Astrometry, a potential exoplanet search technique, and SUSI

Yitping Kok

Peter Tuthill, Gordon Robertson & Bill Tango
University of Sydney

Mike Ireland & Ben Warrington
Macquarie University

- Background
- Instruments around the world
- Progress at SUSI

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Radial velocity

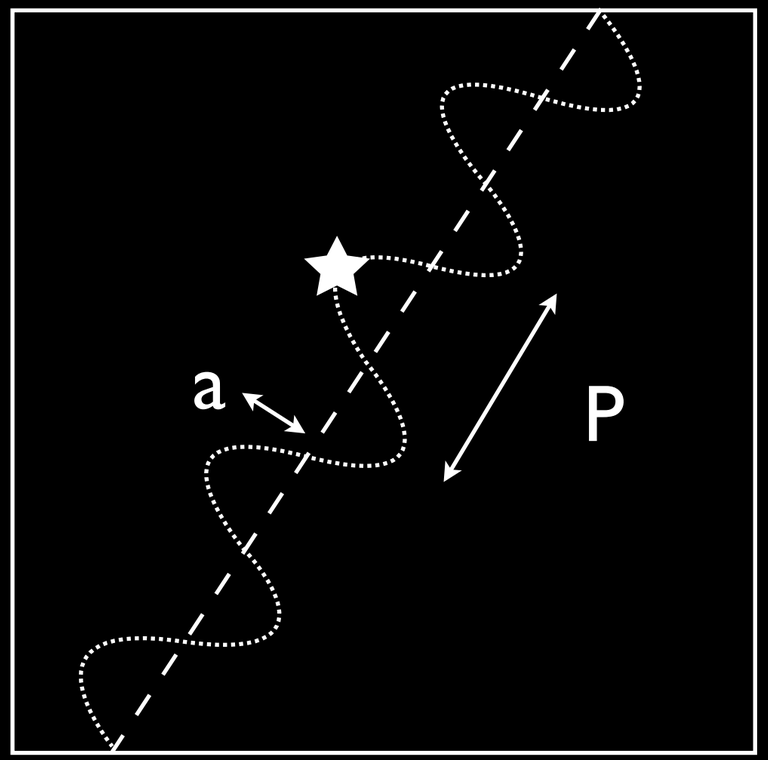
Transits

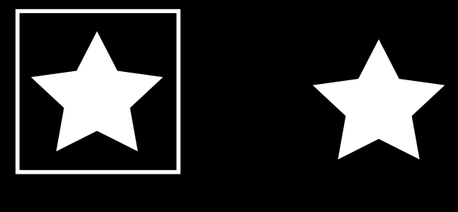
Direct imaging

Timing

Astrometry

astrometric “signature”

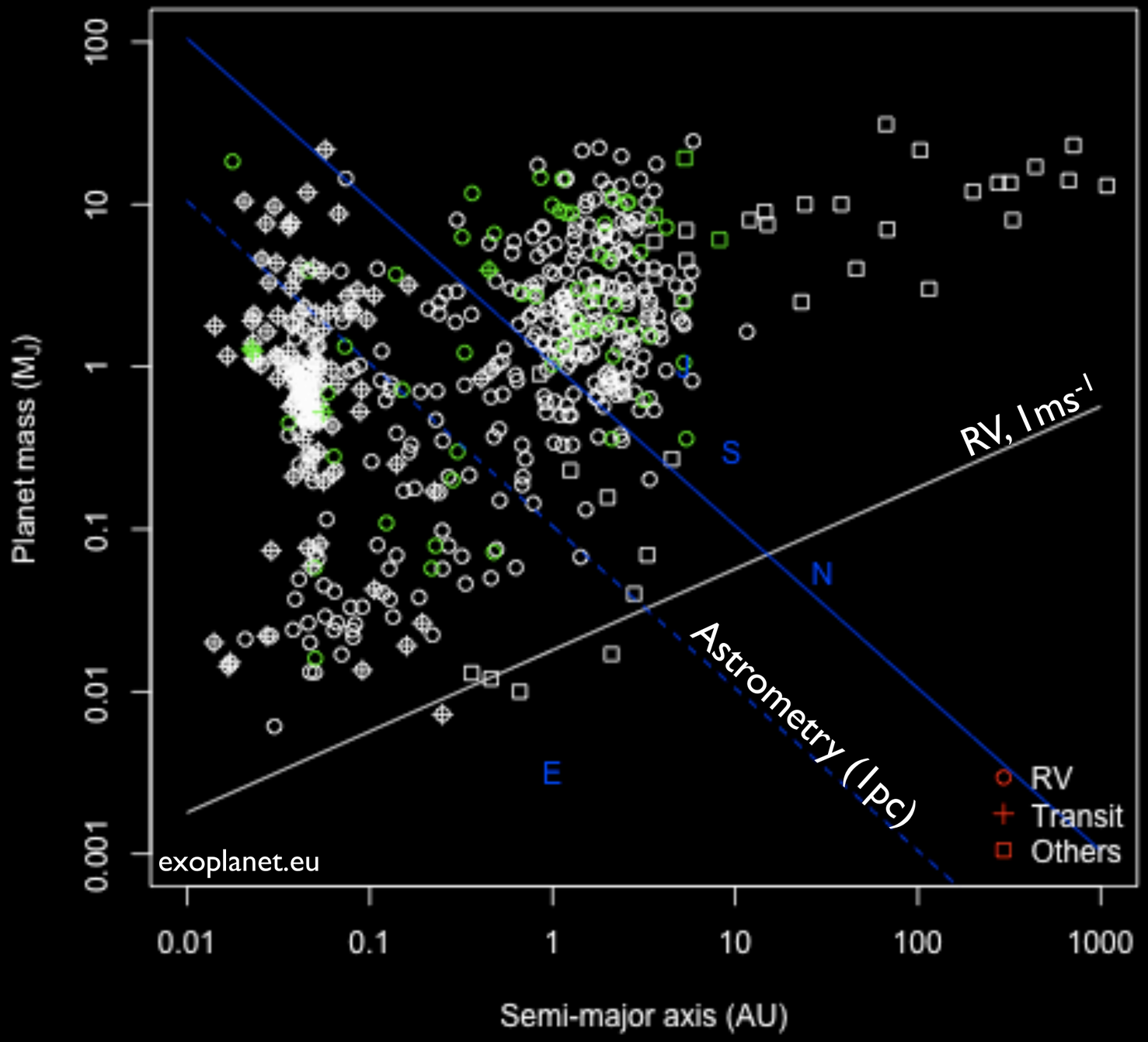




$$a/20\mu as \lesssim a_P/1AU \cdot 10M_P/M_J \cdot 10pc/z \cdot M_\odot/M_\star$$

$a \lesssim 100\mu as$; Jupiter at 100pc

$a \lesssim 6\mu as$; Earth at 1pc


Planet mass (M_J)
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
Semi-major axis (AU)
RV, 1ms^{-1}
Astrometry (1pc)
S
N
E
RV
Transit
Others
exoplanet.eu

- Background
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- Progress at SUSI

Imaging

Space missions

Astrometric instruments

Ground-based

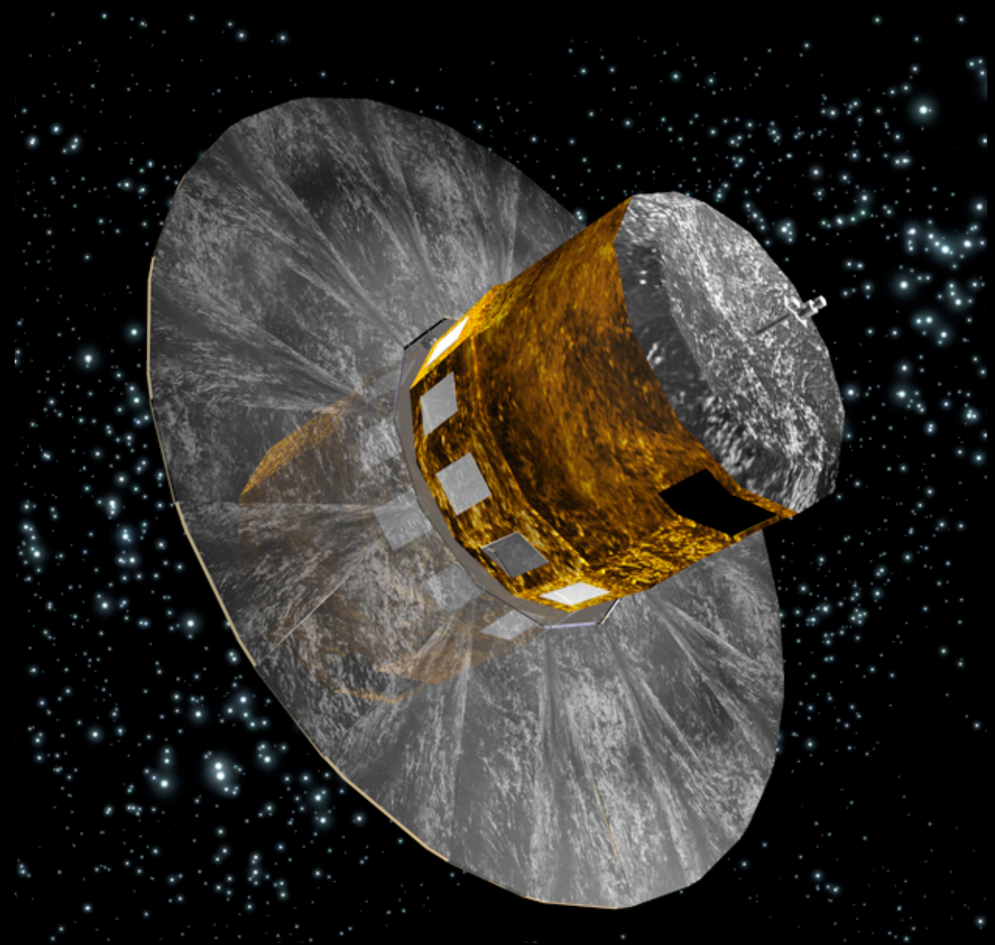
Optical Long Baseline Interferometry (OLBI)

