GRB 201015A:
a relatively faint GRB with a hint of Very High Energy gamma-ray emission

Speaker
Stefano Giarratana

PhD Supervisor
Dr. Marcello Giroletti

Collaborators
Dr. L. Rhodes, Dr. B. Marcote, Prof. R. Fender, Prof. G. Ghirlanda,
Dr. L. Nava, Prof. J. M. Paredes, Dr. M. E. Ravasio, Prof. M. Ribo,...

GRBs in Radio

Long Lasting
(≈ weeks up to years!)

VLBI

Geometry

Dynamics

Long Lasting
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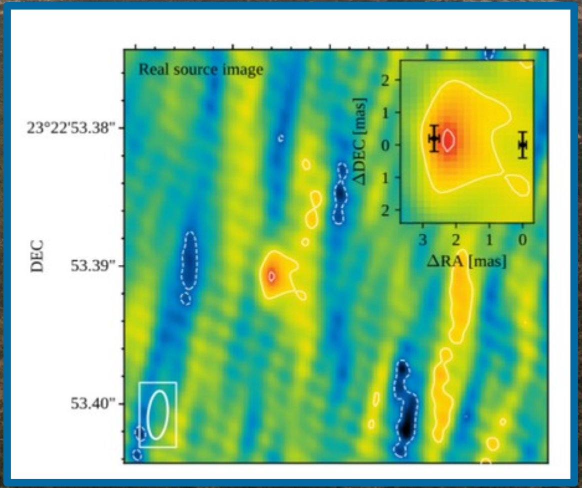
Dynamics



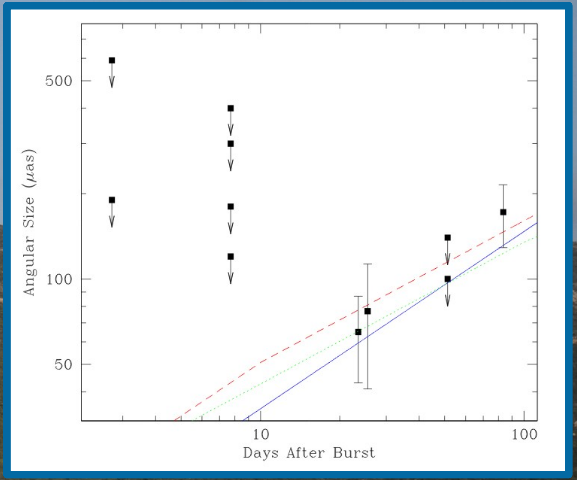
From *Ghirlanda et al. (2019)*.

Long Lasting
(≈ weeks up to years!)

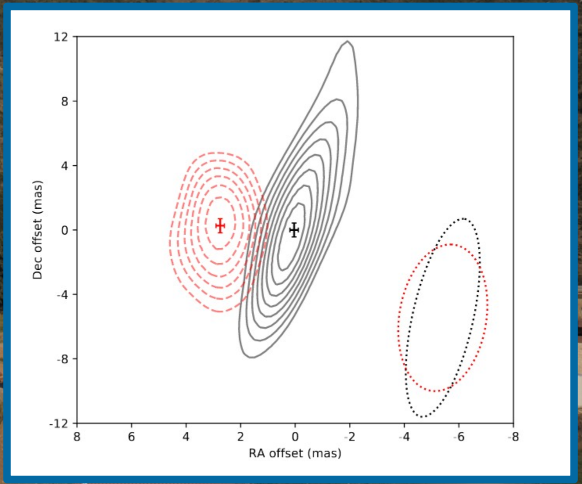
VLBI

Geometry

Dynamics



From *Taylor et al. (2004)*



From *Mooley et al. (2018).*

GRB 201015A

GRB 201015A

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TITLE: GCN CIRCULAR
NUMBER: 28632
SUBJECT: GRB 201015A: Swift detection of a burst
DATE: 20/10/15 22:58:36 GMT
FROM: David Palmer at LANL <palmer@lanl.gov>

V. D'Elia (SSDC), E. Ambrosi (INAF-IASFPA), S. D. Barthelmy (GSFC),
A. D'Ai (INAF-IASFPA), J.D. Gropp (PSU), N. J. Klingler (PSU),
A. Y. Lien (GSFC/UMBC), D. M. Palmer (LANL), B. Sbarufatti (PSU) and
M. H. Siegel (PSU) report on behalf of the Neil Gehrels Swift
Observatory Team:

At 22:50:13 UT, the Swift Burst Alert Telescope (BAT) triggered and
located GRB 201015A (trigger=1000452). Swift did not slew immediately
to the burst due to an observing constraint.
The BAT on-board calculated location is
RA, Dec 354.343, +53.393 which is
RA(J2000) = 23h 37m 22s
Dec(J2000) = +53d 23' 36"
with an uncertainty of 3 arcmin (radius, 90% containment, including
systematic uncertainty). The BAT light curve showed a multi-peaked
structure with a duration of about 10 sec. The peak count rate
was ~700 counts/sec (15-350 keV), at ~0 sec after the trigger.

Due to an observing constraint, Swift will not slew until T0+51.6
minutes. There will be no XRT or UVOT data until this time.

Burst Advocate for this burst is V. D'Elia (delia AT ssdc.asi.it).
Please contact the BA by email if you require additional information
regarding Swift followup of this burst. In extremely urgent cases, after
trying the Burst Advocate, you can contact the Swift PI by phone (see
Swift TOO web site for information: http://www.swift.psu.edu/)

$z \approx 0.426$
$E(iso) \approx 10^{50}$ erg

GRB 201015A

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TITLE: GCN CIRCULAR
NUMBER: 28659
SUBJECT: MAGIC observations of GRB 201015A: hint of very high energy gamma-ray signal
DATE: 20/10/16 16:48:37 GMT
FROM: Oscar Blanch at MAGIC Collaboration <blanch@ifae.es>

O.Blanch (IFAE-BIST Barcelona), M. Gaug (UAB Barcelona), K. Noda (ICRR University of Tokyo), A. Berti (INFN Torino), E. Moretti (IFAE-BIST Barcelona), D. Miceli (University of Udine and INFN Trieste), P. Gliwny (University of Lodz) S. Ubach (UAB Barcelona), B. Schleicher (University of Wuerzburg), M. Cerruti (University of Barcelona) and A. Stamerra (INAF Rome) on behalf of the MAGIC collaboration report:

On October 15, 2020, the MAGIC telescopes observed GRB 201015A following the Swift-BAT trigger (D'Elia et al., GCN 28632). MAGIC started observations under good conditions about 40 seconds after the initial Swift trigger, revealing a hint of signal with significance >3 sigma in the very high energy band. Refined off-line analyses of the data are ongoing.

