Scientific results at ESO with millisecond and nanosecond time resolution

Detectors for Astronomy 2009

Garching, October 14, 2009 - A. Richichi (ESO)

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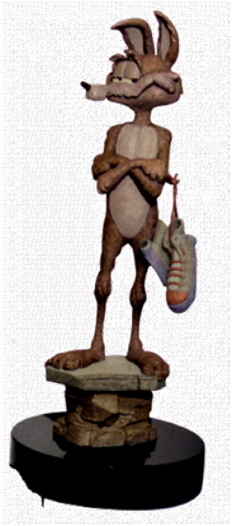


Millisecond: *Observations of Lunar Occultations at the VLT using ISAAC/Aladdin in burst mode*

O. Fors (Barcelona), E. Mason (ESO/Paranal), W.-P. Chen (Taiwan), G. Finger & J. Stegmaier (IR Det Group in Garching)

VISIR
NACO
SOFI
Hawk-I

VLTI
AO

Nanosecond: *Observations with Iqueye at the NTT*

C. Barbieri, G. Naletto, T. Occhipinti, I. Capraro (from various institutes in Padova)

Future: requirements for improved performance

Lunar Occultations

The Moon's limb acts as a straight diffracting edge

The diffraction phenomenon occurs in "vacuum", no turbulence effects.

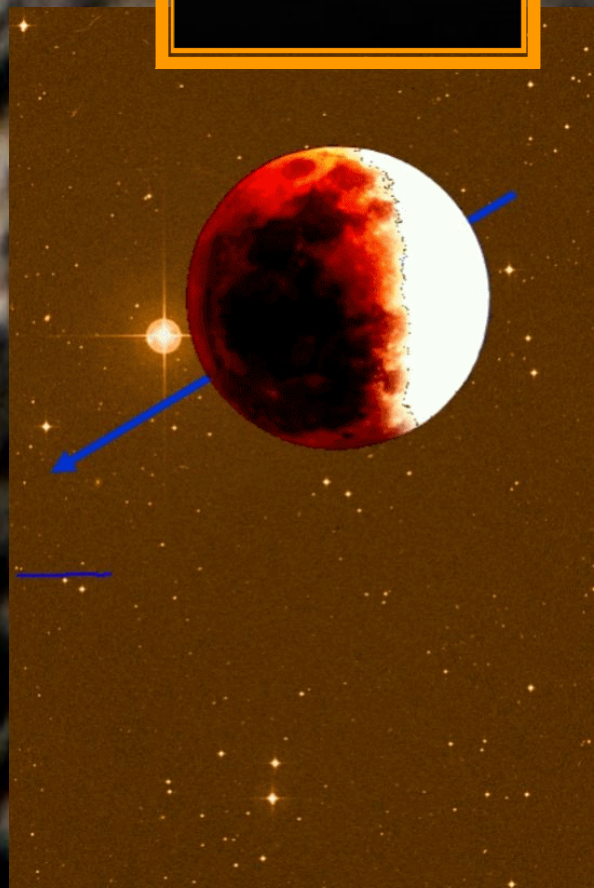
High-angular information is embedded in the diffraction fringes.

Lunar limb irregularities have marginal influence (Fresnel fringes).

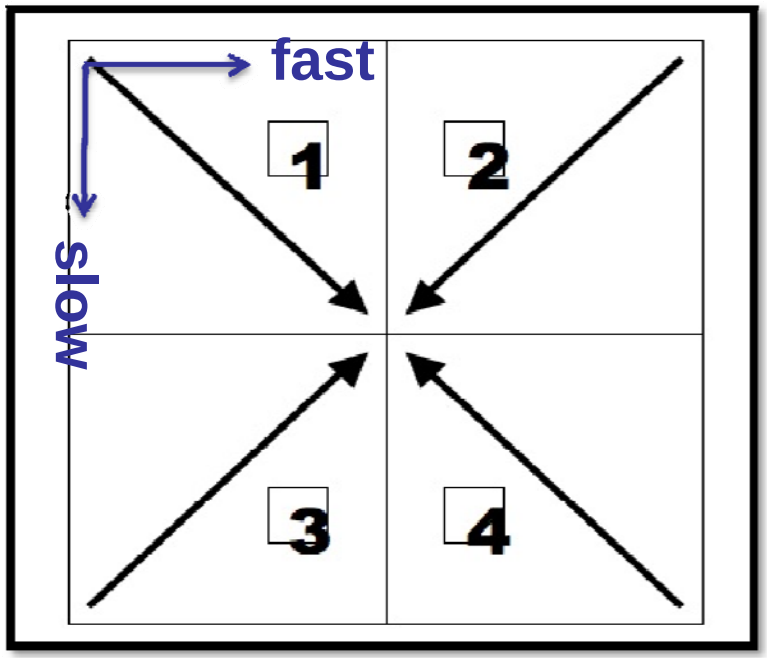
The "resolution" is independent from telescope diameter (but depends on SNR).