Space missions

GAIA

Global **A**strometric **I**nterferometer for **A**strophysics

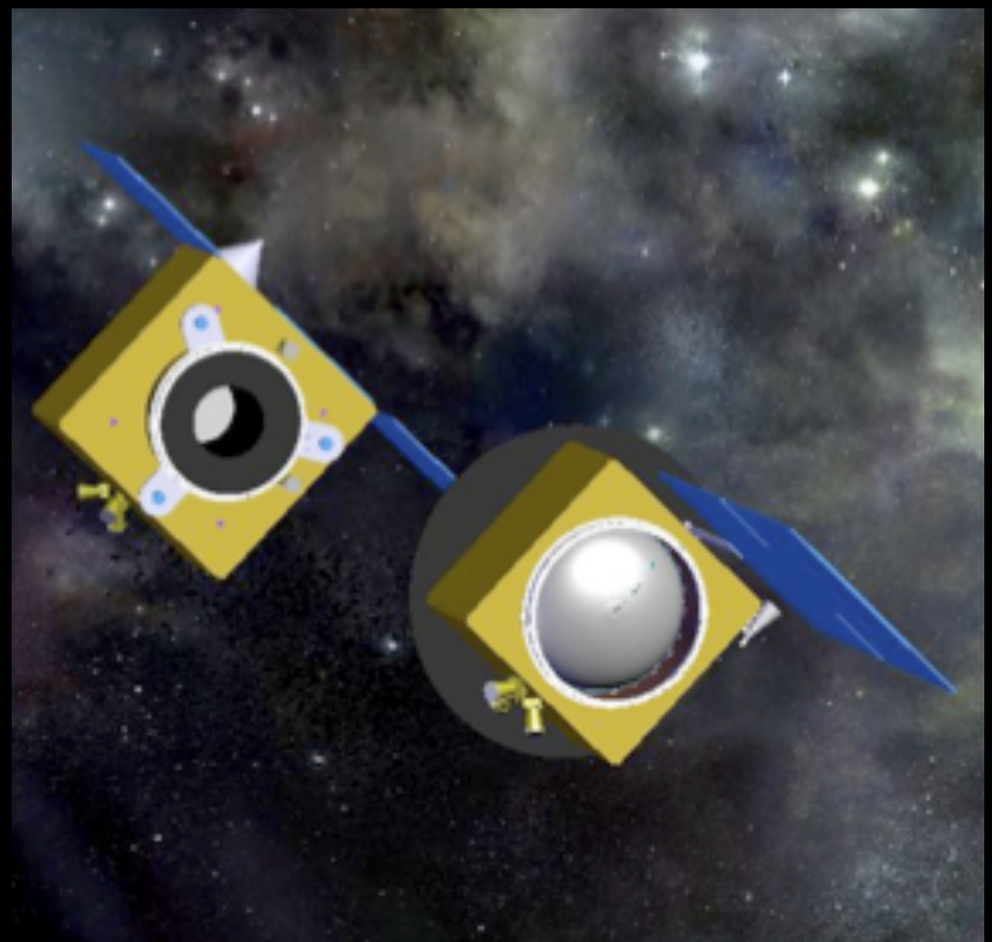
Specification	GAIA
Telescope - #	2
Telescope - D	{1.45m x 0.5m}
Band	V
Limiting magnitude	20
Astrometric precision	7μas
Key science	Stellar astrometry
Operational	2013 -
References	GAIA website



NEAT

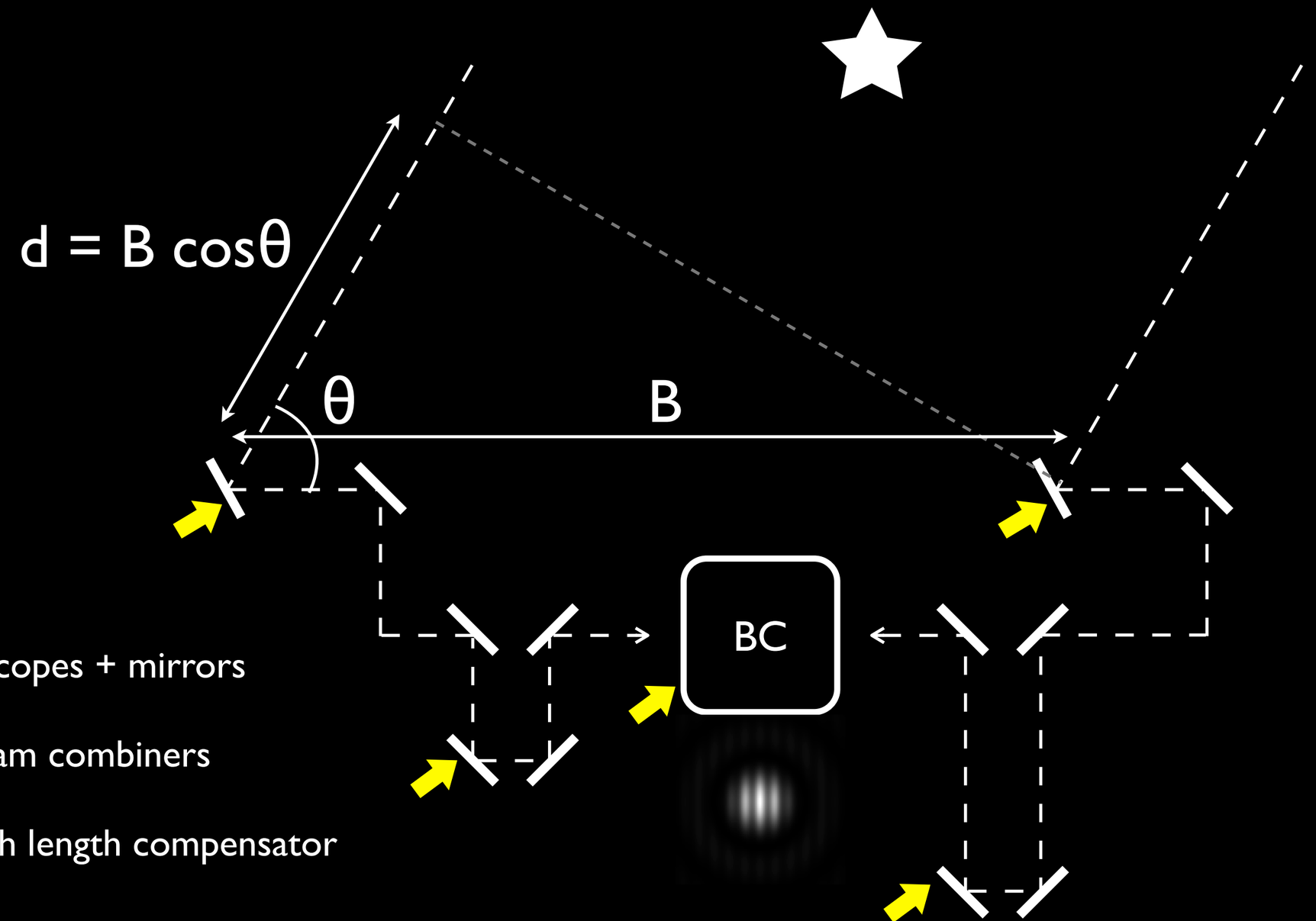
Nearby **E**arth **A**strometric **T**elescope

Specification	NEAT
Telescope - #	1
Telescope - D	1m
Band	R
Limiting magnitude	-
Astrometric precision	0.05μas
Key science	ExoP
Operational	??
References	Malbet et al. (2011)



