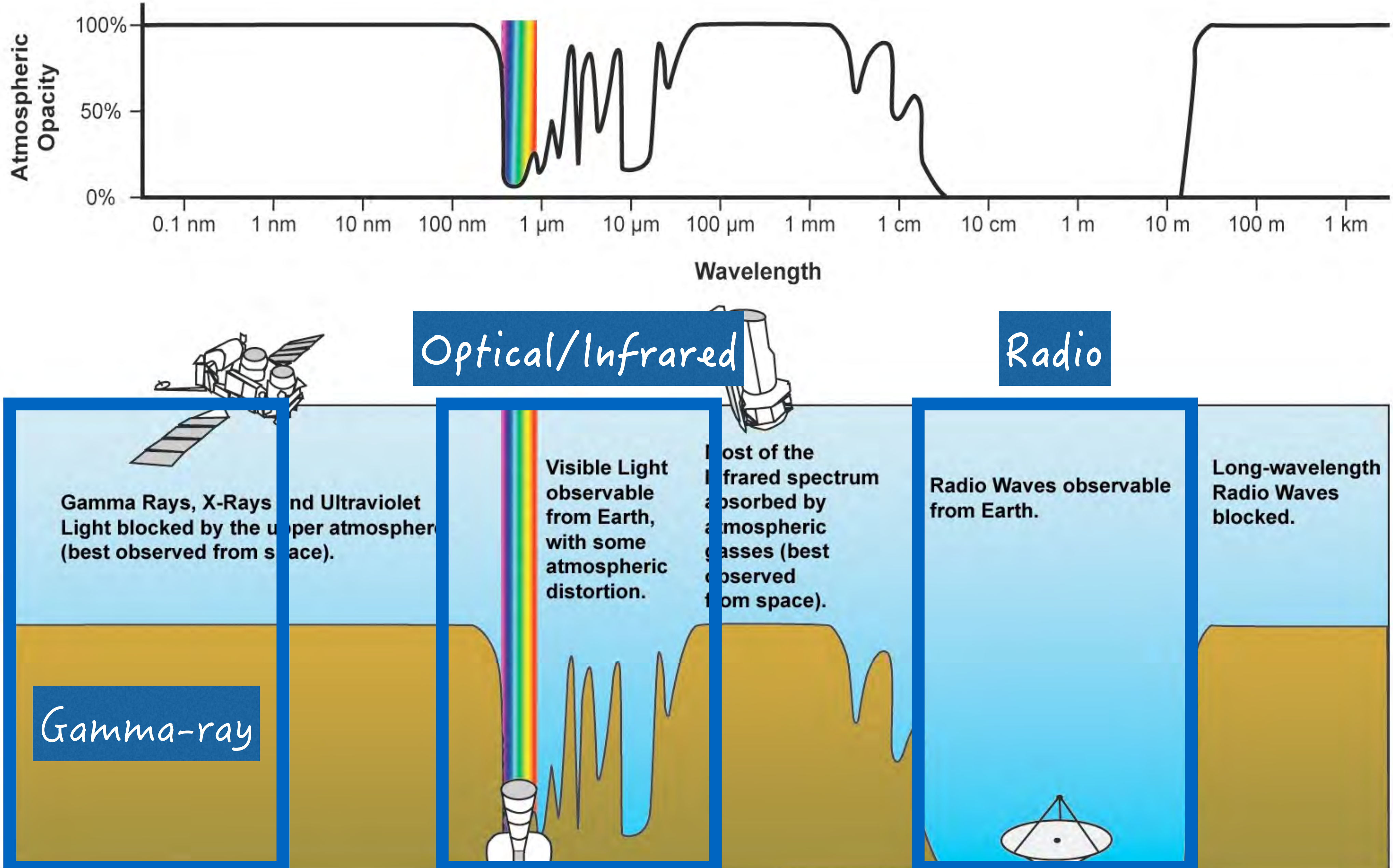
PANORAMA OF GROUND BASED OBSERVATORIES

S. CORBEL (UNIV. P. DIDEROT & CEA SACLAY & OBS. PARIS)

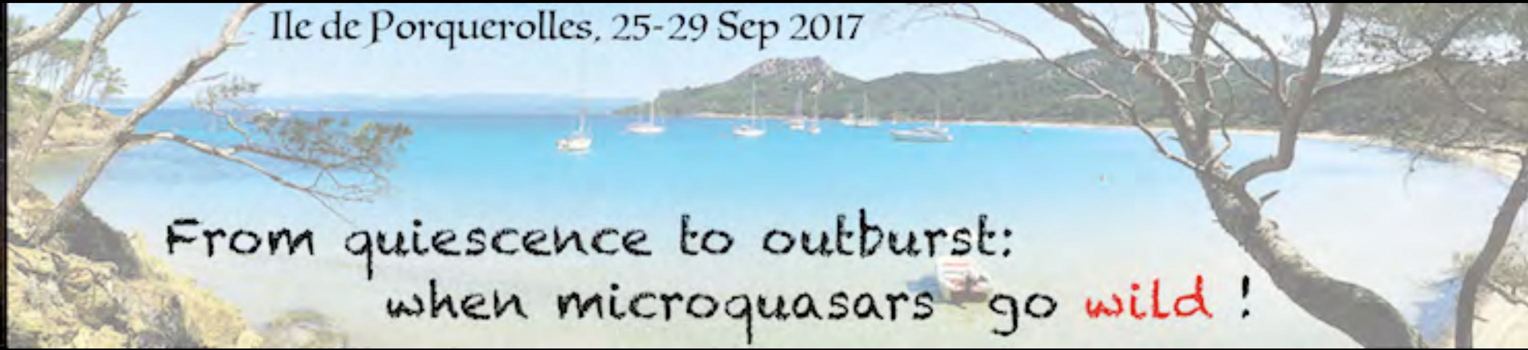
We say ground !

