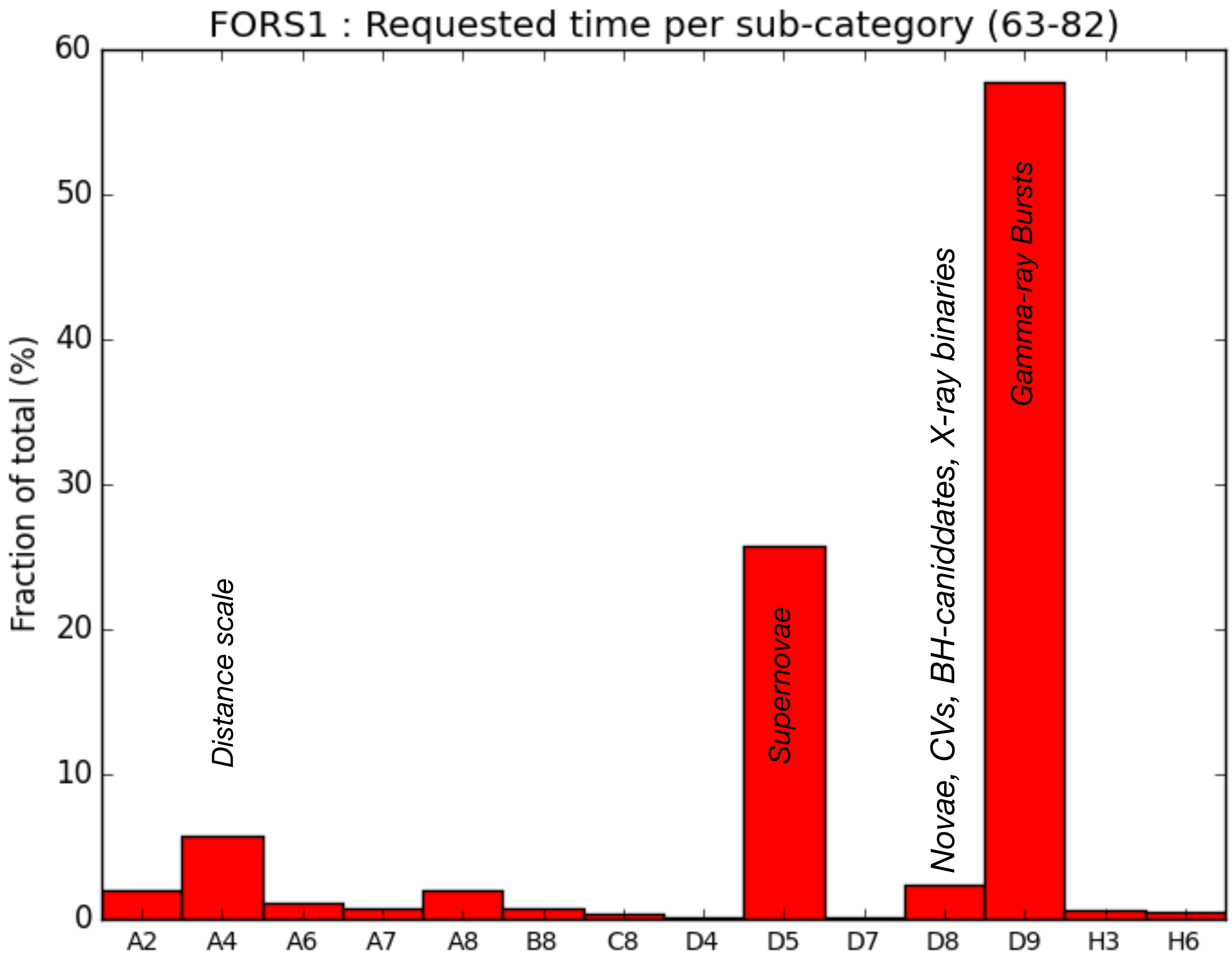
Supernovae, GRBs and GW counterparts with the FORSes

N&o P@@

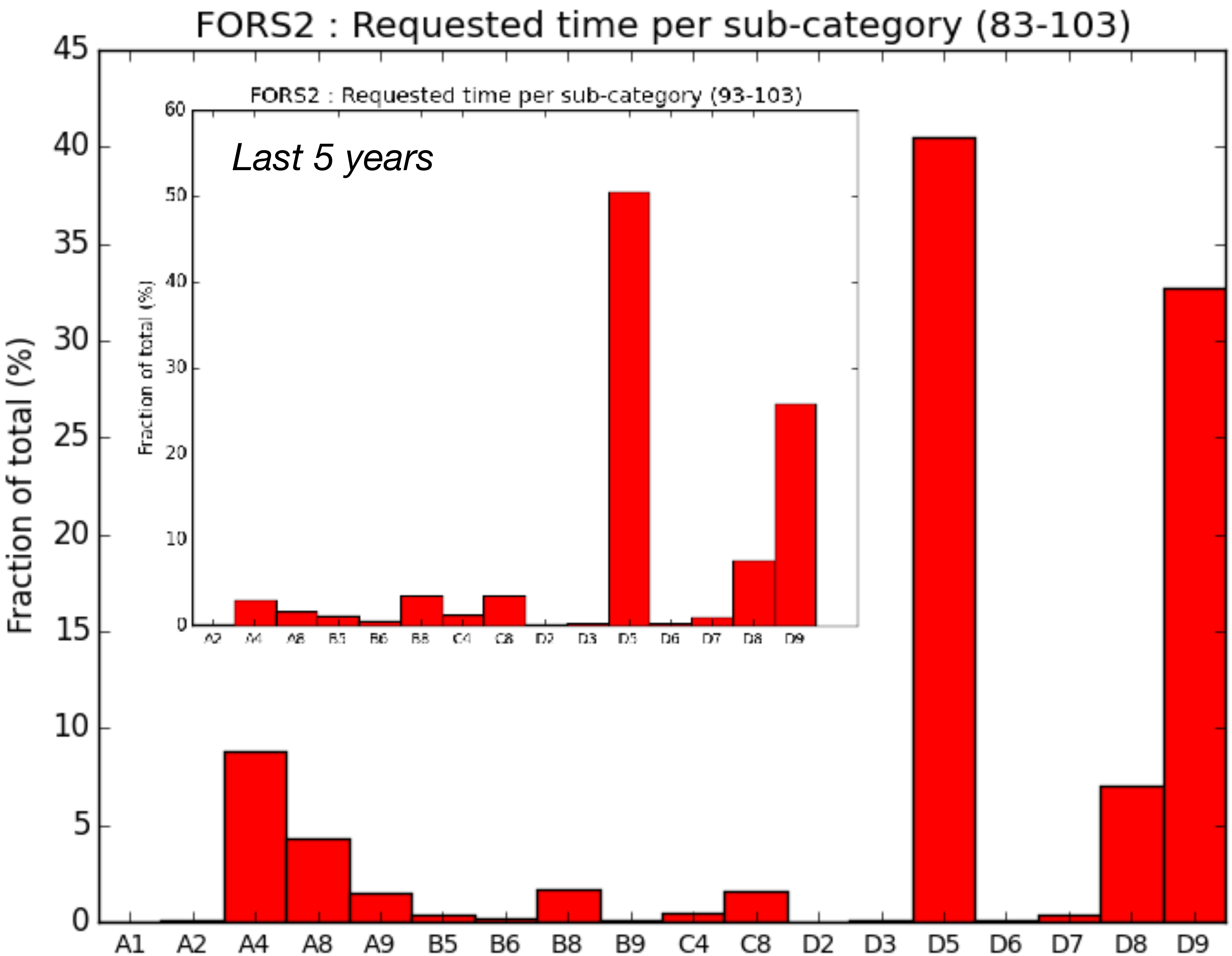
European Southern Observatory

Science at the 5%-level

Target of Opportunity Proposals only



the whole story (so far)



Briefly

- The FORSes Target of Opportunity science is dominated by Supernovae and GRBs;
- In the last 10 years SNe have been (re)gaining popularity over GRBs (but… sGRB regaining interest after the association to kilo-novae and GW events)

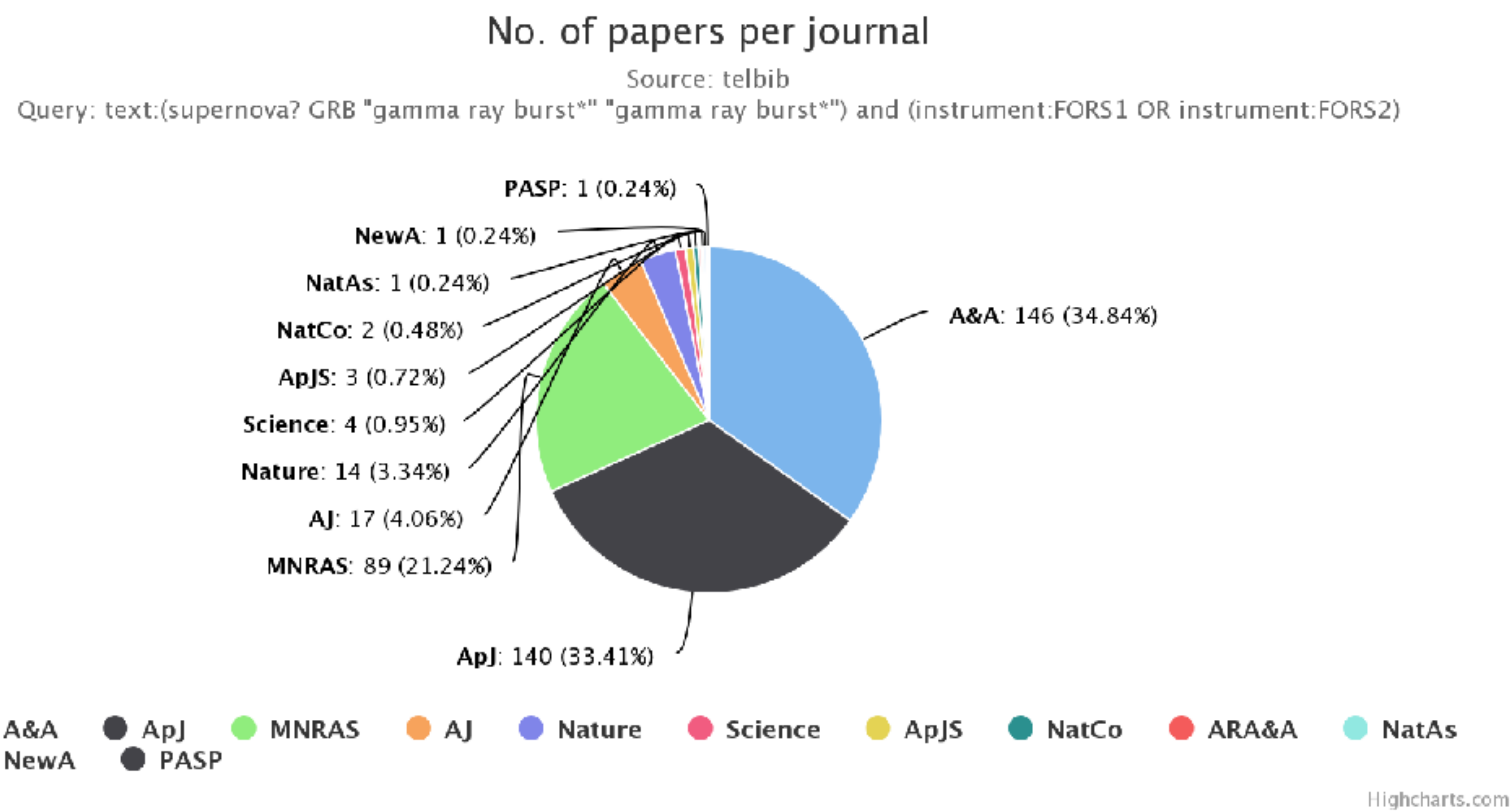
Why?