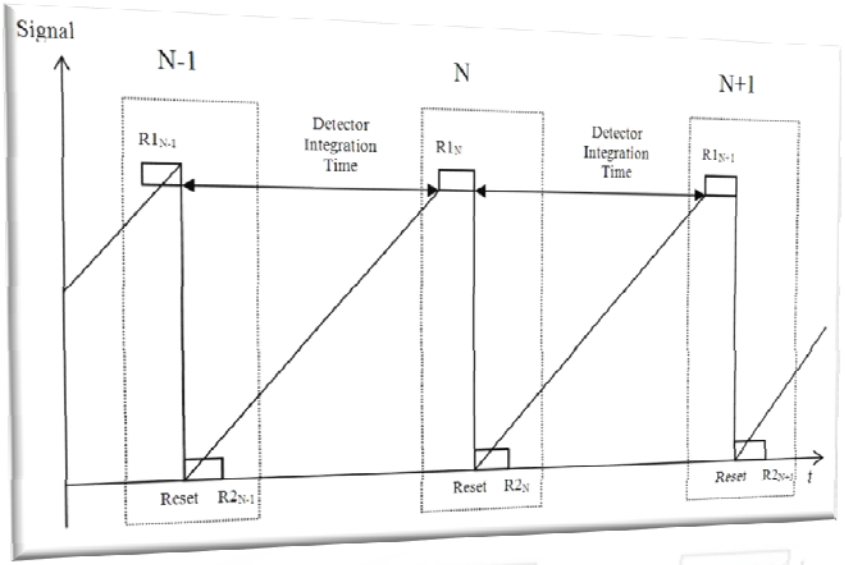
Temporal scales (depending on wavelength and apparent limb velocity) are ~0.1s.

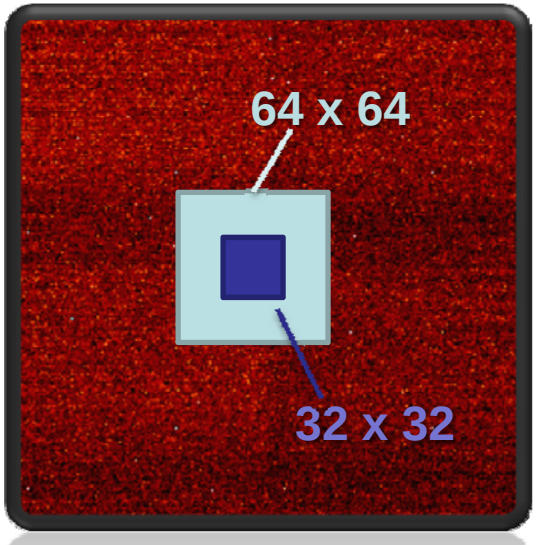
Diffraction patterns of two or more components add linearly.



The ISAAC burst mode



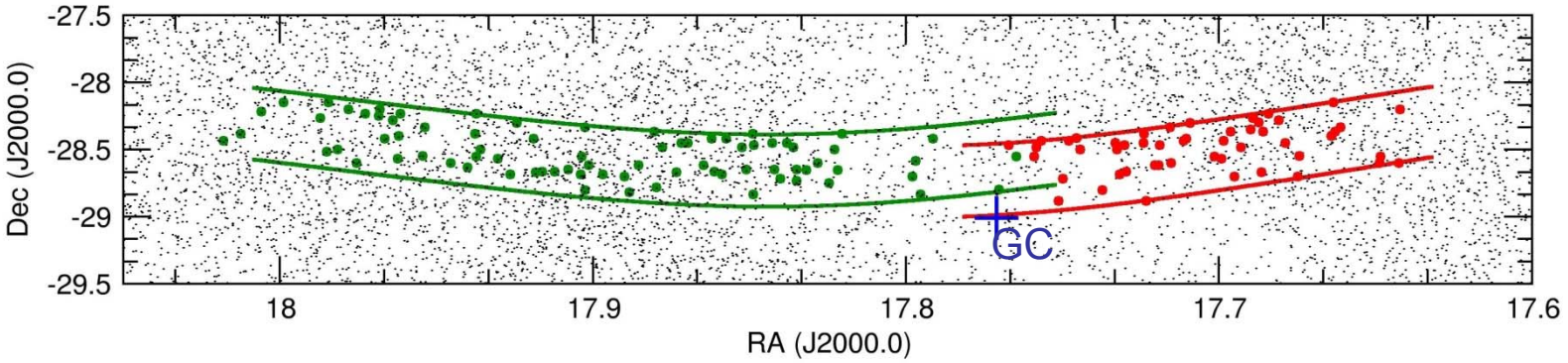




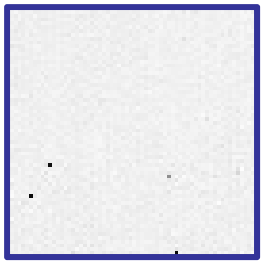
		Burst mode		FastJitter mode	
Window Size [pxs]	Field of View ["]	min DIT [ms]	max NDIT	min DIT [ms]	max NDIT
32x32	4.7x4.7	3.2	16000	12	32000
64x64	9.5x9.5	6.4	16000 *	12	16000
128x128	19x19	14	4000 **	14	4000
256x256	38x38	37	1000 **	37	1000

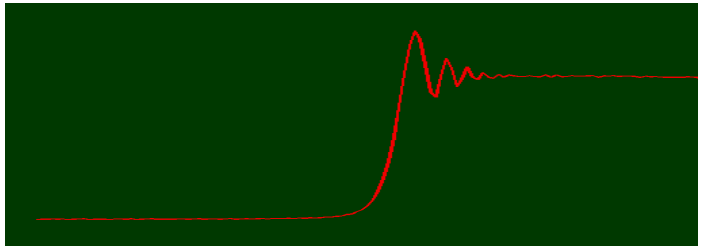
Data cube: Pixel x Pixel x 2 x NDIT

Lunar Appulses to the Galactic Center

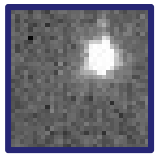


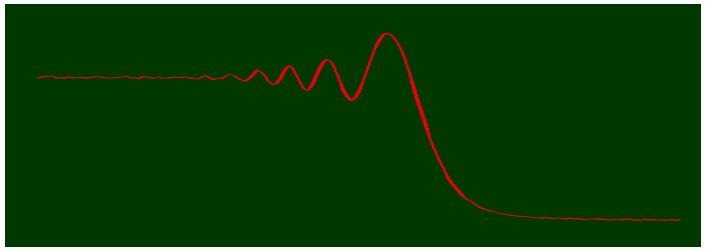
21 March 2006
11” approach to GC 509 events
with K≤7.5 mag ~3 hours
64x64 pix (9.5”), 6.4ms