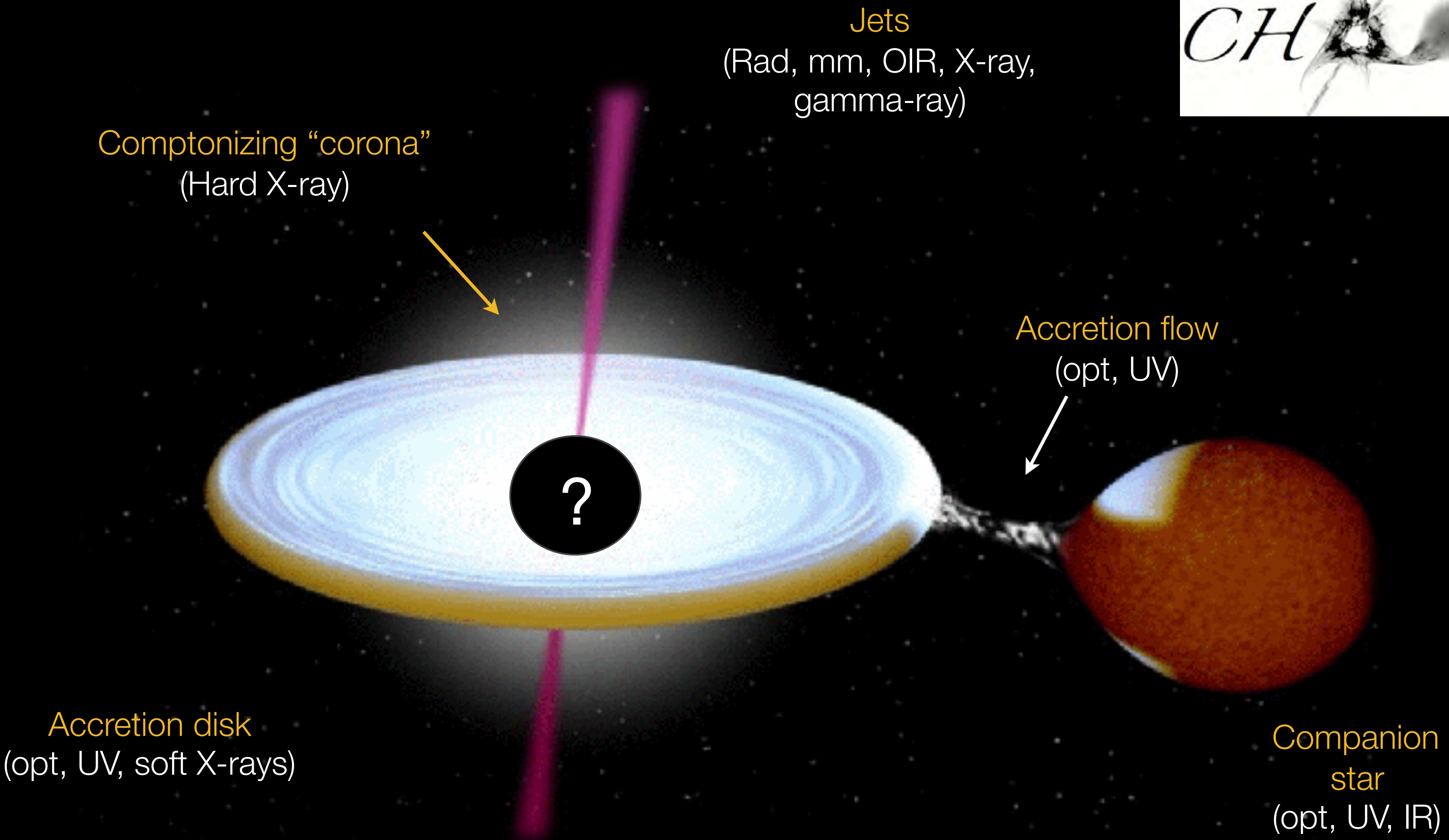


Outline

Please note: this talk does not aim to cover all ground based facilities

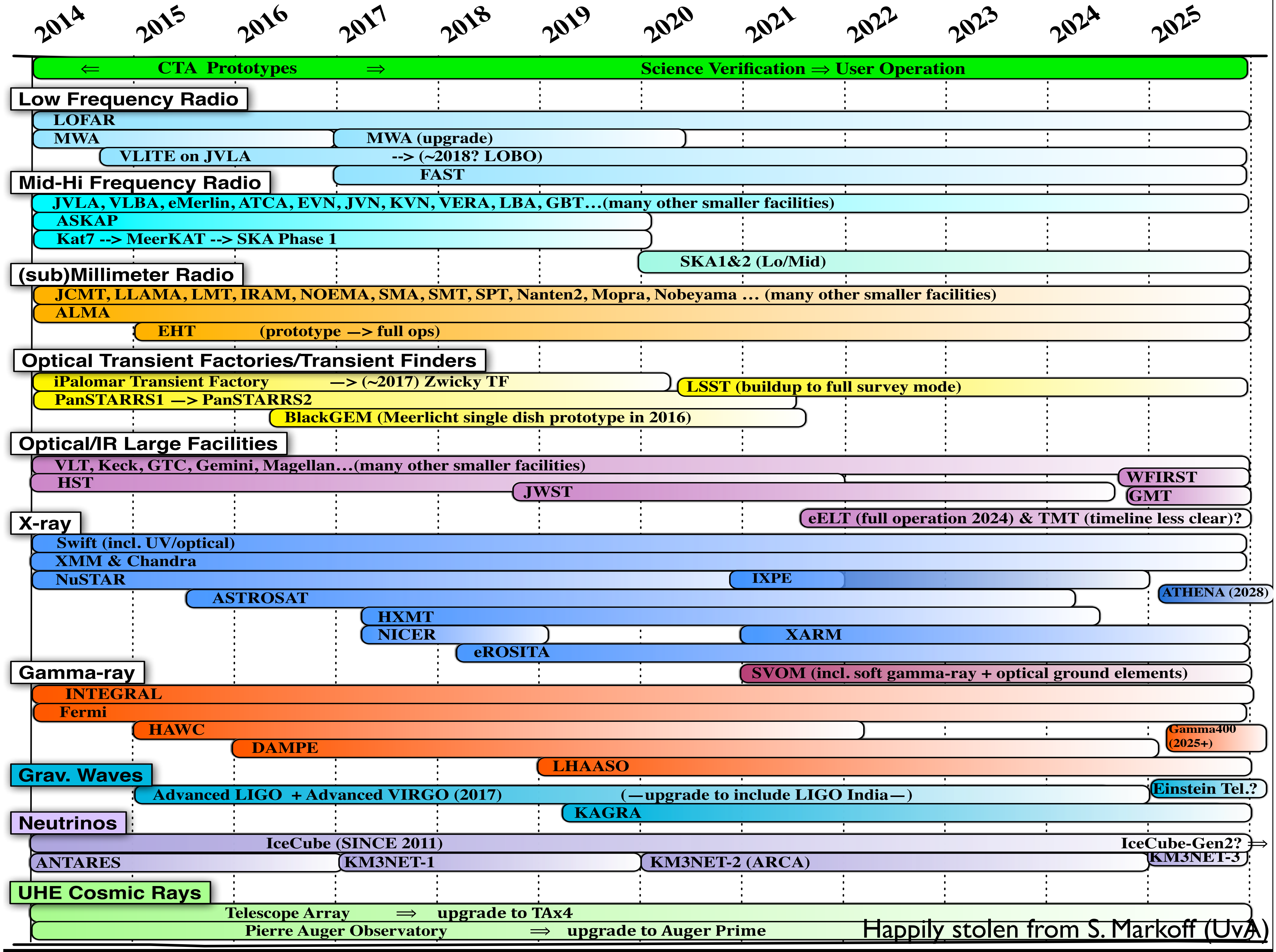
- Microquasars are multi wavele mitters
- A forthcoming revolution in radio-astronomy
- Towards the big giants but not only: optical and infrared
- Getting bigger: high-energy gamma-rays
- See J. Wilms talk for observations from space


Ile de Porquerolles, 25-29 Sep 2017
From quiescence to outburst:
when microquasars go wild !


Jets
(Rad, mm, OIR, X-ray,
gamma-ray)
Comptonizing “corona”
(Hard X-ray)
Accretion flow
(opt, UV)
?
Accretion disk
(opt, UV, soft X-rays)
Companion
star
(opt, UV, IR)

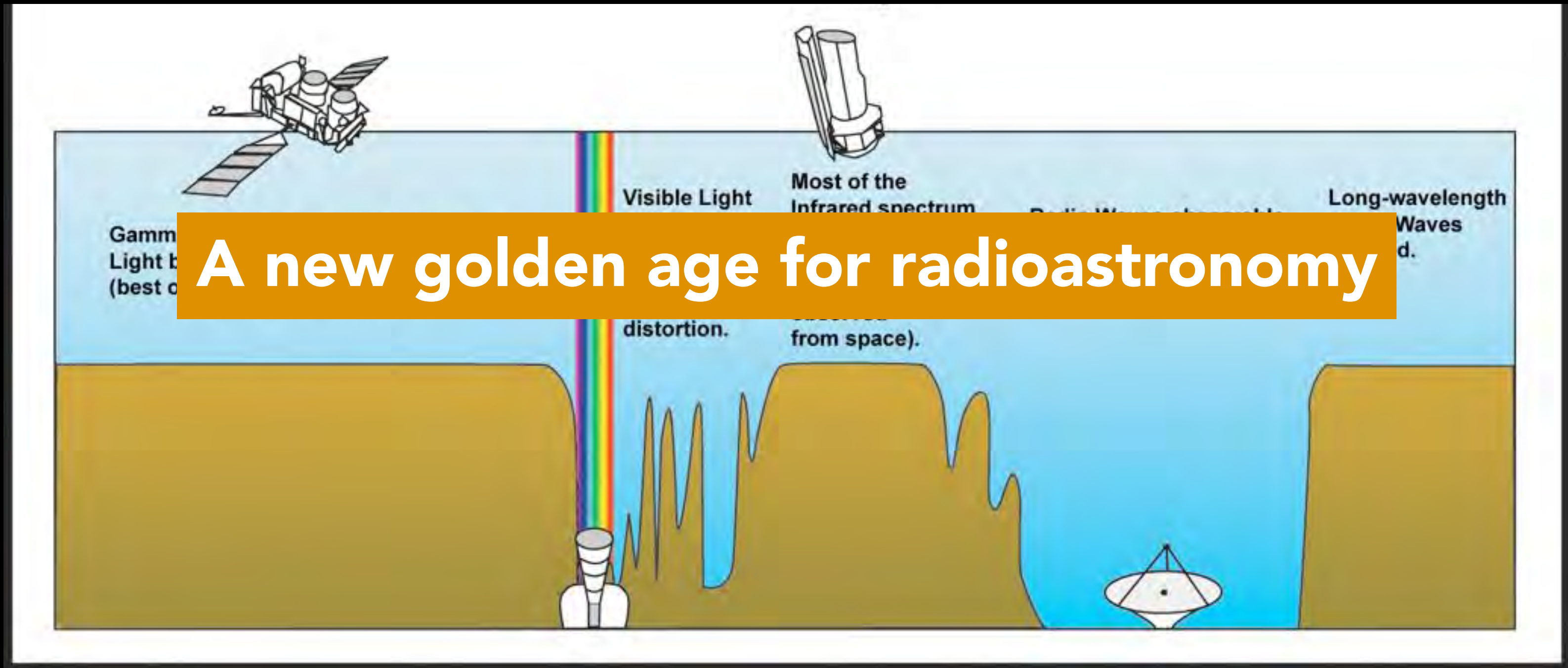
Observational needs

- Radio: fast response to ToO, time coverage, polarimetry, multi-frequencies, high resolution imaging —> **probing the jets**
- OIR: Polarimetry, fast timing, SED, spectroscopy —> **disentangling the various emitting components, mass function**, **base of the jets**, …
- HE γ-rays: sensitivity, **particles acceleration, HE process,**
- **Surveys**: searching for new transients to be later monitor by dedicated pointed observations, including satellites: e.g. LSST, RASM, …


2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
⇐ CTA Prototypes ⇒
Science Verification ⇒ User Operation
Low Frequency Radio
LOFAR
MWA
MWA (upgrade)
VLITE on JVLA
--> (~2018? LOBO)
FAST
Mid-Hi Frequency Radio
JVLA, VLBA, eMerlin, ATCA, EVN, JVN, KVN, VERA, LBA, GBT…(many other smaller facilities)
ASKAP
Kat7 --> MeerKAT --> SKA Phase 1
SKA1&2 (Lo/Mid)
(sub)Millimeter Radio
JCMT, LLAMA, LMT, IRAM, NOEMA, SMA, SMT, SPT, Nanten2, Mopra, Nobeyama … (many other smaller facilities)
ALMA
EHT
(prototype —> full ops)
Optical Transient Factories/Transient Finders
iPalomar Transient Factory
—> (~2017) Zwicky TF
LSST (buildup to full survey mode)
PanSTARRS1 —> PanSTARRS2
BlackGEM (Meerlicht single dish prototype in 2016)
Optical/IR Large Facilities
VLT, Keck, GTC, Gemini, Magellan…(many other smaller facilities)
WFIRST
HST
JWST
GMT
eELT (full operation 2024) & TMT (timeline less clear)?
X-ray
Swift (incl. UV/optical)
XMM & Chandra
NuSTAR
IXPE
ATHENA (2028)
ASTROSAT
HXMT
NICER
XARM
eROSITA
Gamma-ray
SVOM (incl. soft gamma-ray + optical ground elements)
INTEGRAL
Fermi
HAWC
Gamma400
(2025+)
DAMPE
LHAASO
Grav. Waves
Advanced LIGO + Advanced VIRGO (2017)
(—upgrade to include LIGO India—)
Einstein Tel.?
KAGRA
Neutrinos
IceCube (SINCE 2011)
IceCube-Gen2? ⟹
ANTARES
KM3NET-1
KM3NET-2 (ARCA)
KM3NET-3
UHE Cosmic Rays
Telescope Array ⟹ upgrade to TAx4
Pierre Auger Observatory ⟹ upgrade to Auger Prime
Happily stolen from S. Markoff (UvA)