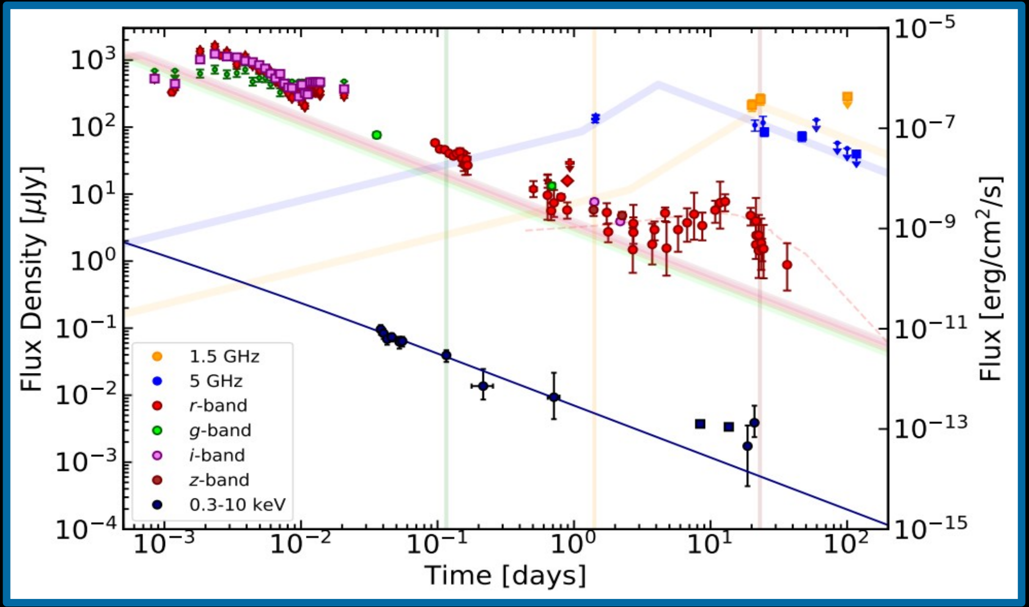
Further MAGIC observations on GRB 201015A are planned in the coming night. We strongly encourage follow-up observations by other instruments at all wavelengths.

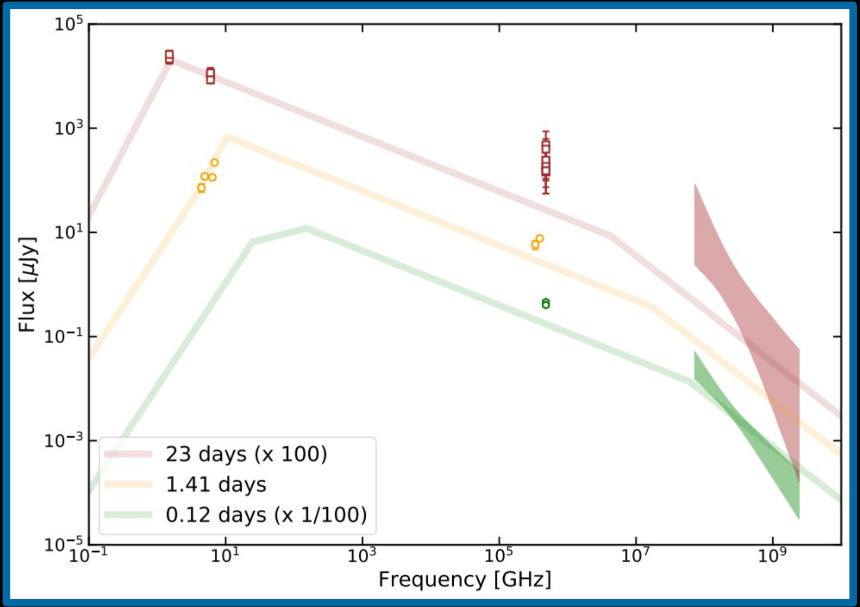
The MAGIC point of contact for this burst is O. Blanch (blanch@ifae.es). Burst Advocate for this burst is M. Gaug (Markus.Gaug@uab.cat)

MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

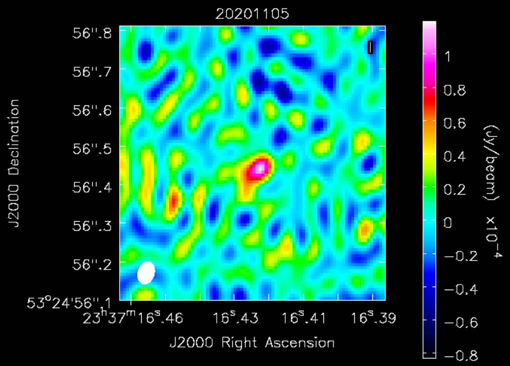
Swift TOO web site for information: http://www.swift.psu.edu/)

