(f, \Omega) = H(f + \Omega/2) H^*(f - \Omega/2) S_0(\Omega)$$



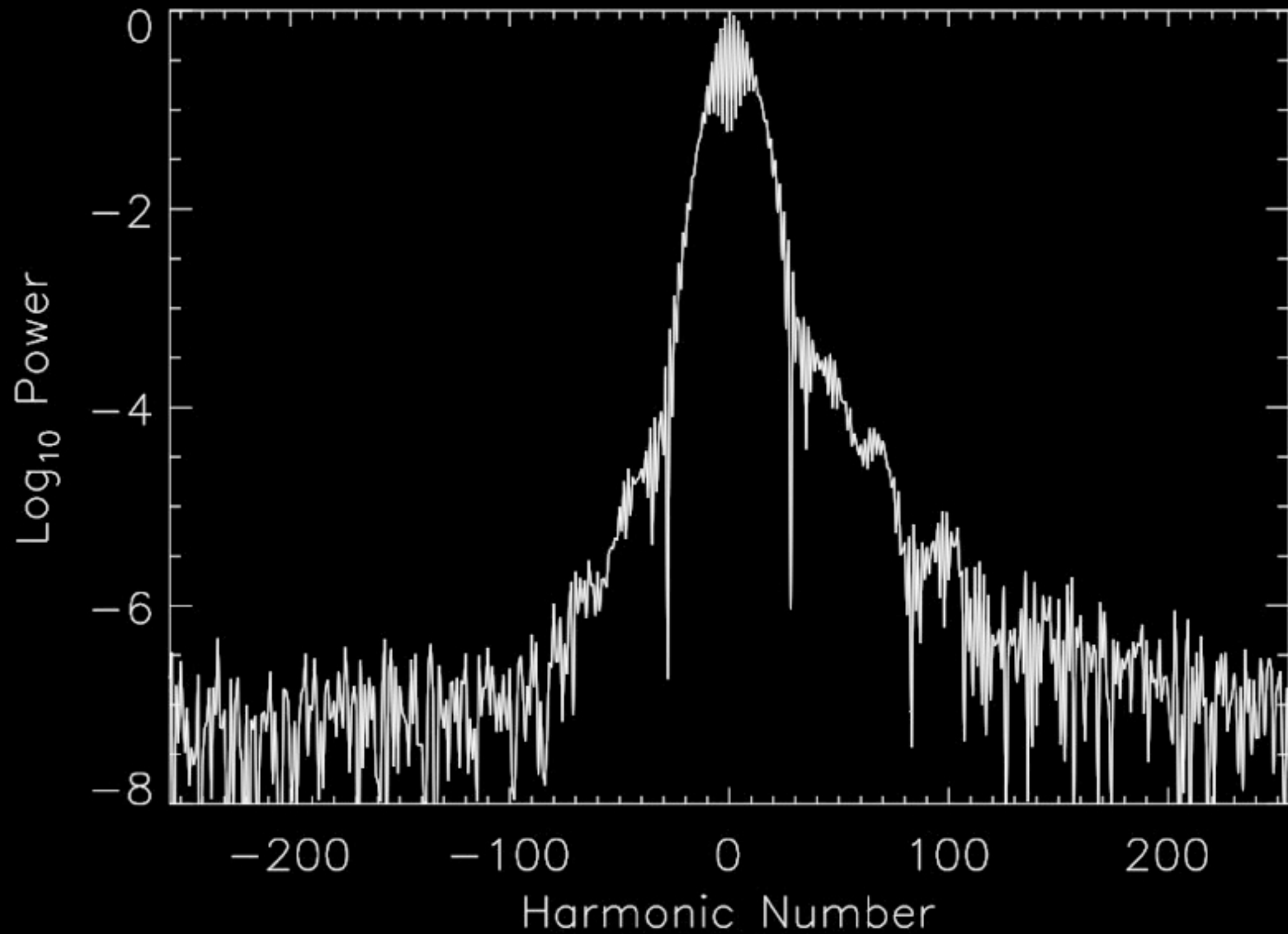
