New approach to observational astronomy to solve the nature of FRBs

Jeff Cooke
and the DWF team

What are FRBs?

Need to detect them

Need to localise them

Then what?

Follow up Nothing so far, *must be fast or faint*

Host galaxy?

Doesn't give us the nature of the event

EM emission? Wavelength? Particles? GW?

Coherent flux?

Need to be on source before the radio

What is needed

Simultaneous detection efforts –

All wavelengths, high energy particles, GWs

Deep, wide-field, fast-cadence

Real-time data processing and analysis

Seconds to minutes identification

Software and human confirmation

Rapid-response triggered observations

Deep, multi-wavelength imaging and spectroscopy

Follow-up cadenced observations

Important for confirmation and classification

What we have

Multi–wavelength, multi–messenger detection

All wavelengths
High energy particles
Gravitational waves

Deep simultaneous observations

The world's largest, most sensitive telescopes
$100,000 per night, 10:1 oversubscription, etc.

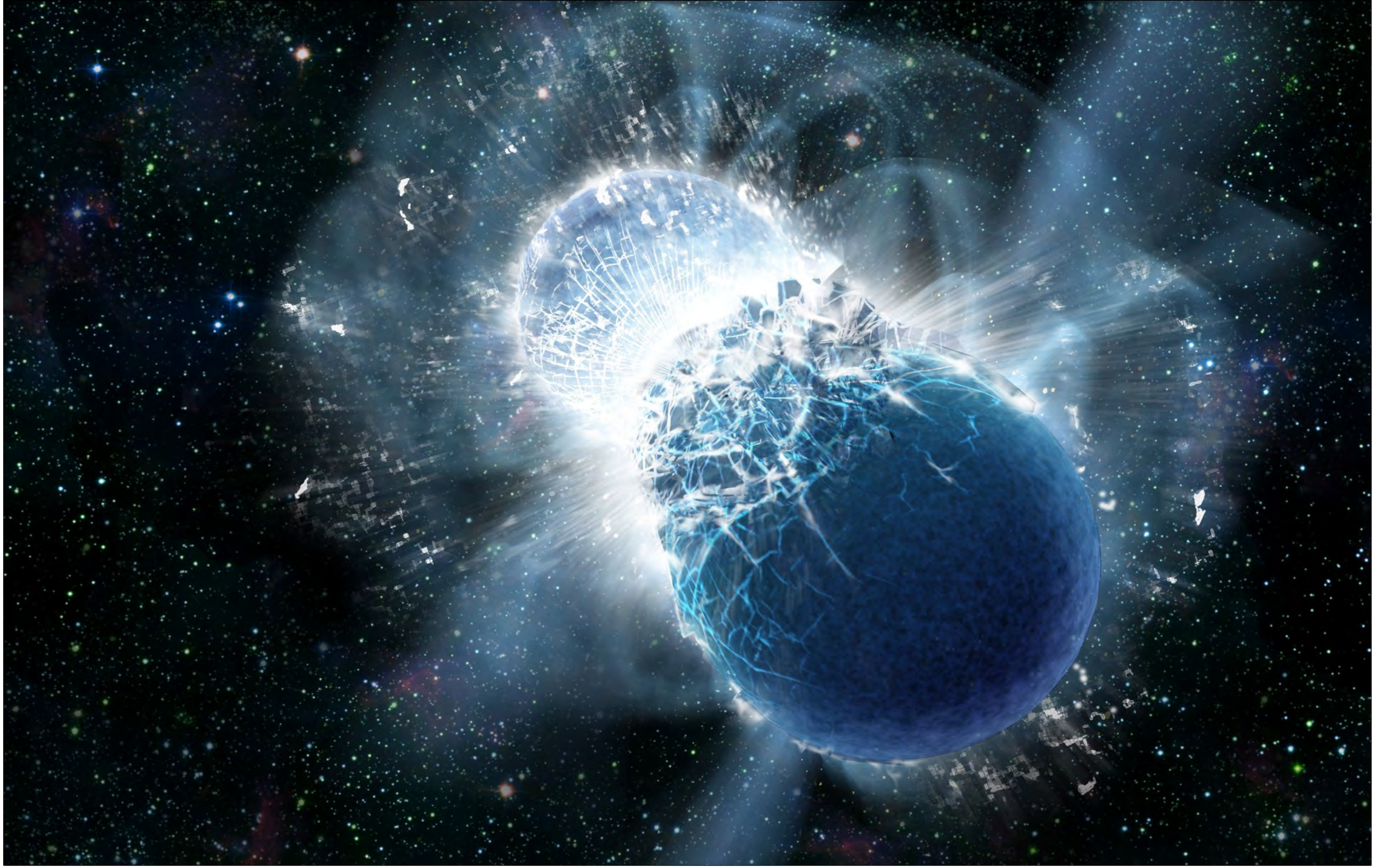
Wide field of view instruments

The largest and best in the world

Fast–cadenced observations

Millisecond to seconds observations