- Obvious high-throughput work-horses for photometry and low-resolution spectroscopy
- Efficient ToO/RRM activation
- [Unique polarimetric capabilities]

some [crude] stats

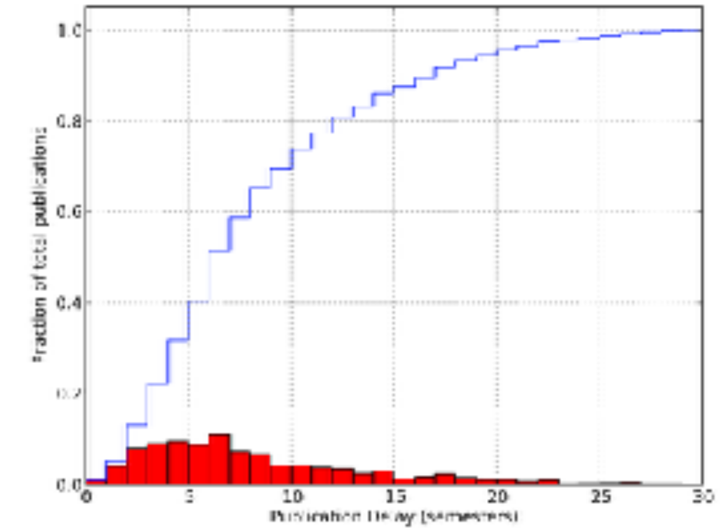
- telbib.eso.org (1998-2019)
- keywords/title/abstract: *supernova* “gamma-ray burst*” “gamma-ray burst*”*
- visual inspection of output (results are very reasonable)
- 419 refereed papers (A&A 146; ApJ 140; Nature 14; Science 4)
- Total citations: 40,490

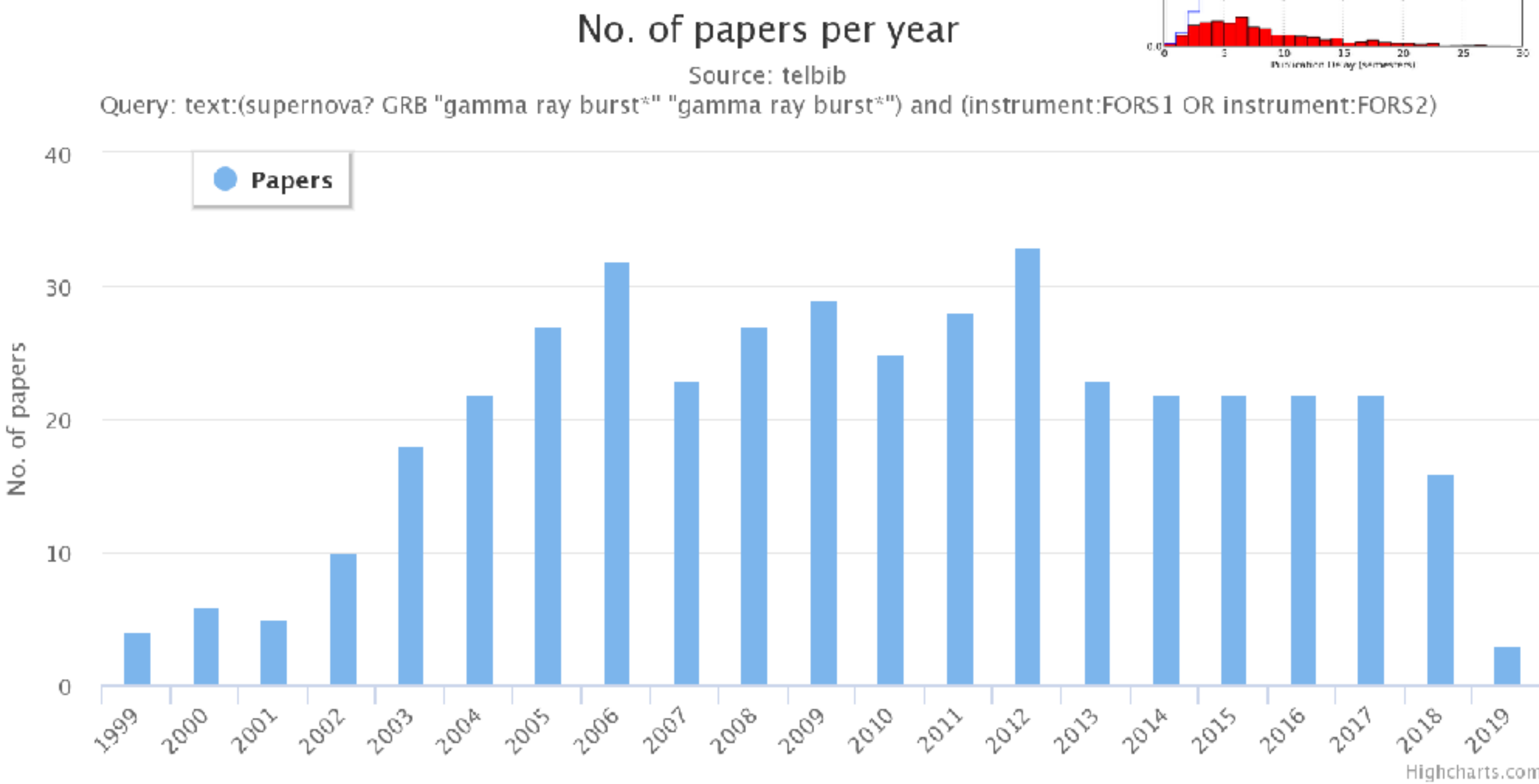
Papers



No. of papers per journal
Source: telbib
Query: text:(supernova? GRB "gamma ray burst*" "gamma ray burst*") and (instrument:FORS1 OR instrument:FORS2)
PASP: 1 (0.24%)
NewA: 1 (0.24%)
NatAs: 1 (0.24%)
NatCo: 2 (0.48%)
ApJS: 3 (0.72%)
Science: 4 (0.95%)
Nature: 14 (3.34%)
AJ: 17 (4.06%)
MNRAS: 89 (21.24%)
A&A: 146 (34.84%)
ApJ: 140 (33.41%)
A&A
ApJ
MNRAS
AJ
Nature
Science
ApJS
NatCo
ARA&A
NatAs
NewA
PASP
Highcharts.com

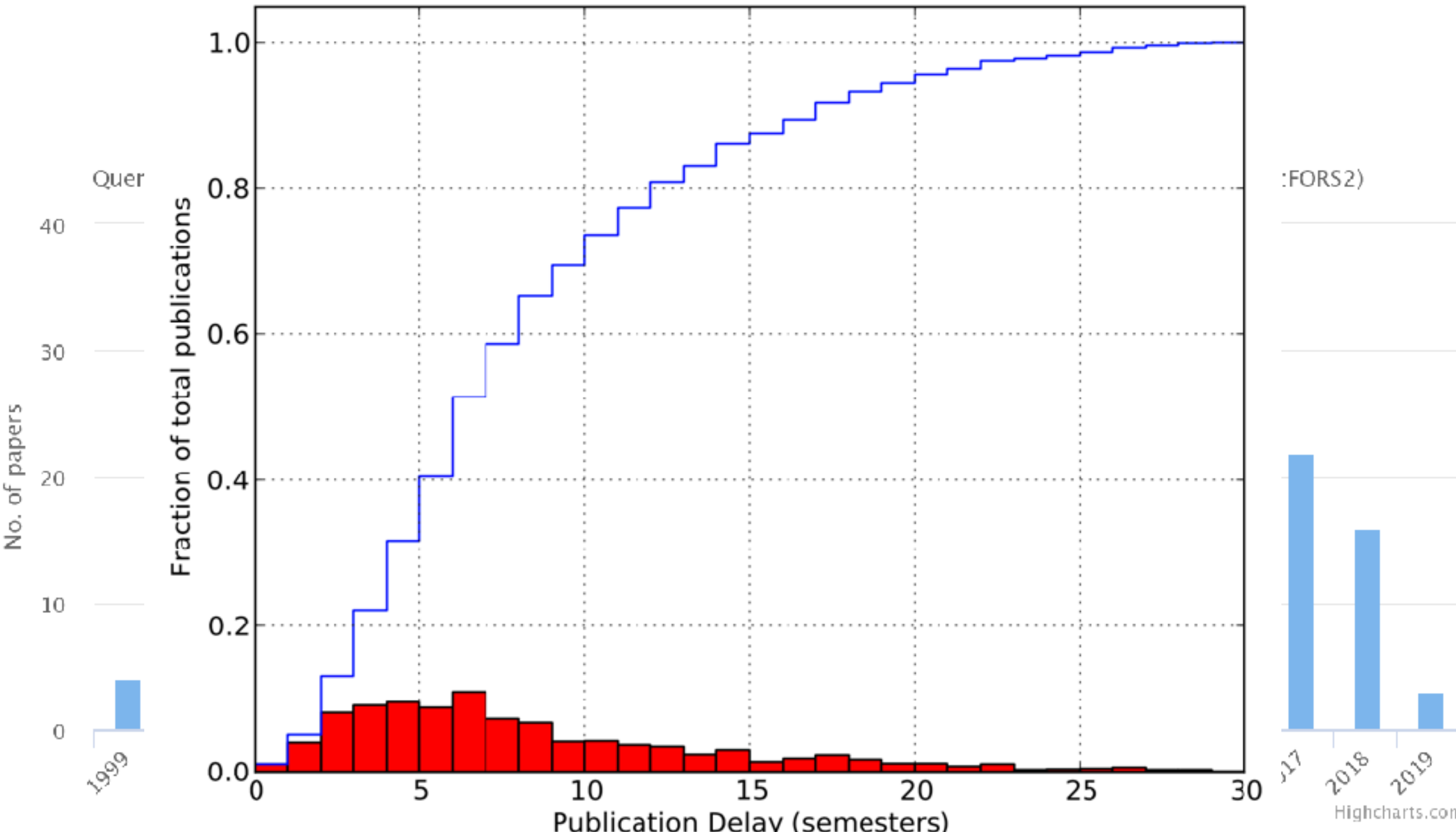
FORStats/1





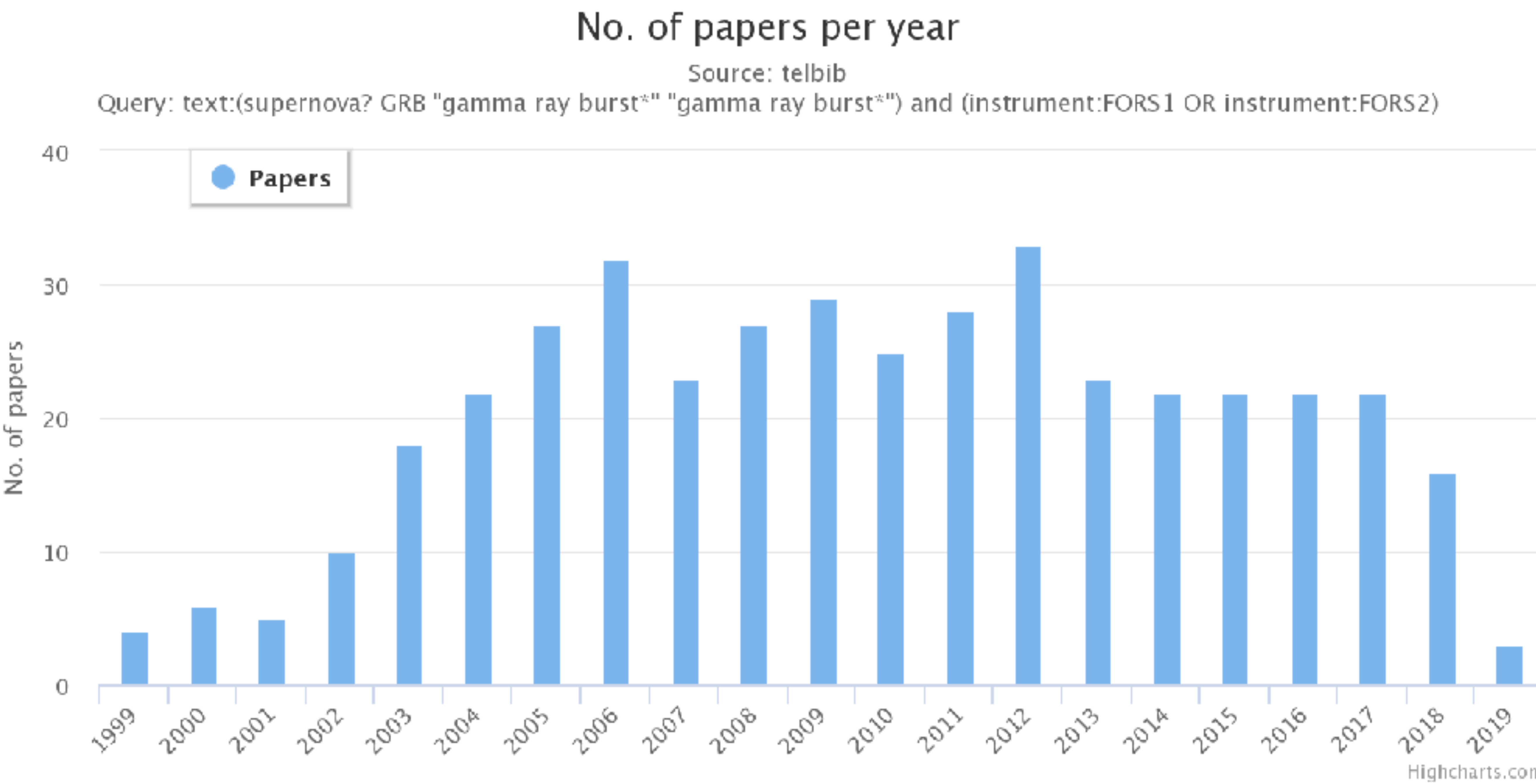
source: telbib.eso.org (consulted Mar 09, 2019)