narrow-angle

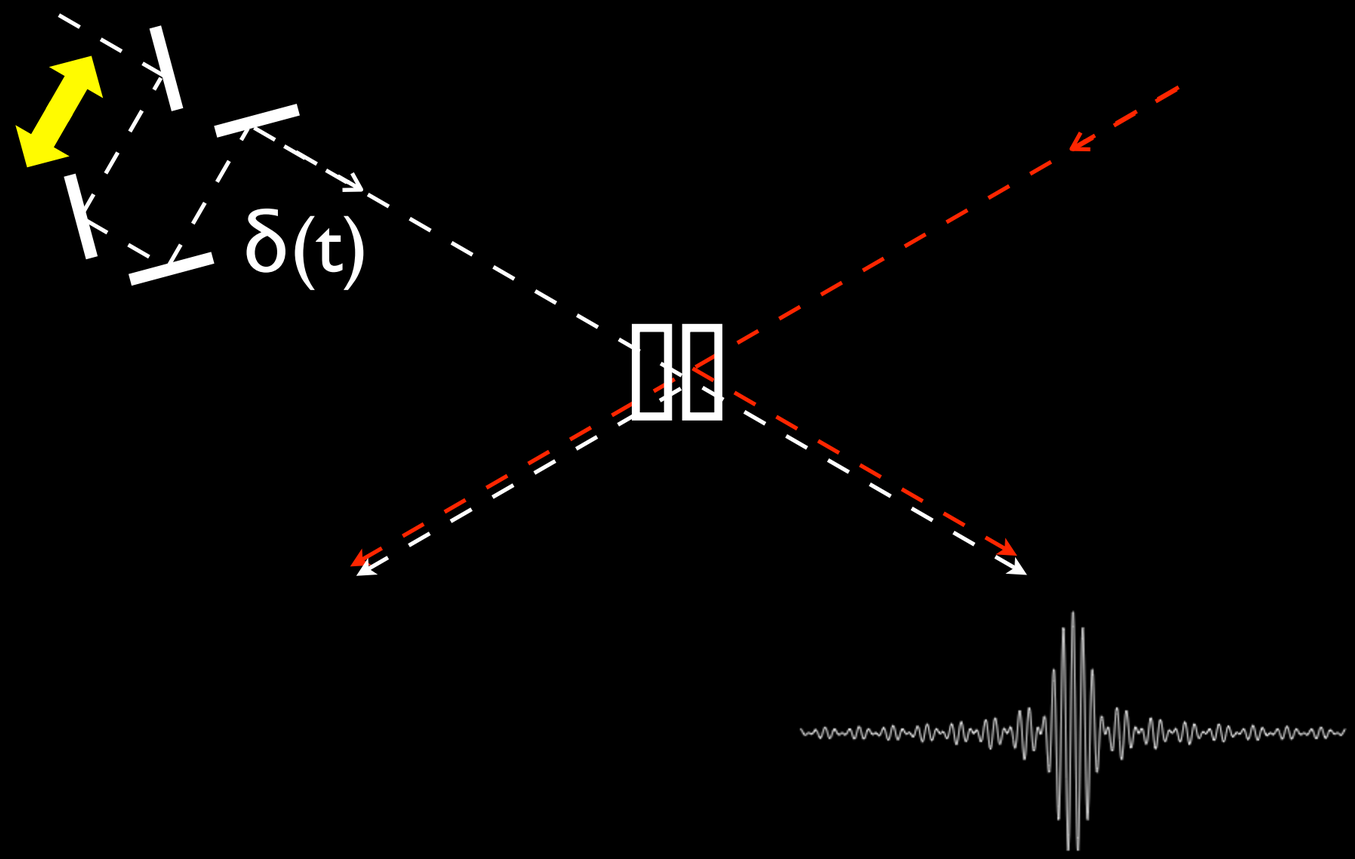
Ground-based astrometry with OLBI



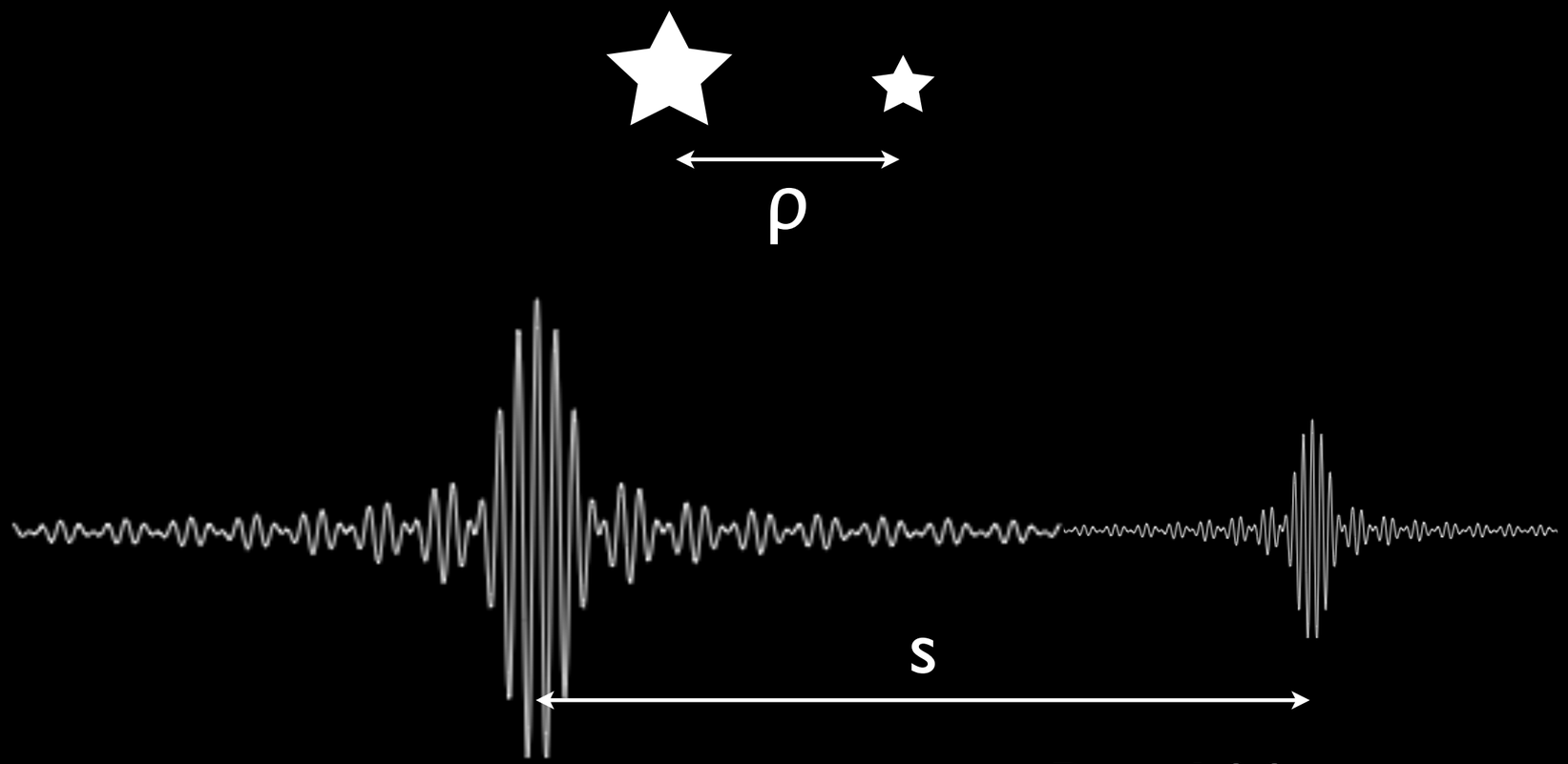
Telescopes + mirrors

Beam combiners

Optical path length compensator



beam combiner



$\rho \propto s/B$

$\Delta\rho \propto \Delta s/B$

B = 100m

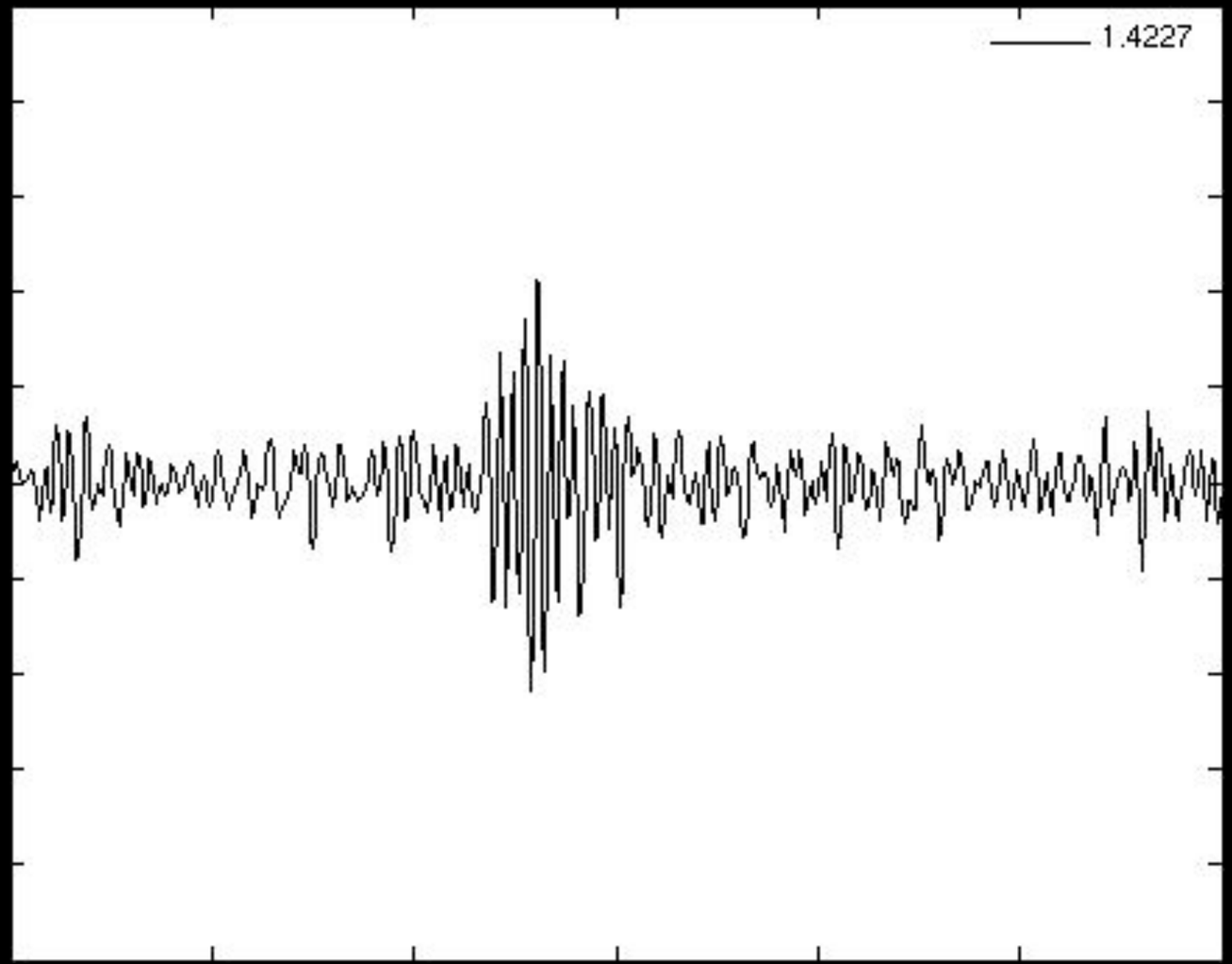
ρ = 1”