5-6 August 2006
12’ approach to GC 1188 events
with K≤7.5 mag 7.8 hours
32x32 pix (4.7”), 3.2ms





Overview of results

	Mar-06	Aug-06	P80	P81	P83	P83V	Total
Total hours	4.2	8.5	0.3	15	15	9.5	52.5
Type of event	Reap	Disap	Disap	Disap	Disap	Disap	-
Attempted events	51	78	4	125	92	210	560
Successful events	30	72	2	116	New data, not yet evaluated		*>500?*
Diameters	3	1	0	9			13
Binaries/Triples	2	7	0	6			15
Shells/Complex	0	2	0	0			2
Planetary Neb CS	0	1	0	0			1
Masers	2	1	0	0			3

Limiting Sensitivity (SNR=1)	K~12-12.5
Limiting Angular Resolution	0.5-2 mas
Dynamic Range at 0.02"	7-8 mag K

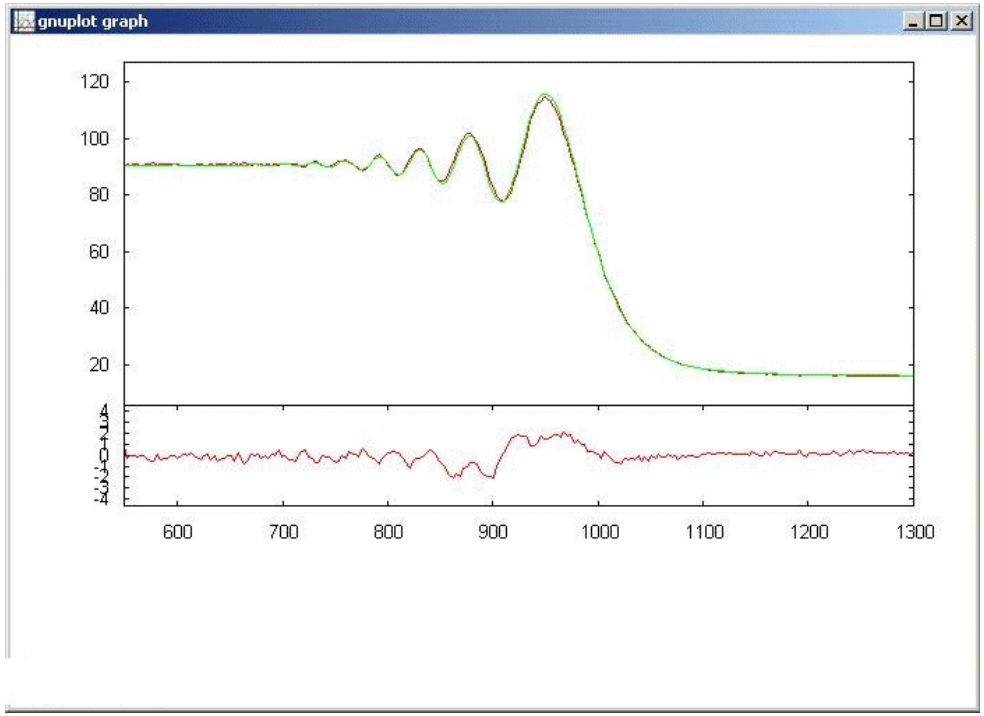
Richichi et al (2008a, 2008b)

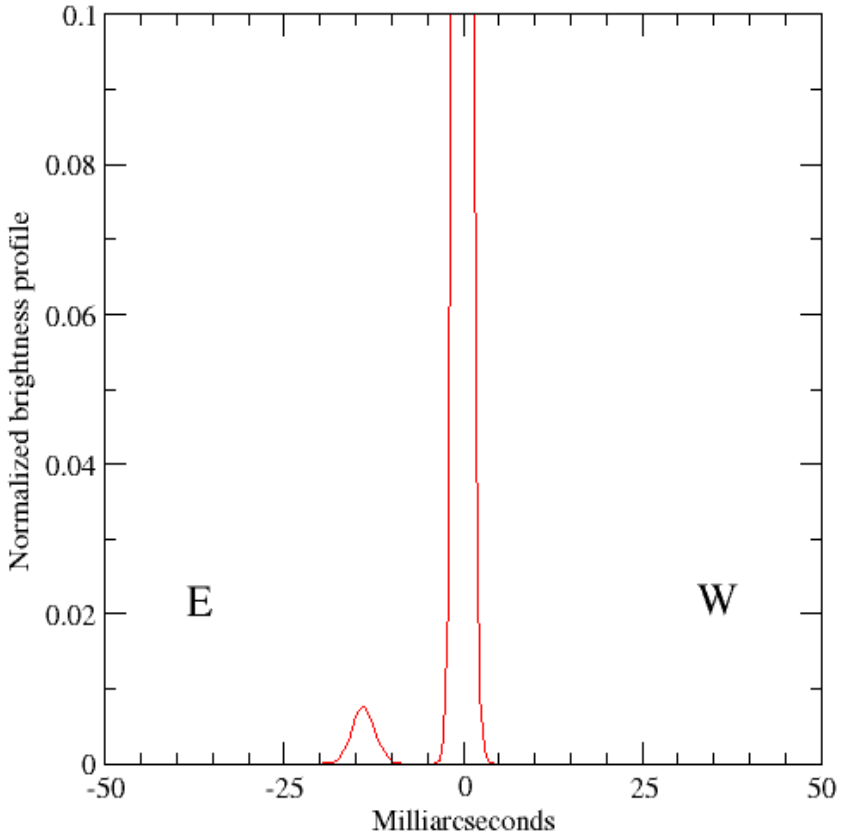
This combination of sensitivity and angular resolution cannot be achieved by any other technique in the near-IR.