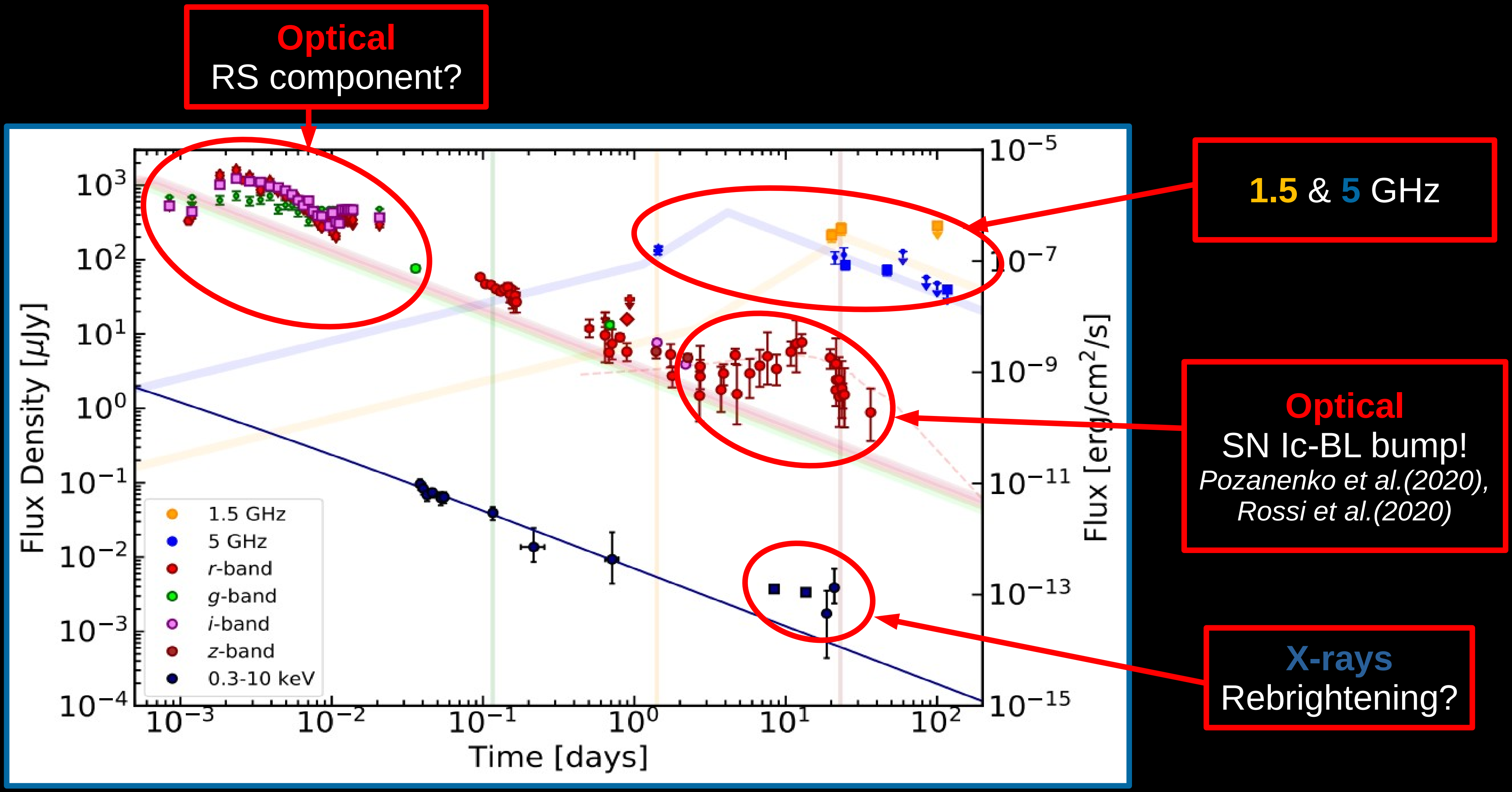
Light curves and Spectra





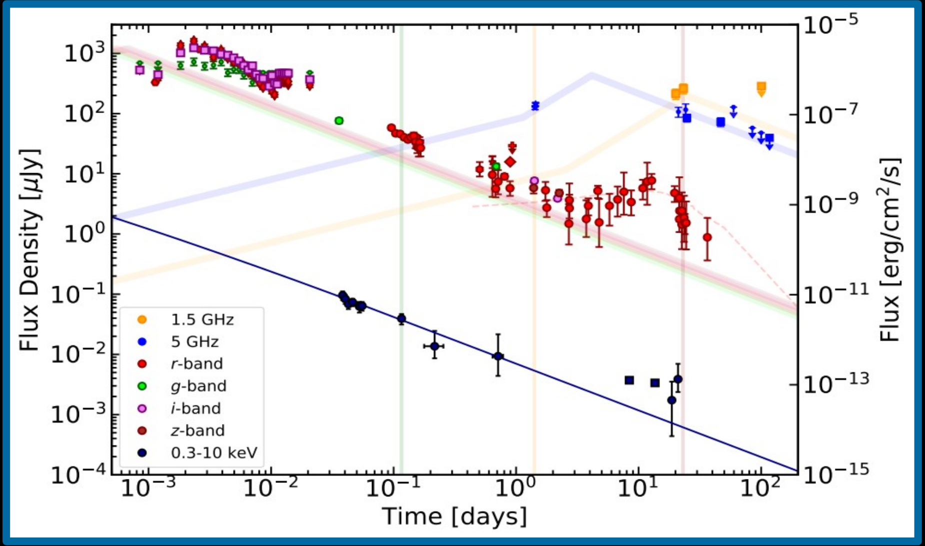
From *Giarratana et al. (2022).*





From *Giarratana et al. (2022).*

Displacement / Expansion



From *Giarratana et al. (2022).*

GRB	z	mas	pc	if z = 0.426
170817A	0.0093	2.44	0.46	0.08
030329	0.1685	0.17	0.5	0.09