Deeper, Wider, Faster program



DWF

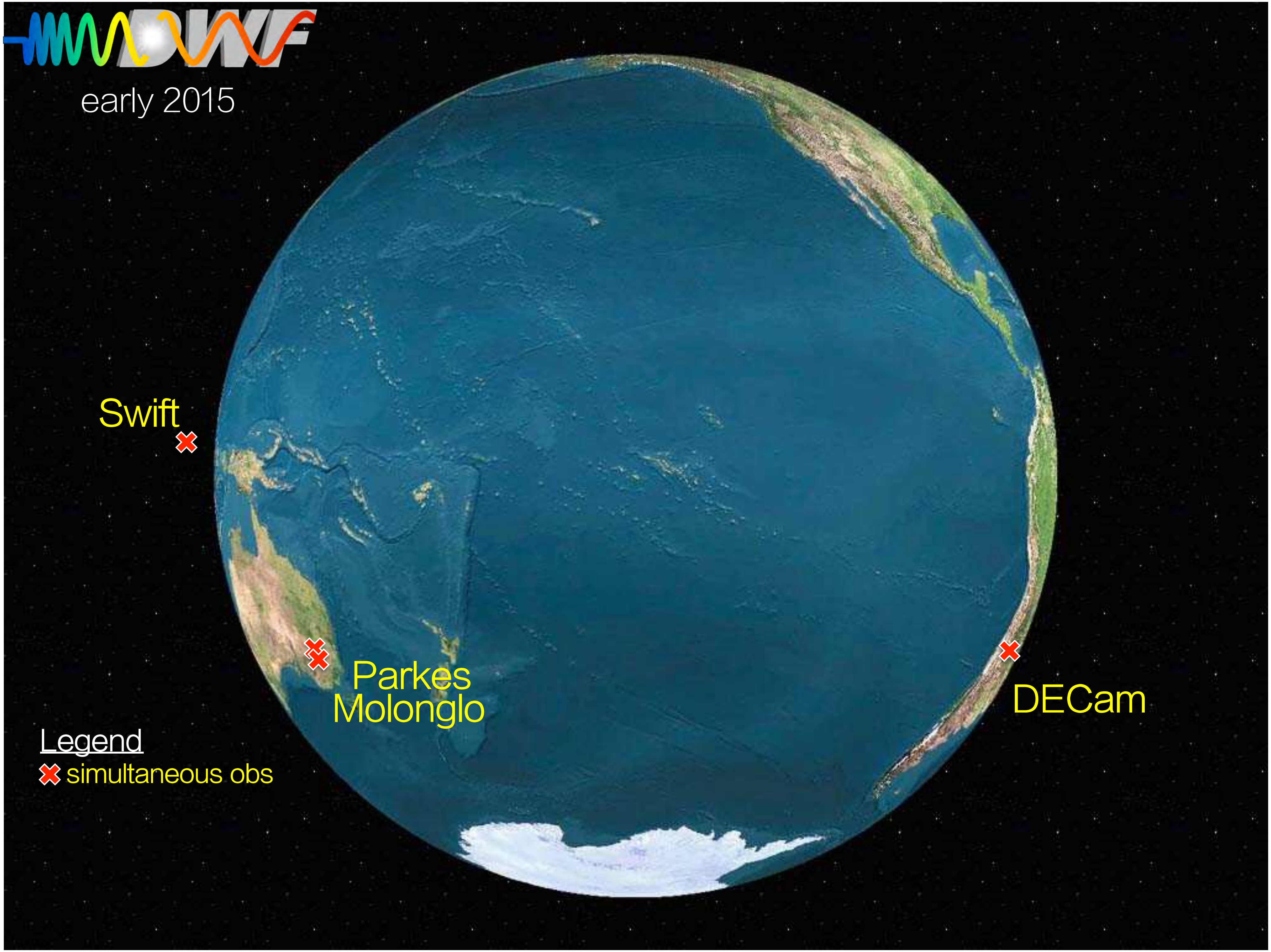
(1) Simultaneous coverage

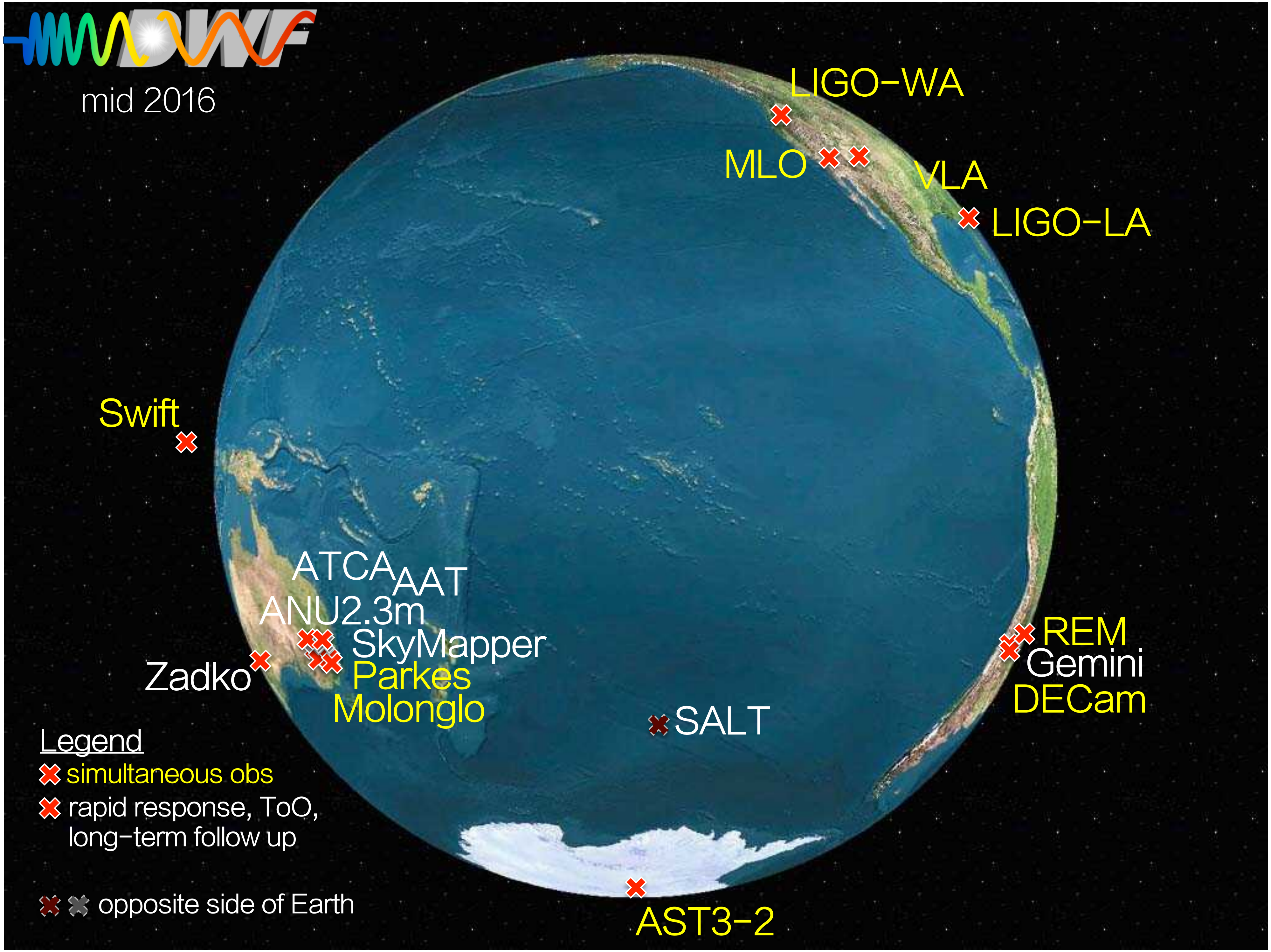
All wavelengths and messengers
- Worldwide coordination

Multiple radio facilities to detect FRBs
- Multiple frequencies to get spectral index, info

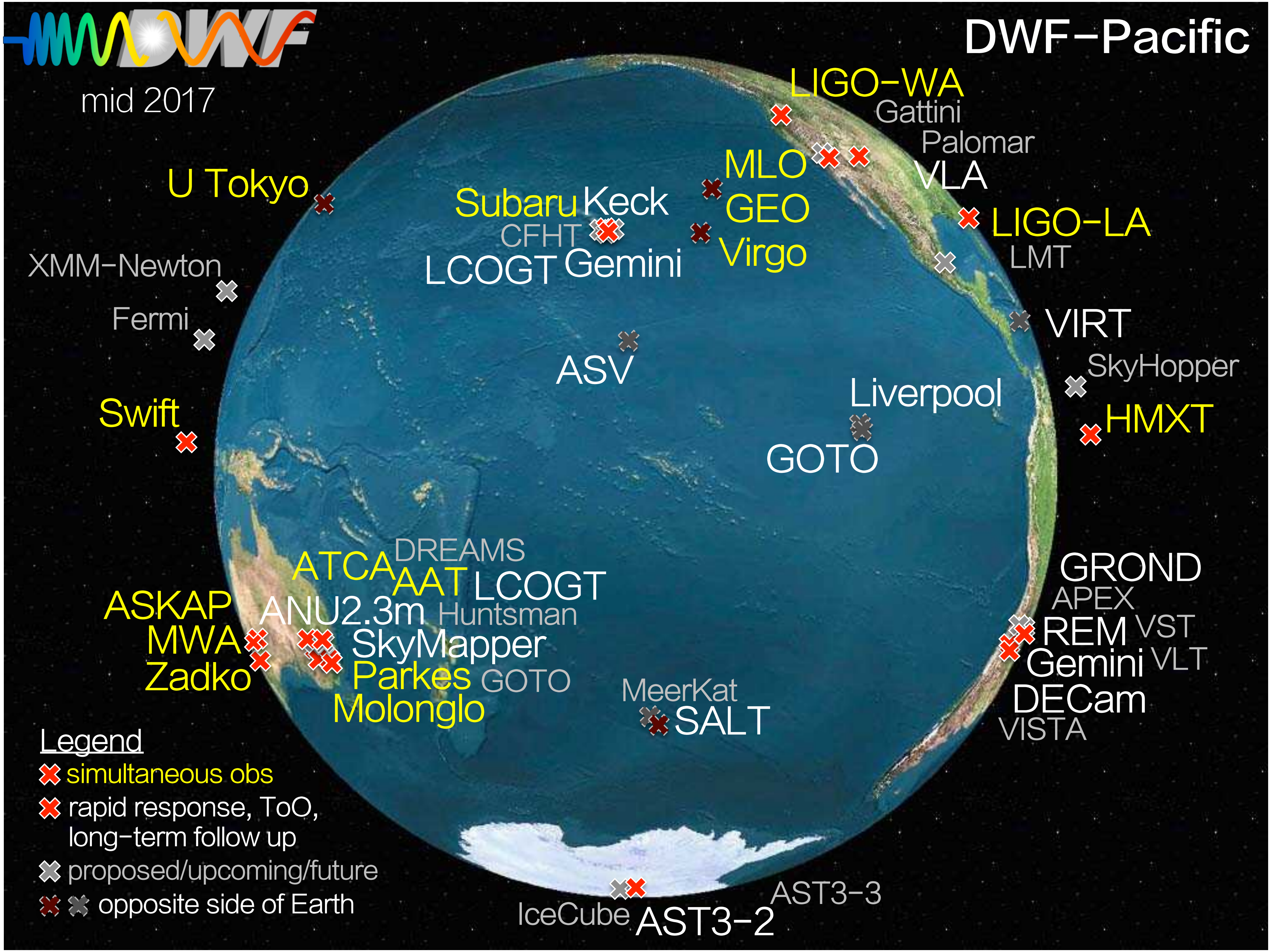
Dense imaging coverage
- Characterising their evolution

Cross-matching of all wavelengths
- Learn what they are


early 2015
Swift
Parkes
Molonglo
DECam
Legend
simultaneous obs



DWF
mid 2016
LIGO-WA
MLO
VLA
LIGO-LA
Swift
ATCA
AAT
ANU2.3m
SkyMapper
Parkes
Molonglo
Zadko
REM
Gemini
DECam
SALT
AST3-2
Legend
simultaneous obs
rapid response, ToO,
long-term follow up
opposite side of Earth


DWF
DWF−Pacific
mid 2017
LIGO−WA
Gattini
Palomar
VLA
MLO
GEO
Virgo
LIGO−LA
LMT
U Tokyo
Subaru
Keck
CFHT
LCOGT
Gemini
XMM−Newton
Fermi
ASV
VIRT
SkyHopper
HMXT
Swift
Liverpool
GOTO
DREAMS
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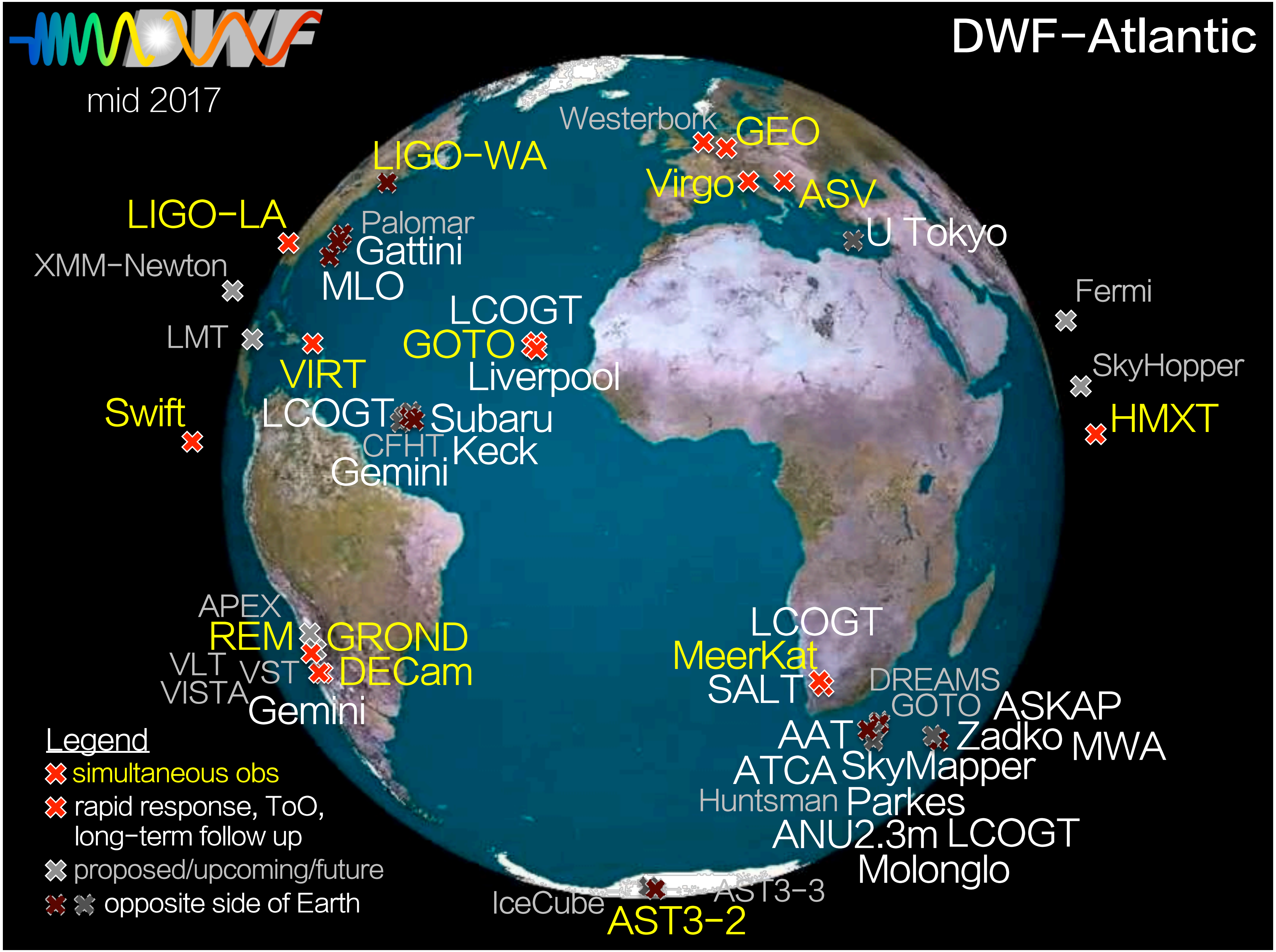
Molonglo
MeerKat
SALT
GROND
APEX
REM
VST
Gemini
VLT
DECam
VISTA
Legend
simultaneous obs
rapid response, ToO, long−term follow up
proposed/upcoming/future
opposite side of Earth
IceCube
AST3−2
AST3−3