PULSE PROFILES



PULSE PROFILES



PULSE PROFILES



DELAY-DOPPLER IMAGES

DELAY

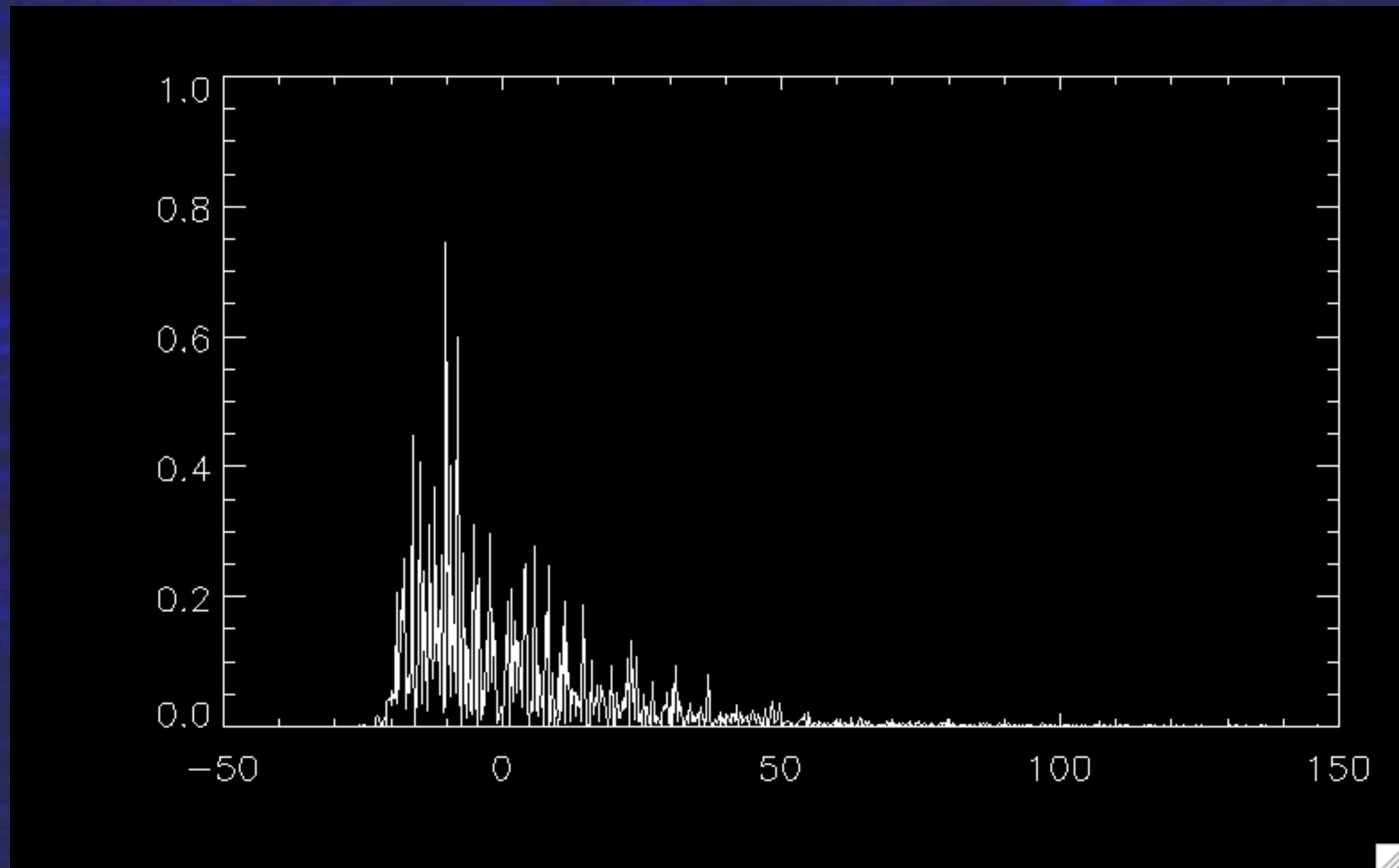


DELAY-DOPPLER IMAGES

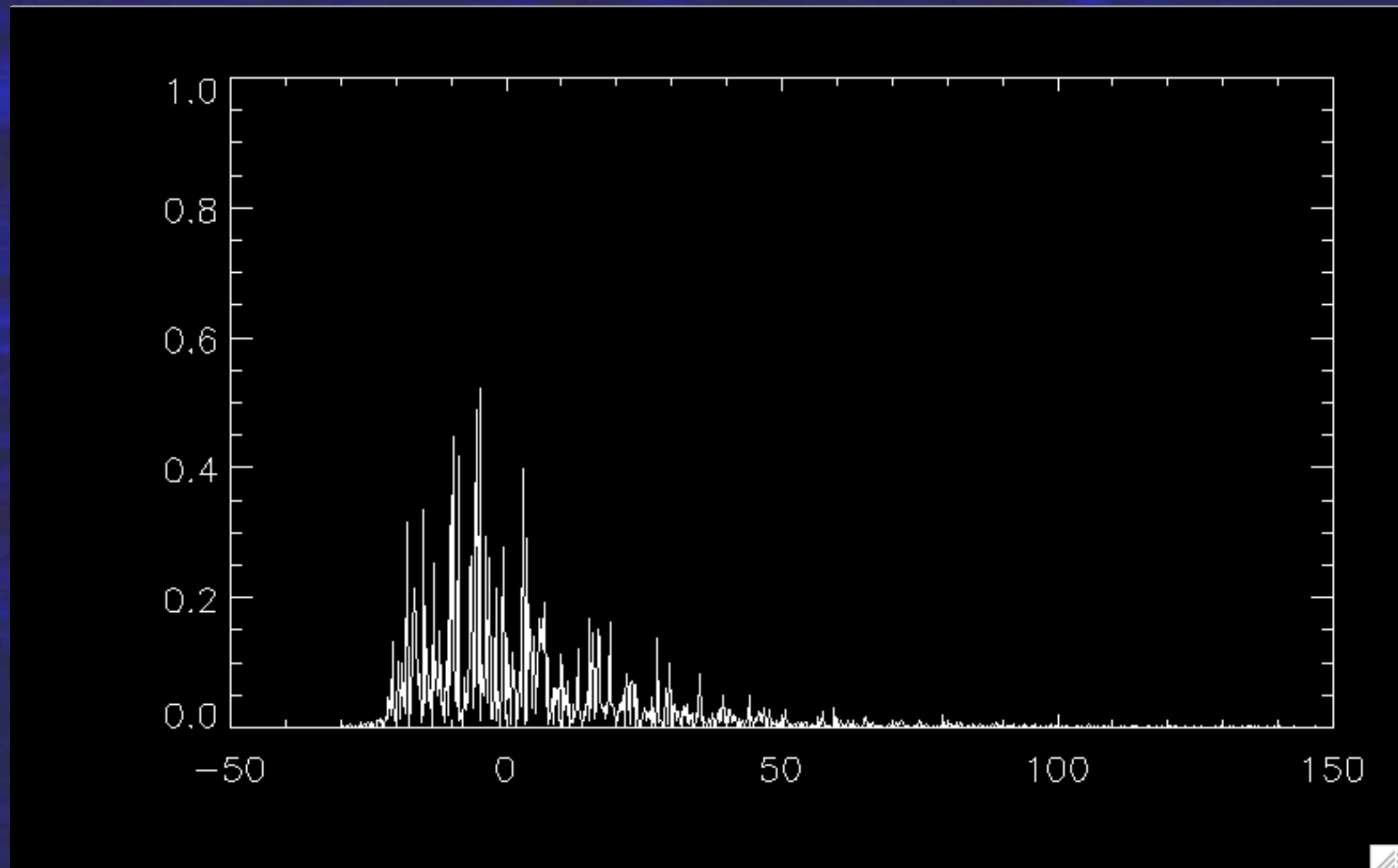