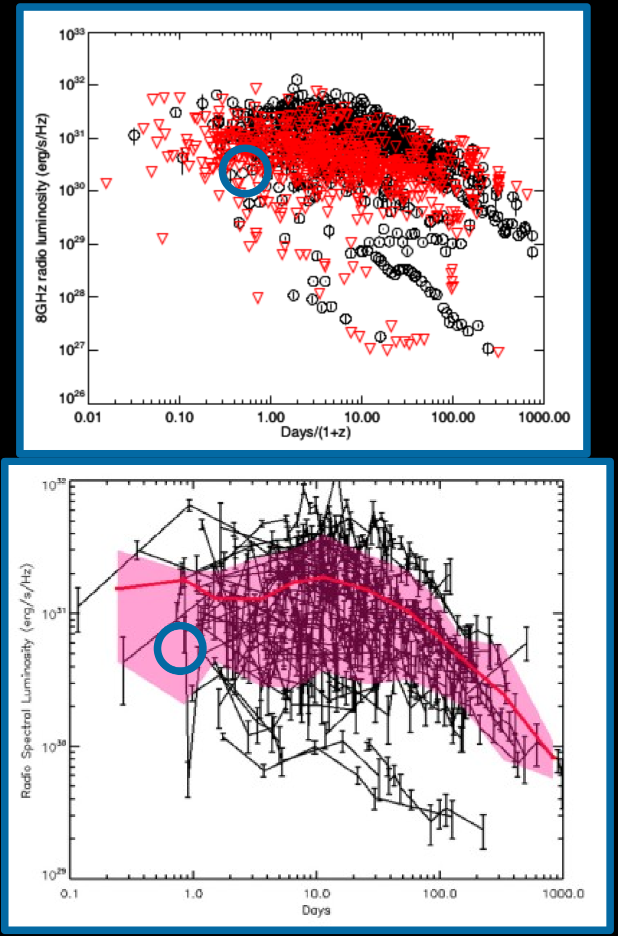
Only for detections with high SNR!

Displacement (< 47d)
$\Gamma(\delta) < 61$
$\Gamma(\alpha) < 40$

Size
< 5pc at 25d
< 16pc at 47d

Global and Microphysical Parameters

Parameter	Value	Median	
		ISM	RS
E [10^52 erg]	0.03 - 1000	12	20
ϵe	0.0001 - 0.99	0.32	0.104
ϵB	0.0000008 - 0.05	0.027	0.00014
n [cm^-3]	0.4 - 20000	1.5	2.15
f	0.01 - 1.00		

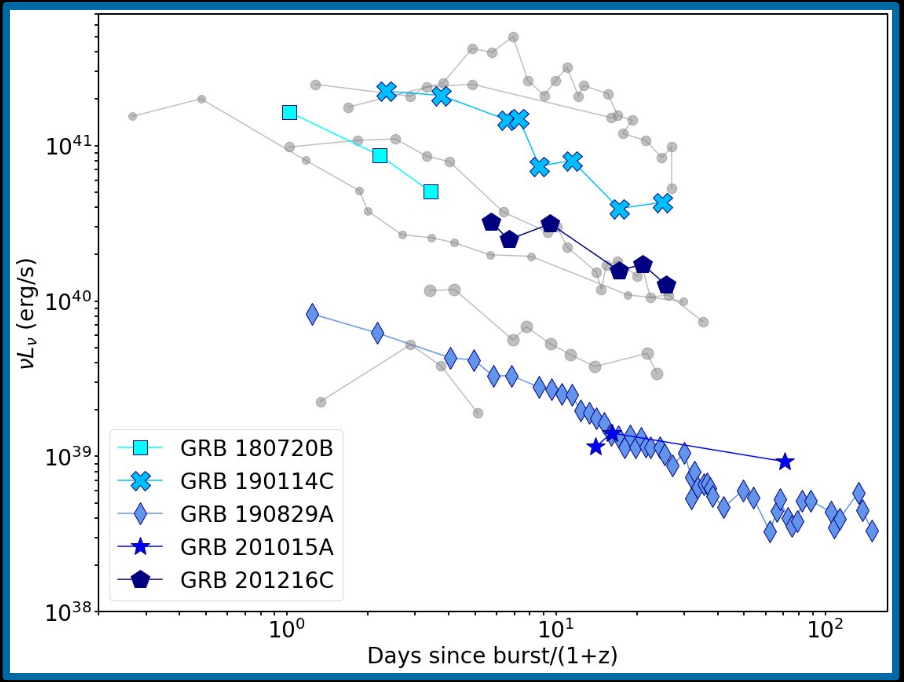


k-corrected radio spectral luminosities (upper panel) and radio light curves in the observer's frame (lower panel) at 8.5 GHz. From *Chandra & Frail 2012*.

GRB 201015A and the other VHE GRBs

Parameter	GRB 201015A	VHE GRBs
ϵ_e	0.0001 - 0.99	0.02 - 0.1
ϵ_B	0.0000008 - 0.05	0.000047 - 0.0001
n [cm^-3]	0.4 - 20000	0.1 - 23

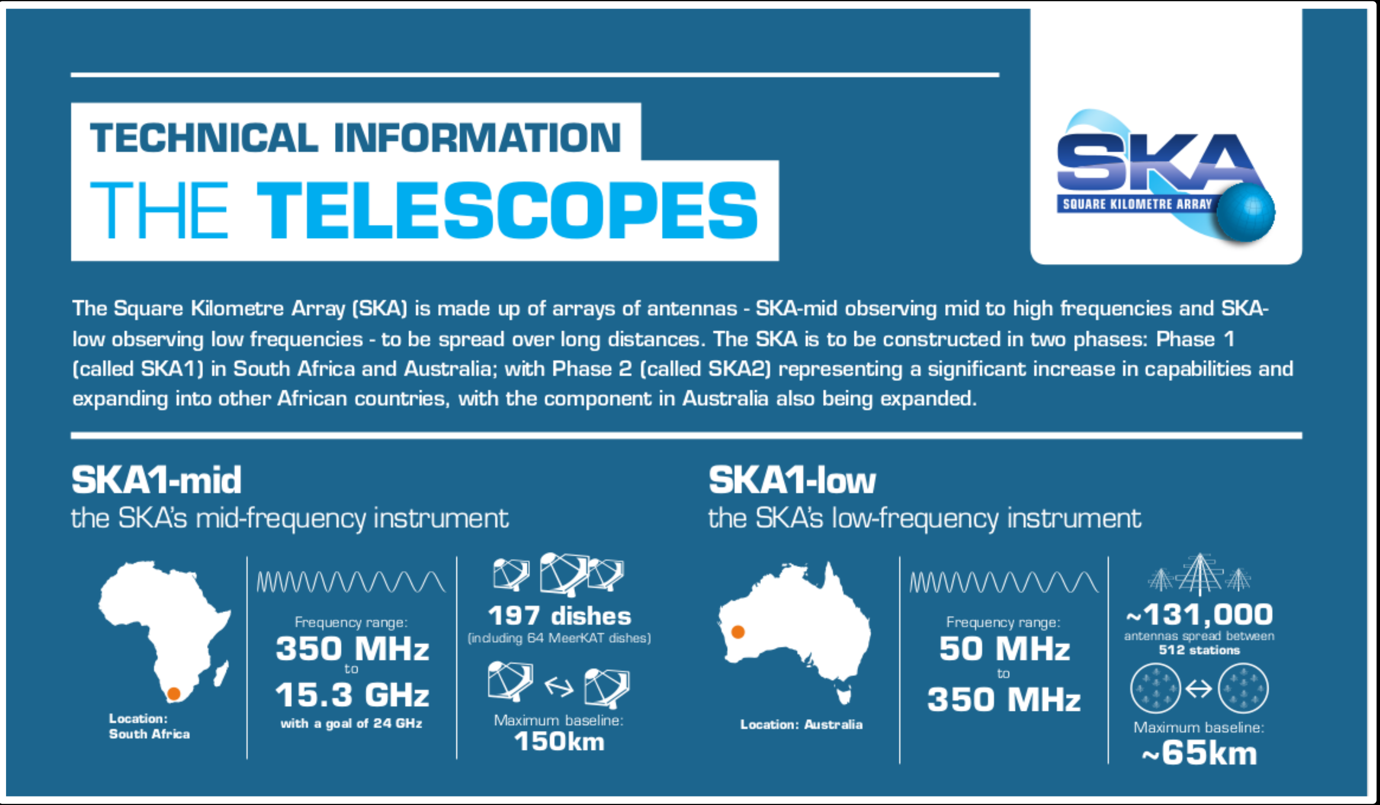
Comparison between GRB 201015A and other 3 VHE GRBs, i.e. GRB 180720B (Wang et al. 2019), 190114C (Misra et al. 2021) and 190829A (Salafia et al. 2022).