s ~ 500μm

Δρ ~ 10-100μas

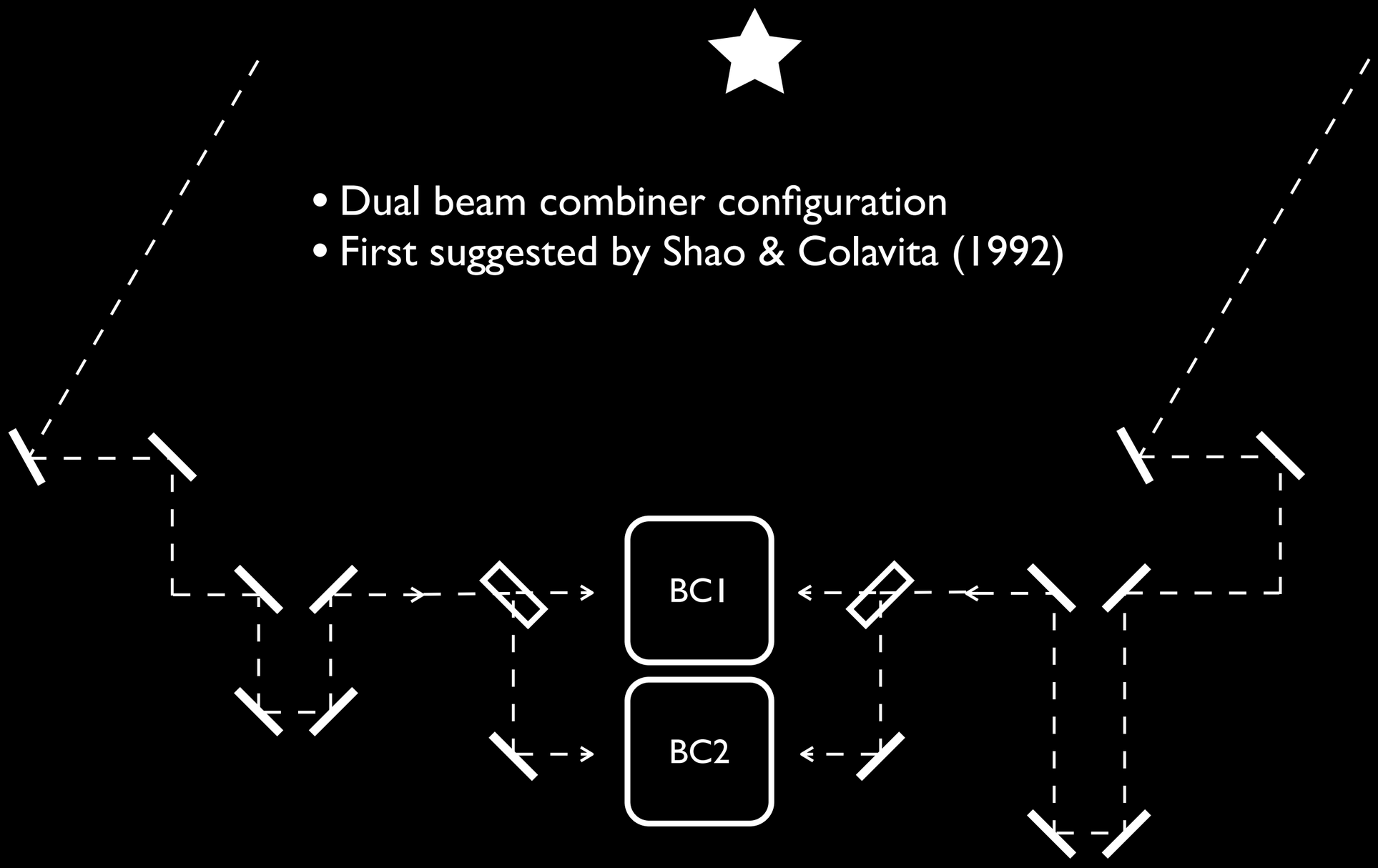
Δs ~ 5-50nm

Canopus

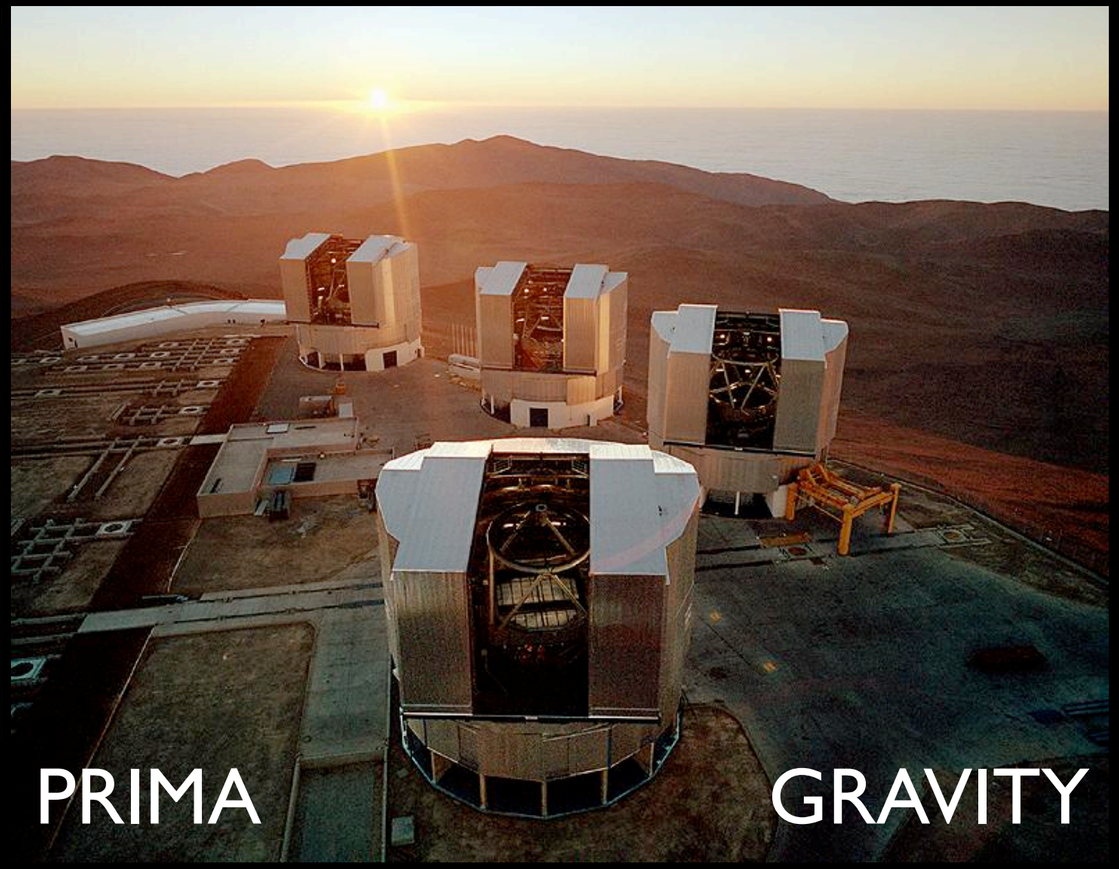


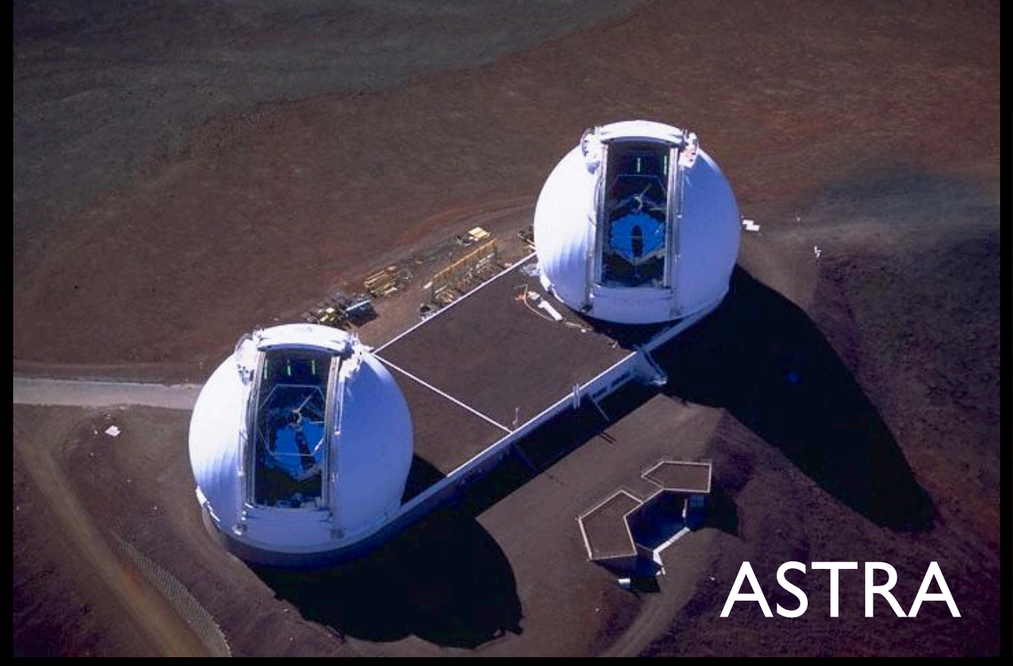
δ~70μm

- Dual beam combiner configuration
- First suggested by Shao & Colavita (1992)