DELAY



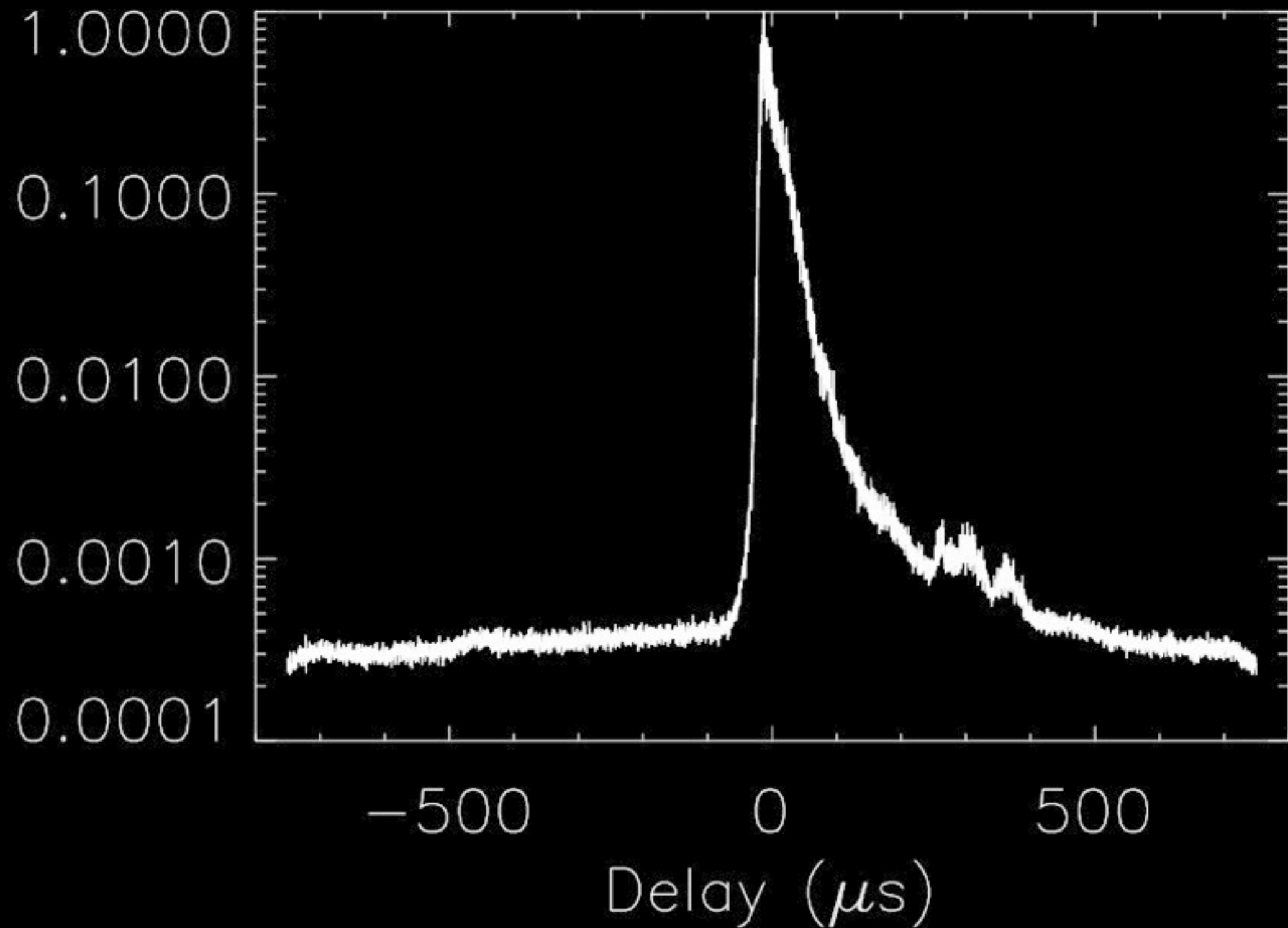
IMPULSE RESPONSE



IMPULSE RESPONSE