Courtesy of L. Rhodes

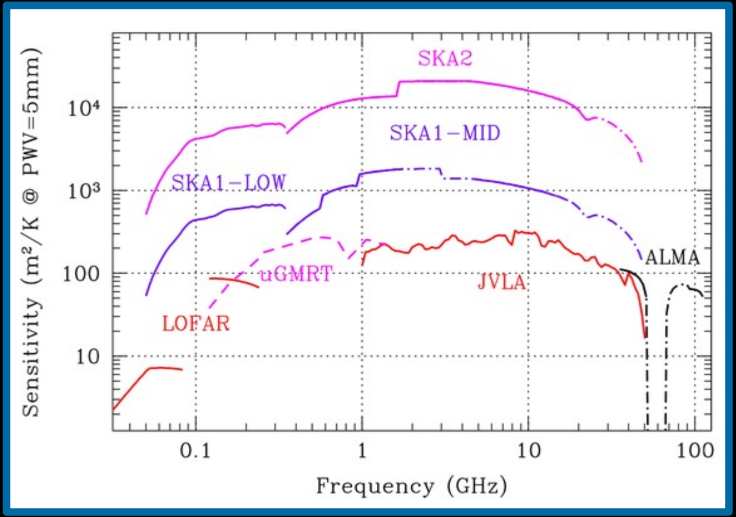
Future of GRBs in Radio

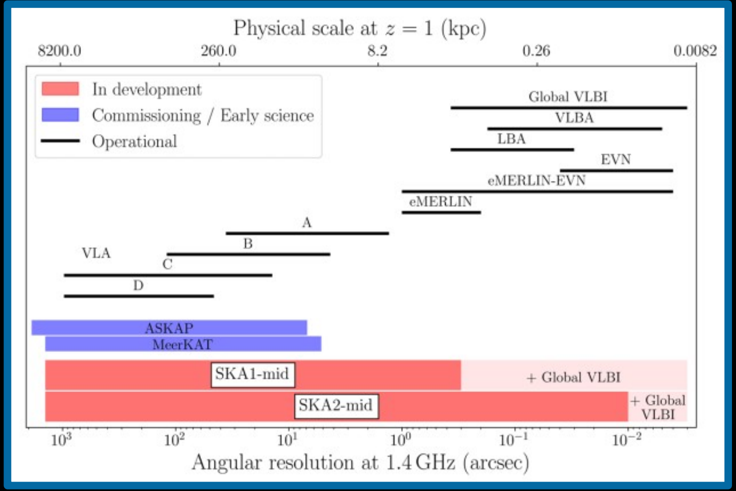
The Square Kilometre Array



Info sheet from the SKAO Public Website: *https://www.skatelescope.org/technical/info-sheets/*

Sensitivity and Resolution





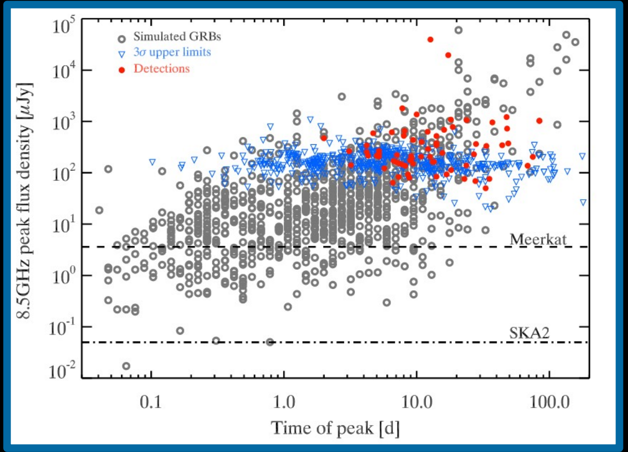
10 μJy/beam

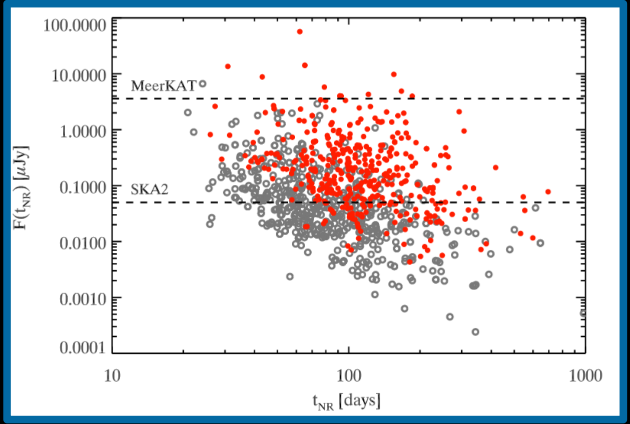
1 min at 1.4 GHz!