MUSCA


PRIMA
GRAVITY


ASTRA


PHASES

Spec	PHASES	ASTRA	PRIMA	GRAVITY	MUSCA
Location	PTI	KI	VLTI	VLTI	SUSI
Telescopes - D	0.40m	10m	1.8m, 8.2m	8.2m	~0.15m
Telescopes - #	2	2	2	4	2
Baselines	87m, 100m	85m	11 - 200m	47 - 130m	5 - 160m
Fringe-tracking band	K (2.2μm)	K	K	K	0.5 - 0.8μm
Science band	K	K	J, H, K, N	K	~0.85μm

Spec	PHASES	ASTRA	PRIMA	GRAVITY	MUSCA
Limiting magnitude	4.5 - 5	15	14	15	4 - 5
Target vs reference star	< 0.3mas	> 5", < 30"	(> 2",) < 120"	< 2"	< 3"
Astrometric precision	24μas	30μas	10μas	10μas	10μas
Key sciences	ExoP	ExoP, GC, AGN, YSO	ExoP, AGN, YSO	GC, AGN	ExoP
Operational	2002 - 2008	2008 - (2012?)	2012 -	2014 -	2012 -
References	Muterspaugh et al. (2010)	Woilez et al. (2010)	Delplancke (2008)	Gillessen et al. (2010)	Kok et al. (in prep.)

Spec	PHASES	ASTRA	PRIMA	GRAVITY	MUSCA
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Astrometric precision	24 as	30 as	10μas	10μas	10μas
Key sciences	Exo	ExoP GC AGN, YSO	ExoP, AGN, YSO	GC, AGN	ExoP
Operational	2002 - 20 3	20 8 - (201 ?)	2012 -	2014 -	2012 -
References	uterspaugh et al. (2010)	Woilez et al. (2010)	Delplancke (2008)	Gillessen et al. (2010)	Kok et al. (in prep.)

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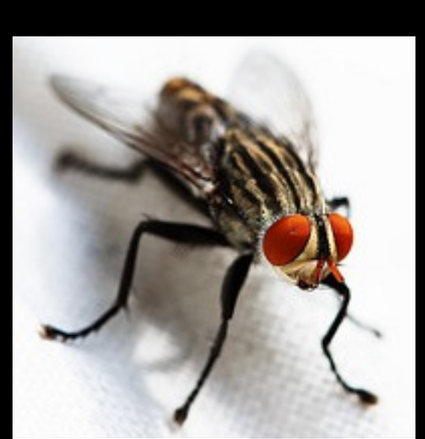
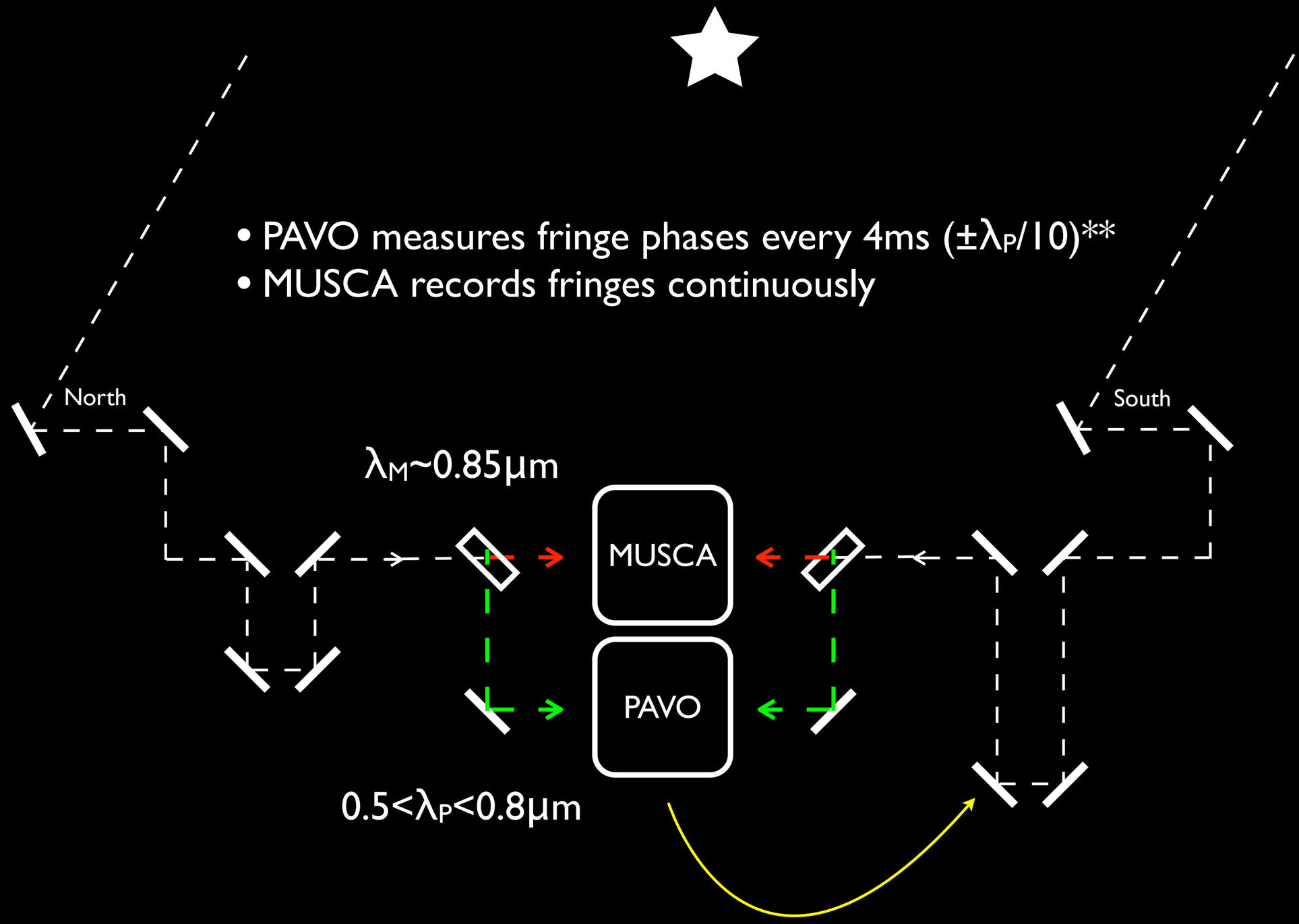
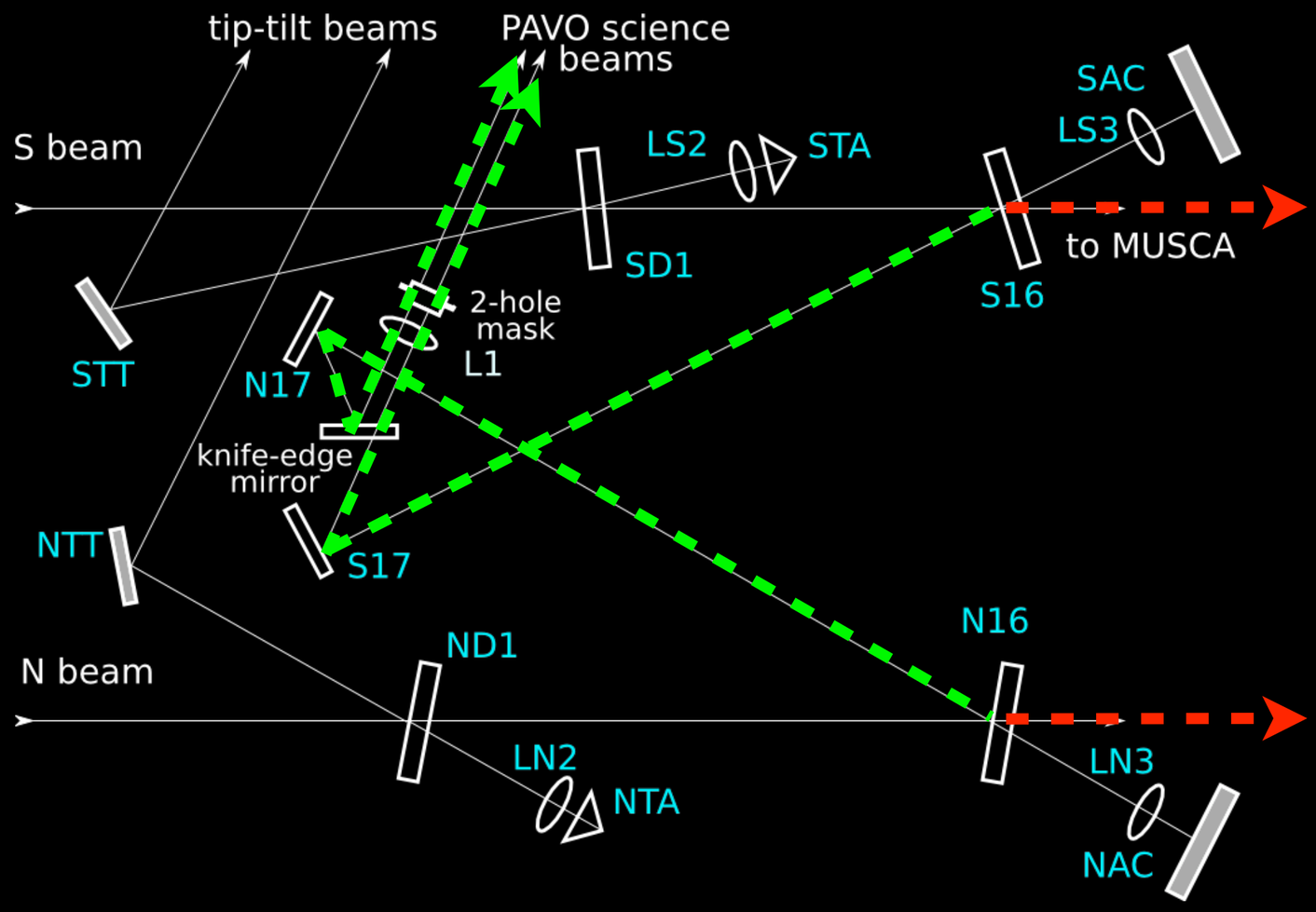
Micro-arcsecond **U**niversity of **S**ydney **C**ompanion **A**strometry (MUSCA) at SUSI