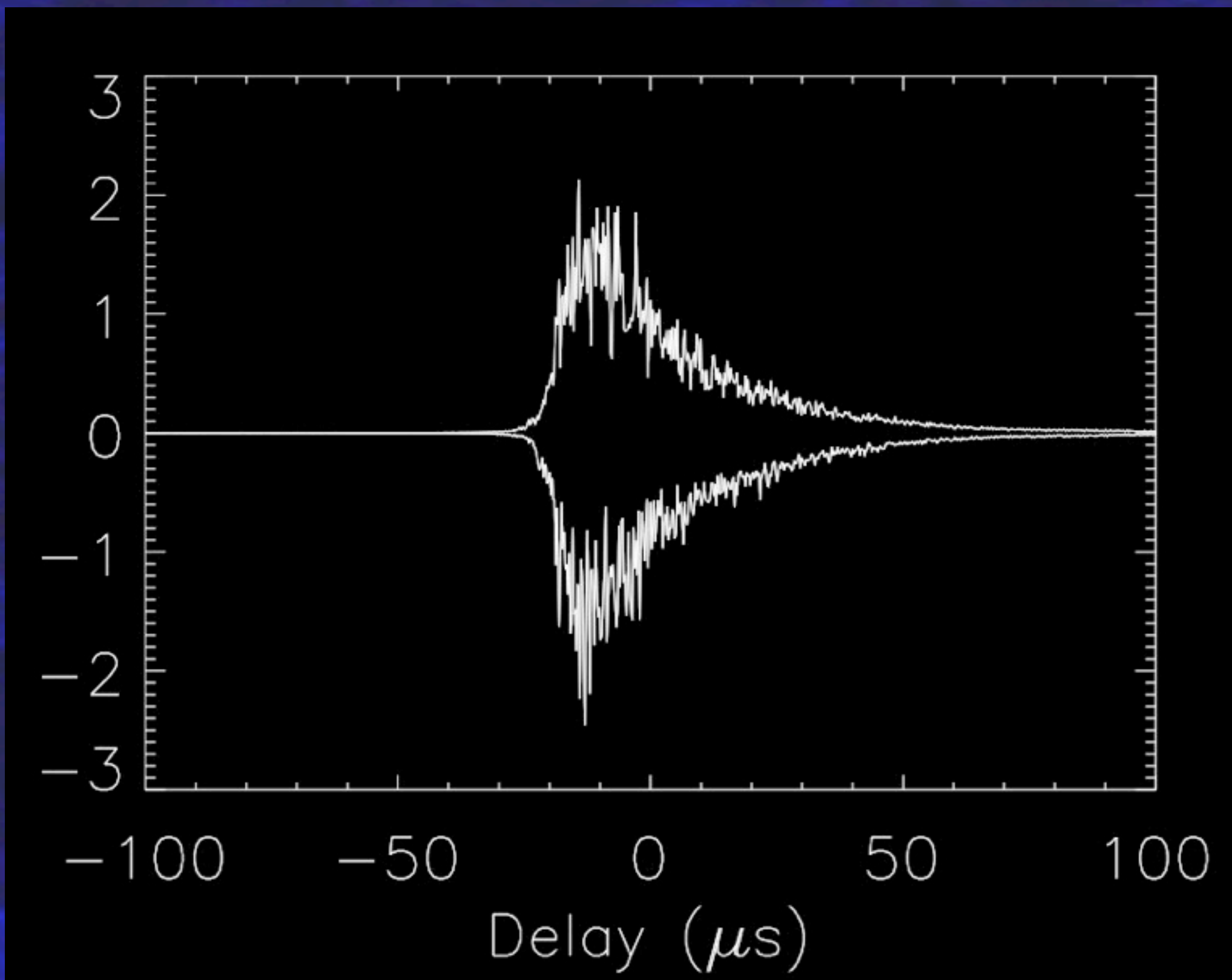
IMPULSE RESPONSE



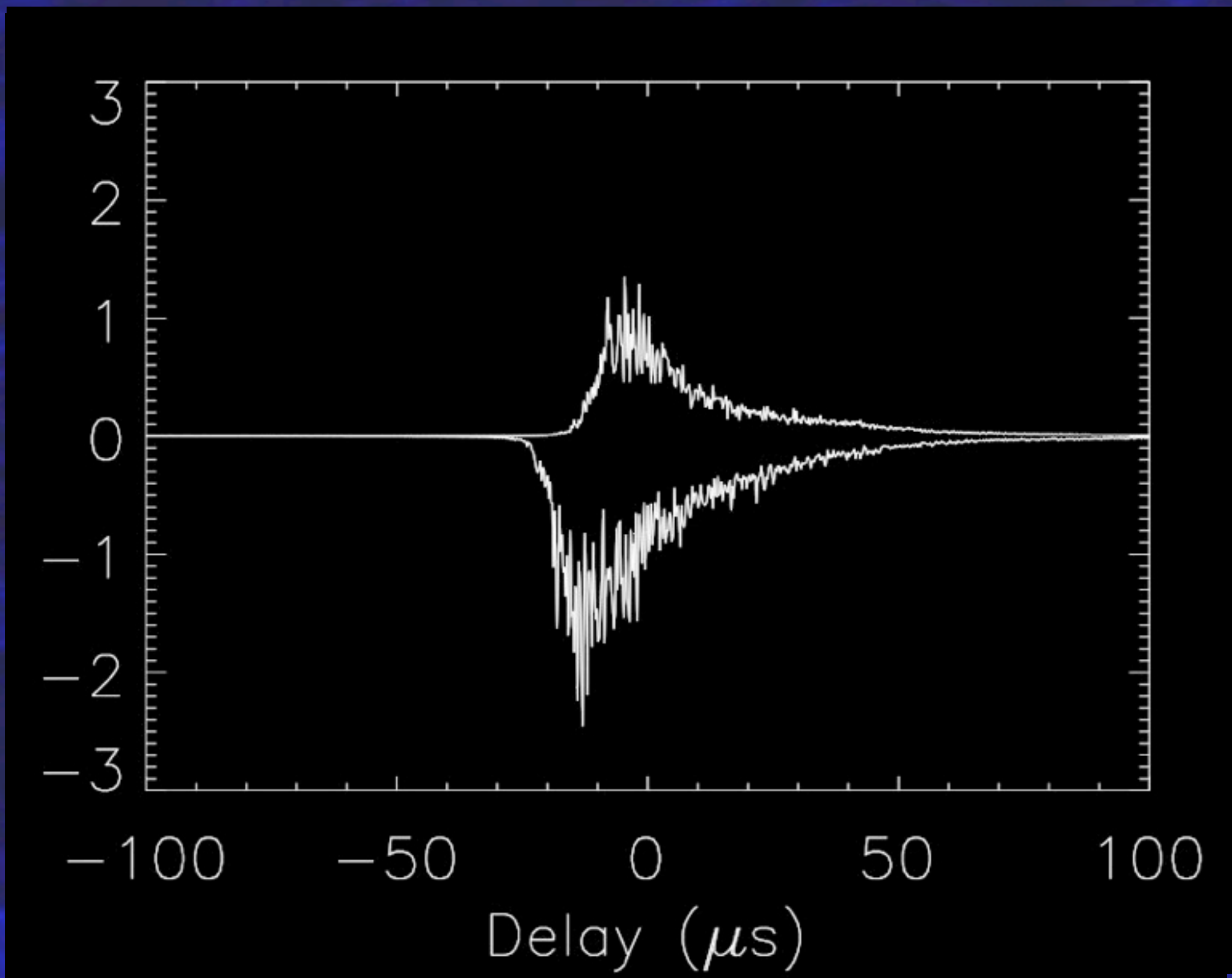
TOA OFFSETS

EPOCH	MJD	IRF CENTROID	
1	53791	42979	ns
2	53847	12093	ns
3A	53873	* 6824	ns
3B	53873	6782	ns