The drawback is that lunar occultations are fixed-time events !

Example of a binary star

2MASS17524903-2822586, K=5.21



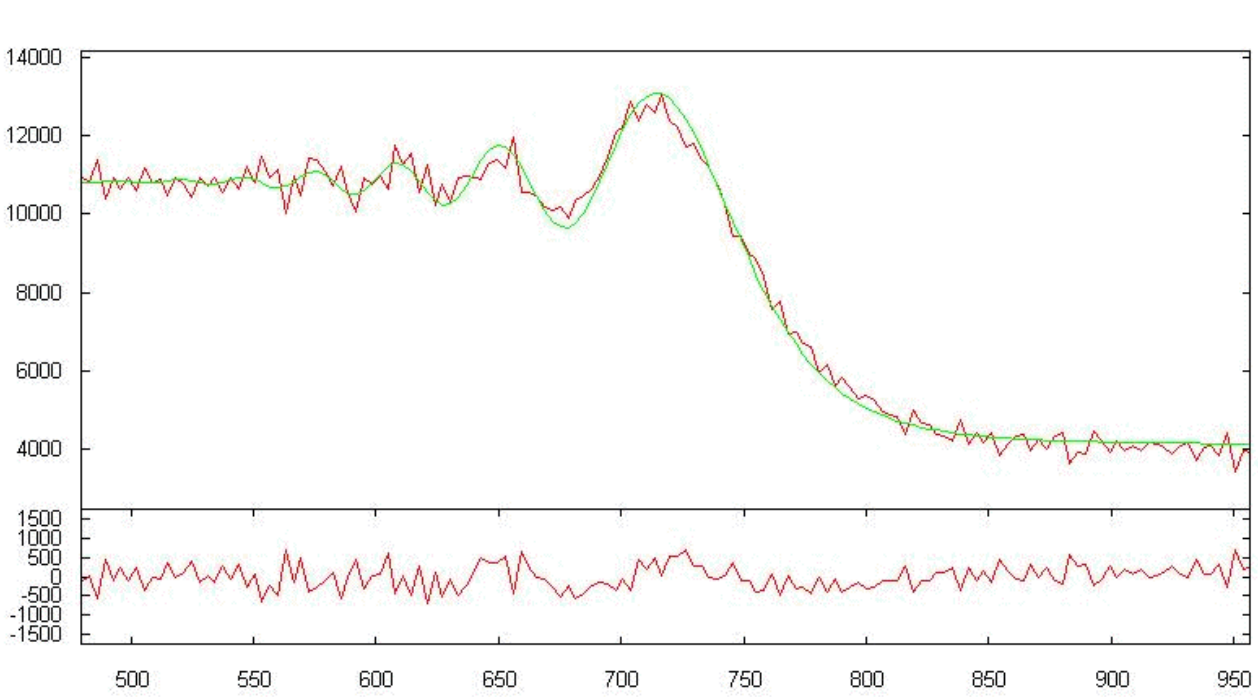


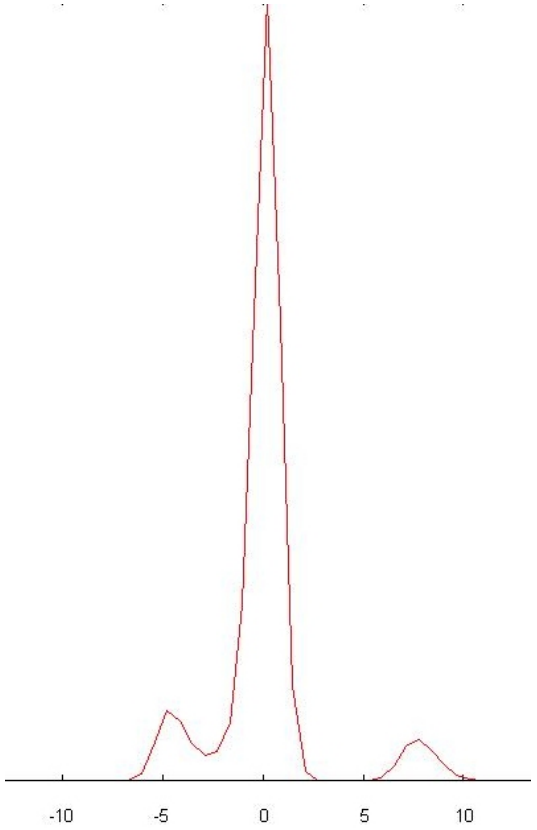
Sep=13.10±2.36 mas