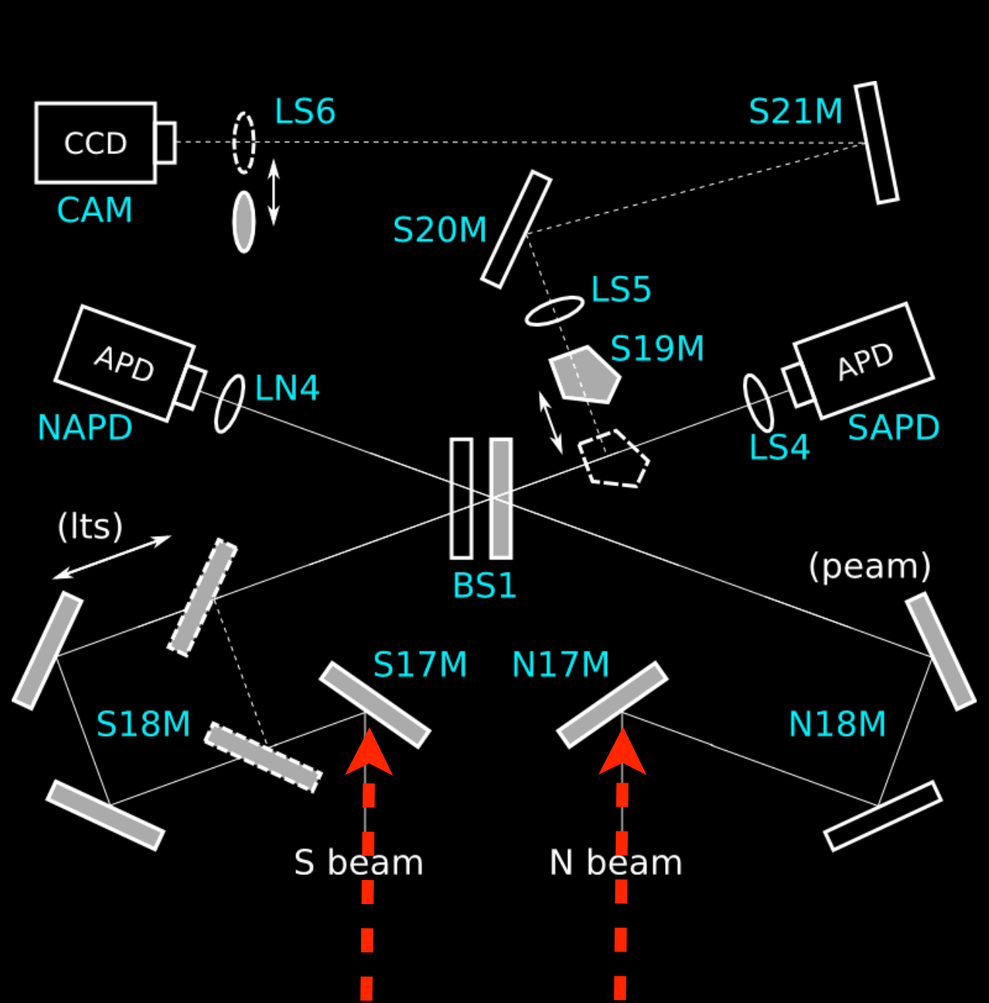
- PAVO measures fringe phases every 4ms ($\pm\lambda_P/10$)**
- MUSCA records fringes continuously

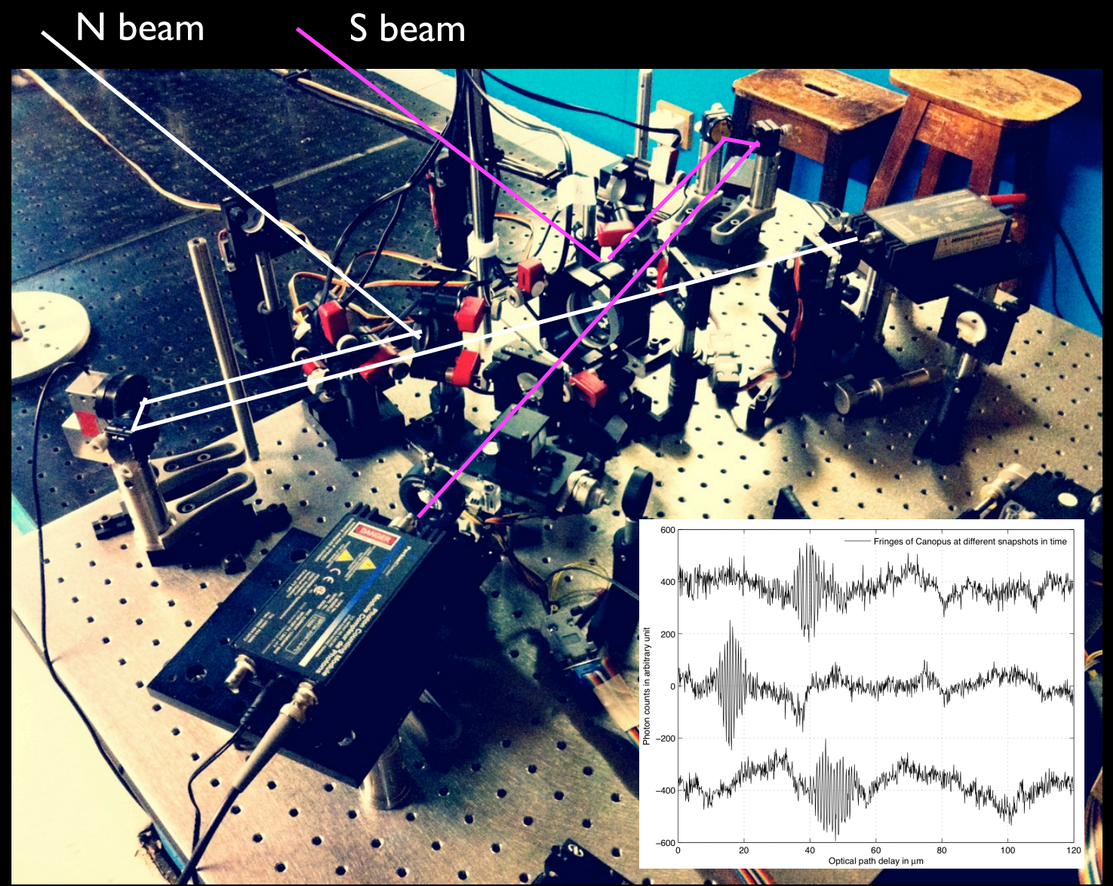


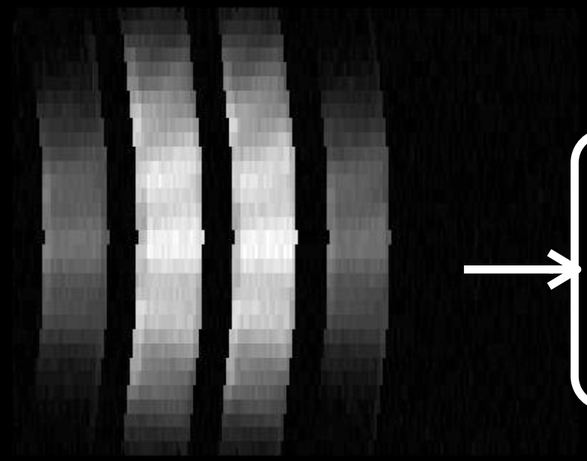
PAVO


tip-tilt beams
PAVO science beams
S beam
LS2
STA
SAC
LS3
SD1
to MUSCA
S16
2-hole mask
L1
STT
N17
knife-edge mirror
NTT
S17
N16
ND1
N beam
LN2
NTA
LN3
NAC

MUSCA


CCD
CAM
LS6
S21M
S20M
LS5
S19M
APD
NAPD
LN4
APD
SAPD
LS4
(lts)
BS1
(peam)
S17M
N17M
S18M
N18M
S beam
N beam

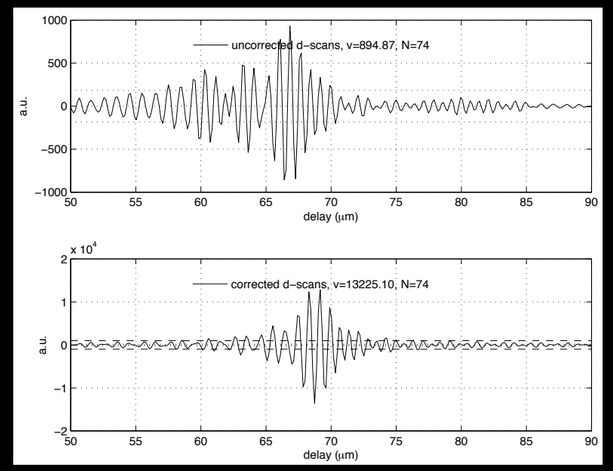

N beam
S beam
Fringes of Canopus at different snapshots in time
Photon counts in arbitrary unit
Optical path delay in µm
600
400
200
0
−200
−400
−600
0
20
40
60
80
100
120