31 sec at 6.7 GHz!

At 1.4 GHz:
0.3 arcsec (SKA1-mid)
10 mas (SKA2-mid)

The Italian SKA White Book





From Ghirlanda et al.(2013) - the Italian SKA White Book:
https://www.ira.inaf.it/SKA-Italy/SKA_IT_WP.v4%2Bcover.pdf

- From 30% to almost 100% of detection rate
- From <15% to 50% detections at the transition time
- Amati relation and cosmological parameters
- +VLBI: structure of the outflow

… Unknown!

To sum up...

GRB 201015A

low luminosity, VHE (?), nearby,
homogeneous environment,
constraints on expansion / proper motion

GRB 201015A

Reverse shock, X-ray rebrightening,...

SKA1 + VLBI

Detection of *almost* 100% GRB radio afterglows, characterisation of their structure and expansion / motion (nearest events)

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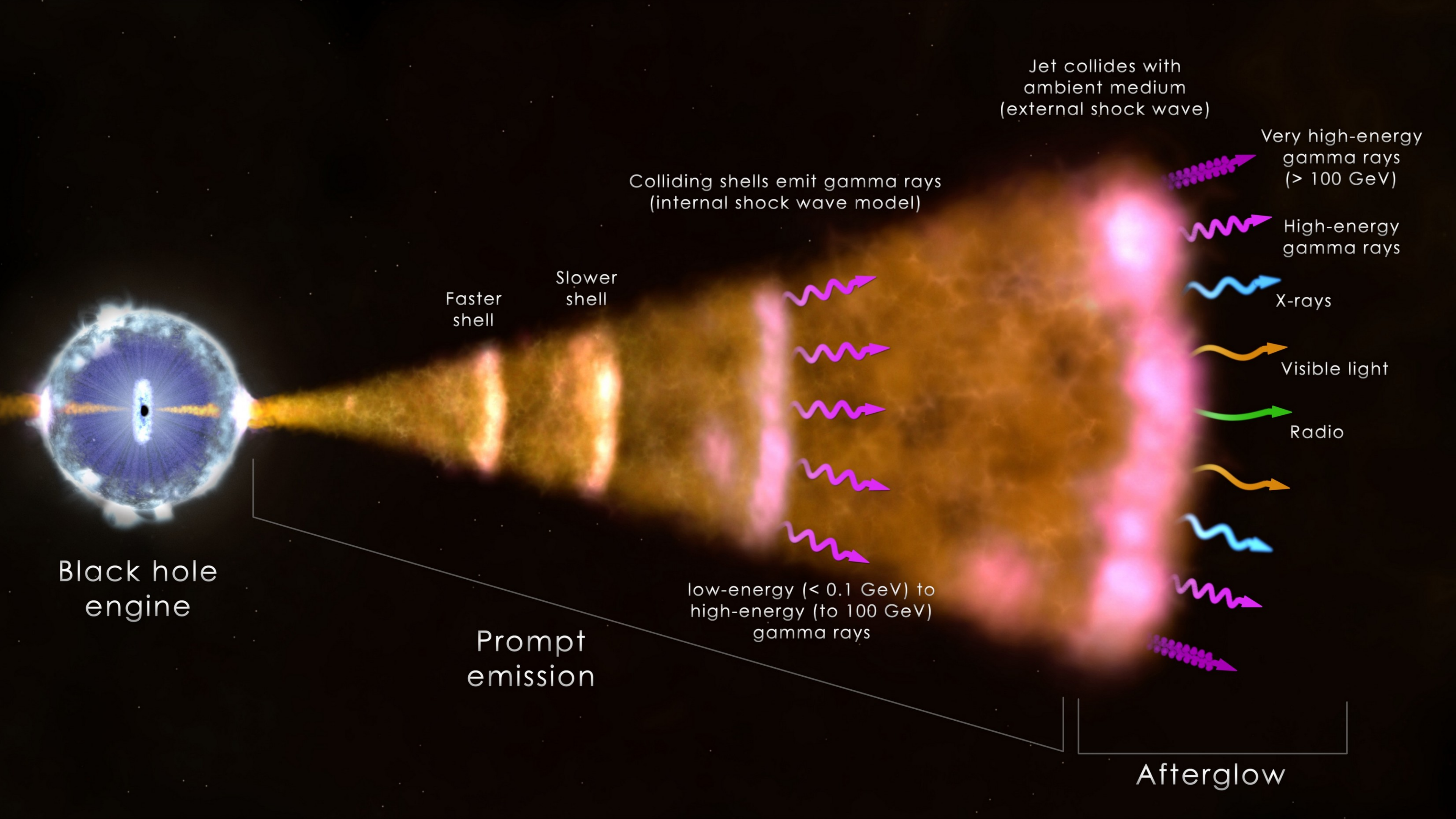
THANKS!!!

Backup Slides



Jet collides with
ambient medium
(external shock wave)
Very high-energy
gamma rays
(> 100 GeV)
Colliding shells emit gamma rays
(internal shock wave model)
High-energy
gamma rays
Slower
shell
Faster
shell
X-rays
Visible light
Radio
Black hole
engine
low-energy (< 0.1 GeV) to
high-energy (to 100 GeV)
gamma rays
Prompt
emission
Afterglow

Short & Long

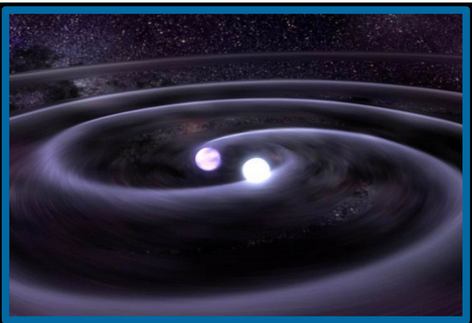
T90 < 2 s
(*Kouveliotou+93*)

Harder spectrum
(*Hurley+92, Kouveliotou+93, Ghirlanda+04*, ...)