ΔK=3.74 0.09 SNR=186.7

Example of a triple star

P83-23 Field star no refs, V=9.3 K=7.8





Pair A-B: Sep=4.1±0.2 mas Pair A-C: Sep=8.4±0.2 mas

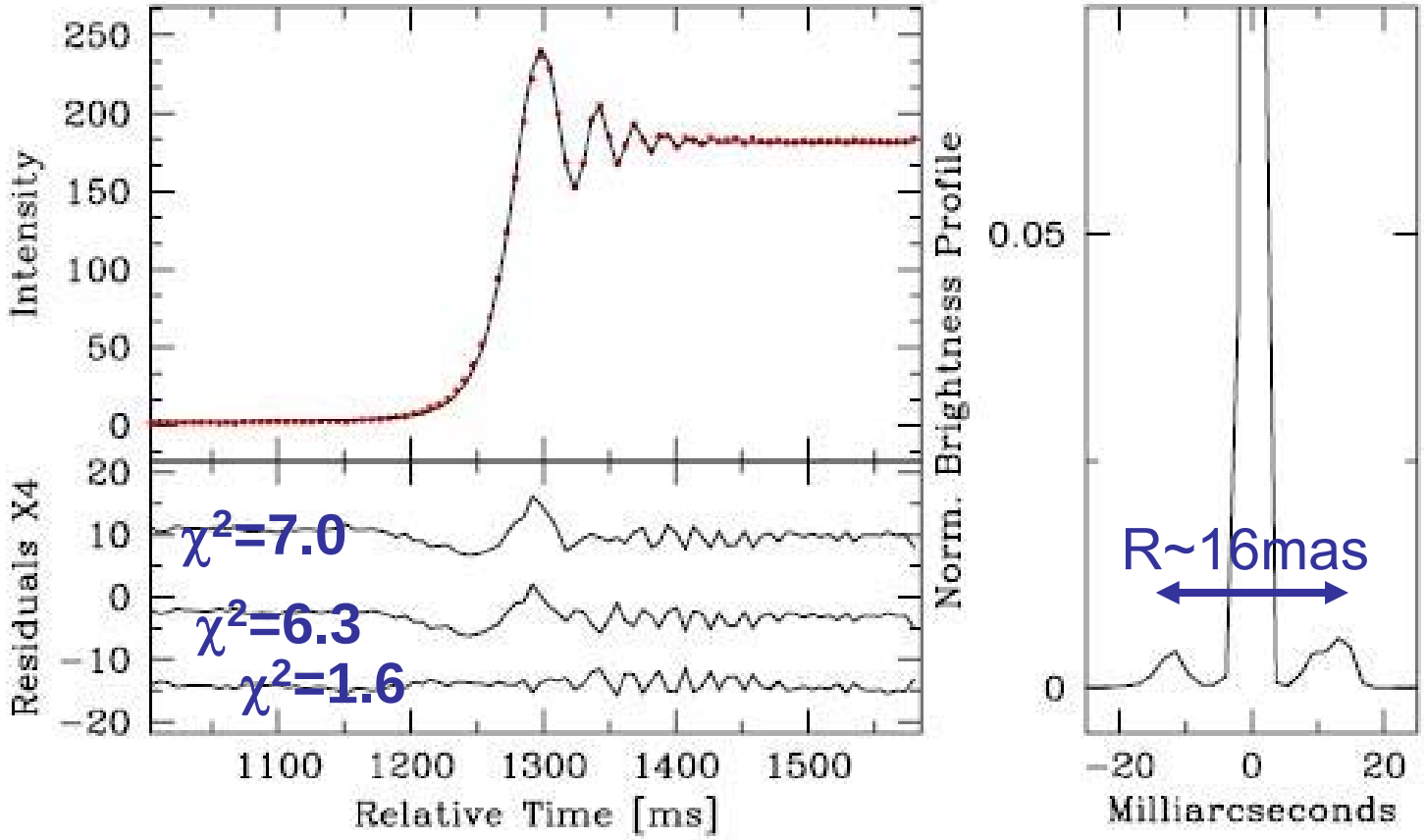
K=8.03, 10.09, 10.41 (±0.02)