FORStats/1



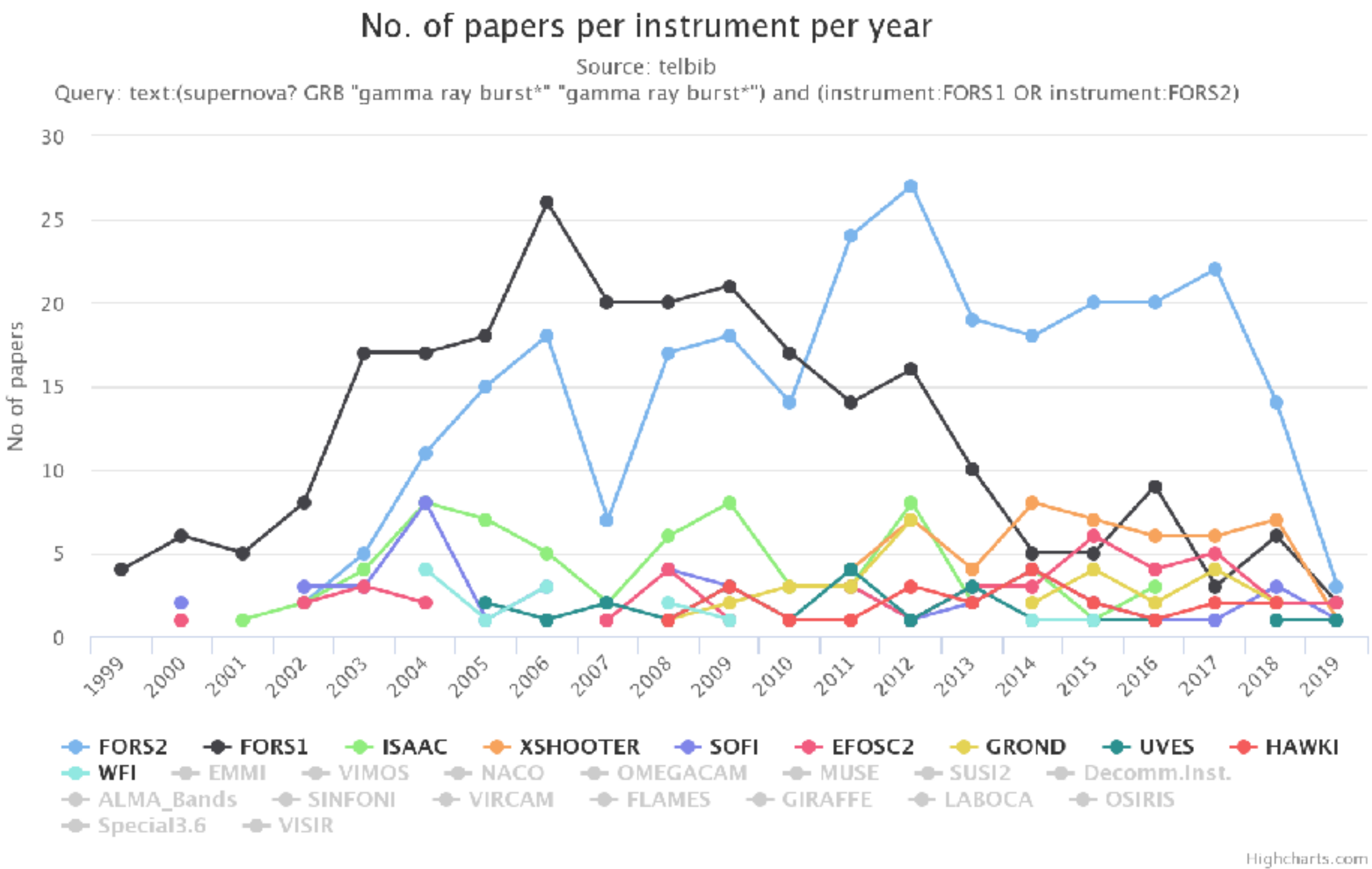
source: telbib.eso.org (consulted Mar 09, 2019)

FORStats/1

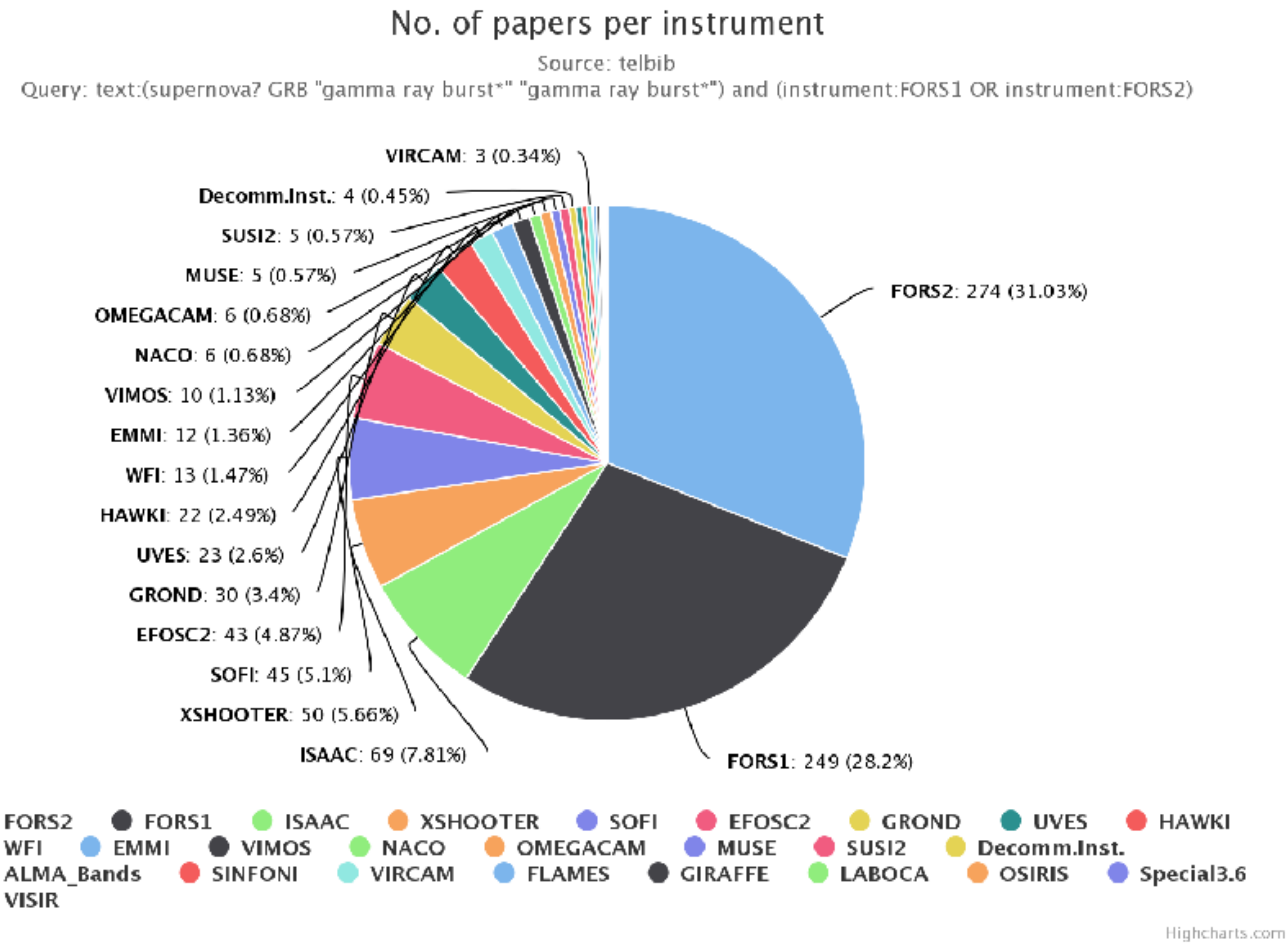


source: telbib.eso.org (consulted Mar 09, 2019)

FORStats/2


No. of papers per instrument per year
Source: telbib
Query: text:(supernova? GRB "gamma ray burst*" "gamma ray burst*") and (instrument:FORS1 OR instrument:FORS2)
No of papers
30
25
20
15
10
5
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
FORS2
FORS1
ISAAC
XSHOOTER
SOFI
EFOSC2
GROND
UVES
HAWKI
WFI
EMMI
VIMOS
NACO
OMEGACAM
MUSE
SUSI2
Decomm.Inst.
ALMA_Bands
SINFONI
VIRCAM
FLAMES
GIRAFFE
LABOCA
OSIRIS
Special3.6
VISIR
Highcharts.com

FORStats/3


No. of papers per instrument
Source: telbib
Query: text:(supernova? GRB "gamma ray burst*" "gamma ray burst*") and (instrument:FORS1 OR instrument:FORS2)
VIRCAM: 3 (0.34%)
Decomm.Inst.: 4 (0.45%)
SUSI2: 5 (0.57%)
MUSE: 5 (0.57%)
OMEGACAM: 6 (0.68%)
NACO: 6 (0.68%)
VIMOS: 10 (1.13%)
EMMI: 12 (1.36%)
WFI: 13 (1.47%)
HAWKI: 22 (2.49%)
UVES: 23 (2.6%)
GROND: 30 (3.4%)
EFOSC2: 43 (4.87%)
SOFI: 45 (5.1%)
XSHOOTER: 50 (5.66%)
ISAAC: 69 (7.81%)
FORS2: 274 (31.03%)
FORS1: 249 (28.2%)
FORS2 FORS1 ISAAC XSHOOTER SOFI EFOSC2 GROND UVES HAWKI
WFI EMMI VIMOS NACO OMEGACAM MUSE SUSI2 Decomm.Inst.
ALMA_Bands SINFONI VIRCAM FLAMES GIRAFFE LABOCA OSIRIS Special3.6
VISIR
Highcharts.com

Impact

- Median citation rate <r>=5.1 cit/yr (25th: 2.9 - 75th: 10.0)
- N(r>= 10 cit/yr): 102 (24%)
- N(r>= 20 cit/yr): 47 (11%)
- N(r>= 50 cit/yr): 13 (3%)
- N(r>= 100 cit/yr): 4 (~1%)
- Max(r)=354 cit/yr (Abbott et al. 2017, GW170817)
- N(c>=100 cit): 86 (21%)

Top 10

1. **Riess+, 2004**, *Type Ia Supernova Discoveries at z>1 from the Hubble Space Telescope: Evidence for Past Deceleration and Constraints on Dark Energy Evolution* (3236);
2. **Astier+, 2006**, *The Supernova Legacy Survey: measurement of ΩM, ΩΛ and w from the first year data set* (2015)
3. **Tonry+, 2003**, *Cosmological Results from High-z Supernovae* (1539)
4. **Knop+, 2003**, *New Constraints on ΩM, ΩΛ, and w from an Independent Set of 11 High-Redshift Supernovae Observed with the Hubble Space Telescope* (1355)
5. **Giavalisco+, 2004**, *The Great Observatories Origins Deep Survey: Initial Results from Optical and Near-Infrared Imaging* (1254)
6. **Hjorth+, 2003**, *A very energetic supernova associated with the γ-ray burst of 29 March 2003* (1029)
7. **Amanullah+, 2010**, *Spectra and Hubble Space Telescope Light Curves of Six Type Ia Supernovae at 0.511<z<1.12 and the Union2 Compilation* (1000)
8. **Wood-Vasey+, 2007**, *Observational Constraints on the Nature of Dark Energy: First Cosmological Results from the ESSENCE Supernova Survey* (788)
9. **Abbott+, 2017**, *Multi-messenger observations of a Binary Neutron Star Merger* (708)
10. **Conley+, 2011**, *Supernova Constraints and Systematic Uncertainties from the First Three Years of the Supernova Legacy Survey* (497)