< z > ≈ 0.5
(*Berger13*, ...)

All morphological types of galaxies
(*Berger09, Fong+13, Berger13*, ...)

[Recently] Associated with KNe
(*Tanvir+13*, …)



Credits: NASA/Goddard Space Flight Center

T90 ≥ 2 s
(*Kouveliotou+93*)

Softer spectrum
(*Hurley+92, Kouveliotou+93, Ghirlanda+04*, ...)

< z > ≈ 2.0
(*Berger13*, ...)

High star-forming regions
(*Berger09, Fong+13, Berger13*, ...)

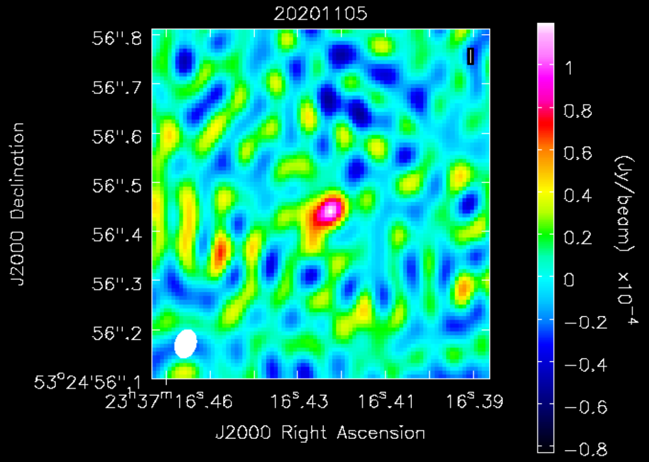
[Almost always] Associated with SNe
(*Galama+98*, …)

Credits: Hubble Legacy Archive

GRB 201015A

EVN

3 epochs
4.57 – 5.11 GHz
rms ≈ 10 μJy/beam
beam ≈ 3.4x2.8 mas



e-MERLIN

3 epochs
1.5 GHz
rms ≈ 44 μJy/beam
beam ≈ 0.18”x0.12”

5 epochs
4.50 – 5.01 GHz
rms ≈ 24 μJy/beam
beam ≈ 0.06”x0.04”

Afterglow Modeling

$$F_{max}, \nu_m, \nu_{sa}, \nu_c, p$$

Spectrum at a given epoch

Repeat for different epochs

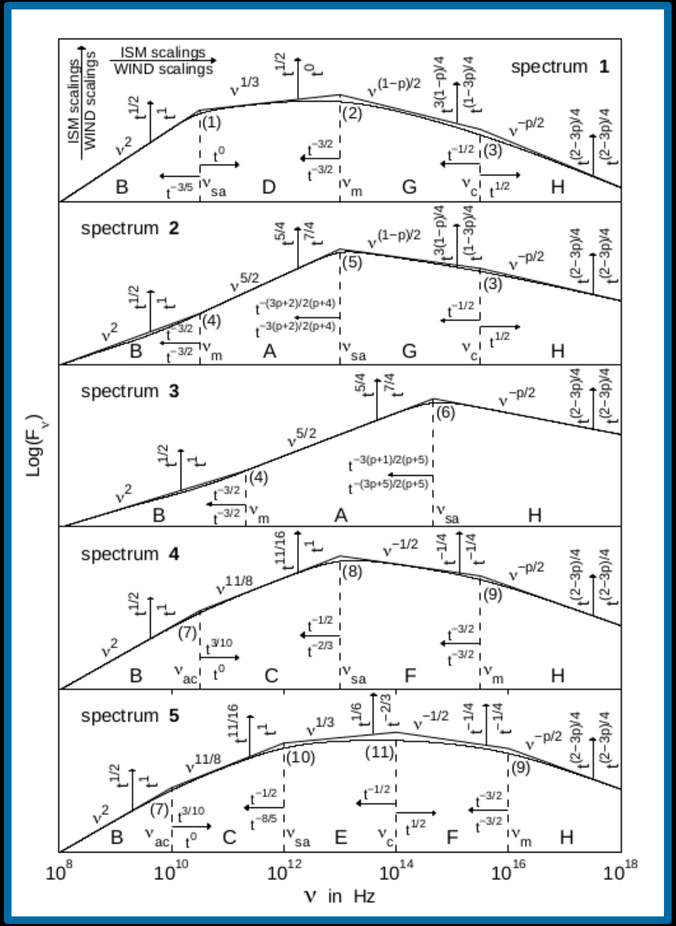
$$E_{52}, \epsilon_e, \epsilon_B, n_0$$

Multi-wavelength **Light curves**

$$\rho \propto r^{-k}$$

k=0 ISM

k=2 WIND



Models for the spectrum and the temporal evolution of the afterglow. From *Granot & Sari (2002).*