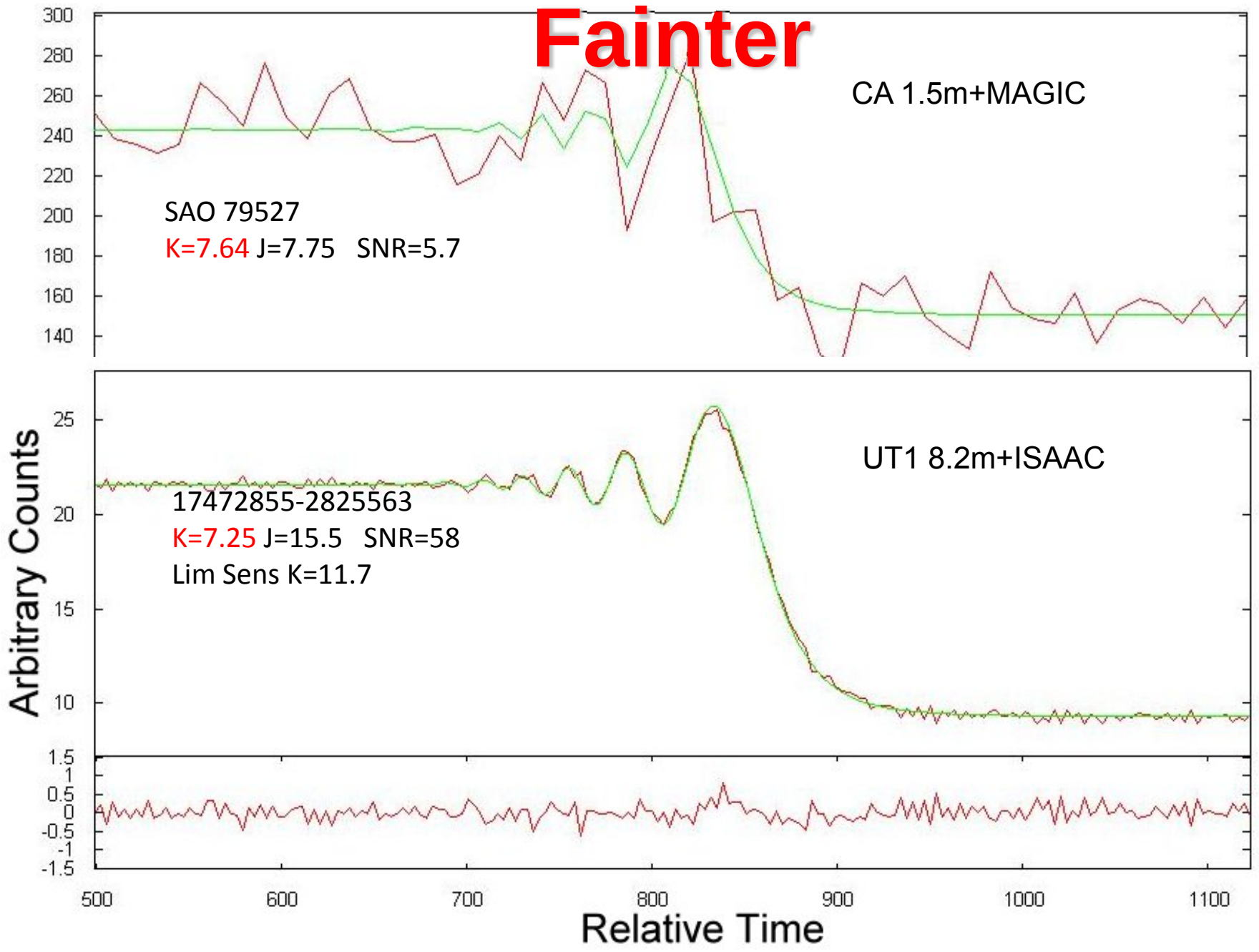
Example of a circumstellar shell

2MASS 17453224-2833429 = ISOGAL-P J174532.3-283338

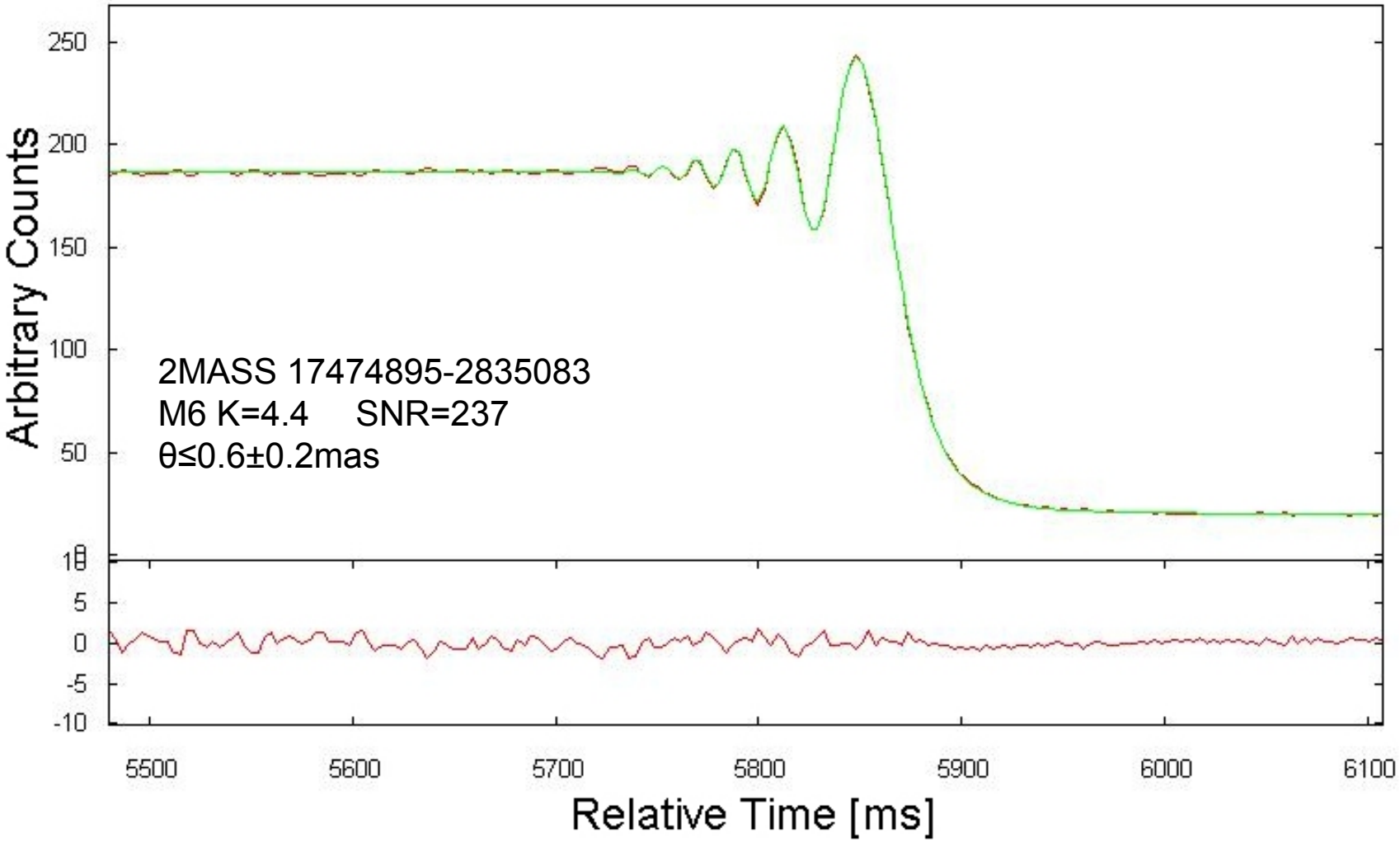
IR source K=5.3, J-K=3.7; no optical cross-ID; SiO Maser