1999 - Status quo

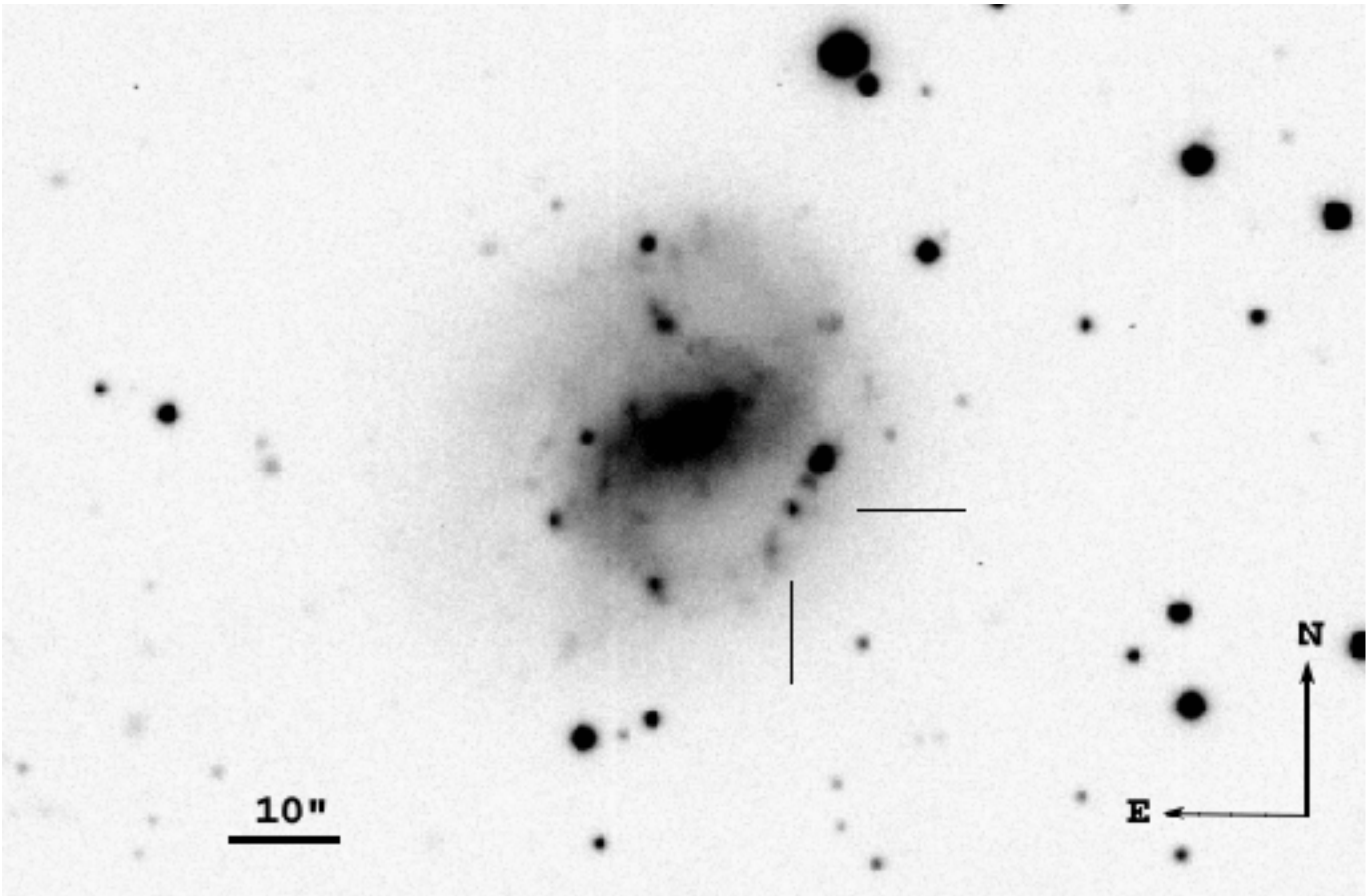
MENU ∨ **nature**
International journal of science

Letter | Published: 15 October 1998

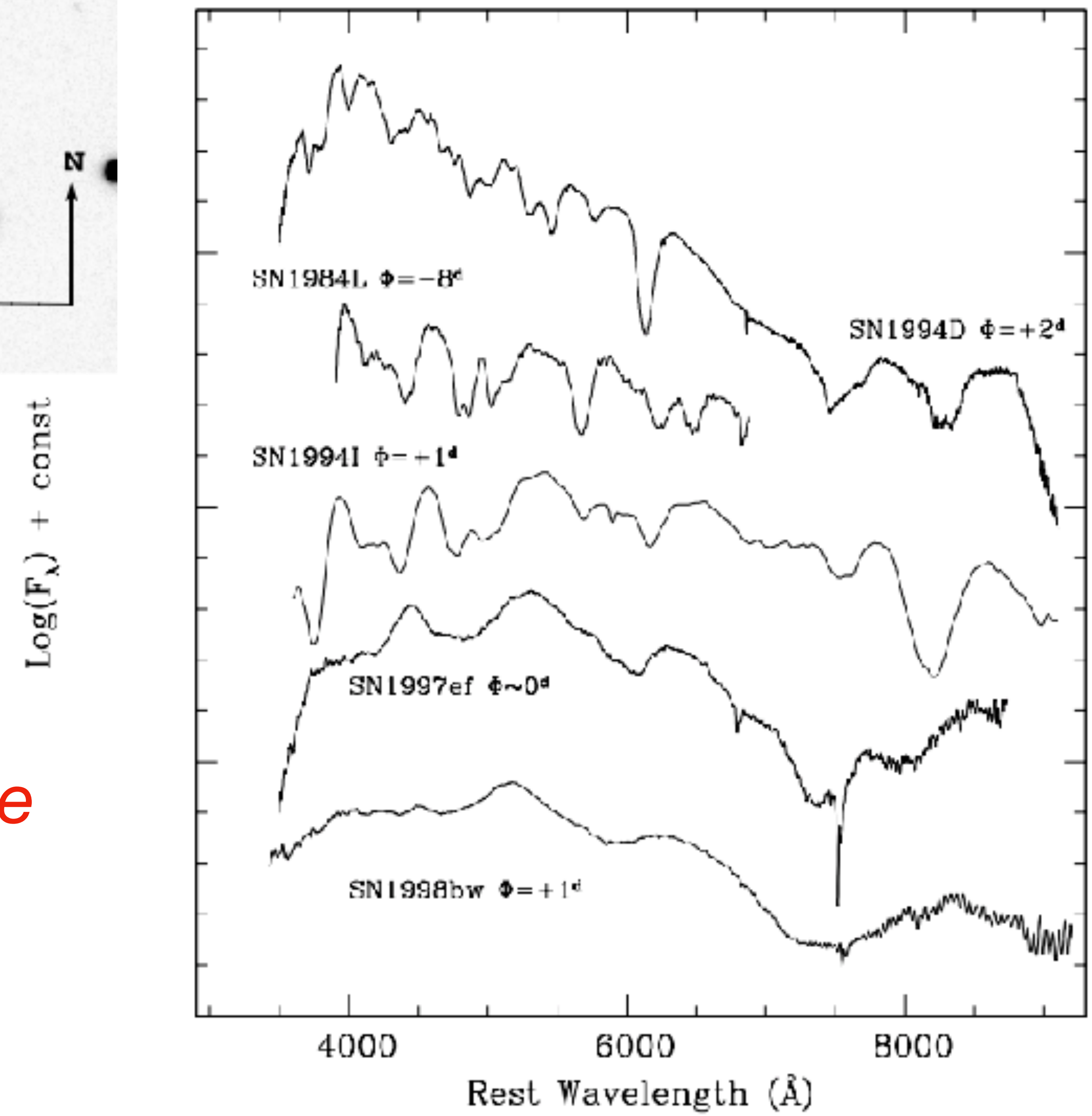
An unusual supernova in the error box of the γ-ray burst of 25 April 1998

T. J. Galama ✉, P. M. Vreeswijk, J. van Paradijs, C. Kouveliotou, T. Augusteijn, H. Böhnhardt, J. P. Brewer, V. Doublier, J.-F. Gonzalez, B. Leibundgut, C. Lidman, O. R. Hainaut, F. Patat, J. Heise, J. in't Zand, K. Hurley, P. J. Groot, R. G. Strom, P. A. Mazzali, K. Iwamoto, K. Nomoto, H. Umeda, T. Nakamura, T. R. Young, T. Suzuki, T. Shigeyama, T. Koshut, M. Kippen, C. Robinson, P. de Wildt, R. A. M. J. Wijers, N. Tanvir, J. Greiner, E. Pian, E. Palazzi, F. Frontera, N. Masetti, L. Nicastro, M. Feroci, E. Costa, L. Piro, B. A. Peterson, C. Tinney, B. Boyle, R. Cannon, R. Stathakis, E. Sadler, M. C. Begam & P. Ianna - Show fewer authors

Nature **395**, 670–672 (15 October 1998) | Download Citation ⤓



Patat+



The SN-GRB Rosetta Stone

The first FORS papers

- **Wijers+, 1999**, *Detection of Polarization in the Afterglow of GRB 990510 with the ESO Very Large Telescope*
- **Bauermann+, 1999**, *VLT observations of GRB 990510 and its environment*
- **Israel+, 1999**, *ESO deep observations of the optical afterglow of GRB 990510*
- **Covino+, 1999**, *GRB 990510: linearly polarized radiation from a fireball*
- **Turatto+, 2000**, *The Properties of Supernova 1997CY Associated with GRB 970514*
- **Sollerman+, 2000**, *SN 1998bw at Late Phases*
- **Sahu+, 2000**, *Discovery of the Optical Counterpart and Early Optical Observations of GRB 990712*

The first…

The discovery of polarization in the afterglow of GRB 990510 with the ESO Very Large Telescope

R.A.M.J. Wijers (SUNY Stony Brook), P.M. Vreeswijk, T.J. Galama, E. Rol (Univ. of Amsterdam), J. van Paradijs (Univ. of Amsterdam and UAH), C. Kouveliotou (USRA and NASA/MSFC), T. Giblin (UAH), N. Masetti, E. Palazzi, E. Pian (TESRE), F. Frontera (TESRE and Univ. of Ferrara), L. Nicastro (IFCAI), R. Falomo (Padova), P. Soffitta, L. Piro (IAS, Roma)

(Submitted on 22 Jun 1999)

Following a BeppoSAX alert (Piro 1999a) and the discovery of the OT at SAAO (Vreeswijk et al. 1999a), we observed GRB 990510 with the FORS instrument on ESO's VLT Unit 1 (`Antu'). The burst is unremarkable in gamma rays, but in optical is the first one to show good evidence for jet-like outflow (Stanek et al. 1999, Harrison et al. 1999). We report the detection of significant linear polarization in the afterglow: it is (1.6 +/- 0.2)% 0.86 days after trigger, and after 1.81 days is consistent with that same value, but much more uncertain. The polarization angle is constant on a time scale of hours, and may be constant over one day. We conclude that the polarization is intrinsic to the source and due to the synchrotron nature of the emission, and discuss the random and ordered field geometries that may be responsible for it.