Radio

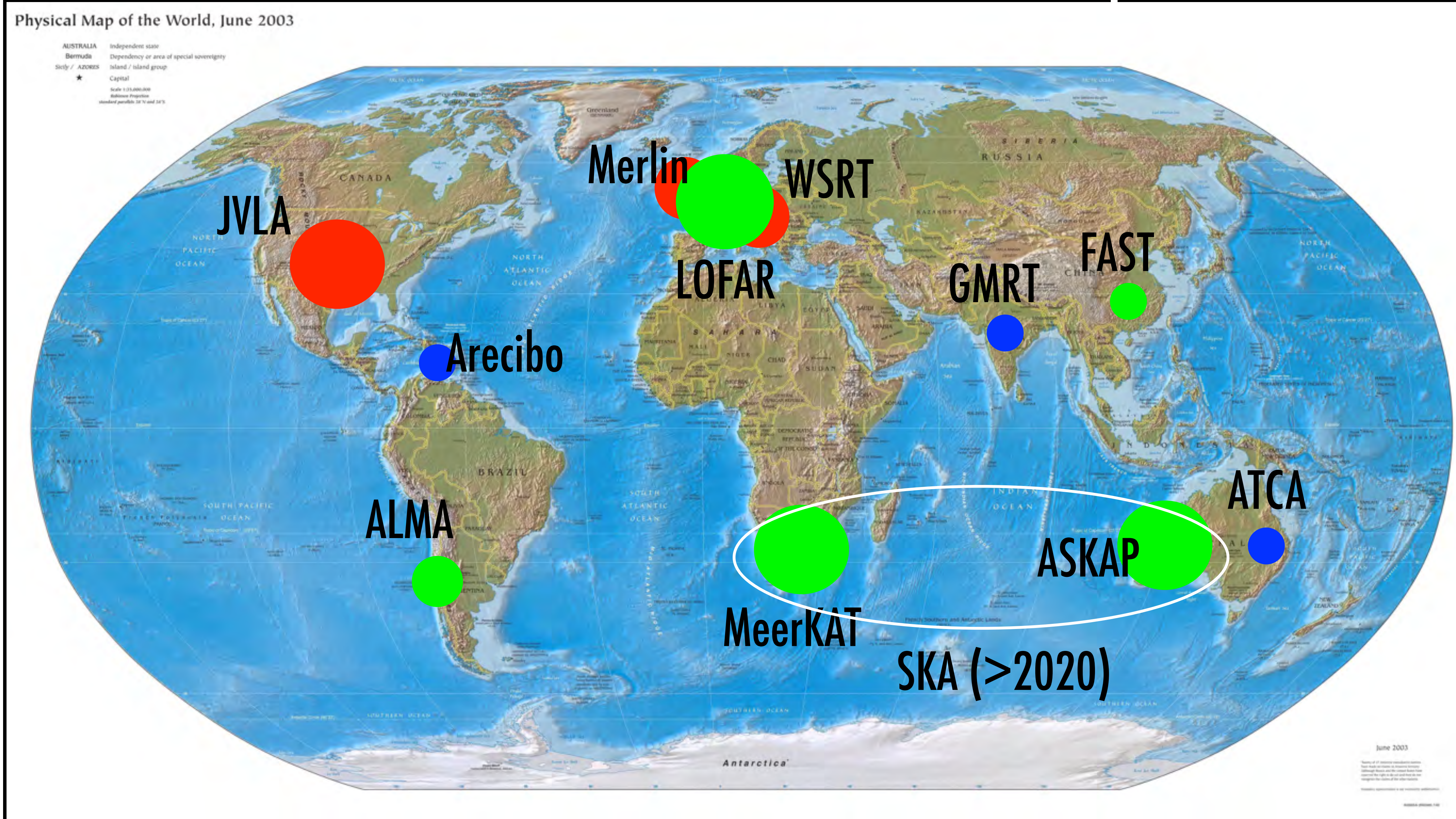
MINUTE BREAK: RADIOASTRONOMY



A new golden age for radioastronomy

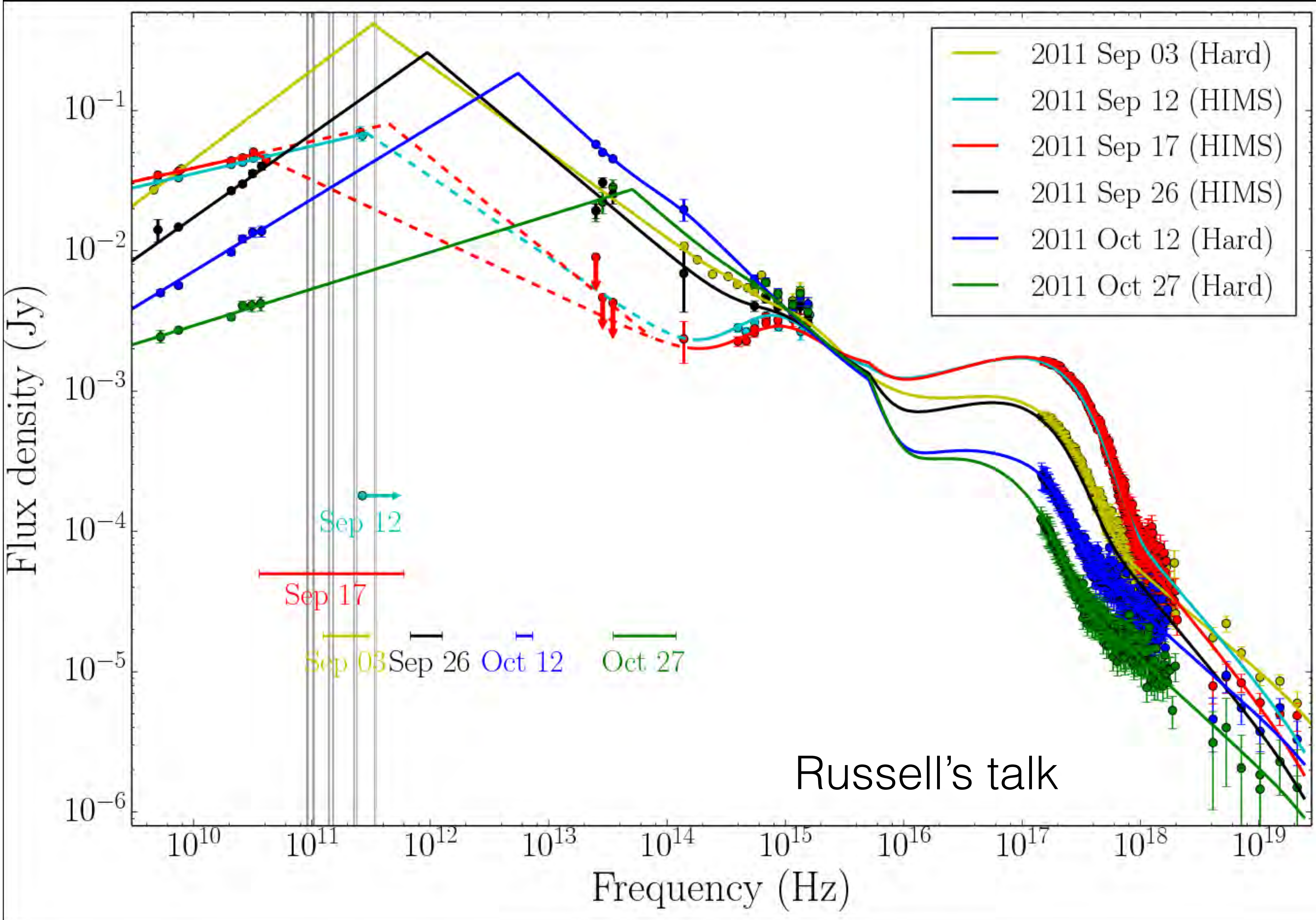
Phased arrays v.s. **pointed telescope**

Main radio telescopes



ALMA

- An array of 66 antennas, using aperture synthesis over the entire accessible mm/submm wavelength range up to 1 THz



2011 Sep 03 (Hard)
2011 Sep 12 (HIMS)
2011 Sep 17 (HIMS)
2011 Sep 26 (HIMS)
2011 Oct 12 (Hard)
2011 Oct 27 (Hard)
Sep 12
Sep 17
Sep 03
Sep 26
Oct 12
Oct 27
Flux density (Jy)
Frequency (Hz)
Russell's talk

THE SKA PRECURSORS

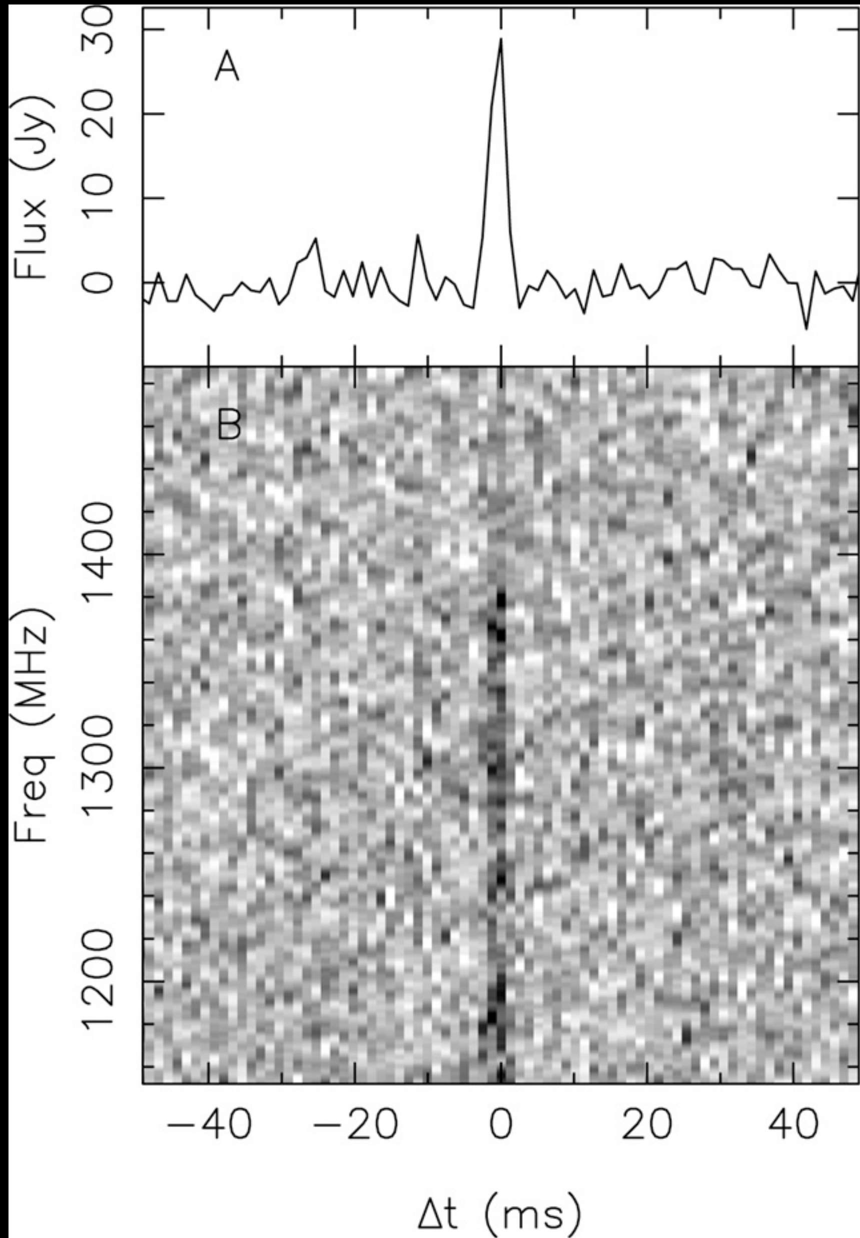
SKA PRECURSORS: ASKAP

- Location: Australia
- Max Baseline : 6 km
- Frequency coverage: 0.7-1.8 GHz
- 36 antennas (12 m) with PAF (30 deg^2 FOV)
- Fully operational in 2017 ? (partially since 2015) , not sure if all antennas equipped with PAF

Large FOV —> Surveys

FIRST ASKAP FRB IN MAY 2017!