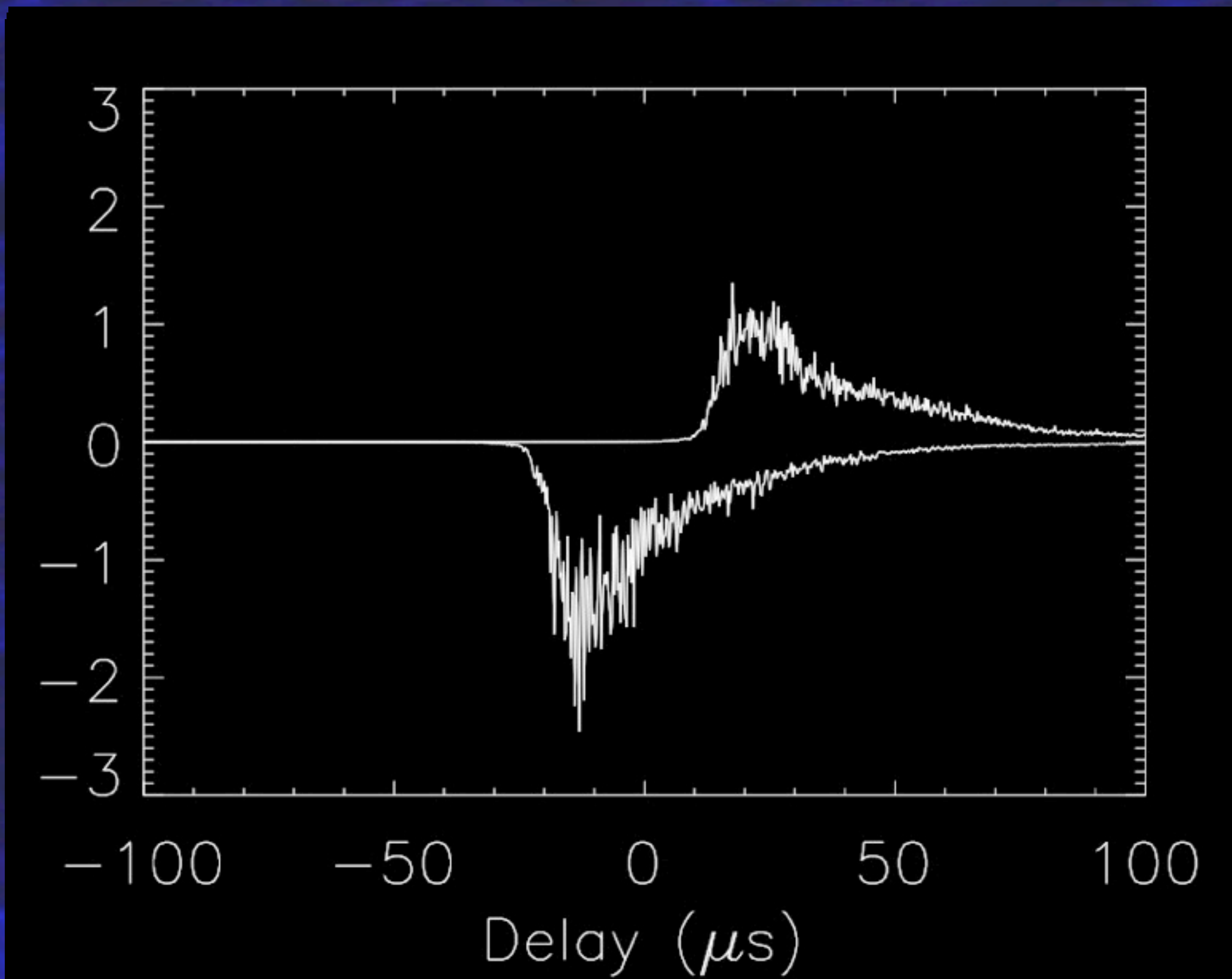
TOA OFFSETS



TOA OFFSETS



TOA OFFSETS



I NEED AN ENORMOUS COMPUTER

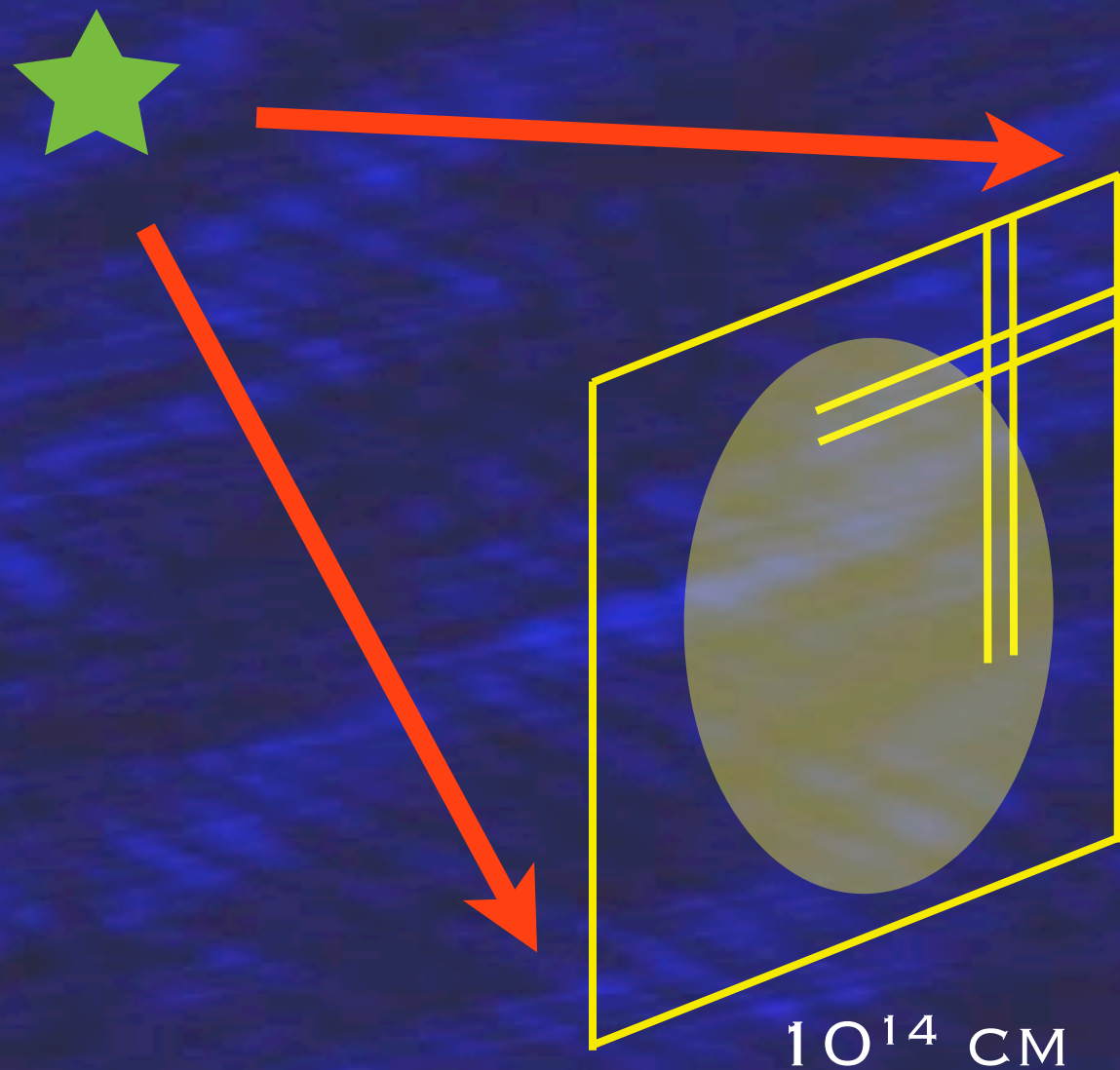
MODEL: THIN PHASE SCREEN

ARRAY DIMENSIONS $\sim 10^6$
 10^{14} CM @ RESN. 10^8 CM

1D : NO PROBLEM

2D : NO GO

BUT ARRAY SIZE $\sim 10^4$ OK
-> L-BAND



SUMMARY

- * THE ISM IS BEAUTIFUL, ENIGMATIC AND PERTURBING
- * MUCH LARGER EFFECT THAN ANTICIPATED GW SIGNAL
- * NEED TO PRECISELY CHARACTERISE THE EFFECTS OF PROPAGATION AT THE EPOCH OF EACH PULSE TOA
- * FIRST STEP: CYCLIC SPECTROSCOPY GIVES $H(f,t)$
- * MEASURED $H(f,t)$ FOR B1937+21 (3 EPOCHS, 430 MHz)
 - * BROADENING OUT TO HUNDREDS OF MICROSEC
 - * AND SHIFTS UP TO 40 MICROSEC (EPHEMERIS ERROR)
- * SECOND STEP: BESPOKE PHYSICAL MODELS OF TRANSFER
- * IMPOSSIBLE TO COMPUTE 2D/3D MODELS FOR LOW FREQ
 - * MAY BE OK AT L-BAND. HOPE SCREENS ARE FROZEN !