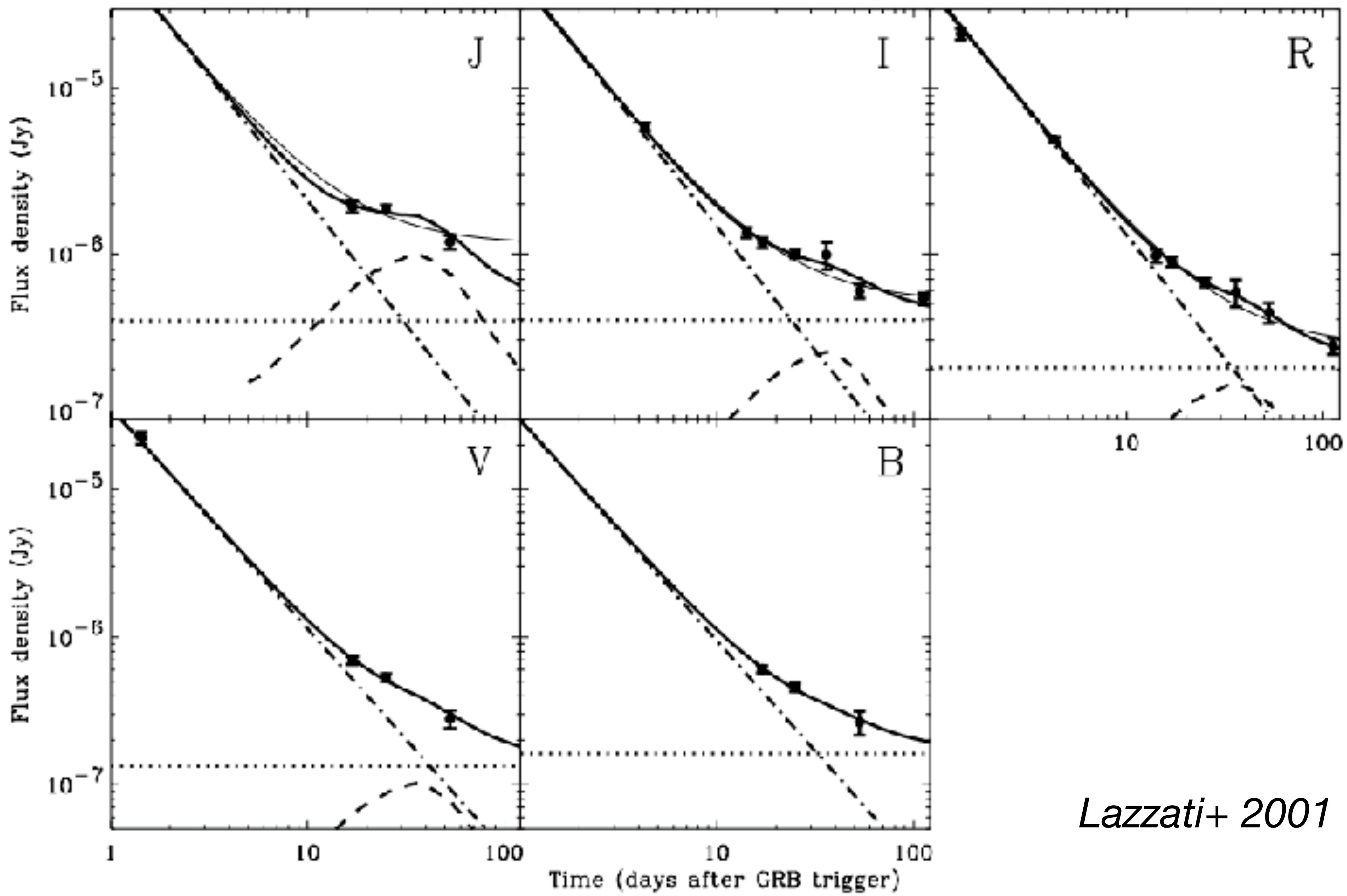
12 papers on GRB polarization

Wijers, R. A.	Detection of Polarization in the Afterglow of GRB 990510 with the ESO Very Large Telescope	ApJ	523	L33-L36	1999

Wijers, R. A.	Detection of Polarization in the Afterglow of GRB 990510 with the ESO Very Large Telescope	ApJ	523	L33-L36	1999

Looking for the SN signature

998 D. Lazzati et al.: Supernova in GRB 000911



Lazzati+ 2001

Fig. 1. Lightcurves of the afterglow of GRB 000911. From top left to bottom right, the J, I, R, V and B lightcurves are plotted. The thick solid curves show the best fits obtained with our three component model. The dashed, dotted and dot–dashed lines show the SN, galaxy and ES components, respectively. The thin solid lines in the J, I and R panels indicate the best fit for a model comprising only the galaxy and ES (without SN). The thin line is indistinguishable from the thick solid line for the V and B filters.

The smoking gun…

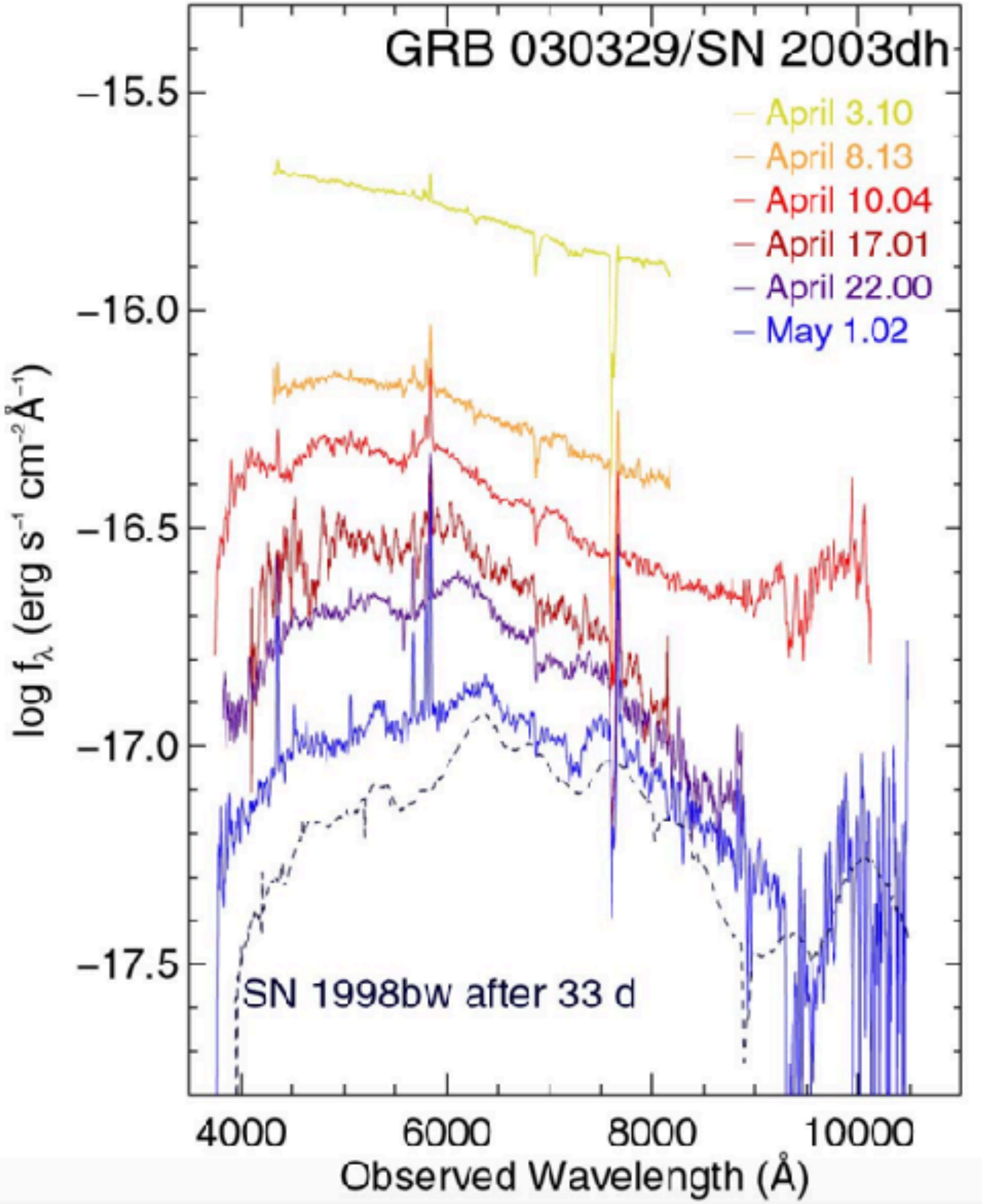
A very energetic supernova associated with the gamma-ray burst of 29 March 2003

Jens Hjorth, Jesper Sollerman, Palle Møller, Johan P. U. Fynbo, Stan E. Woosley, Chryssa Kouveliotou, Nial R. Tanvir, Jochen Greiner, Michael I. Andersen, Alberto J. Castro-Tirado, José María Castro Cerón, Andrew S. Fruchter, Javier Gorosabel, Páll Jakobsson, Lex Kaper, Sylvio Klose, Nicola Masetti, Holger Pedersen, Kristian Pedersen, Elena Pian, Eliana Palazzi, James E. Rhoads, Evert Rol, Edward P. J. van den Heuvel, Paul M. Vreeswijk, Darach Watson, Ralph A. M. J. Wijers

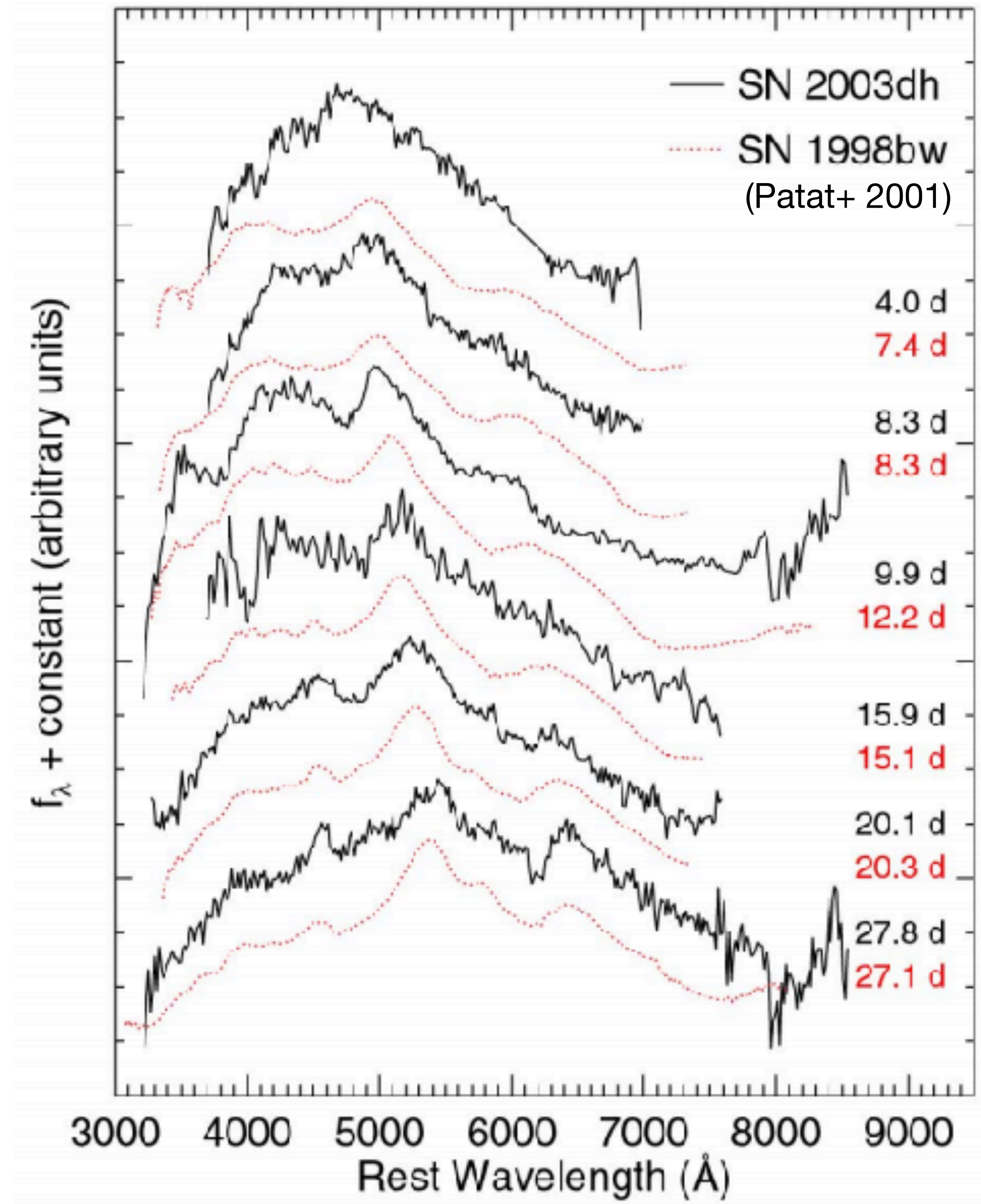
(Submitted on 17 Jun 2003)

Over the past five years evidence has mounted that long-duration (> 2 s) gamma-ray bursts (GRBs)--the most brilliant of all astronomical explosions--signal the collapse of massive stars in our Universe. This evidence was originally based on the probable association of one unusual GRB with a supernova, but now includes the association of GRBs with regions of massive star formation in distant galaxies, the appearance of supernova-like 'bumps' in the optical afterglow light curves of several bursts and lines of freshly synthesized elements in the spectra of a few X-ray afterglows. These observations support, but do not yet conclusively demonstrate, the idea that long-duration GRBs are associated with the deaths of massive stars, presumably arising from core collapse. Here we report evidence that a very energetic supernova (a hypernova) was temporally and spatially coincident with a GRB at redshift z = 0.1685. The timing of the supernova indicates that it exploded within a few days of the GRB, strongly suggesting that core-collapse events can give rise to GRBs, thereby favouring the 'collapsar' model.