« ASKAP has found its first FRB after less than four days of searching (8 antennas). The discovery came so quickly that the telescope looks set to become a world champion in this fiercely competitive area of astronomy. » ASKAP press release. CRAFT

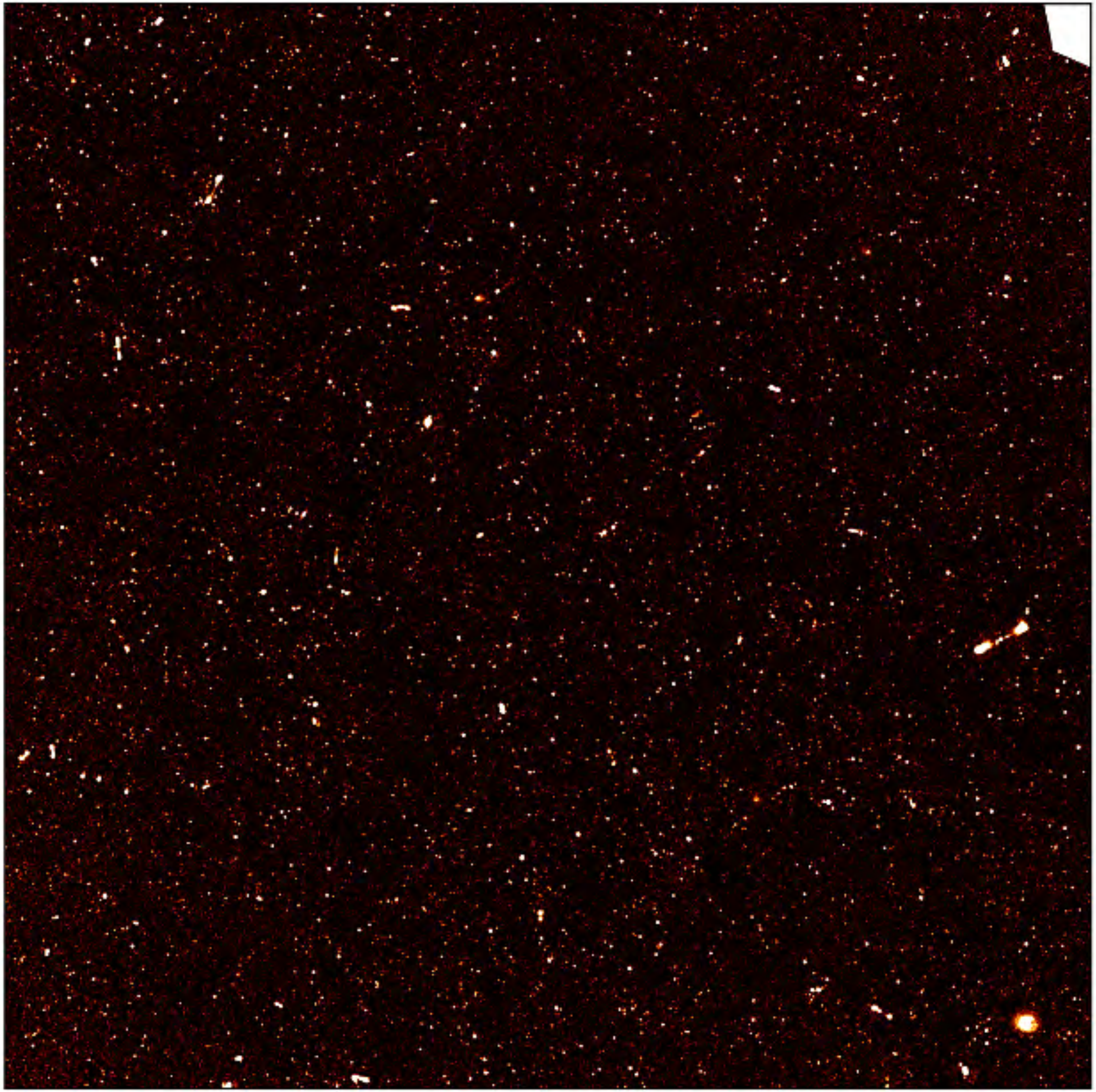


THE VAST SURVEY

	VAST-Wide	VAST-Deep		VAST-Galactic	Commensal
		Multi-field	Single Field		
Observing time (h)	4 380	3 200	400	600	1.5 years
Survey area (deg^2)	10 000	10 000	30	750	10 000
Time per field	40 s	1 h	1 h	16 min	12 h
Repeat	Daily	7 times	Daily	64 times	None
Observing freq (MHz)			1 130–1 430		
Bandwidth (MHz)			300		
RMS sensitivity (mJy beam^{-1})	0.5	0.05		0.1	0.01
Field of view (deg^2)			30		
Angular resolution			10 arcsec		
Spectral resolution			10 MHz		
Time resolution			5 s		
Polarisation products			*IQUV*		

SKA PRECURSORS: MEERKAT

- Location: South Africa
- 64 antennas (13.5 m) over an 8-km baseline
- Frequency coverage: 0.5-10 GHz
- FOV: 1.69 deg^2 @ 1 GHz
- Fully deployed in March 2018 (32 in march 2017)



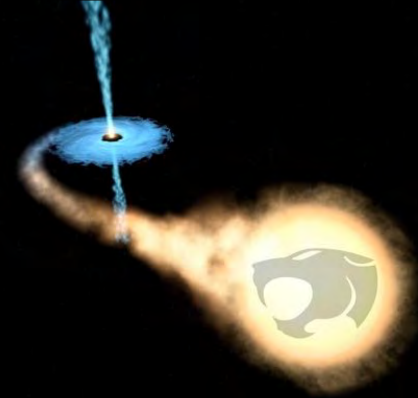
Commissioning image of MeerKAT

16 ant.
1.3° x 1.3°
1.4 GHz
rms ~ 6.5 μJy

Goal with full array ~1 μJy

Ref: Fender (private com)

THUNDERKAT
(PI: FENDER/WOUDT)



A MeerKAT Large Survey Project for synchrotron radio transients

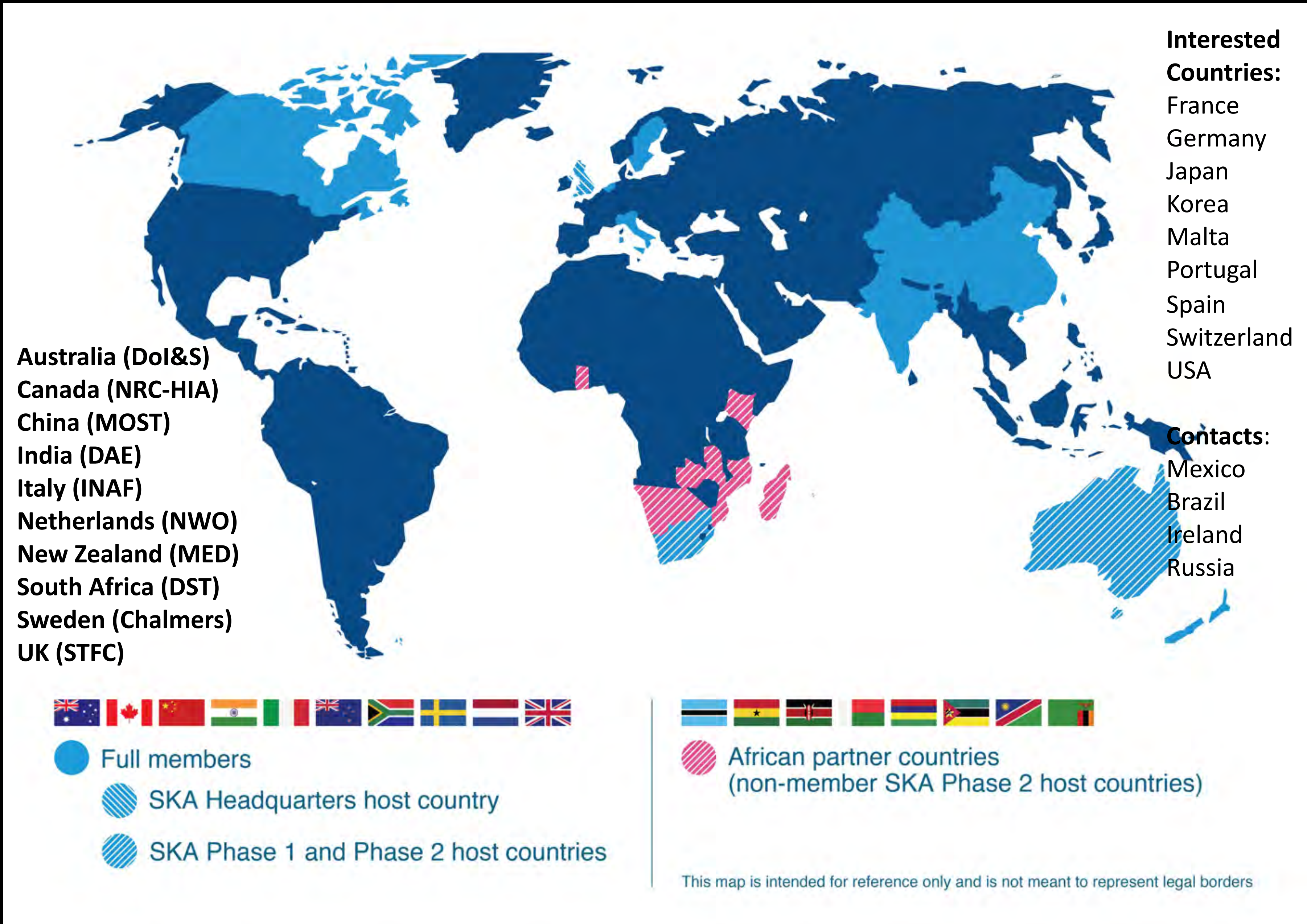
- **Survey** and **monitor** populations of Galactic and extragalactic **synchrotron radio transients**
- **Commensal** observations + **pointed** observations (~2000 h) typically for follow-up + simultaneous optical observations with **MeerLicht**.
- **Large international collaboration** (56 co-Is from 9 countries)