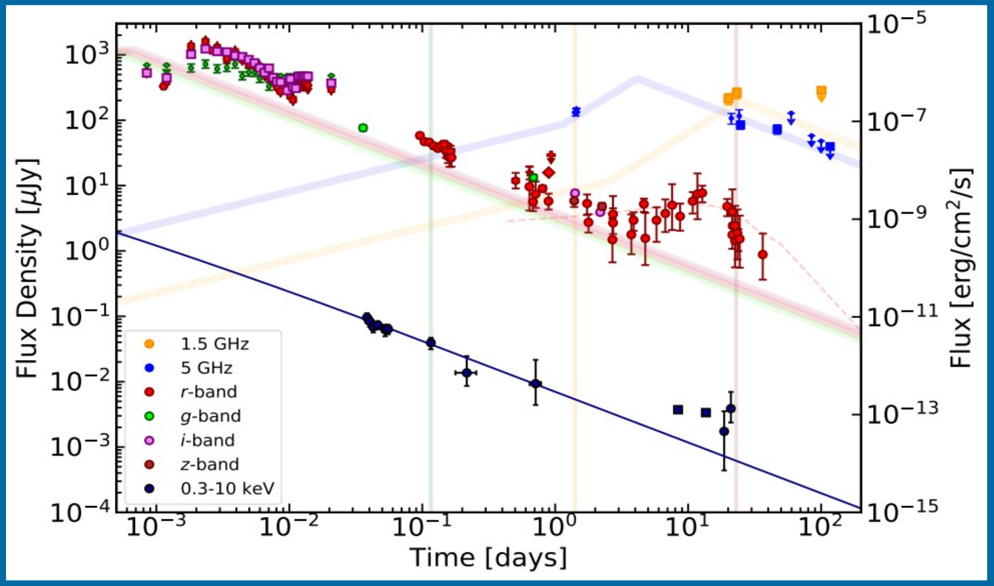
GRB 201015A Observations

Array	Date	Freq [GHz]	Flux [μJy]	R.M.S [μJy/b]	Beam size
e-MERLIN	20/11/05	4.76	107	17	0.06”x0.04”
e-MERLIN	20/11/08	4.76	116	26	0.06”x0.04”
EVN	20/11/09	4.84	85	9	1.8x0.9mas
EVN	20/12/01	4.91	73	10	3.4x2.8mas
e-MERLIN	20/12/14	6.80	-	43	0.12”x0.07”
e-MERLIN	21/01/08	4.76	-	19	0.04”x0.04”
e-MERLIN	21/01/23	4.76	-	16	0.07”x0.03”
EVN	21/02/09	4.91	-	13	3.1x3.6mas
e-MERLIN	20/11/04	1.5	213	34	0.18”x0.12”
e-MERLIN	20/11/07	1.5	261	40	0.19”x0.12”
e-MERLIN	21/01/24	1.5	-	57	0.17”x0.14”

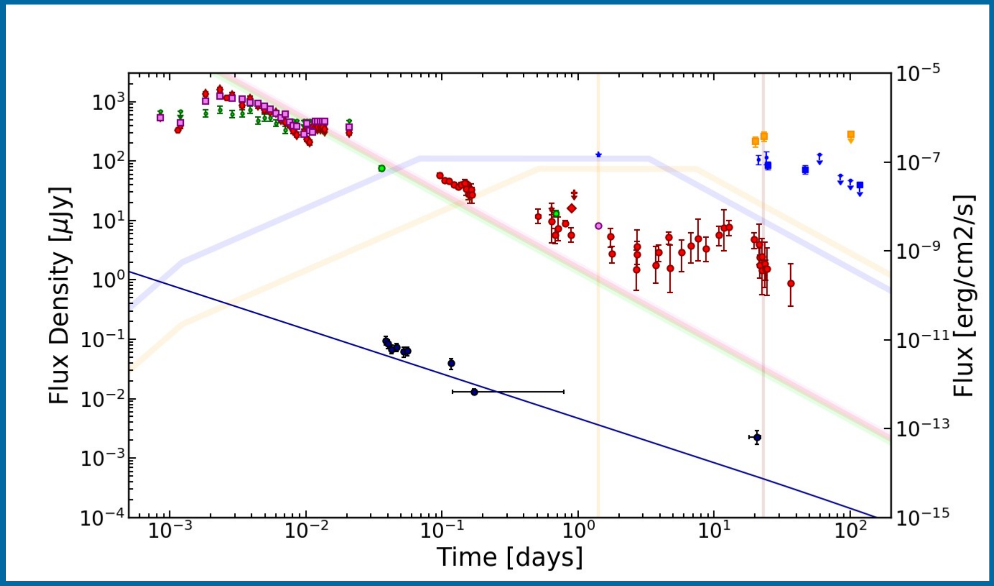
GRB 201015A Calibration

	Epoch	Flux cal / Fringe Finder	Bandpass	Phase cal	Calibration
e-MERLIN (5 GHz)	20/11/05	1331+3030 (1), 0319+4130 (2)	1407+2827	2322+5057 (3), 2353+5518 (4)	1 → 3,4 → 2 2 → 3,4 → targ
e-MERLIN (5 GHz)	20/11/08	1331+3030 (1)	1407+2827	2322+5057 (2)	1 → 2 → targ
e-MERLIN (5 GHz)	20/12/14, 21/01/08, 21/01/23	1331+3030 (1)	1407+2827	2322+5057 (2), 2353+5518 (3)	1 → 2,3 → targ
EVN	20/11/09, 20/11/09, 21/02/09	0854+2006, 3C84, 0555+3948, 0102+5824	0854+2006, 3C84, 0555+3948, 0102+5824	2353+5518	A-priori amp → fringe fitting and phase cal → selfcal
e-MERLIN (1.5 GHz)	20/11/04, 20/11/07, 21/01/24	1331+3030 (1)	1407+2827	2353+5518 (2)	1 → 2 → targ

ISM vs WIND



Homogeneous Interstellar medium (ISM)



Wind-like circum-burst medium (WIND)

SKA Performance Sheet

SKA1 Telescope Expected Performance – Imaging

Nominal Frequency	110 MHz	300 MHz	770 MHz	1.4 GHz	6.7 GHz	12.5 GHz
Range [GHz]	0.05-0.35	0.05-0.35	0.35-1.05	0.95-1.76	4.6-8.5	8.3-15.3
Telescope	Low	Low	Mid	Mid	Mid	Mid
FoV [arcmin]	327	120	109	60	12.5	6.7
Max. Resolution (arcsec)	11	4	0.7	0.4	0.08	0.04
Max. Bandwdith [GHz]	0.3	0.3	1	1	4	5
Cont. rms, 1 hr (μJy/beam)[a]	26	14	4.4	2	1.3	1.2
Line rms, 1 hr [μJy/beam][b]	1850	800	300	140	90	85
Resolution Range for Cont. and Line rms [arcsec][c]	12–600	6–300	1–145	0.6–78	0.13–17	0.07–9
Channel width (uniform resolution across max. bandwidth) [kHz]	5.4	5.4	15.2	15.2	61.0	79.3
Spectral zoom windows X narrowest bandwidth [MHz]	4 X 4.0	4 X 4.0	4 X 3.125	4 X 3.125	4 X 3.125	4 X 3.125
Finest zoom channel width [Hz]	244	244	190	190	190	190

Info sheet from the SKAO Public Website: *https://www.skatelescope.org/technical/info-sheets/*