DWF-Atlantic
mid 2017
Westerbork
GEO
LIGO-WA
Virgo
ASV
LIGO-LA
Palomar
Gattini
U Tokyo
XMM-Newton
MLO
Fermi
LCOGT
GOTO
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AST3-3
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Legend
simultaneous obs
rapid response, ToO, long-term follow up
proposed/upcoming/future
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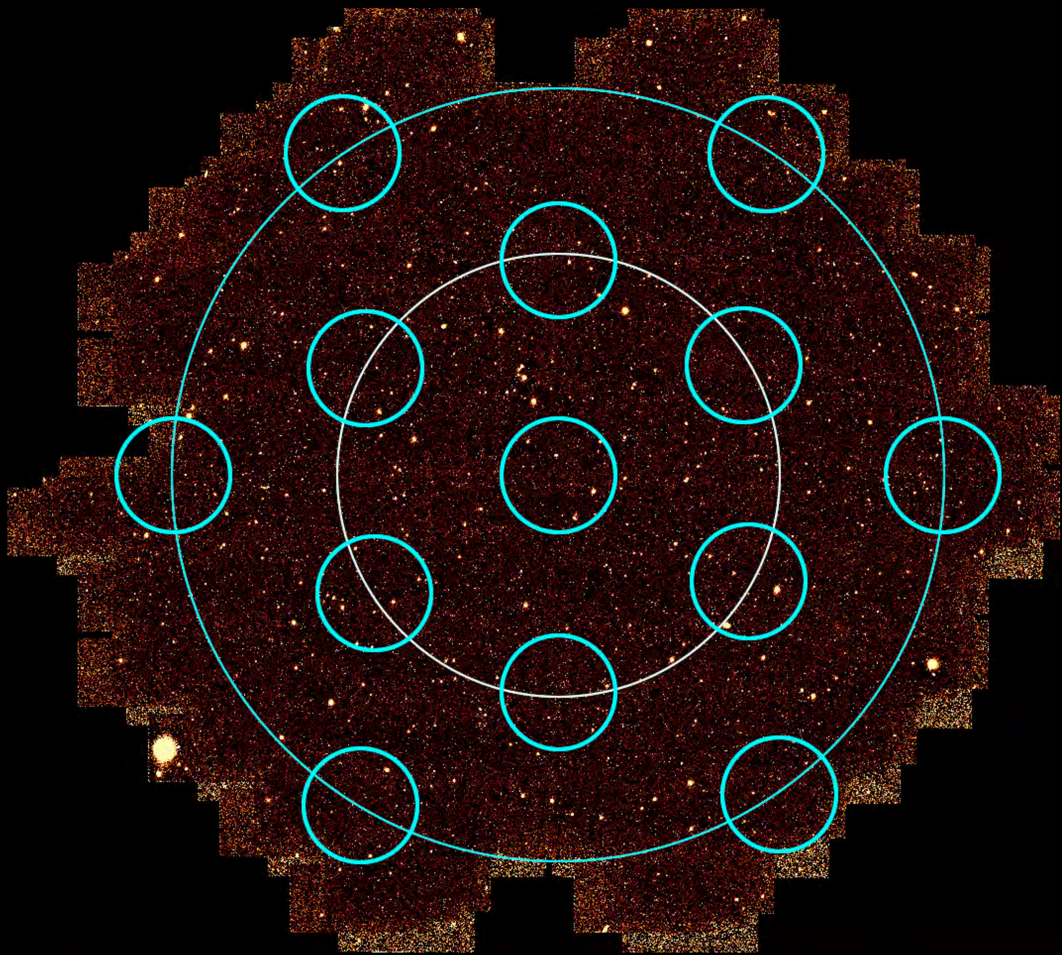
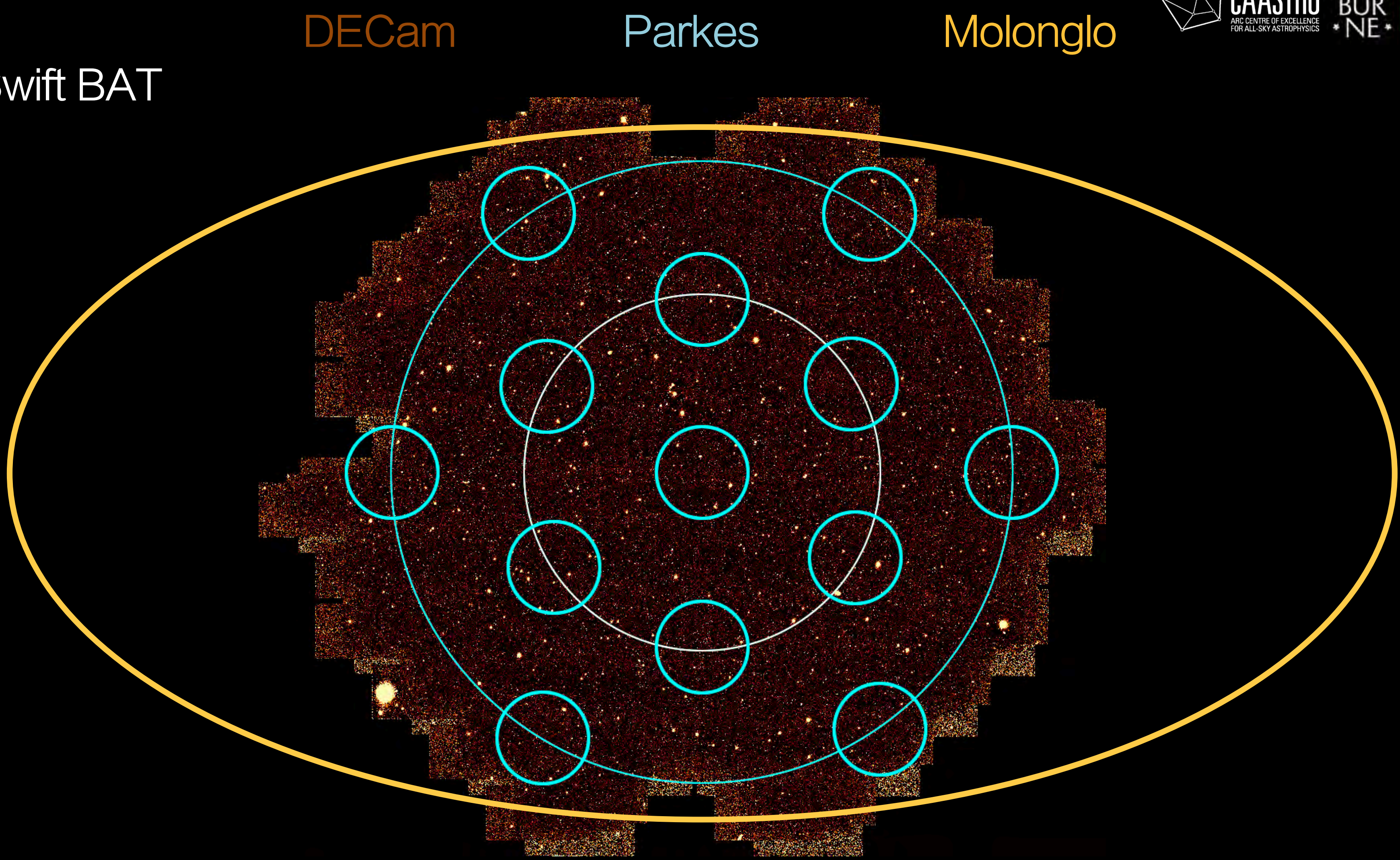
Fields of view