SKA

SKA– KEY SCIENCE DRIVERS: THE HISTORY OF THE UNIVERSE

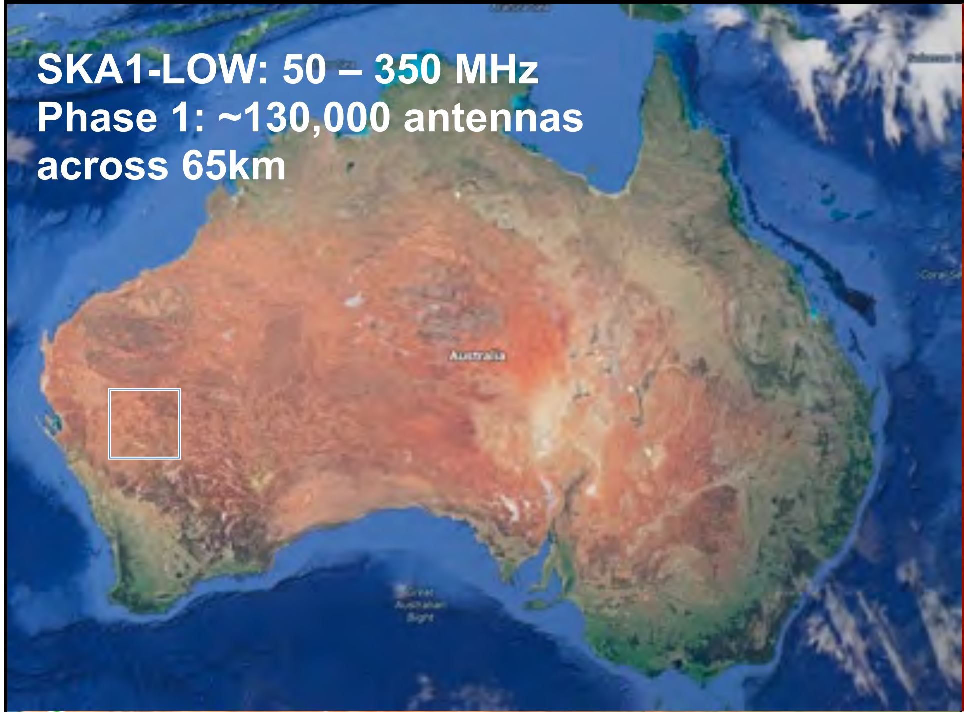
Extremely broad range of science!

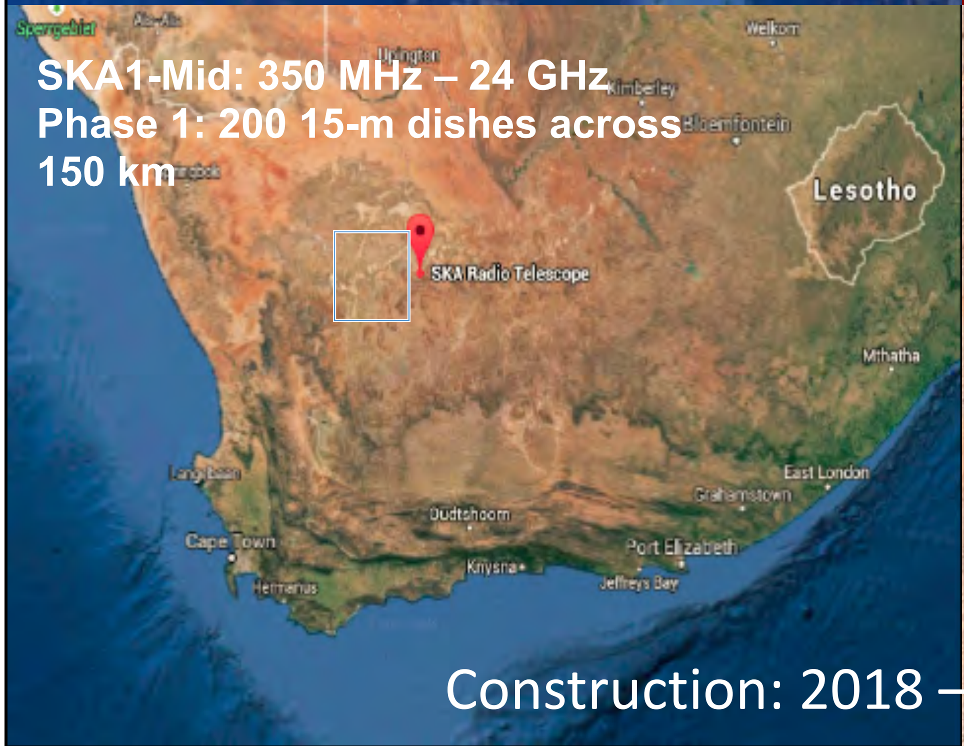
SKA ORGANISATION: 10 COUNTRIES, MORE TO JOIN



THE SQUARE KILOMETER ARRAY (SKA)

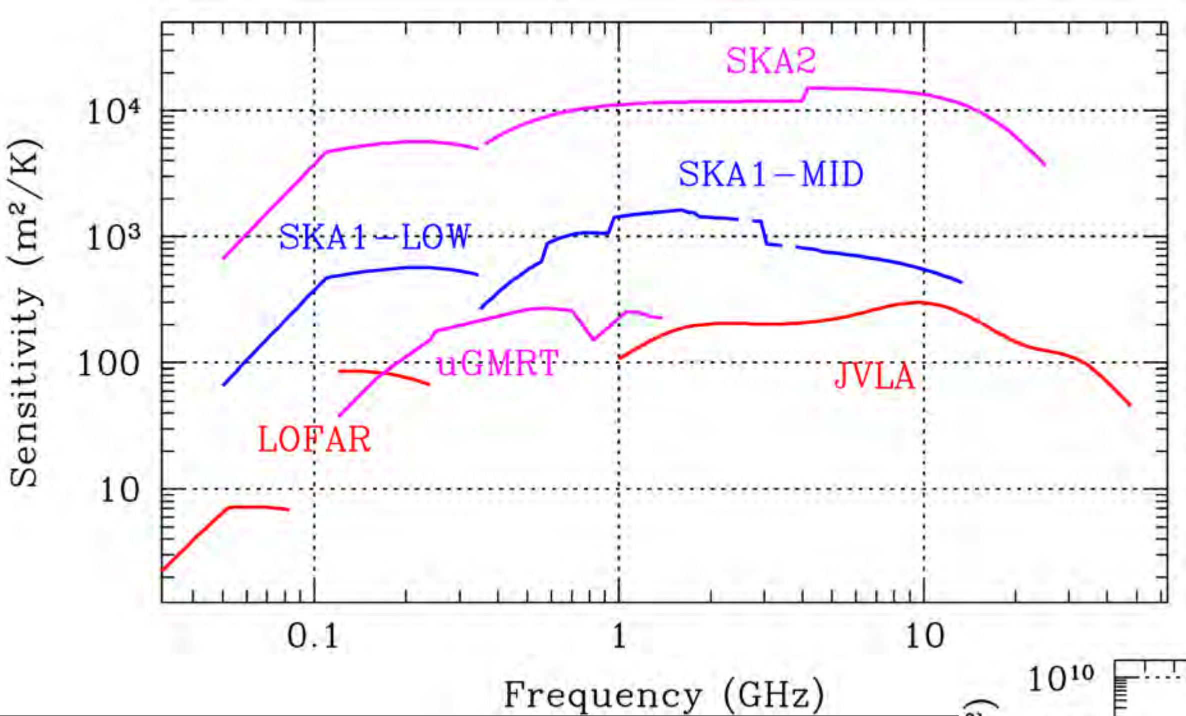
- 3 sites; 2 telescopes + HQ —-> 1 Observatory
- Design Phase: > €170M; 600 scientists+engineers
- Phase 1:
  - Construction: 2018 – 2024
  - Construction cost cap: 674.1M€ (inflation-adjusted)
  - Operations cost: under development
- Phase 2: start mid-2020s
  - ~2000 dishes across 3500km of Southern Africa
  - Major expansion of SKA1-Low across Western Australia
- A telescope available for 50+ years !!!





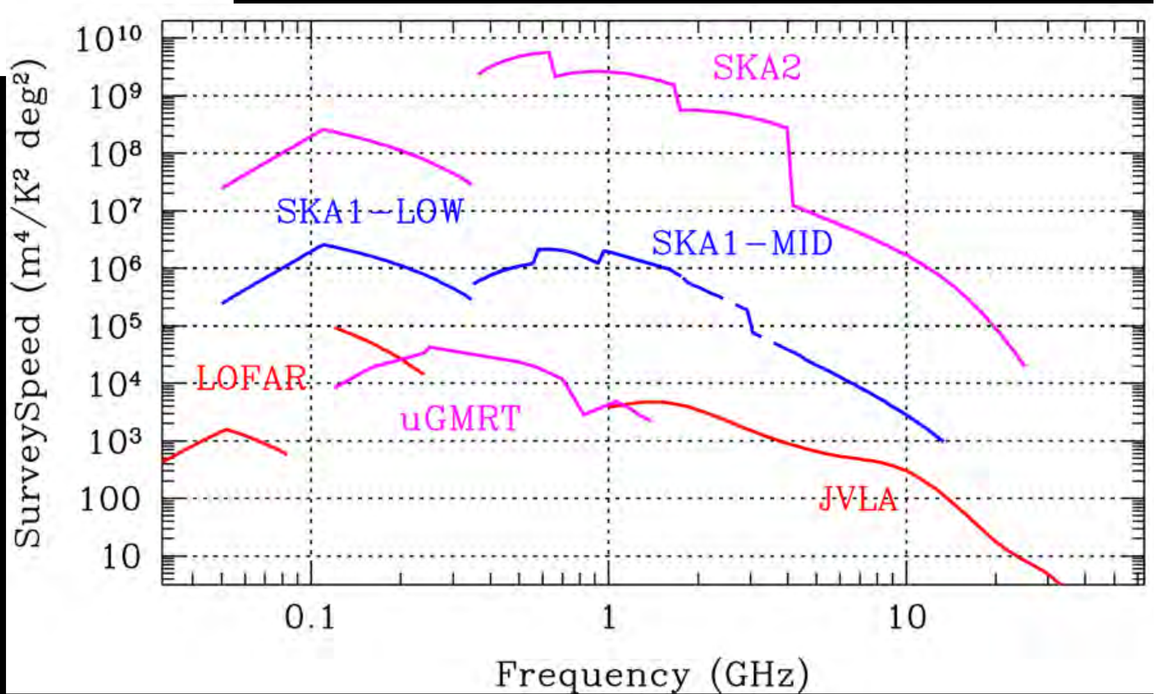
Construction: 2018 – 2024; Cost cap: €675M

SKA1 CAPABILITY VS STATE-OF-THE-ART



Point-source sensitivity:

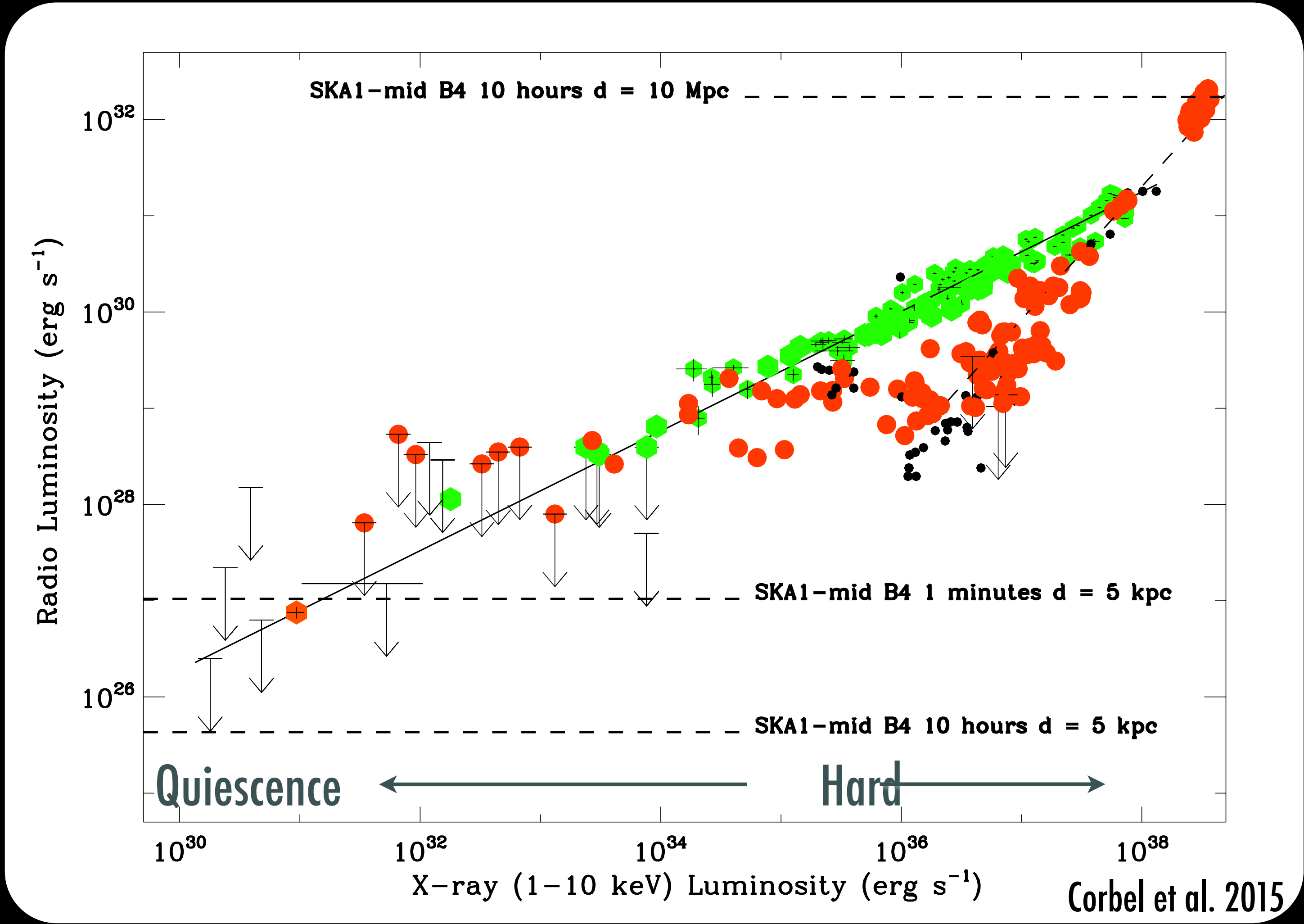
~ 4 – 20 times state-of-the-art



Survey speed:

~ 10 - 100 times state-of-the-art

SLOW TRANSIENTS: MICROQUASARS



- **SKA**: probing **a significant fraction of the whole outburst** duration for almost all BHs in our Galaxy
- All **flaring transient BHs** accessible in the local Universe (possibly also up to Virgo @ 15 Mpc)

Other important radio facilities

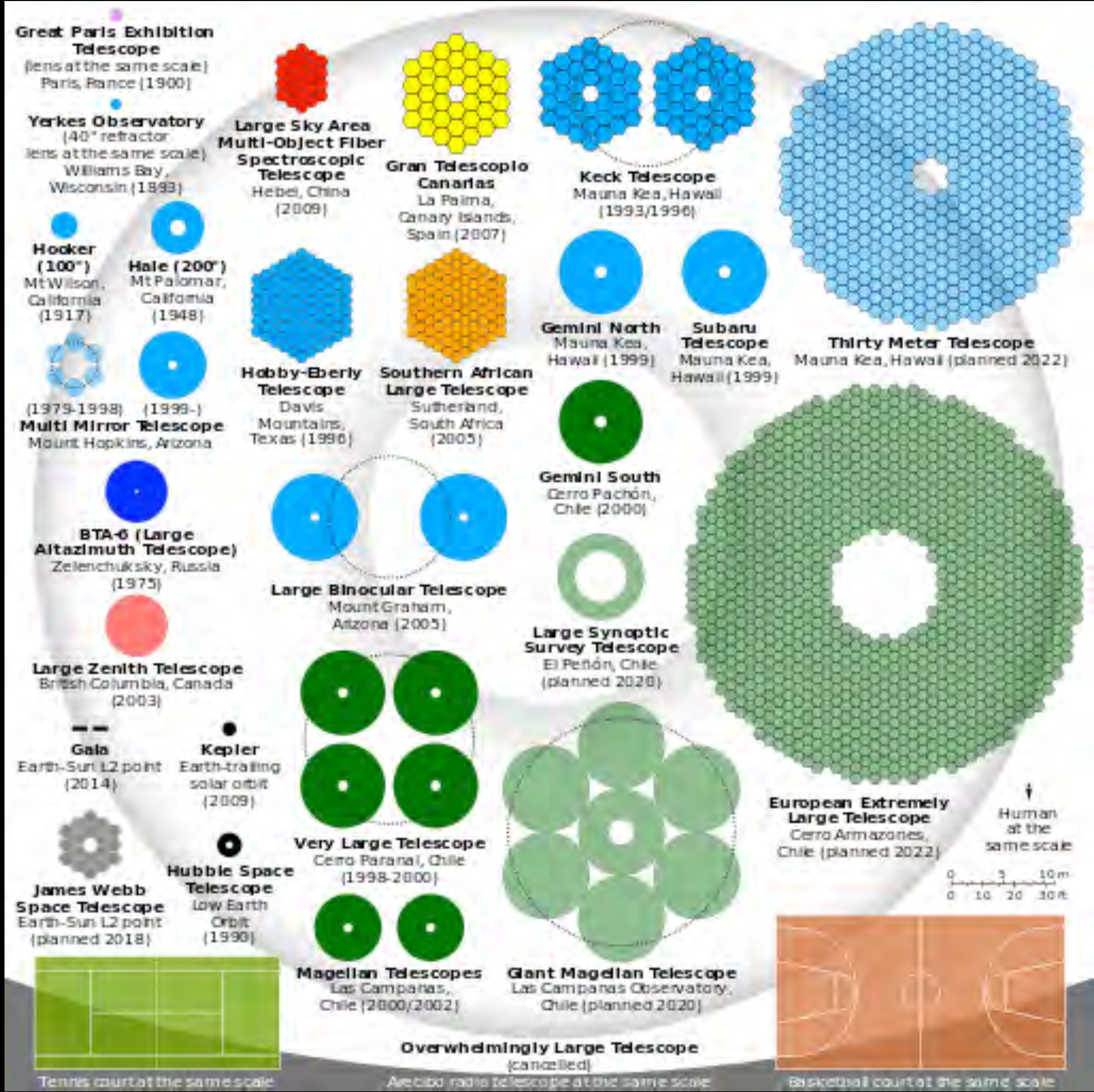
- Low frequencies: **LOFAR** (Europe), **NenuFAR** (France). See J. Girard's talk.

- **ngVLA** (USA): Major upgrade of the VLA (sensitivity x 10, 1 to 116 GHz (20 GHz bandwidth), compact core + extended baselines 100s km)

- Do not forget **VLBI** with all current facilities. Important to probe the structure of the jets and their associated proper motion.

OIR

Thanks PG + D. Russell for inputs



Great Paris Exhibition Telescope
(lens at the same scale)
Paris, France (1900)
Yerkes Observatory
(40" refractor
lens at the same scale)
Williams Bay, Wisconsin (1893)
Large Sky Area Multi-Object Fiber Spectroscopic Telescope
Hebei, China (2009)
Gran Telescopio Canarias
La Palma, Canary Islands, Spain (2007)
Keck Telescope
Mauna Kea, Hawaii (1993/1996)
Hooker (100")
Mt Wilson, California (1917)
Hale (200")
Mt Palomar, California (1948)
Hobby-Eberly Telescope
Davis Mountains, Texas (1996)
Southern African Large Telescope
Sutherland, South Africa (2005)
Gemini North
Mauna Kea, Hawaii (1999)
Subaru Telescope
Mauna Kea, Hawaii (1999)
Thirty Meter Telescope
Mauna Kea, Hawaii (planned 2022)
(1979-1998) (1999-)
Multi Mirror Telescope
Mount Hopkins, Arizona
Gemini South
Cerro Pachón, Chile (2000)
BTA-6 (Large Altazimuth Telescope)
Zelenchuksky, Russia (1975)
Large Binocular Telescope
Mount Graham, Arizona (2005)
Large Synoptic Survey Telescope
El Peñón, Chile (planned 2020)
Large Zenith Telescope
British Columbia, Canada (2003)
Gaia
Earth-Sun L2 point (2014)
Kepler
Earth-trailing solar orbit (2009)
European Extremely Large Telescope
Cerro Armazones, Chile (planned 2022)
Human at the same scale
0 5 10 m
0 10 20 30 ft
James Webb Space Telescope
Earth-Sun L2 point (planned 2018)
Hubble Space Telescope
Low Earth Orbit (1990)
Very Large Telescope
Cerro Paranal, Chile (1998-2000)
Magellan Telescopes
Las Campanas, Chile (2000/2002)
Giant Magellan Telescope
Las Campanas Observatory, Chile (planned 2020)
Overwhelmingly Large Telescope
(cancelled)
Tennis court at the same scale
Arecibo radio telescope at the same scale
Basketball court at the same scale

ELT

First light instrumentations

- **HARMONI**, High Angular Resolution Monolithic Optical and Near-infrared Integral field spectrograph (spectroscopy in the 0.47–2.45 μm range)
- **MAORY**, Multi-conjugate Adaptive Optics RelaY for the ELT
- **MICADO**, Multi-AO Imaging Camera for Deep Observations (IR 0.8–2.4 μm image in large FOV, 6 to 12 mas)
- **METIS**, Mid-infrared 3–20 μm ELT Imager and Spectrograph