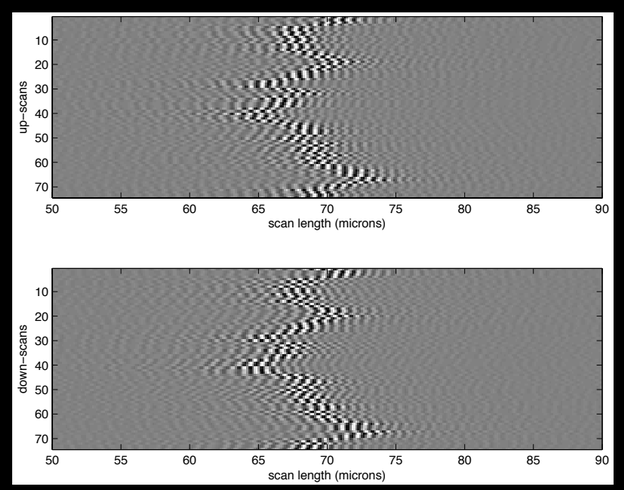
PAVO

Pipeline I

OPD
at λ_M

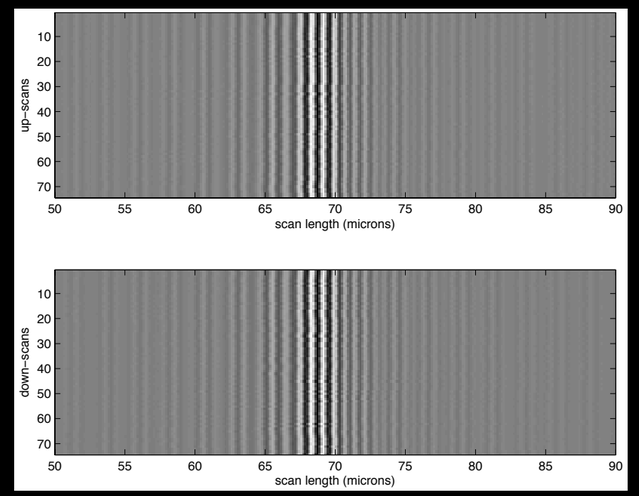


add



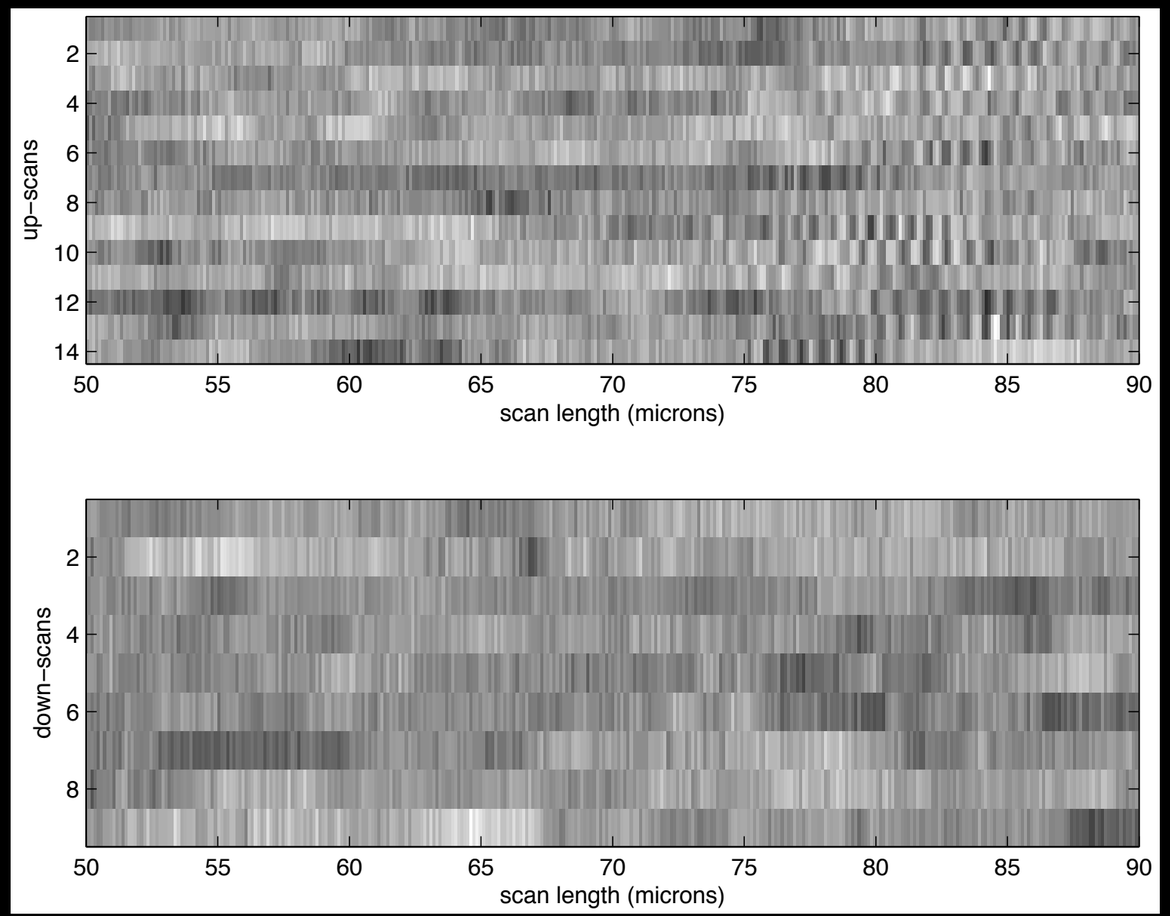
MUSCA

Pipeline II

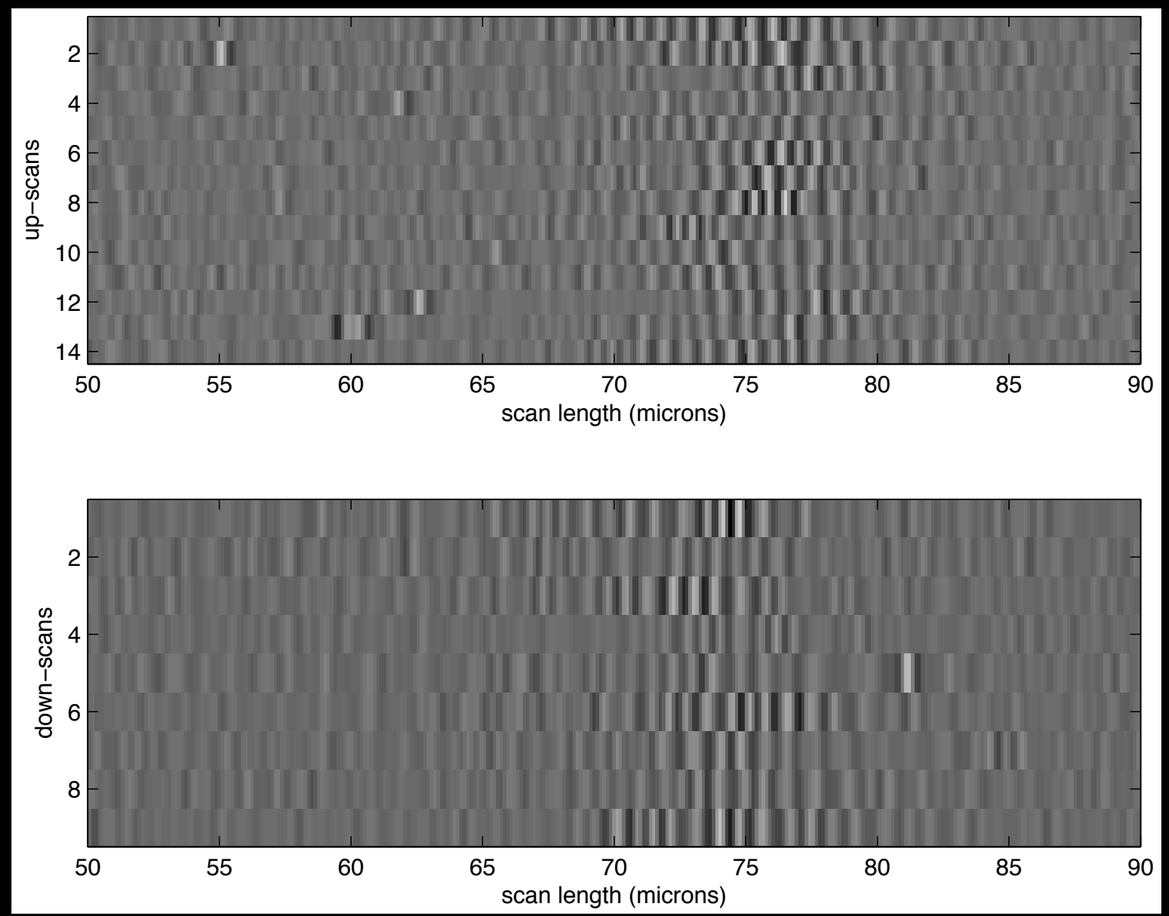


Phase-referenced fringes

Canopus

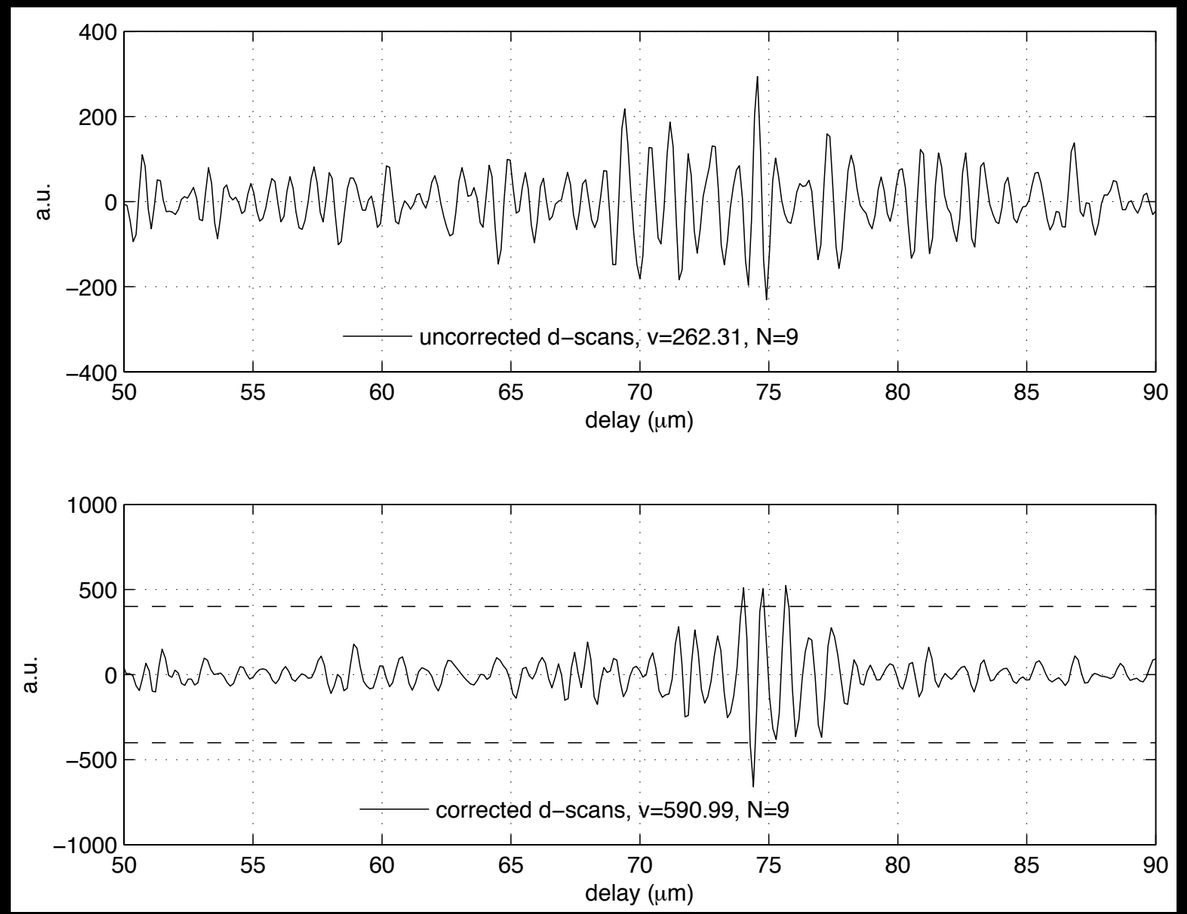


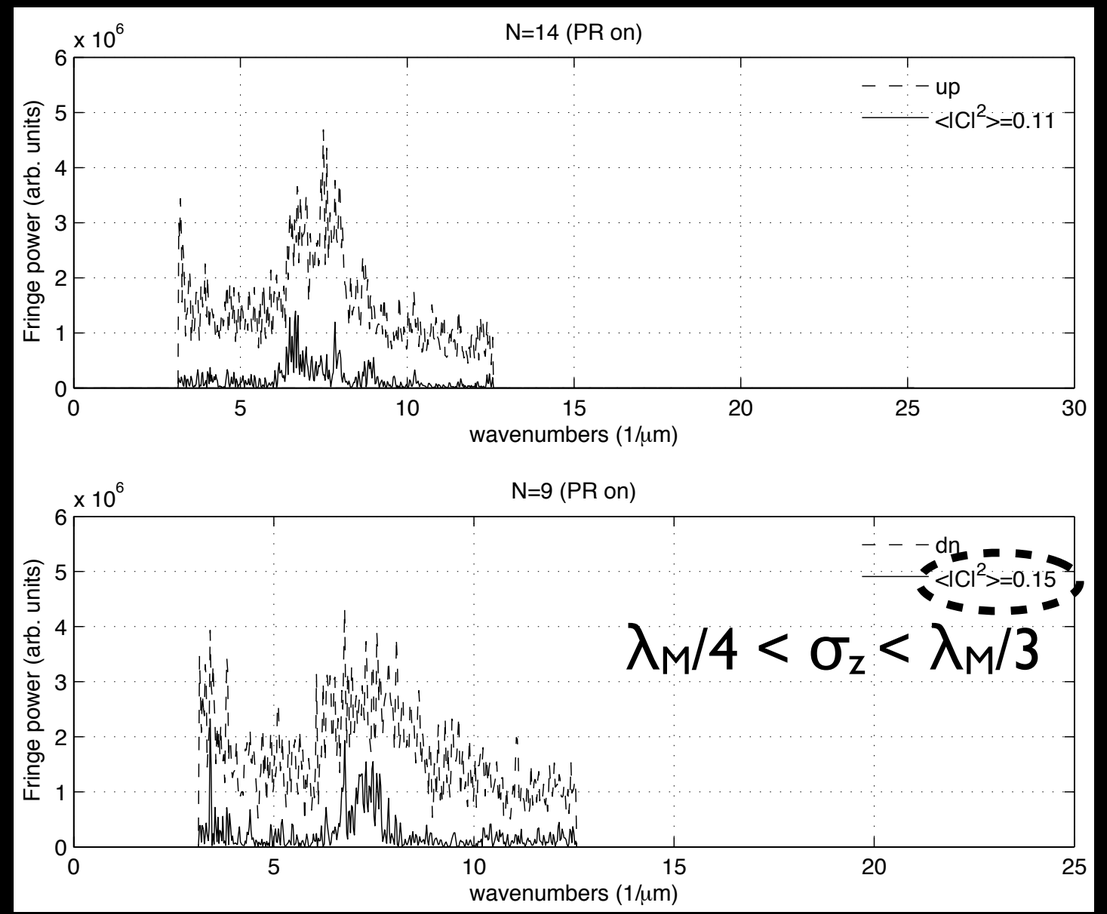
Before PR



After PR

Canopus