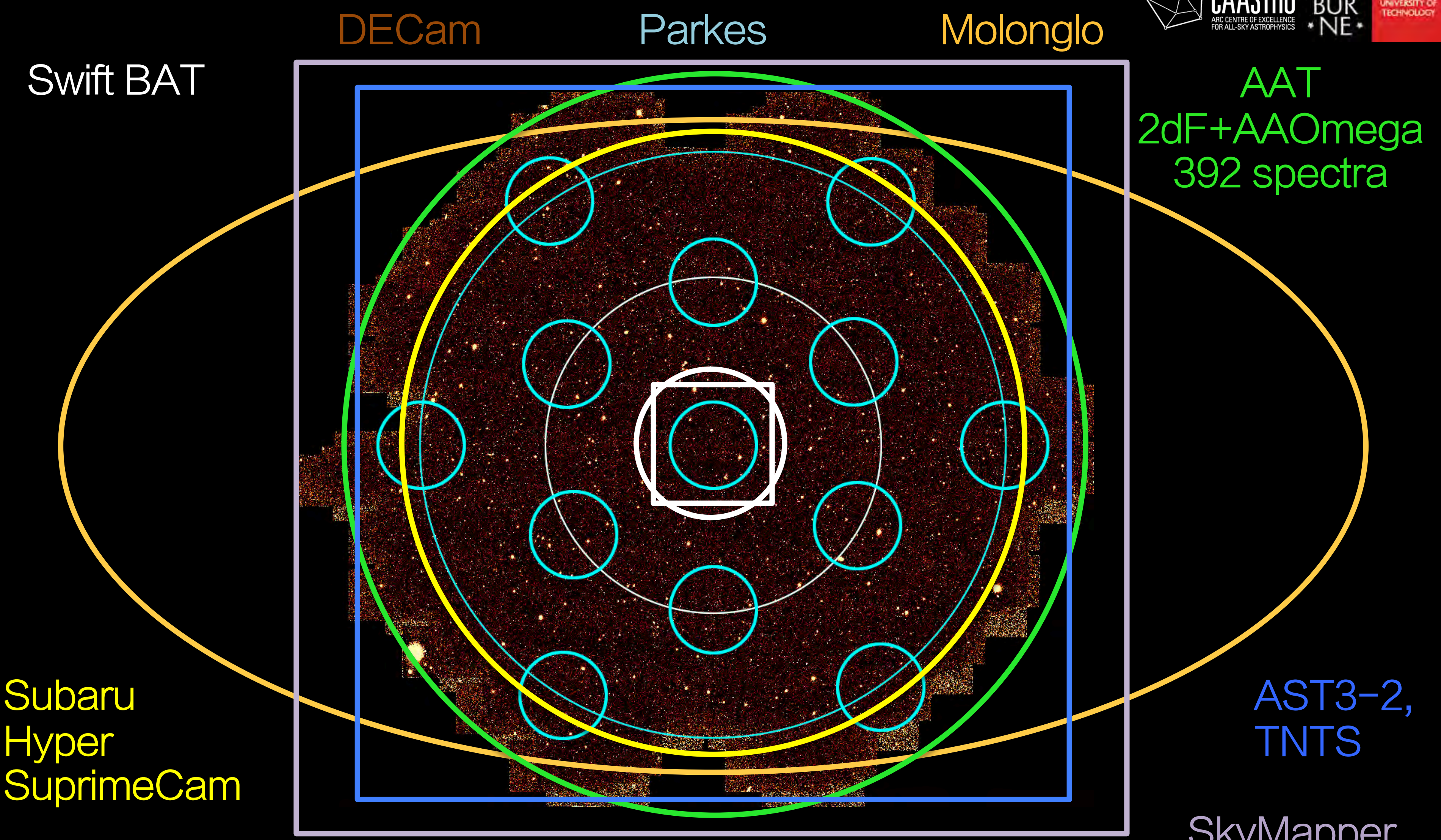
DECam Parkes



Fields of view



Fields of view



XRT, UVOT, Zadko, GROND, MLO, ATCA,
AST-3, ~30 other facilities

What DWF is

We are a full detection program and follow up

LIGO-Hanford, LIGO-Livingston, Virgo, GEO600,
MWA, Molonglo, ASKAP, ATCA, Parkes, VLA, MeerKAT,
GROND, REM, Gattini
Keck, SALT, HET, Subaru, VLT, Gemini, Palomar, CTIO,
AAT, Lick, ANU 2.3m, Lijiang, Xinglong, ASV,
SkyMapper, LCOGT, Kiso, CNEOST, TNTS, MLO,
Zadko, AST3-2, VIRT, La Hita, Huntsman, Panetix
Swift, HXMT
Pierre Auger, HAWC

Future: Green Bank, APEX, LMT, VISTA, GOTO, Liverpool, VST, CFHT, ASTROSAT, XMM-Newton, HESS, MAGIC, FACT

What DWF has

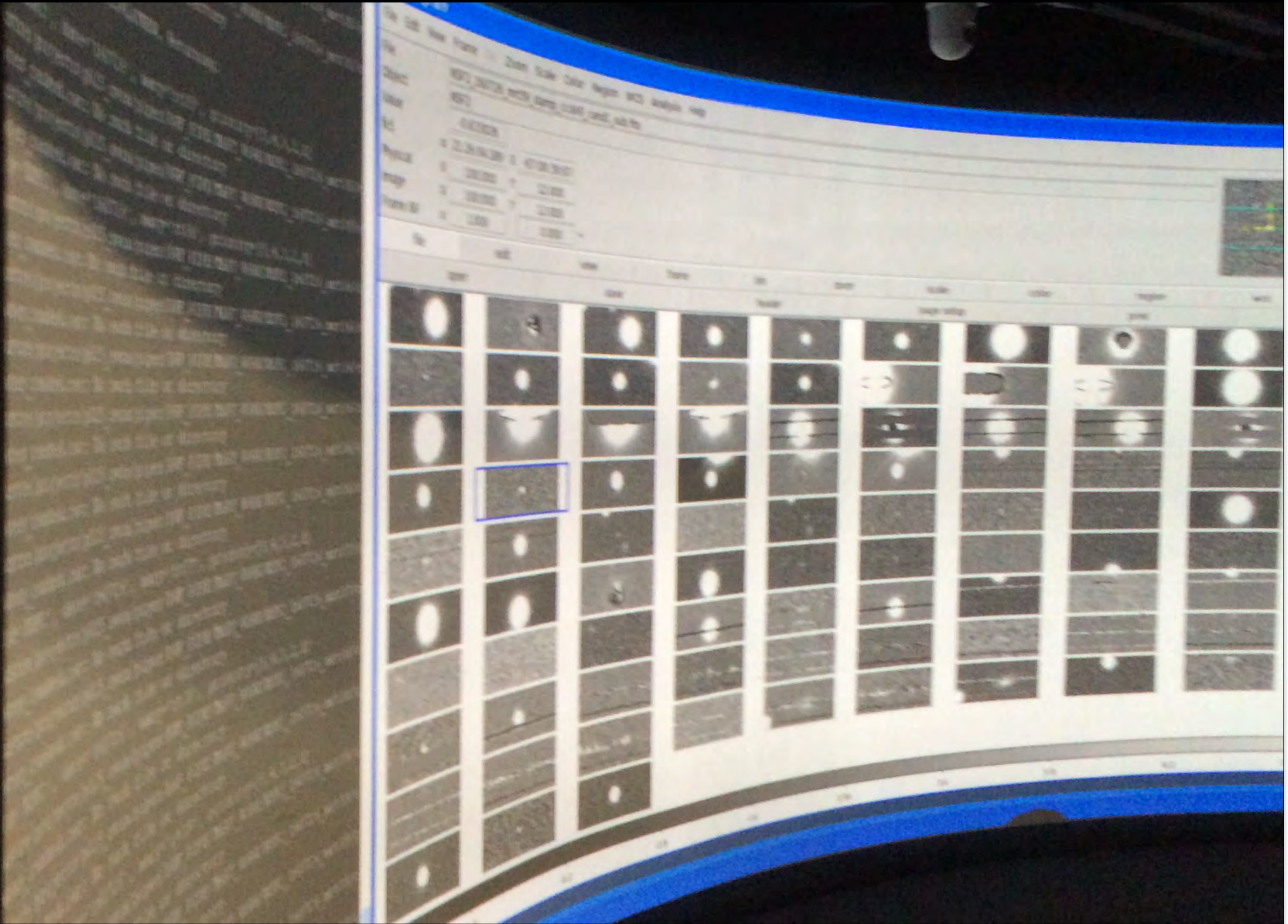
(2) Real time data processing and analysis

- Events are fast
  - Need to identify them before they fade
- Swinburne supercomputer
  - Smart people to code
- Candidate analysis
  - Software and human inspection
- Fast analysis
  - Hundreds of candidates in minutes, continuously