OIR Needs

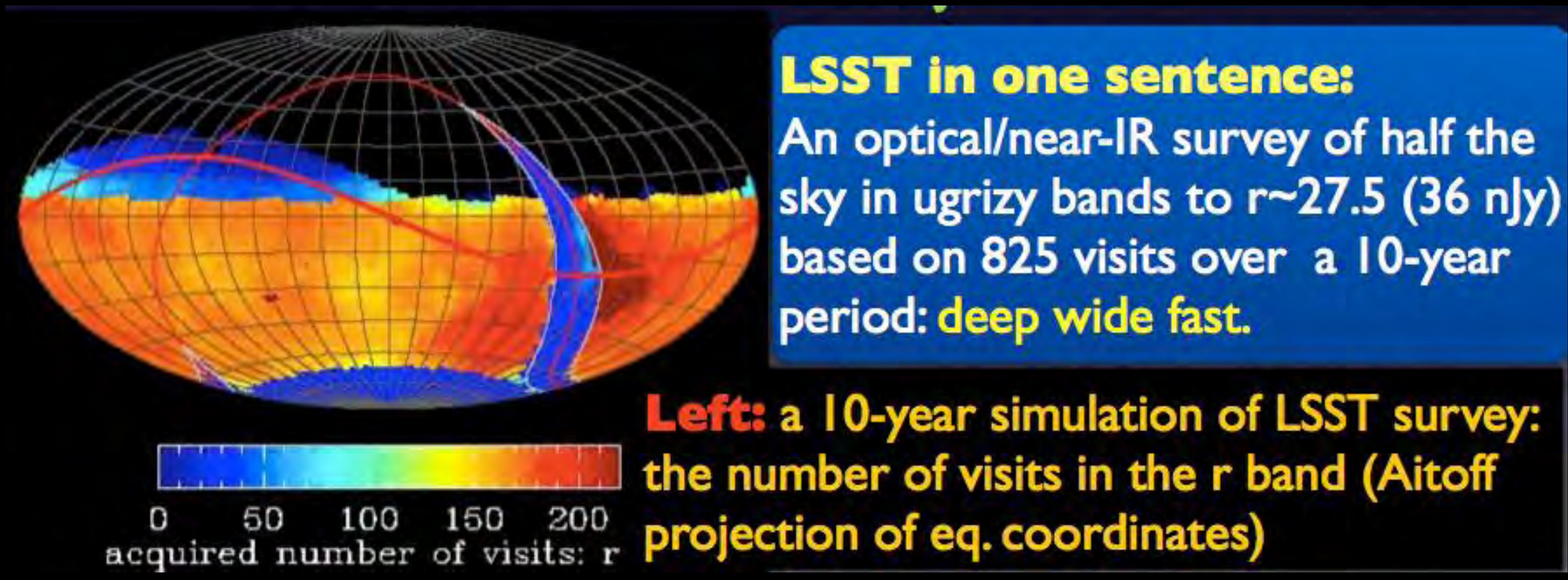
- Not sure how much time of the giants will be devoted to our field (same applies to JWST).
- But what do we need ?
  - Broad band spectroscopy
  - Fast timing (e.g. HAWK-I @ VLT; e.g. Vincentelli's talk).
  - OIR polarimetry (inc. on short timescale, see jets).
  - VLTI ? See example of SS433 with Gravity (Petrucci et al. 2017)
- Can be done with smaller telescopes: CIRCE @ 10m GTC; SOXS @ 4m ESO/NTT

SOXS: Son Of X-Shooter @ NTT

- New instrument selected at ESO-NTT, PI: S. Campana. 2020 ?
- Wide spectral coverage (U to H: 0.35-1.75 μm) and good spectral resolution (R~4,500)
- Continuum spectrum R~20-20.5 S/N=10 in 1 hr
- Dedicated for transients. 180 n/yr (for 5 yr). 5% of time open for public fast ToO
- Will start in 2018 with current instruments (EFOSC2+SOFI)

LSST

- A 8.4 m telescope dedicated to Transients located in Chile
- 20,000 sq degree every 3-4 nights, twice a night
- $\sim 10^6$ transients/variable objects, released within 60s



High Energy Gamma-rays

CTA Observatory

- **CTA** : very wide energy range and excellent angular resolution and sensitivity in comparison to any existing gamma-ray detector.

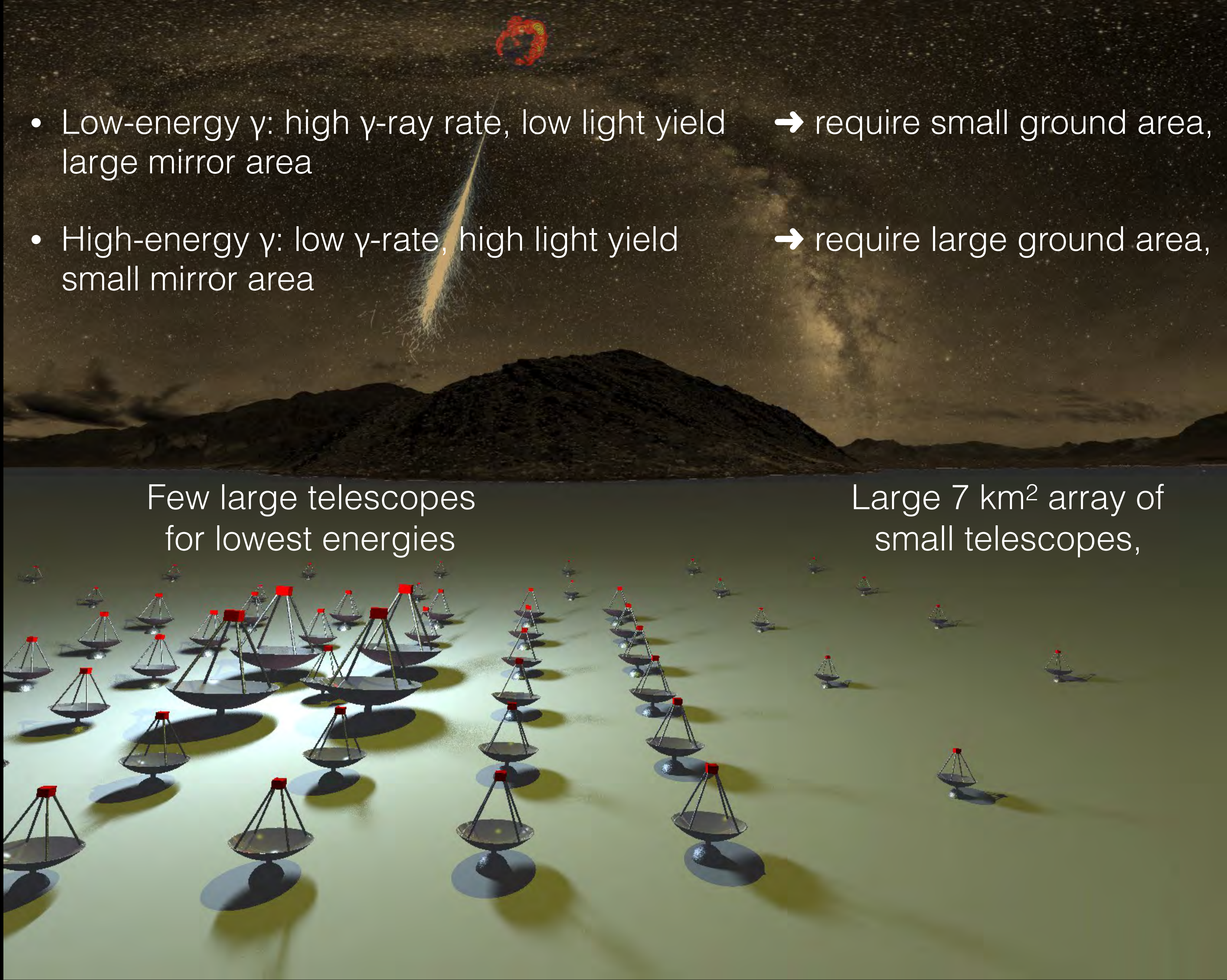
- **Energies** up to 300 TeV will push CTA beyond the edge of the known electromagnetic spectrum, providing a completely new view of the sky.

- **2 sites**:

  - **CTA Southern Site:** 4 Large-Sized Telescopes, 25 Medium-Sized Telescopes and 70 Small-Sized Telescopes (Chile)

  - **CTA Northern Site**: 4 Large-Sized Telescopes and 15 Medium-Sized Telescopes (Spain)

- Low-energy γ: high γ-ray rate, low light yield ➜ require small ground area, large mirror area
- High-energy γ: low γ-rate, high light yield ➜ require large ground area, small mirror area