Hjorth+, 2003

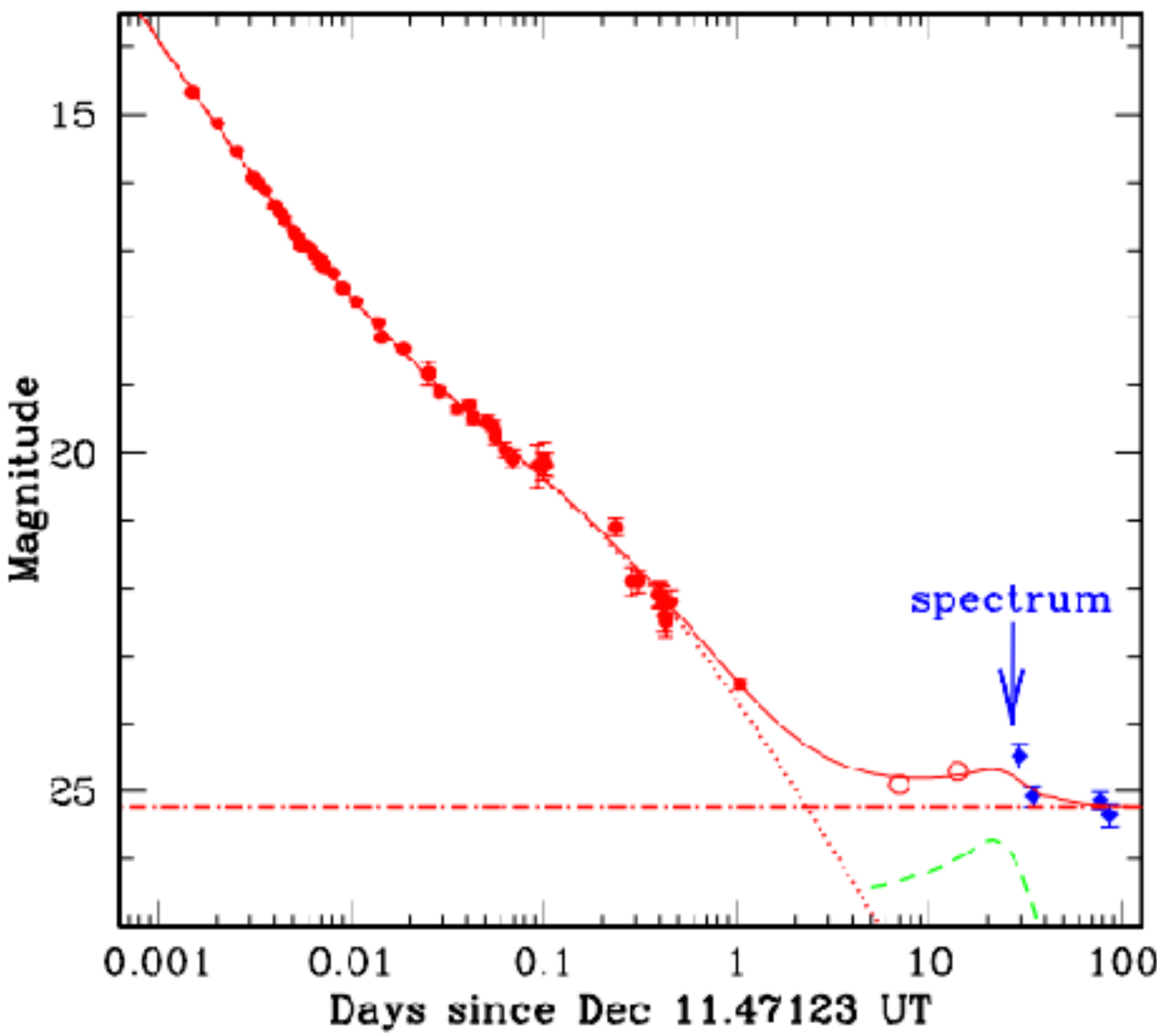


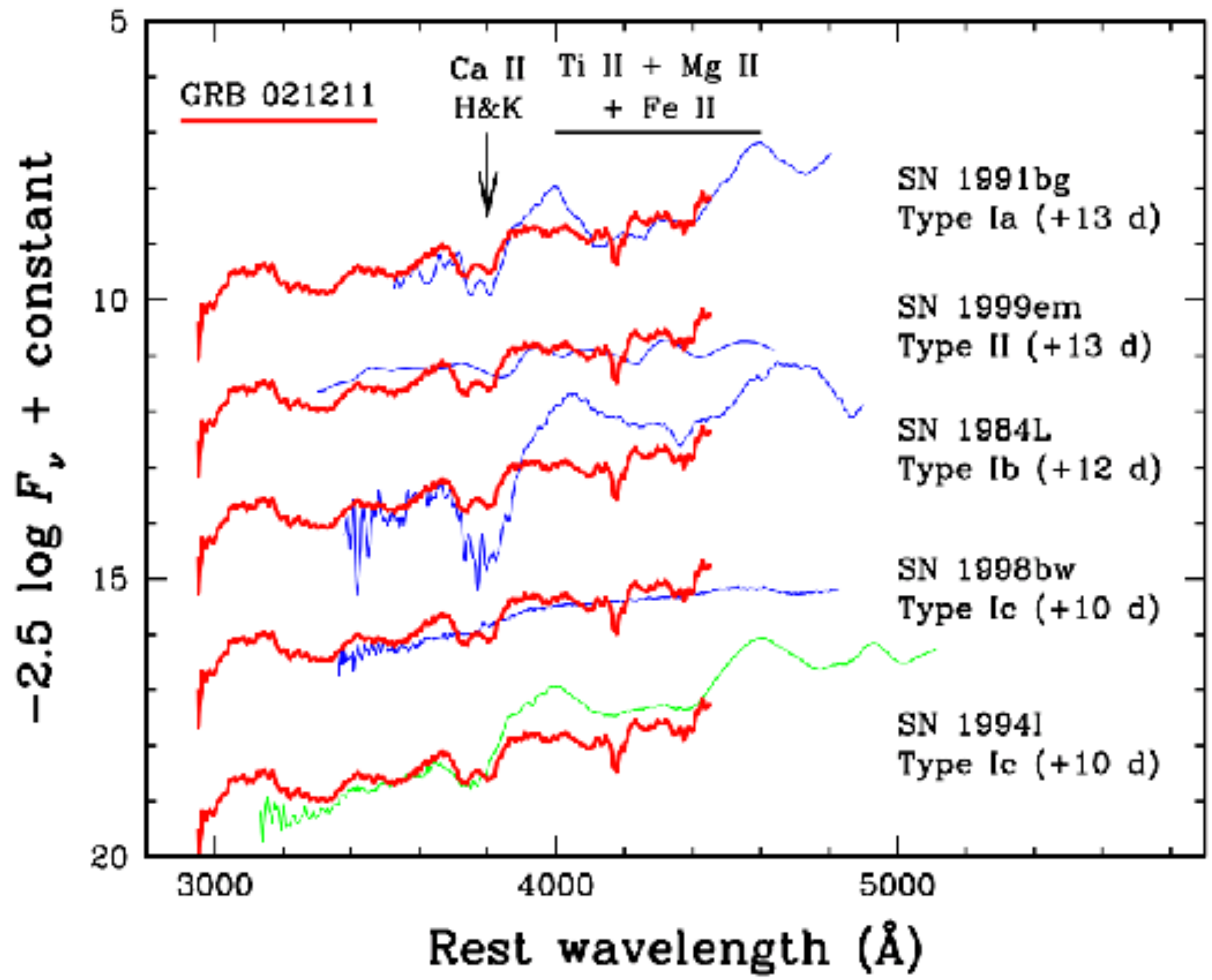
GRB 030329/SN 2003dh
April 3.10
April 8.13
April 10.04
April 17.01
April 22.00
May 1.02
SN 1998bw after 33 d
−15.5
−16.0
−16.5
−17.0
−17.5
log f_λ (erg s^{-1} cm^{-2}Å^{-1})
4000
6000
8000
10000
Observed Wavelength (Å)



SN 2003dh
SN 1998bw
(Patat+ 2001)
4.0 d
7.4 d
8.3 d
8.3 d
9.9 d
12.2 d
15.9 d
15.1 d
20.1 d
20.3 d
27.8 d
27.1 d
f_λ + constant (arbitrary units)
3000
4000
5000
6000
7000
8000
9000
Rest Wavelength (Å)

...and further evidences



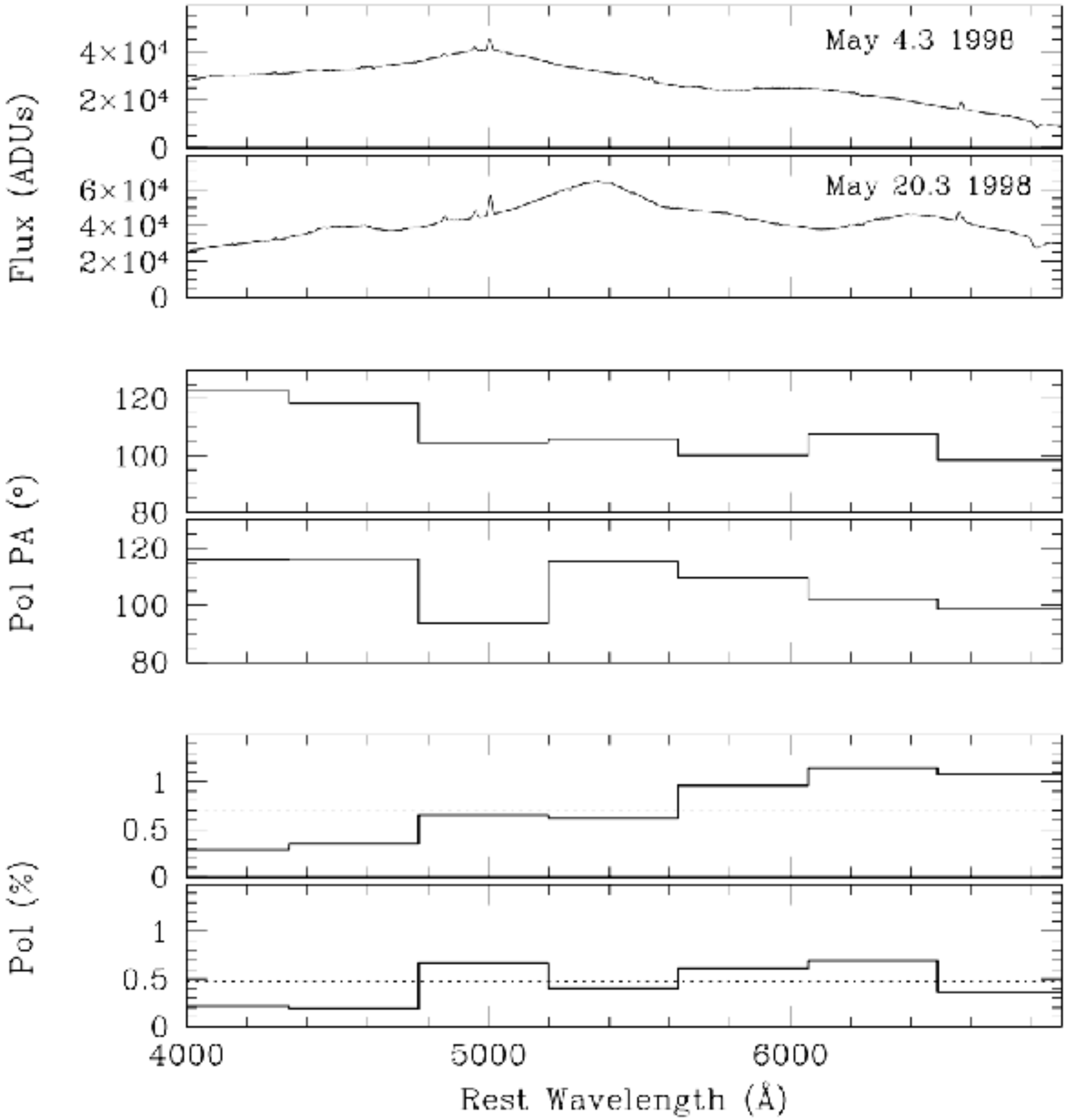


Della Valle+ 2003

The beginning of SN spectropolarimetry at ESO

Kasen, Danie	Analysis of the Flux and Polarization Spectra of the Type Ia Supernova SN 2001el: Exploring the Geometry of the High-Velocity Ejecta	ApJ	593	788-808	2003
Della Valle, I	Evidence for supernova signatures in the spectrum of the late-time bump of the optical afterglow of GRB 021211	A&A	406	L33-L37	2003
Hjorth, Jens,	A very energetic supernova associated with the γ-ray burst of 29 March 2003	Nature	423	847-850	2003
Le Floc'h, E.,	Very Large Telescope and Hubble Space Telescope Observations of the Host Galaxy of GRB 990705	ApJ	581	L81-L84	2002
Fransson, Cl	Optical and Ultraviolet Spectroscopy of SN 1995N: Evidence for Strong Circumstellar Interaction	ApJ	572	350-370	2002
Piro, L., Frail	The Bright Gamma-Ray Burst of 2000 February 10: A Case Study of an Optically Dark Gamma-Ray Burst	ApJ	577	680-690	2002
Castro Ceró	The bright optical afterglow of the long GRB 001007	A&A	393	445-451	2002
Covino, S., L	Polarimetric observations of GRB 011211	A&A	392	865-868	2002
Bloom, J. S.,	The Observed Offset Distribution of Gamma-Ray Bursts from Their Host Galaxies: A Robust Clue to the Nature of the Progenitors	AJ	123	1111-1148	2002
Gorosabel, J	Strategies for prompt searches for GRB afterglows: The discovery of the GRB 001011 optical/near-infrared counterpart using colour-colour selection	A&A	384	23-Nov	2002
Maiolino, R.,	Discovery of two infrared supernovae: A new window on the SN search	A&A	389	84-92	2002
Sollerman, J.	Supernova 1998bw - the final phases	A&A	386	944-956	2002
Jensen, B. L.	The afterglow of the short/intermediate-duration gamma-ray burst GRB 000301C: A jet at z=2.04	A&A	370	909-922	2001
Lazzati, D., (	The optical afterglow of GRB 000911: Evidence for an associated supernova?	A&A	378	996-1002	2001
Björnsson, G	The Jet and the Supernova in GRB 990712	ApJ	552	L121-L124	2001
Vreeswijk, P	VLT Spectroscopy of GRB 990510 and GRB 990712: Probing the Faint and Bright Ends of the Gamma-Ray Burst Host Galaxy Population	ApJ	546	672-680	2001
Andersen, M	VLT identification of the optical afterglow of the gamma-ray burst GRB 000131 at z=4.50	A&A	364	L54-L61	2000