g2 gSTAR SwinSTAR

Real-time analysis - Dec 2015, Jul/Aug 2016

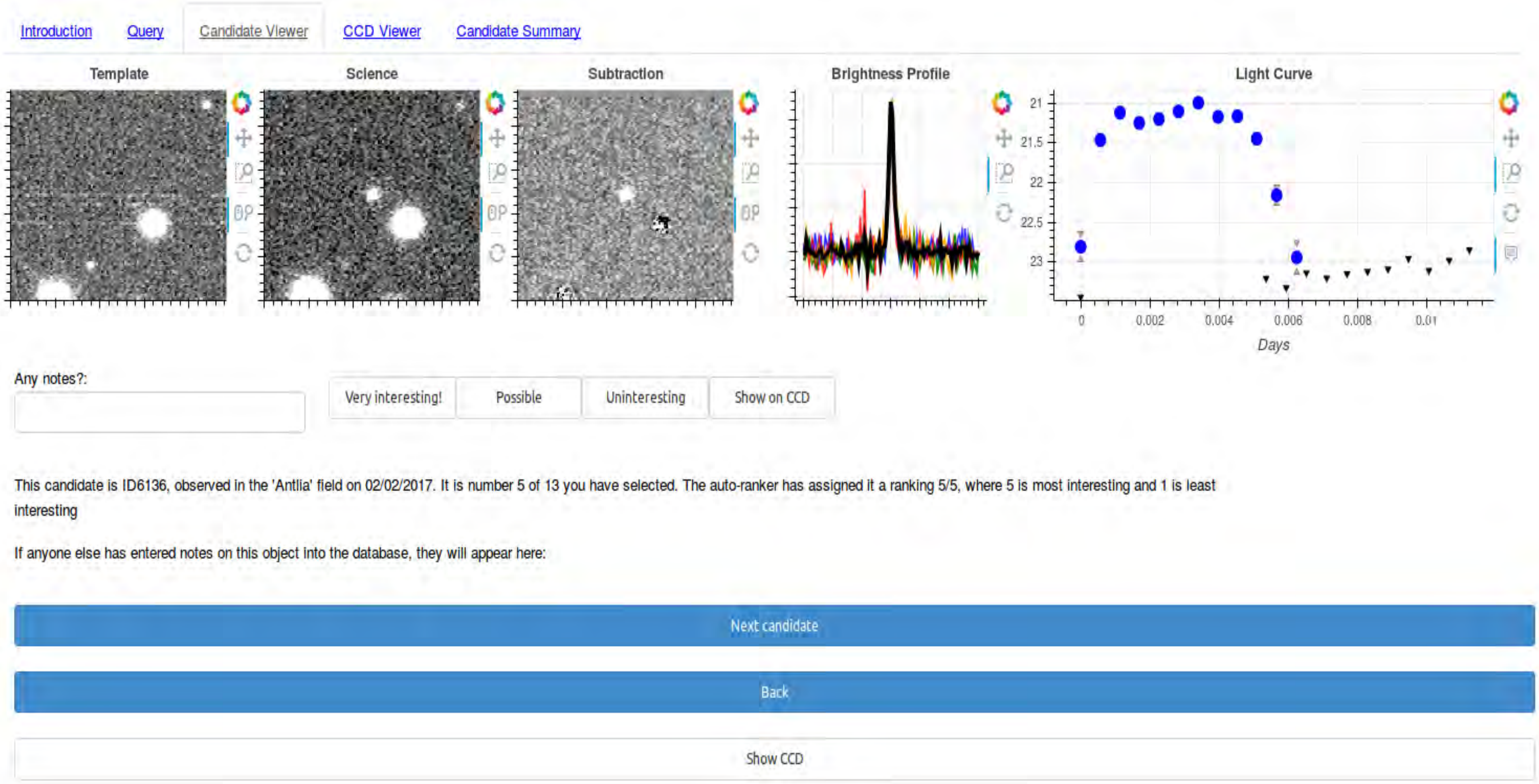
Movie



Real-time analysis - Feb 2017

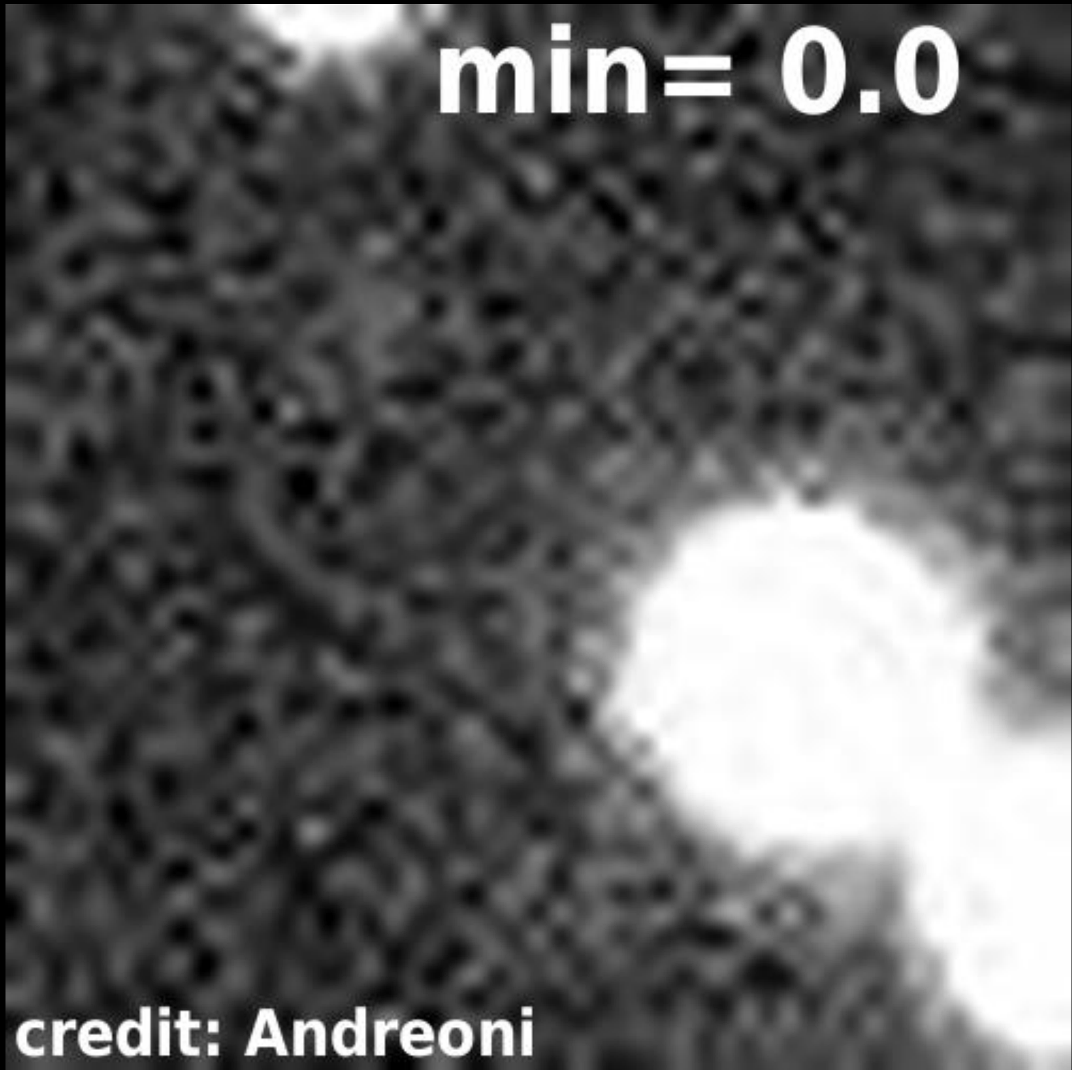
Real-time analysis - Feb 2017

Real-time analysis



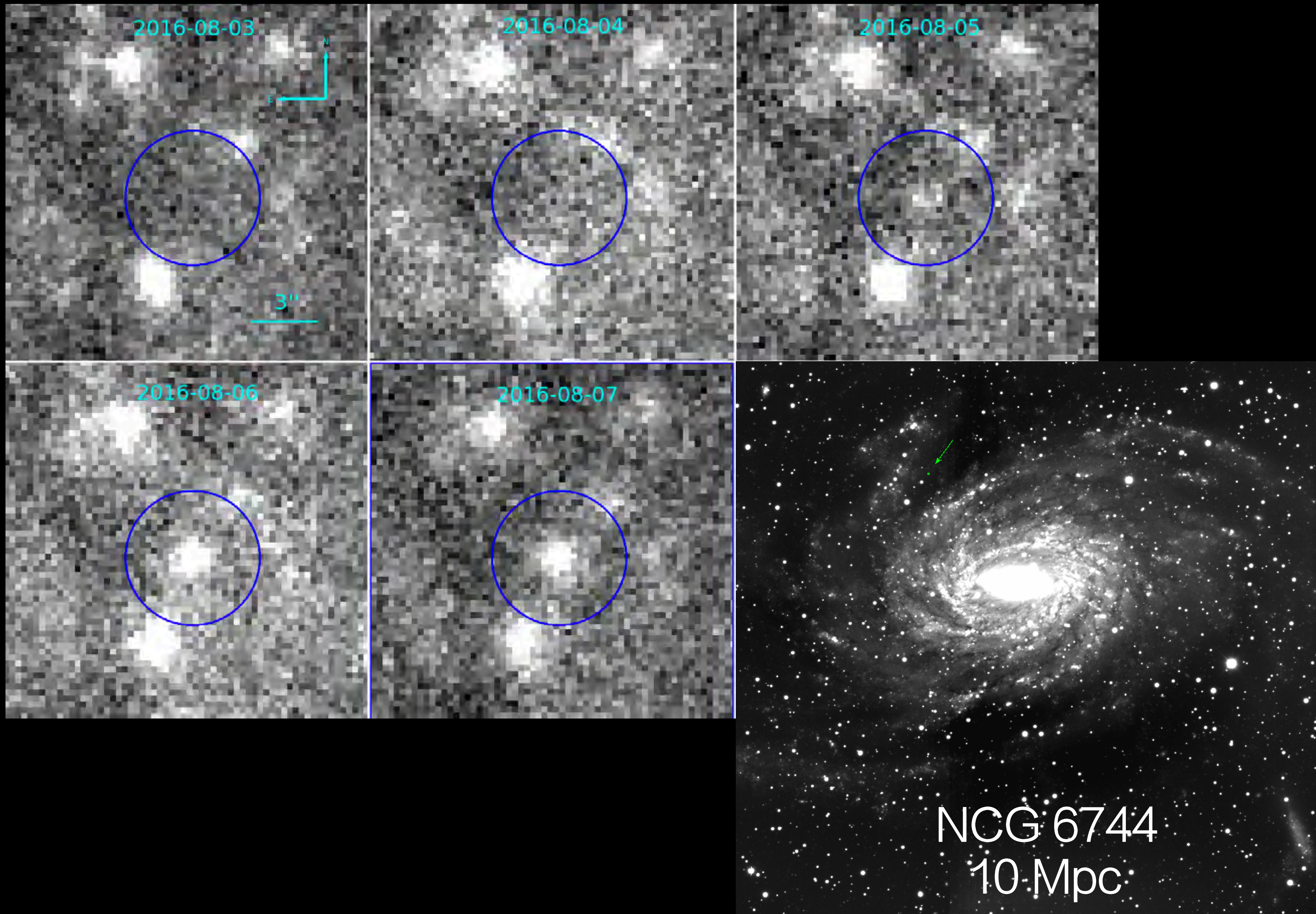
Fast transient

Movie



ID = dwf16 9497

Extragalactic novae



What DWF has

(3) Rapid-response triggers (minutes)