probably fore-GC star ("low" A_K=1.1mag) 1kpc-> shell ~20AU

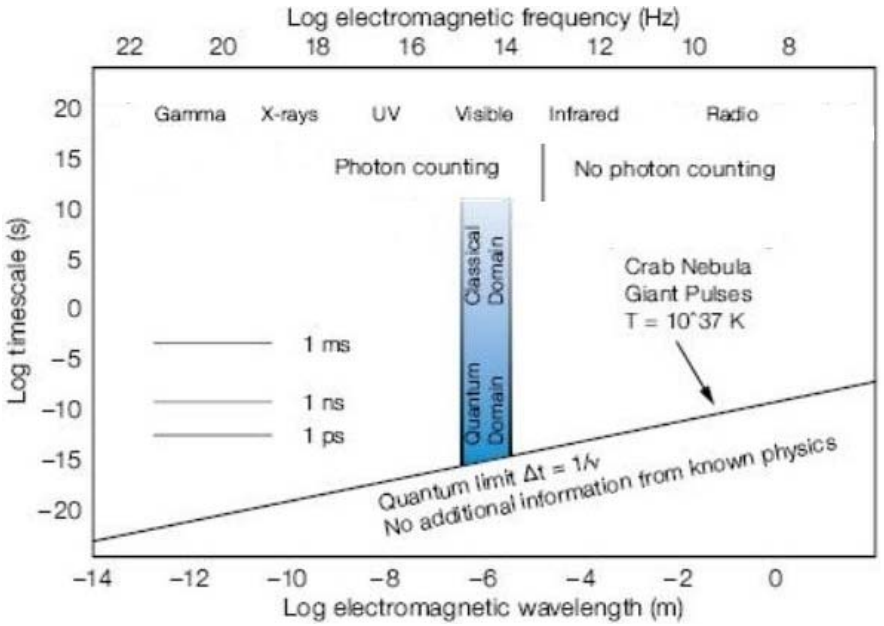



Fainter
CA 1.5m+MAGIC
SAO 79527
K=7.64 J=7.75 SNR=5.7
UT1 8.2m+ISAAC
17472855-2825563
K=7.25 J=15.5 SNR=58
Lim Sens K=11.7
Arbitrary Counts
Relative Time
300
280
260
240
220
200
180
160
140
25
20
15
10
1.5
1
0.5
0
-0.5
-1
-1.5
500
600
700
800
900
1000
1100

More accurate

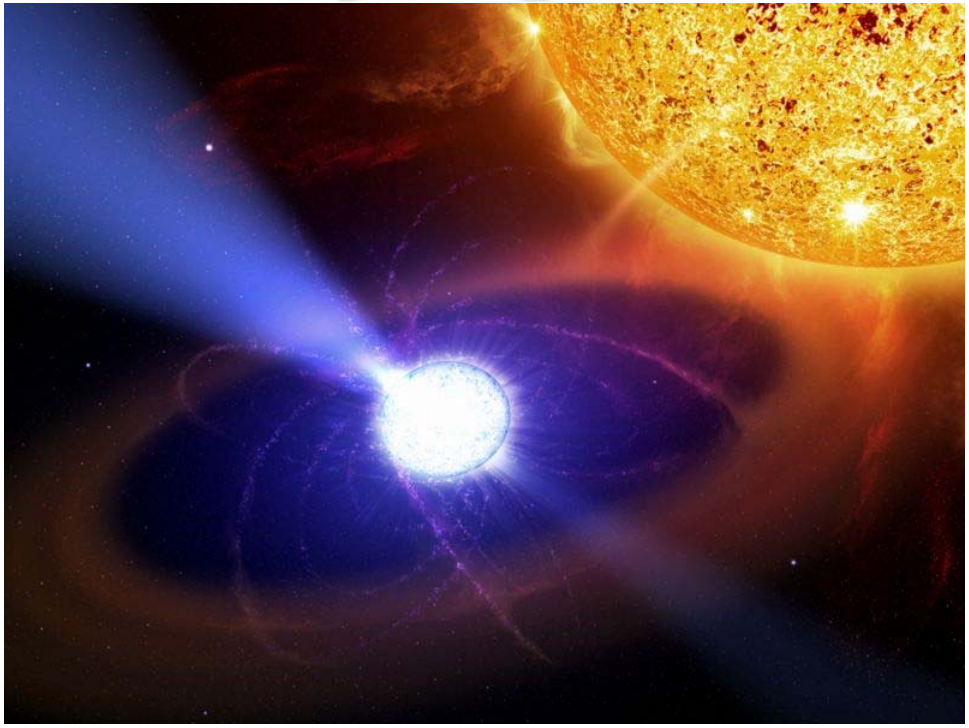


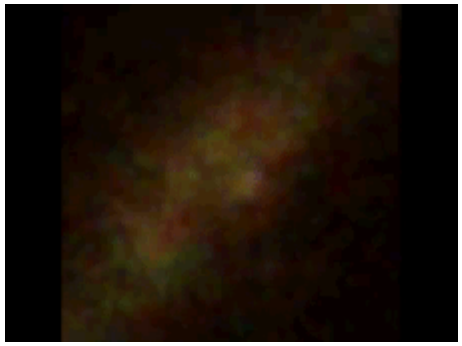
Iqueye: pushing the limits of astrophotonics

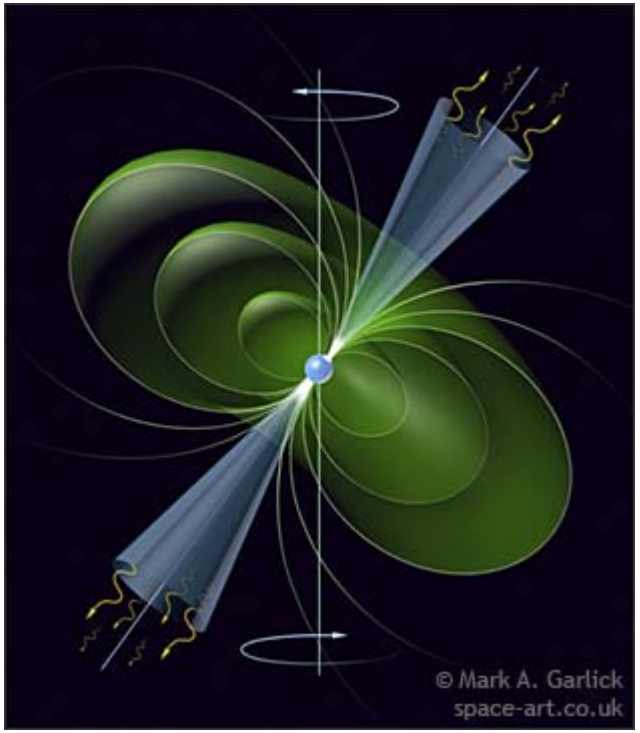


Currently 70ns (SPAD dead time), but theoretically capable of 50ps time resolution. Individual photon time-tagging (CERN board). Absolute time via improved GPS (limit 0.5ns/1hr).