SN1998bw (Patat+)



Kasen, Danie	Analysis of the Flux a of the High-Velocity	788-808	2003
Della Valle, I	Evidence for supern 021211	L33-L37	2003
Hjorth, Jens,	A very energetic sup	847-850	2003
Le Floc'h, E.,	Very Large Telescop	L81-L84	2002
Fransson, Cl	Optical and Ultravio	350-370	2002
Piro, L., Frail	The Bright Gamma-I	680-690	2002
Castro Cerón	The bright optical af	445-451	2002
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Bloom, J. S.,	The Observed Offset Nature of the Proger	111-1148	2002
Gorosabel, J	Strategies for promp counterpart using cc	23-Nov	2002
Maiolino, R.,	Discovery of two inf	84-92	2002
Sollerman, J.	Supernova 1998bw -	944-956	2002
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SPECTROPOLARIMETRY OF THE TYPE Ic SUPERNOVA SN 2002ap IN M74: MORE EVIDENCE FOR ASYMMETRIC CORE COLLAPSE[1]

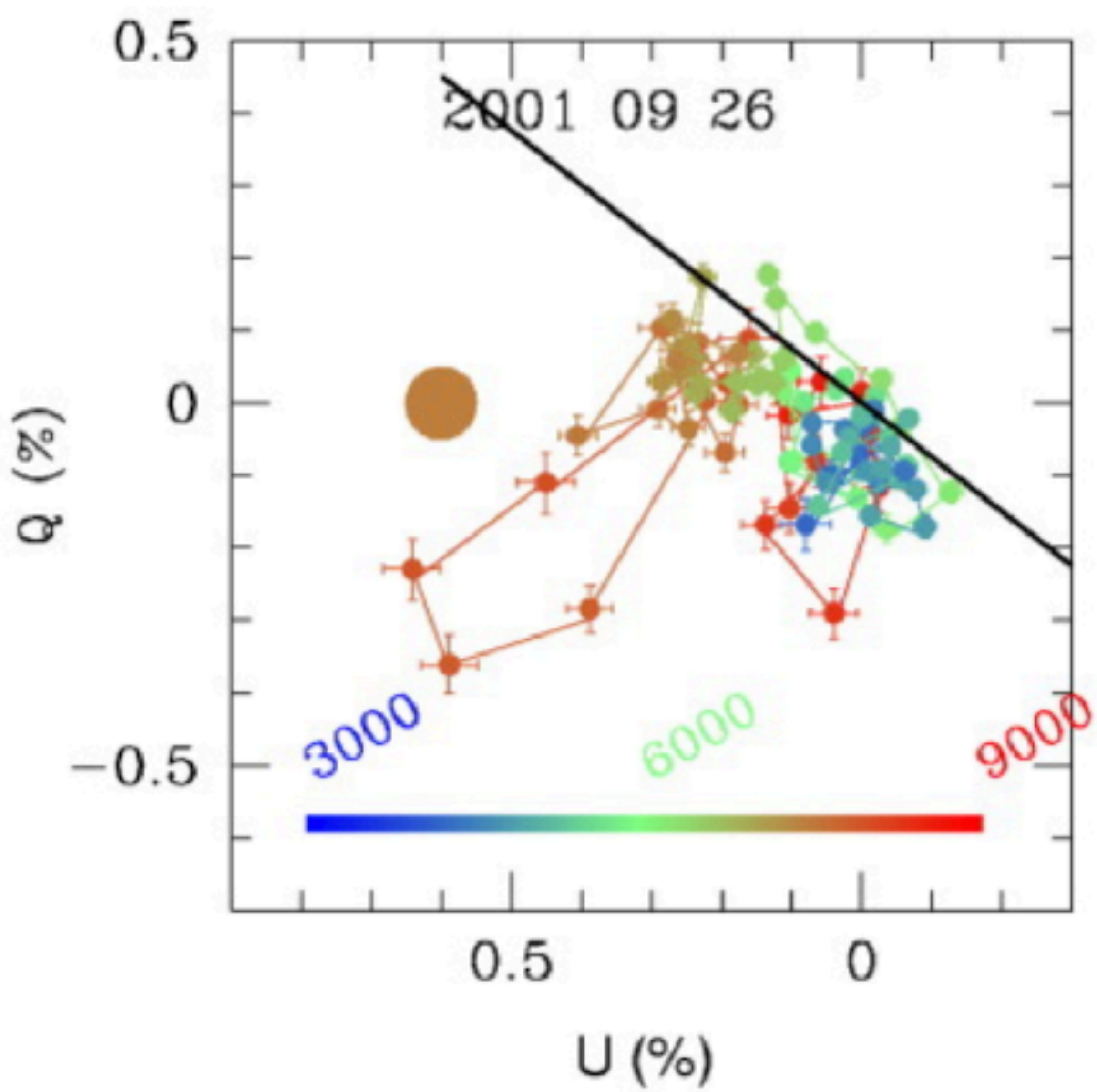
LIFAN WANG,[2] DIETRICH BAADE,[3] PETER HÖFLICH,[4] AND J. CRAIG WHEELER[4]

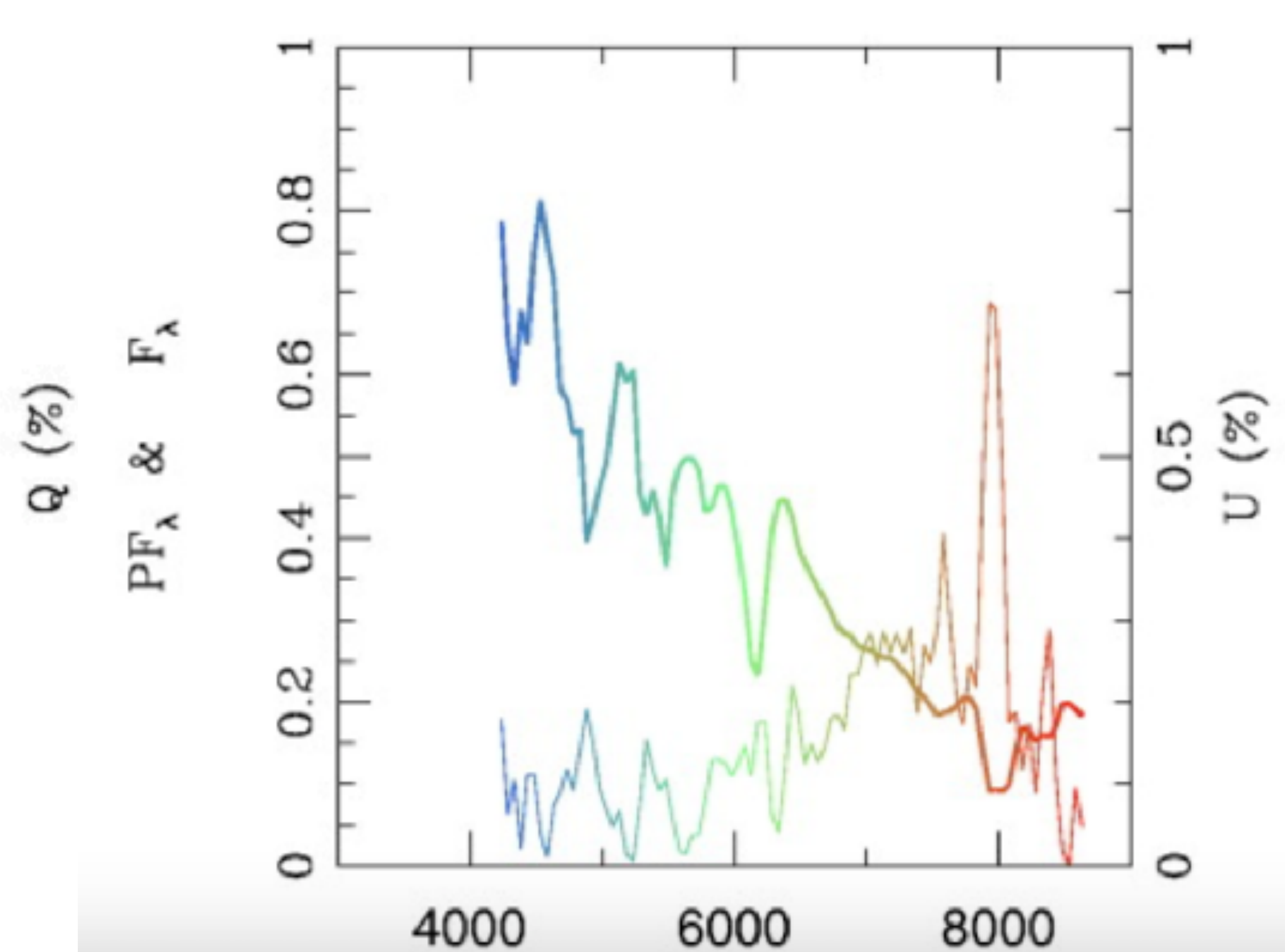
Received 2002 June 19; accepted 2003 March 19

ABSTRACT

High-quality spectropolarimetry (range 417–860 nm; spectral resolution 1.27 nm with 0.265 nm pixel^{-1}) of SN 2002ap was obtained with the ESO Very Large Telescope Melipal (+FORS1) at three epochs that correspond to −6, −2, +1, and +3 days for a *V* maximum of 2002 February 9. The polarization spectra show three distinct broad (~100 nm) features at ~400, 550, and 750 nm that evolve in shape, amplitude, and orientation in the *Q*-*U* plane. The continuum polarization grows from nearly zero to ~0.5%. The 750 nm feature is polarized at a level $\gtrsim$1%. We identify the 550 and 750 nm features as Na I D and O I 777.4 nm moving at about 20,000 km s^{-1}. The blue feature may be Fe II. The position angle of the continuum is ~83°, and that of the O I line is ~133°. This indicates that the ^{56}Ni that provides the continuum luminosity is distributed with a systematically different geometry than that of the fast-moving outer oxygen structure. The lack of significant polarization prior to optical maximum indicates that the photosphere was not extremely highly distorted at early times but became more aspherical toward optical maximum. The structure is consistent with the impact of a bipolar flow from the core that has severely distorted, but is stopped within, the outer envelope of a carbon/oxygen core. The difference in position angle of the oxygen feature and the continuum demands a symmetry breaking that may be difficult to provide in a single-star model. This difference may be a clue to the binary nature of the progenitor. We conclude that the features that characterize SN 2002ap, specifically its high velocity, can be accounted for in an asymmetric model with a larger ejecta mass than SN 1994I such that the photosphere remains longer in higher velocity material. The characteristics of "hypernovae" may be the result of orientation effects in a mildly inhomogeneous set of progenitors, rather than requiring an excessive total energy or luminosity. In the analysis of asymmetric events with spherically symmetric models, it is probably advisable to refer to "isotropic equivalent" energy, luminosity, ejected mass, and nickel mass.