Events are fast

Can acquire them quickly before they fade

Events are faint

We have the largest telescopes in the world

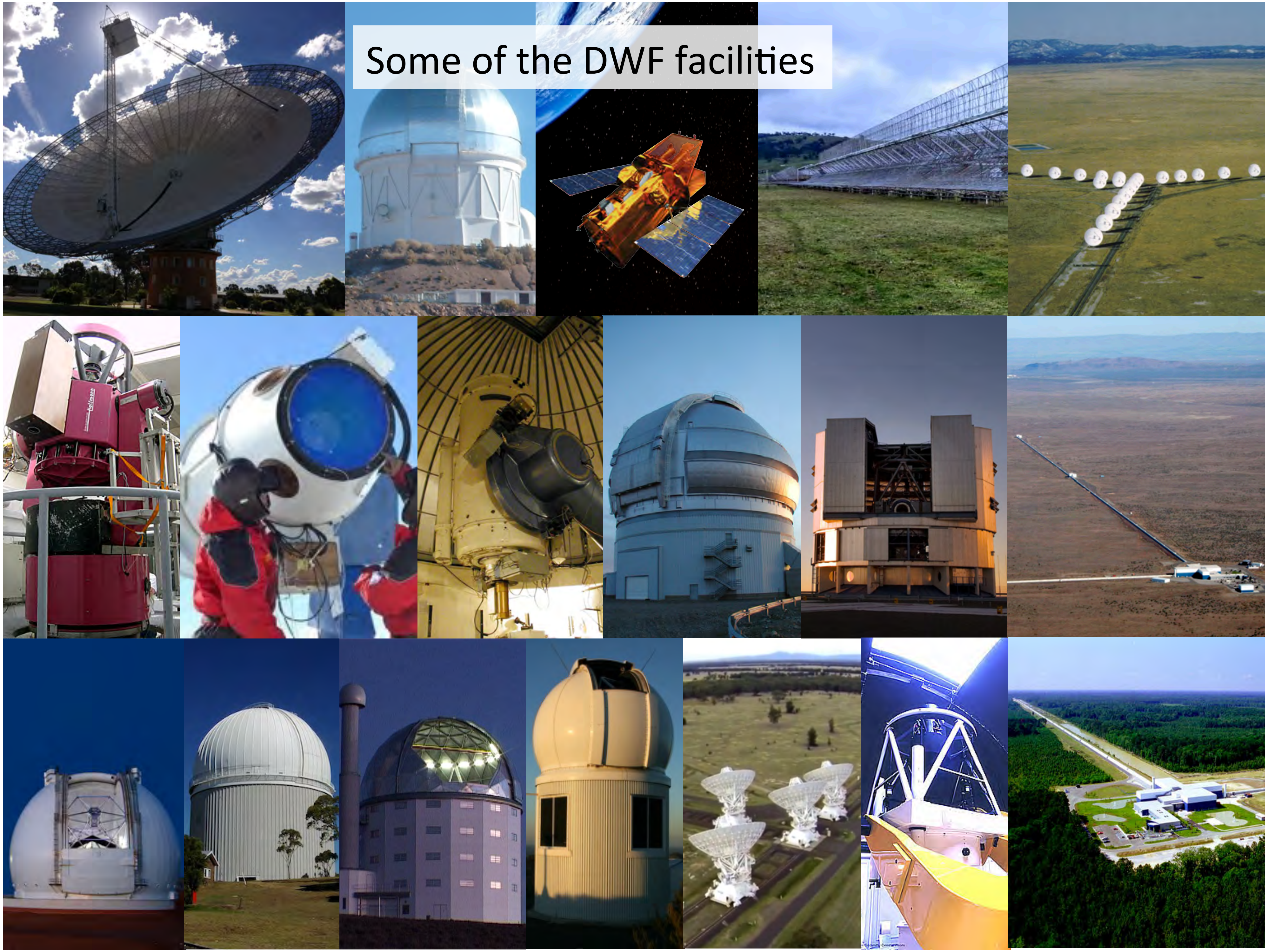
The Earth is round and turns

Telescopes are all over the world *(and in space)*

Coordination and collaboration

All types of facilities, institutions, collaborators

Some of the DWF facilities



What DWF has

(4) Conventional and longer–term follow up

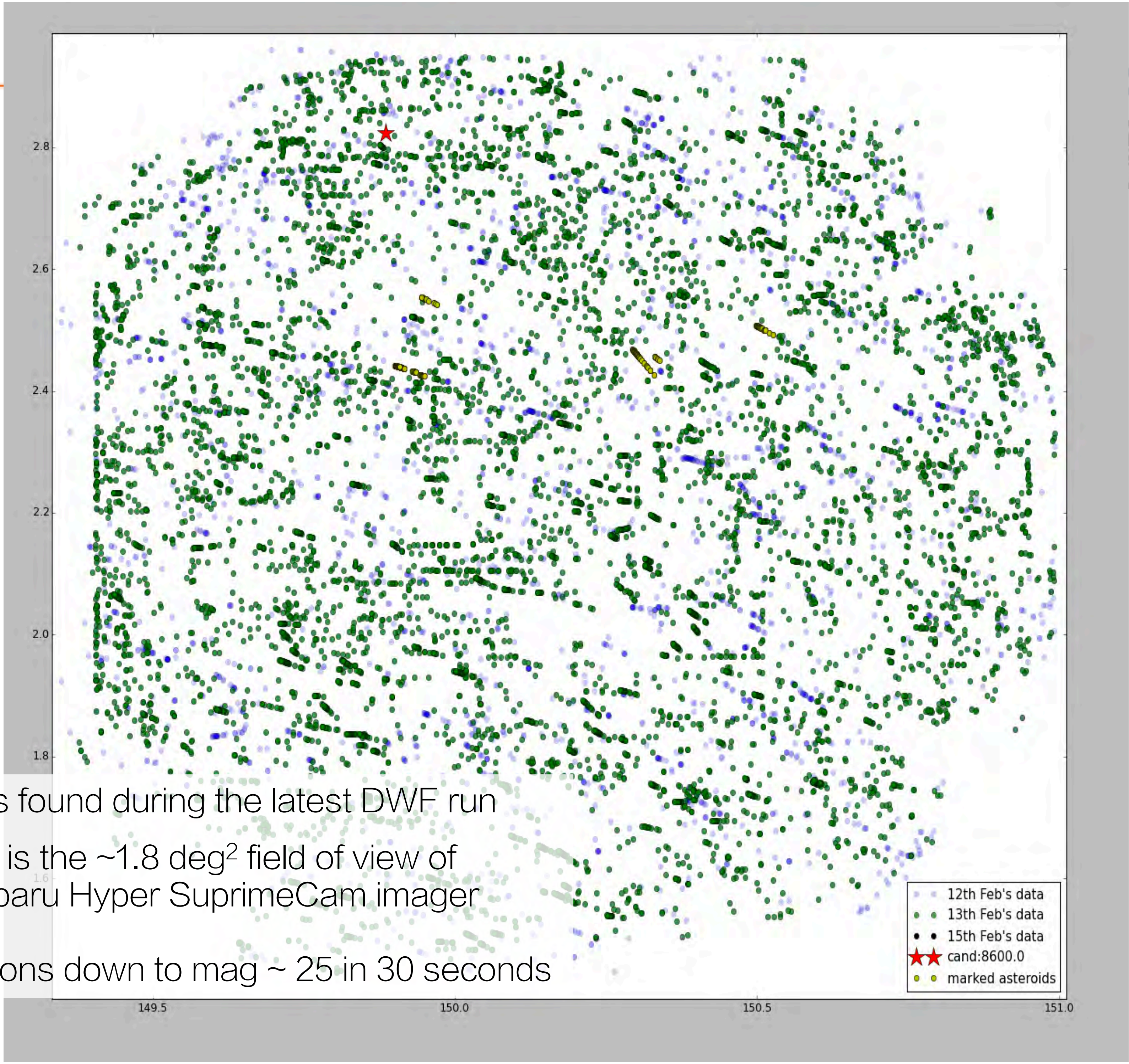
- Some FRB models predict association with slower–evolving events
- Confirm transient nature
  - Variable, repeat?
- The Earth is round and turns
  - We have a network of telescopes all over the world *(and in space)*
- Coordination and collaboration
  - All types of facilities, institutions, collaborators