Visible light phase-referenced fringes

Progress of MUSCA

Hardware design & setup ✓

On-sky fringes ✓

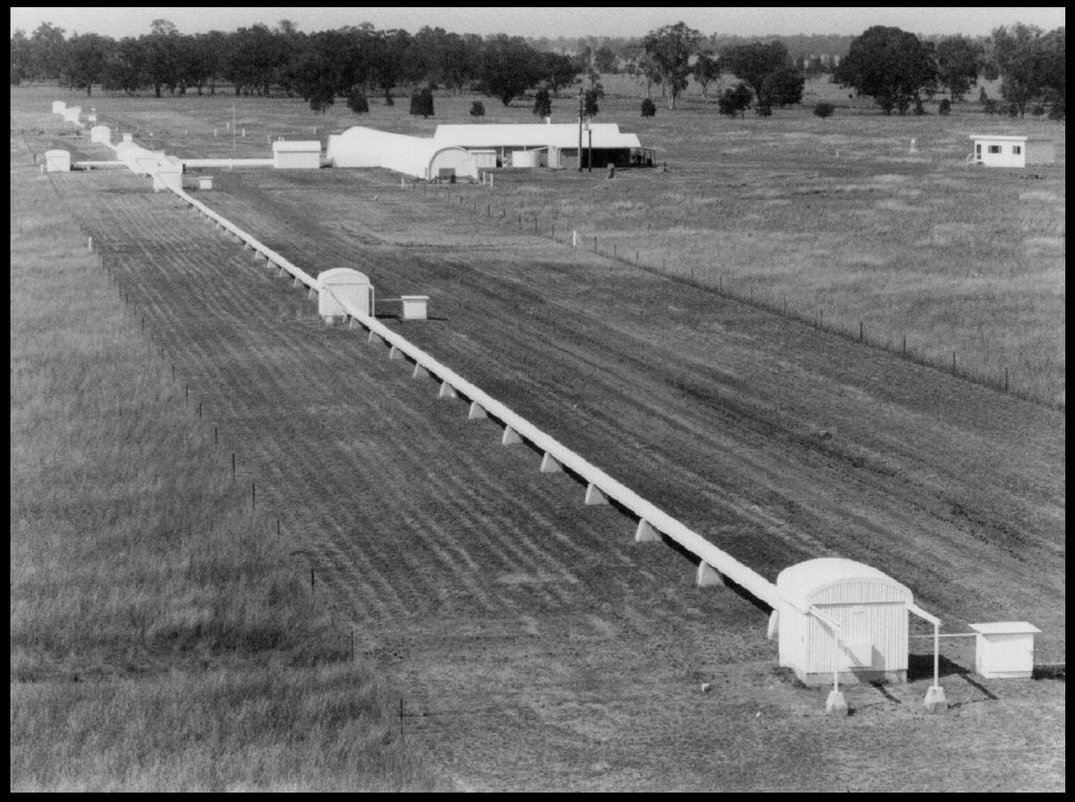
On-sky self-phase-referencing ✓

Understand errors

On-sky narrow-angle astrometry

narrow-angle

Astrometry, a new tool for the next generation planet hunters...



MUSCA
SUSI
5 pros + 1 student

PRIMA, GRAVITY
VLTI
A big team of pros + students