Studying Pulsars with Iqueye

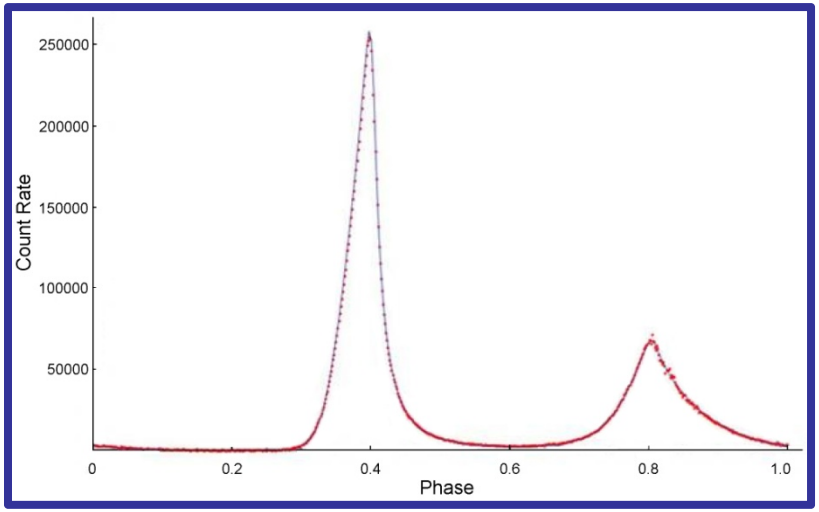






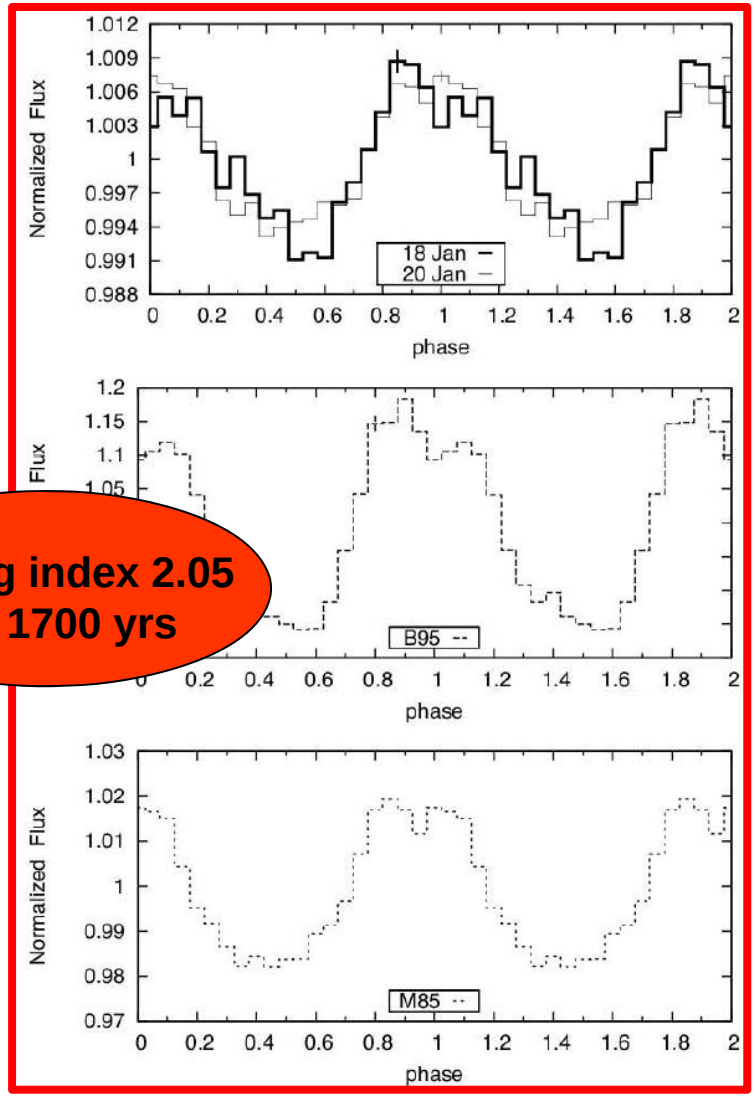
Magnetized, rapidly spinning (few seconds to millisecond) neutron stars. Physical properties and emission mechanisms still not completely understood and not well constrained by observations. Details of light curves of crucial importance.

Studying Pulsars with Iqueye



Crab Nebula, P=33ms
2hrs on 4m telescope
few seconds on 1.8m Asiago+Aqueye
Period agrees with radio to 1ns

Braking index 2.05
Age 1700 yrs



B0540-69 in LMC, V=23mag, P=50.6ms (error 8ns)

Iqueye & NTT (top, Gradari et al submitted)
HST 1995 (middle)
Cerro Tololo 4m (1985)

Wish list

BURST MODE

- Faster data dump! (now ~3min for 20s data)
- Faster read-out (RON often not a concern)
- Improve pixel synchronicity
- bigger pixel scale desirable
- flexibility of window positioning
- avoid bad cosmetics in the subarray

IQUEYE

- reduce SPAD dead time
- improve time base (GALILEO?)
- offer to open time?
- think ahead... E-ELT? (low image quality ok)