Most recent DWF run

Last night end of 4 night run

DWF “war room” control room at Swinburne for 2018 onwards

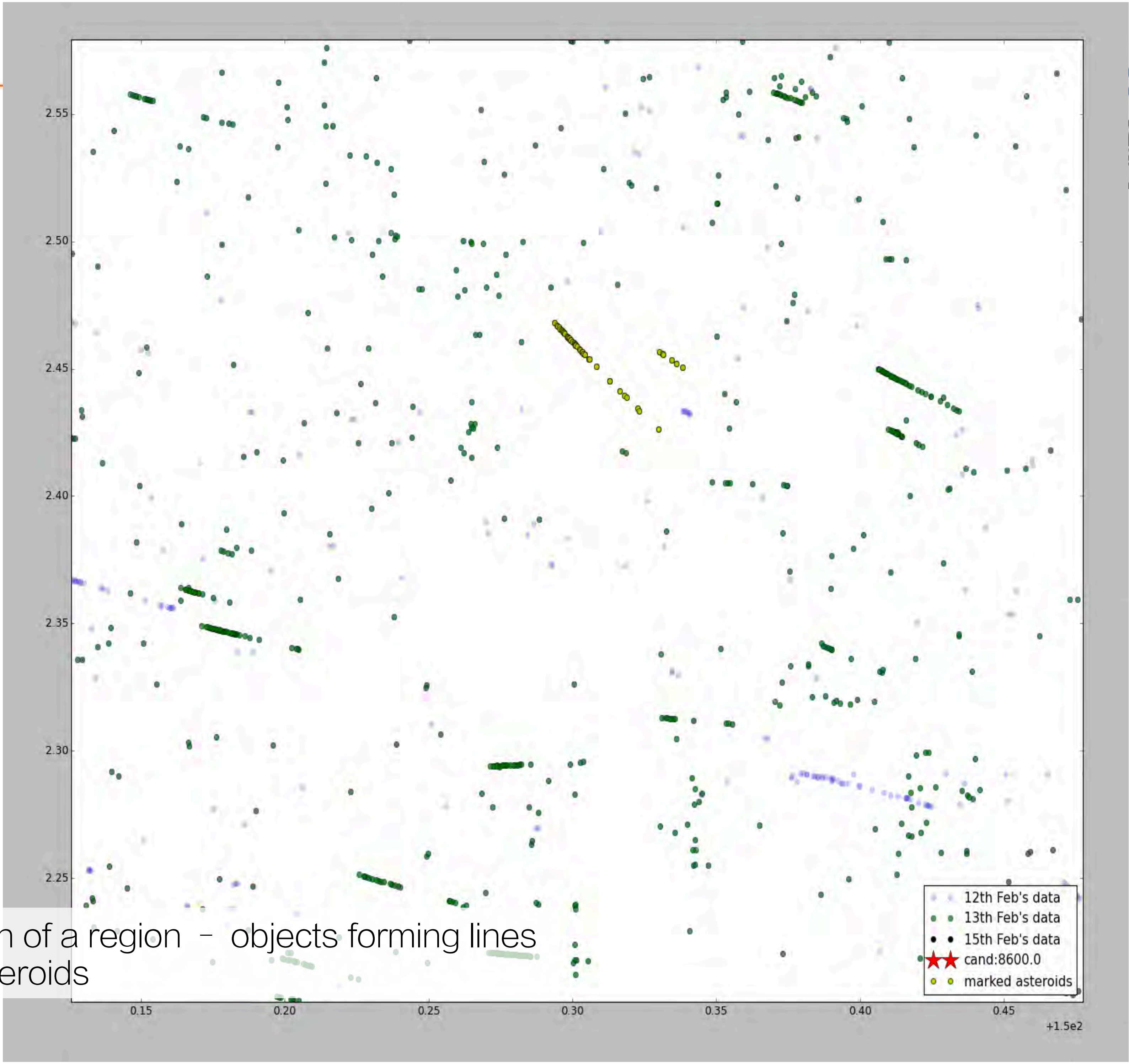

RED HOT CHILI PEPPERS



Objects found during the latest DWF run

Shown is the ~1.8 deg^2 field of view of the Subaru Hyper SuprimeCam imager

Detections down to mag ~ 25 in 30 seconds



Zoom in of a region – objects forming lines are asteroids

DWF summary

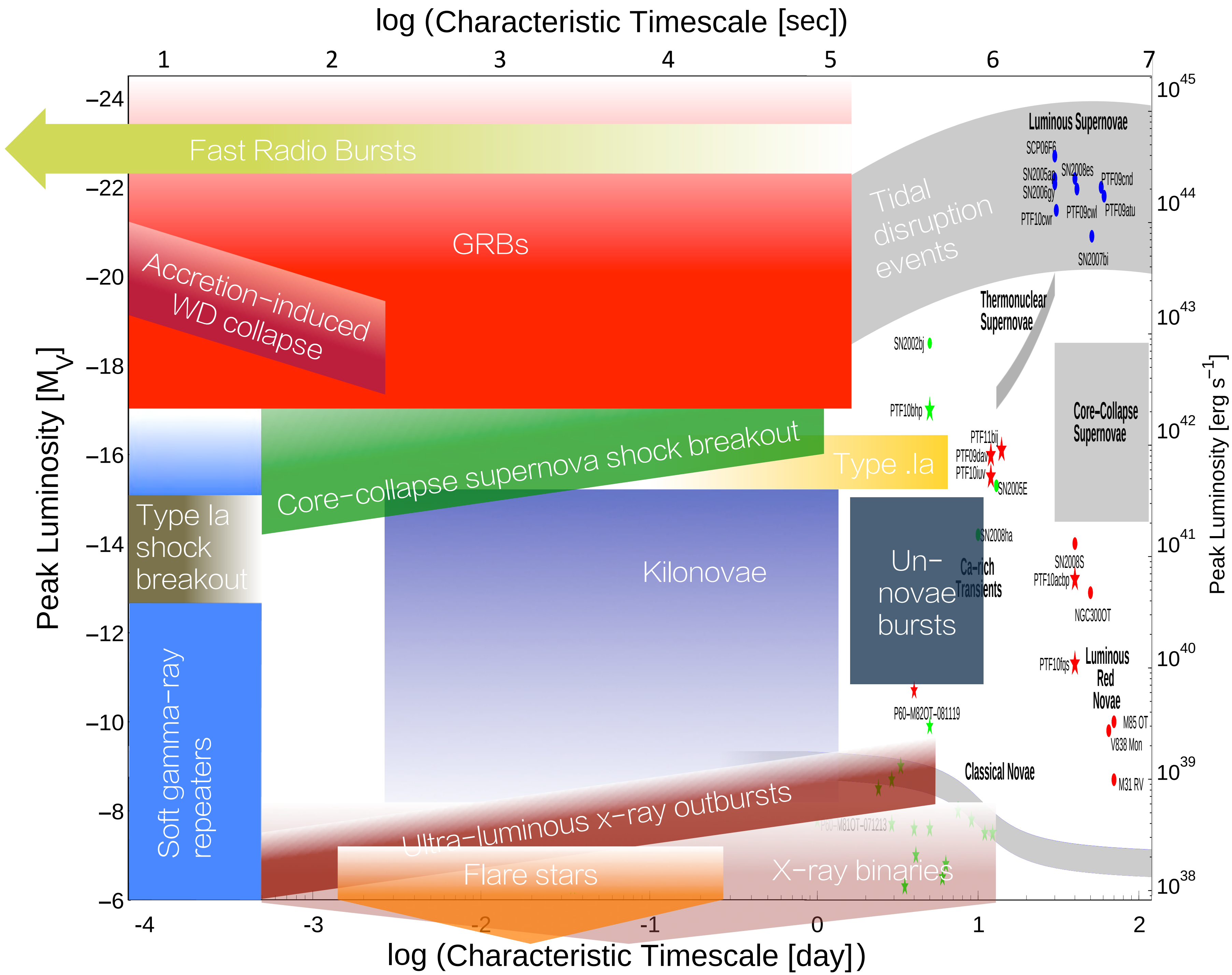
The fast time domain is essentially *unexplored territory*

Multi-facility, multi-wavelength global collaborative effort is the only means to capture and study FRBs and understand their nature

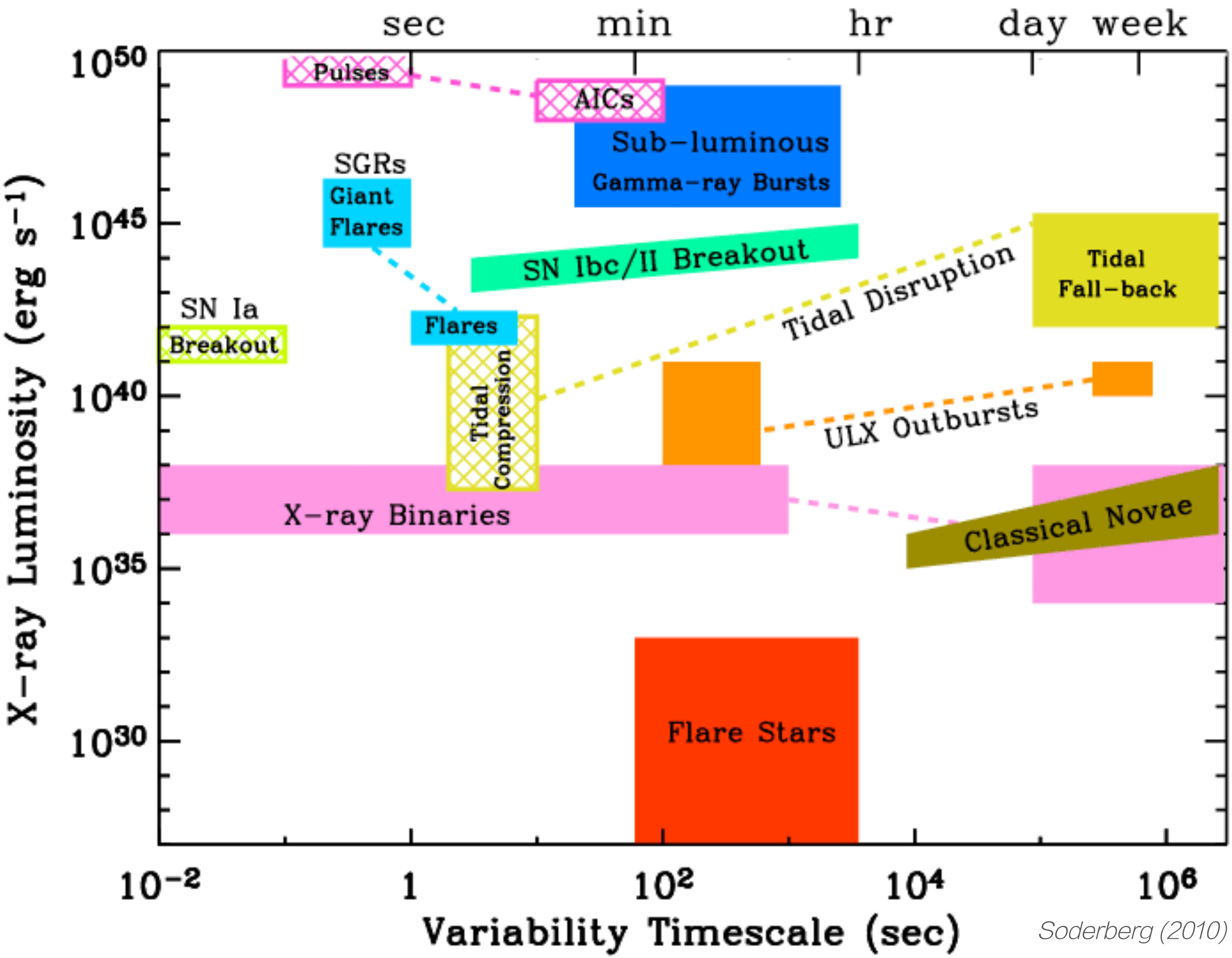
DWF is the first program to achieve this aim

- Simultaneous, fast-cadenced multi-wavelength detection facility
- Real-time reduction, analysis, and candidate identification
- Rapid-response triggered spectroscopy and imaging
- Long-term monitoring to classify associated slower events, etc.

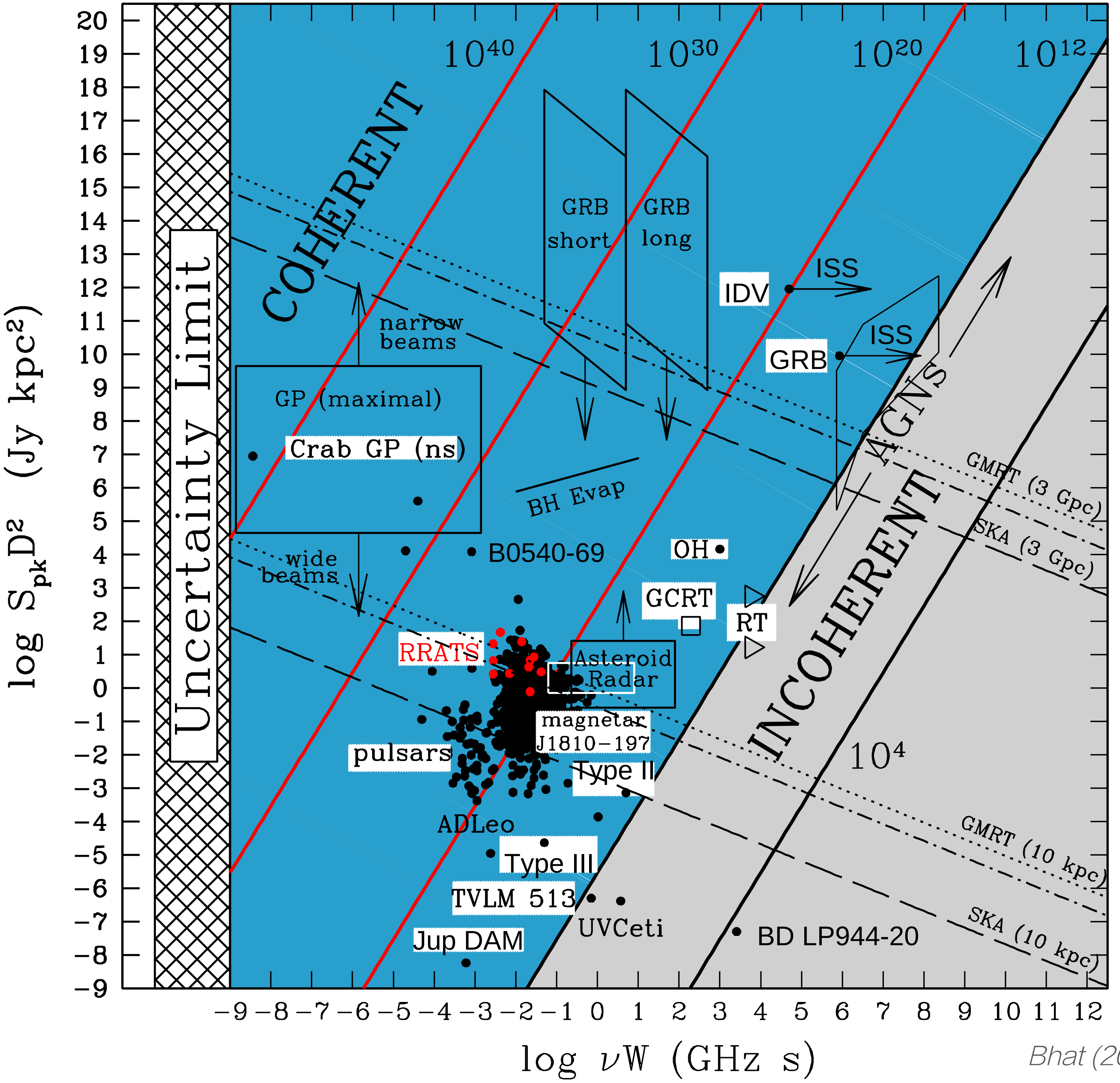
DWF can resolve the nature of FRBs in a “*single shot*”



log (Characteristic Timescale [sec])
1
2
3
4
5
6
7
Peak Luminosity [M_V]
−24
−22
−20
−18
−16
−14
−12
−10
−8
−6
Peak Luminosity [erg s^{-1}]
10^{45}
10^{44}
10^{43}
10^{42}
10^{41}
10^{40}
10^{39}
10^{38}
Fast Radio Bursts
GRBs
Accretion−induced WD collapse
Tidal disruption events
Luminous Supernovae
SCP06F6
SN2005ap
SN2008es
SN2006gy
PTF09cnd
PTF10cwr
PTF09cwl
PTF09atu
SN2007bi
Thermonuclear Supernovae
SN2002bj
PTF10bhp
Core-Collapse Supernovae
PTF11bij
PTF09dav
PTF10iuv
SN2005E
Core−collapse supernova shock breakout
Type .Ia
Type Ia shock breakout
Kilonovae
Un-novae bursts
SN2008ha
Ca-rich Transients
SN2008S
PTF10acbp
NGC300OT
PTF10fqs
Luminous Red Novae
P60-M82OT-081119
M85 OT
V838 Mon
Classical Novae
M31 RV
Soft gamma−ray repeaters
Ultra−luminous x-ray outbursts
Flare stars
X−ray binaries
-4
-3
-2
-1
0
1
2
log (Characteristic Timescale [day])