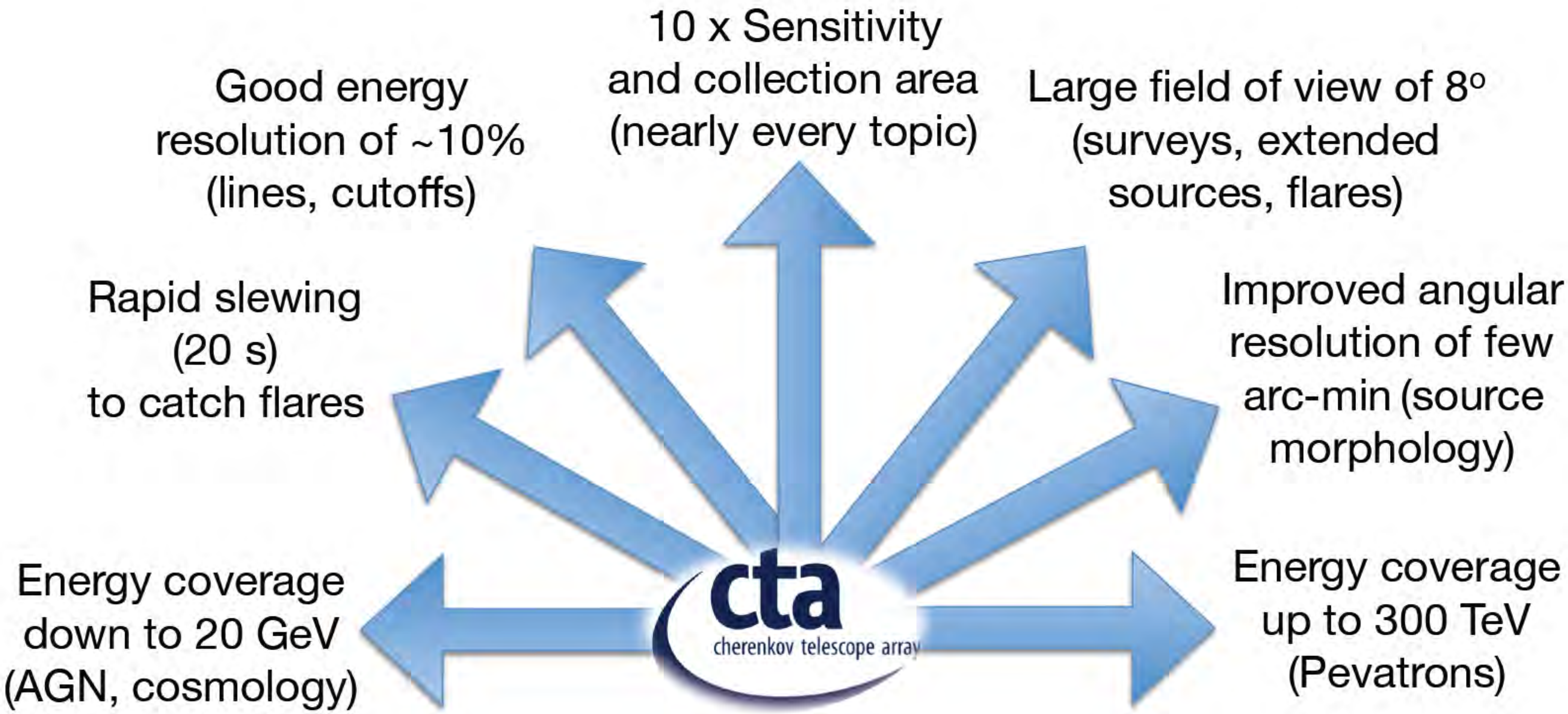


Science with CTA

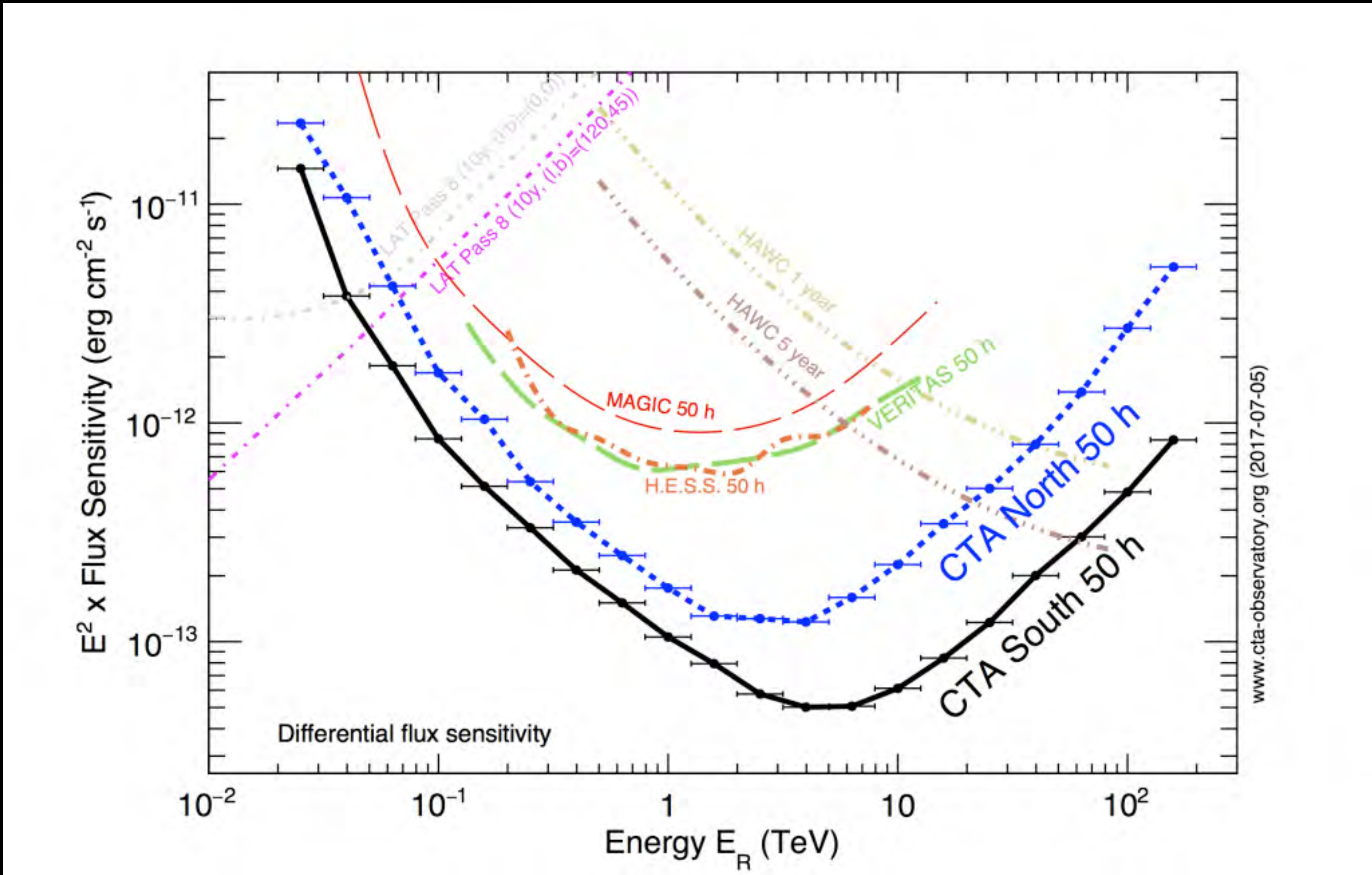
- **Theme 1: Cosmic particles acceleration**
  - How and where are particles accelerated?
  - How do they propagate?
  - What is their impact on the environment?
- **Theme 2: Probing extreme environnement**
  - Processes close to neutron stars and black holes?
  - Processes in relativistic jets, winds and explosions?
  - Exploring cosmic voids
- Theme 3: Physics frontiers, beyond the standard model (DM, ALP, …)

CTA consortium

32 Countries, 210 Institutes,1350 members


10 x Sensitivity
and collection area
(nearly every topic)
Good energy
resolution of ~10%
(lines, cutoffs)
Large field of view of 8°
(surveys, extended
sources, flares)
Rapid slewing
(20 s)
to catch flares
Improved angular
resolution of few
arc-min (source
morphology)
Energy coverage
down to 20 GeV
(AGN, cosmology)
cta
cherenkov telescope array
Energy coverage
up to 300 TeV
(Pevatrons)

CTA sensitivity



CTA and microquasars

- HE detections: Cyg X-3 (Fermi LAT, Agile), V404 Cyg (Loh et al. 2016), Cyg X-1 (Magic?, Fermi)

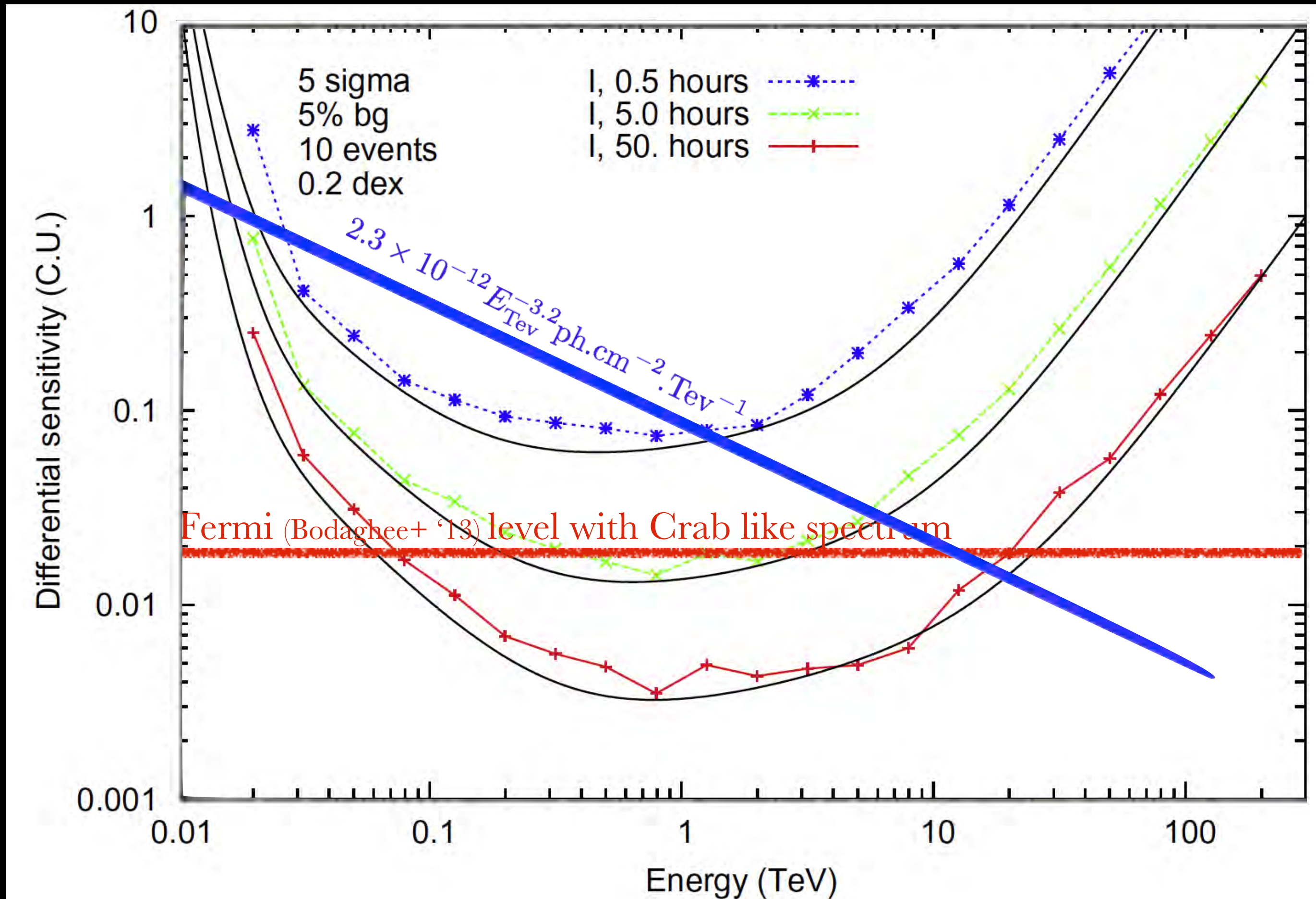


Fig. : Courtesy J. Rodriguez

Conclusions

- Excellent new facilities in radio, lots of excitements to come. Surveys + follow-up. Radio all sky monitor

- OIR: not clear how much time from the big giants will be devoted to microquasars. However, needs for dedicated instrumentation for polarimetry, timing, broad band spectroscopy. Alerts from LSST.

- HE γ-rays: CTA, a sensitive instrument, but need the targets to cooperate !