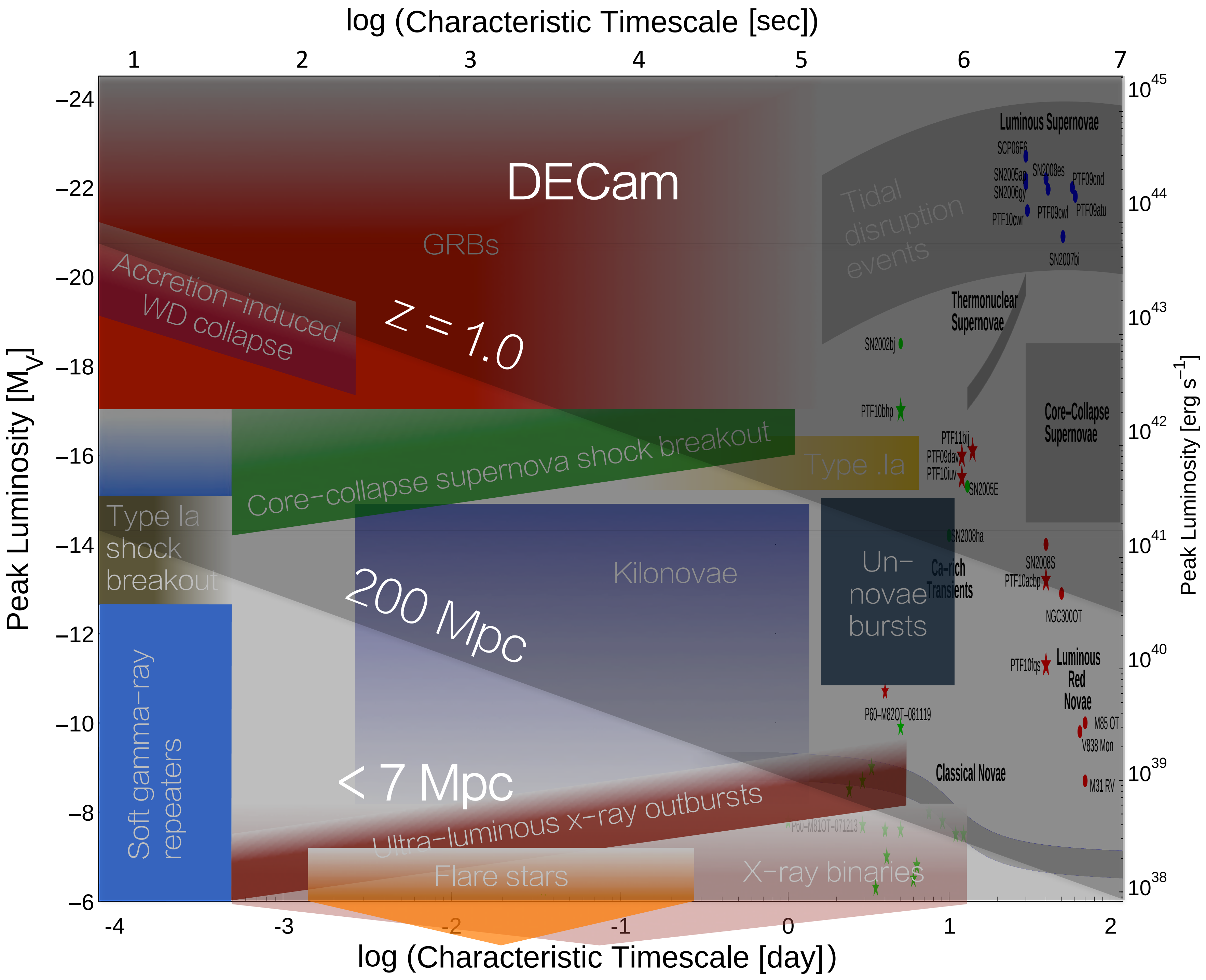


Soderberg (2010)



log $S_{pk}D^2$ (Jy kpc^2)
log νW (GHz s)
Uncertainty Limit
COHERENT
INCOHERENT
10^{40}
10^{30}
10^{20}
10^{12}
10^4
GRB short
GRB long
narrow beams
wide beams
GP (maximal)
Crab GP (ns)
BH Evap
B0540-69
OH
GCRT
RT
IDV
ISS
GRB
ISS
AGNs
GMRT (3 Gpc)
SKA (3 Gpc)
GMRT (10 kpc)
SKA (10 kpc)
RRATs
Asteroid Radar
magnetar J1810−197
pulsars
Type II
ADLeo
Type III
TVLM 513
UVCeti
Jup DAM
BD LP944-20

Bhat (2011)



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10^{45}
10^{44}
10^{43}
10^{42}
10^{41}
10^{40}
10^{39}
10^{38}
-4
-3
-2
-1
0
1
2
log (Characteristic Timescale [day])
DECam
GRBs
Accretion-induced WD collapse
Z = 1.0
Tidal disruption events
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SN2006gy
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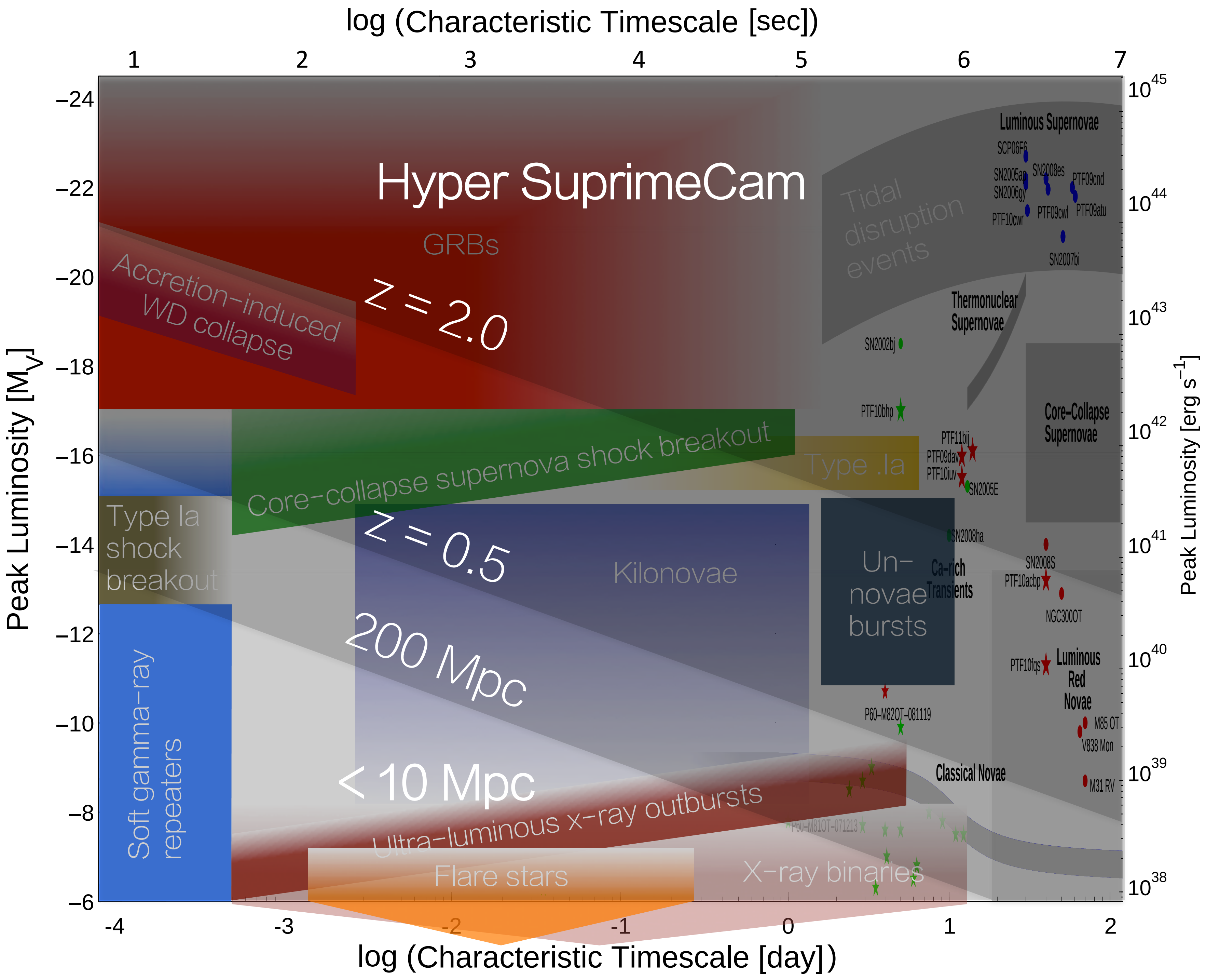
< 7 Mpc
Ultra-luminous x-ray outbursts
P60-M81OT-071213
Flare stars
X-ray binaries


log (Characteristic Timescale [sec])
log (Characteristic Timescale [day])
Peak Luminosity [M_V]
Peak Luminosity [erg s^-1]
Hyper SuprimeCam
GRBs
Accretion-induced WD collapse
z = 2.0
z = 0.5
200 Mpc
< 10 Mpc
Tidal disruption events
Luminous Supernovae
Thermonuclear Supernovae
Core-Collapse Supernovae
Core-collapse supernova shock breakout
Type .Ia
Type Ia shock breakout
Kilonovae
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