First direct evidence of chemical asymmetries in a Type Ia SN

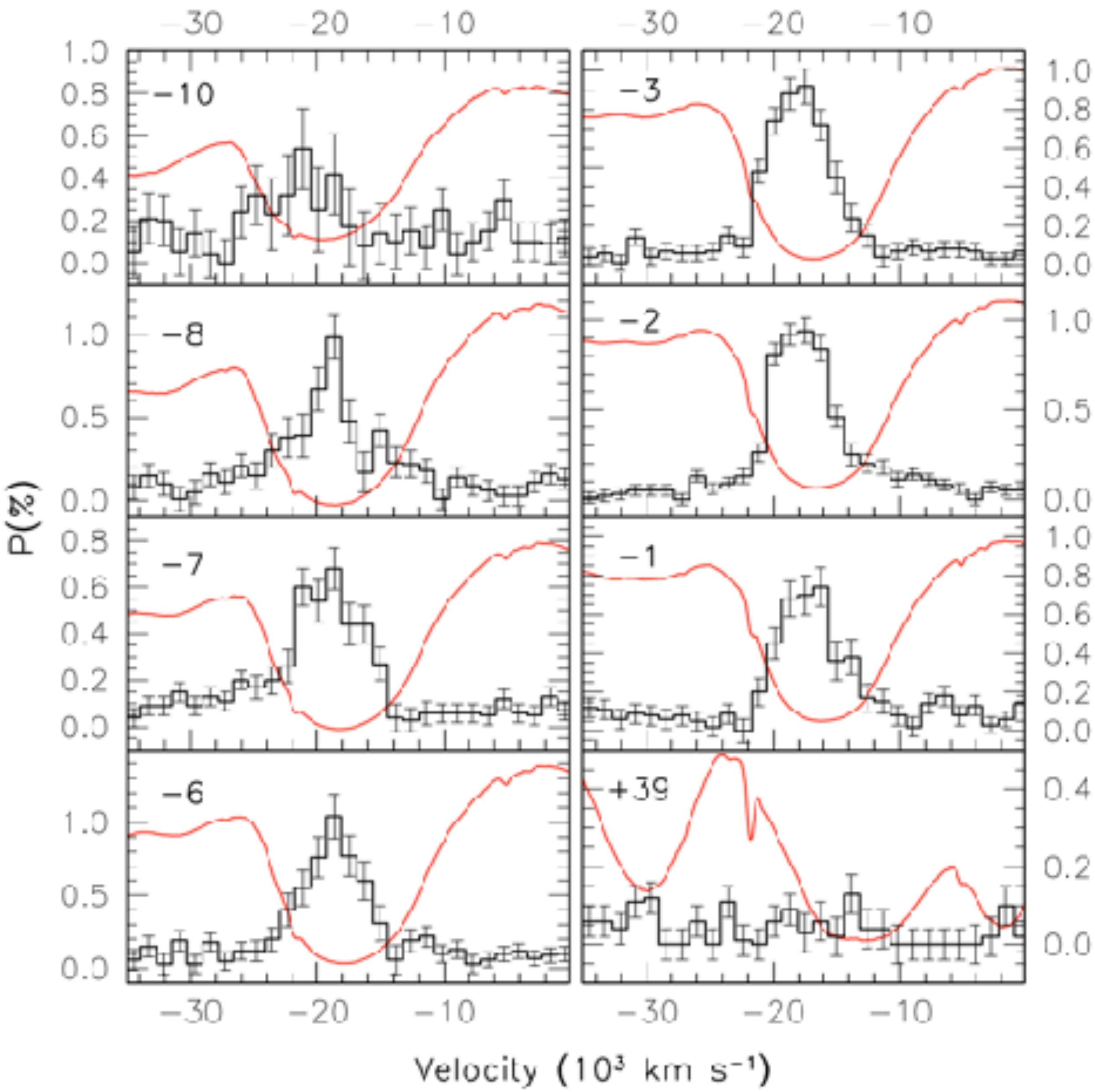




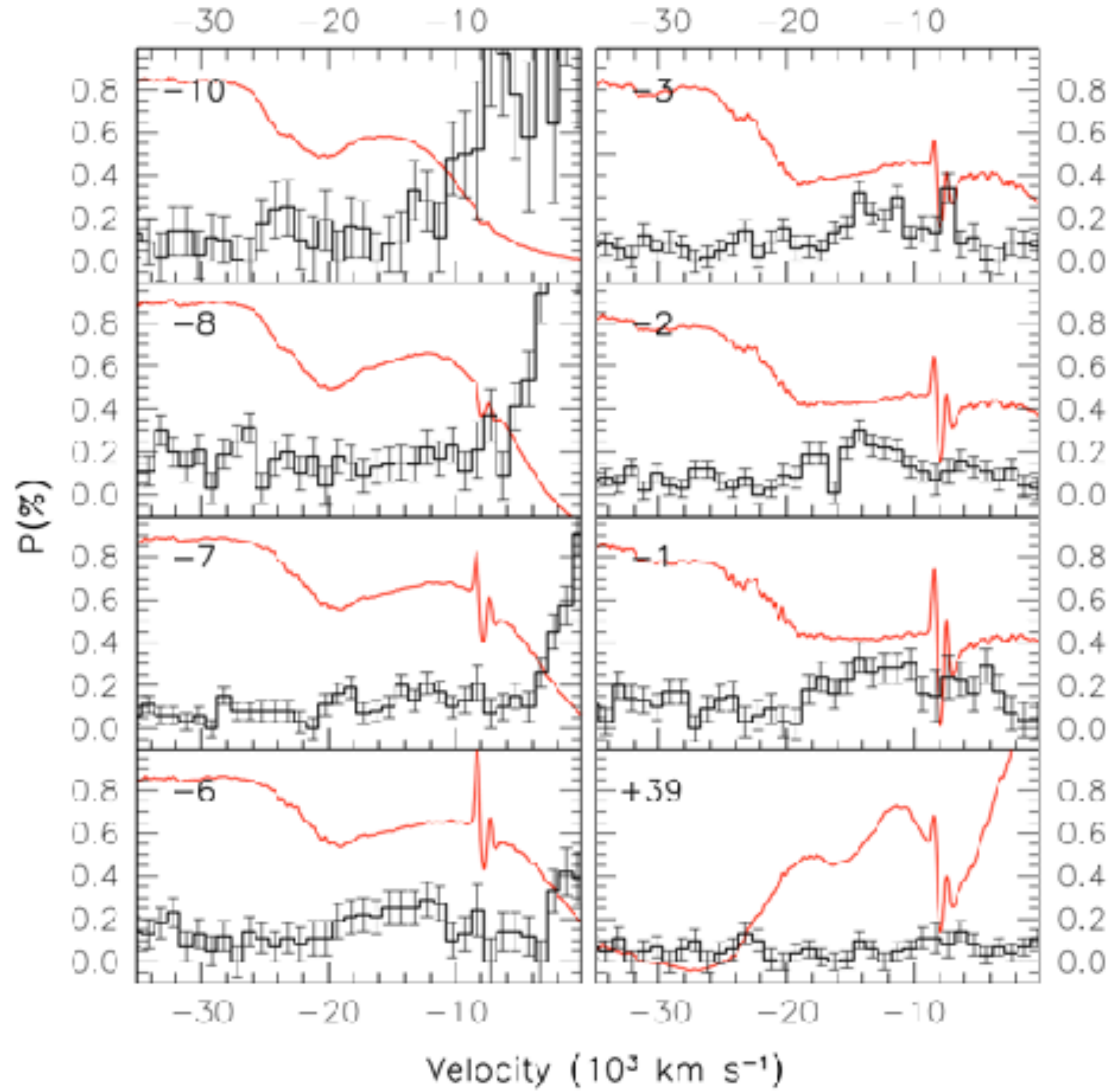
Wang+ 2003

Important insights

SiII



OI



Polarimetry

- 42 refereed papers (10%), 1805 citations (4.5%)
- 6 with >10 cit/yr
- Remains a niche technique
- Nice results, but not yet conclusive for SNe
- Important results for GRBs (linear+circular detections)
- Photon-starving, very low sample increase rate…

Other FORS-based hits

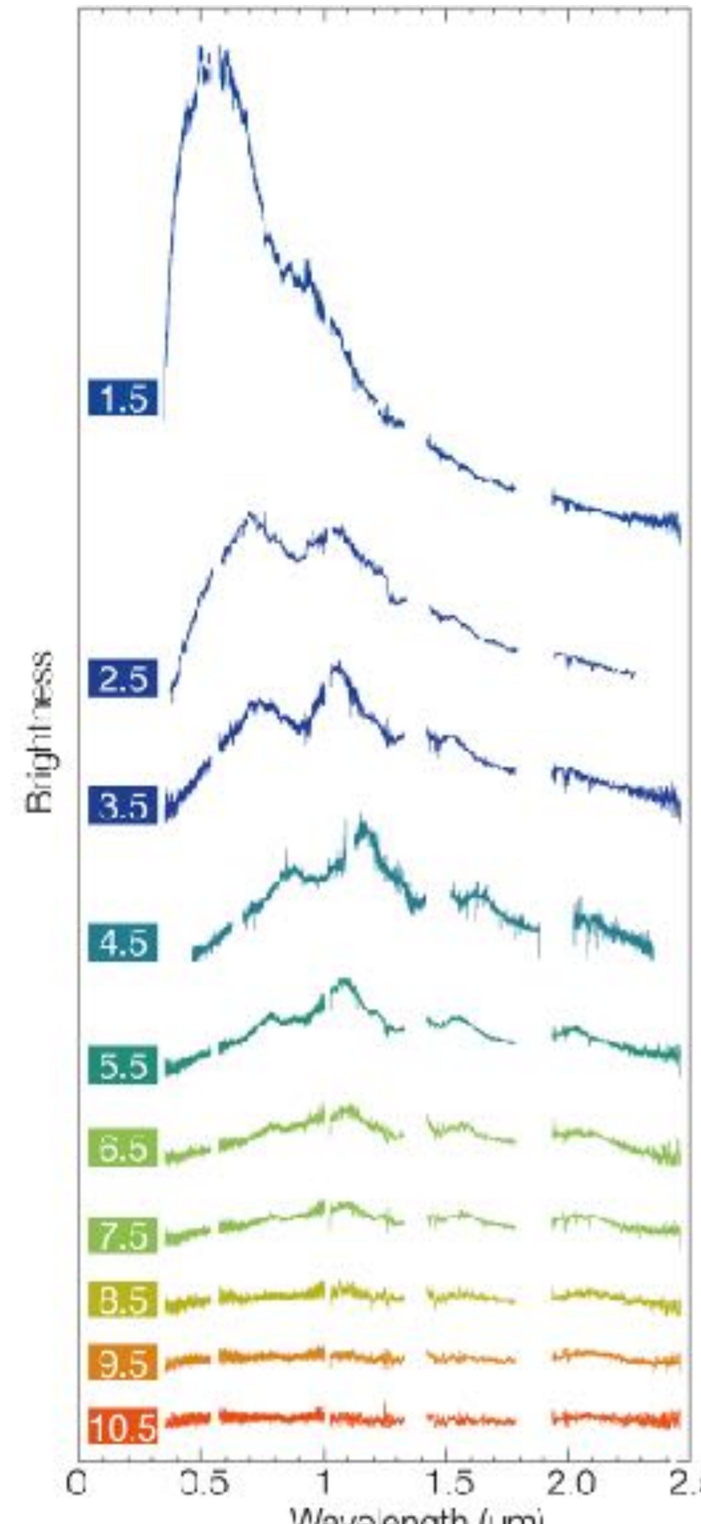
- **Malesani+, 2004**, *SN 2003lw and GRB 031203: A Bright Supernova for a Faint Gamma-Ray Burst* (358)
- **Mazzali+, 2006**, *A neutron-star-driven X-ray flash associated with supernova SN 2006aj* (253)
- **Fynbo+, 2006**, *No supernovae associated with two long-duration γ-ray bursts* (325)
- **Della Valle+, 2006**, *An enigmatic long-lasting γ-ray burst not accompanied by a bright supernova* (329)
- **Pian+, 2006**, *An optical supernova associated with the X-ray flash XRF 060218* (408)
- **Fynbo+, 2009**, *Low-resolution Spectroscopy of Gamma-ray Burst Optical Afterglows: Biases in the Swift Sample and Characterization of the Absorbers* (292)

take home

- The FORSes made a major contribution in the field of GRBs, and in the association between long-duration GRB and supernovae.
- They contributed to large-scale projects in the SN Type Ia/cosmology field (SN Legacy Survey, ESSENCE, SN Factory, …), in synergy with Gemini, Keck, Subaru, HST
- They generated a wealth of data for single SNe of all types

FORS in the GW era

- All started with the Ligo-Virgo O2 campaign
- The ESO community was ready to react, with approved ToO programmes on X-S, FORS2, …
- X-Shooter played THE role: the spectral sequence is just a marvel in itself



First polarization measurements in a GW

The unpolarized macronova associated with the gravitational wave event GW170817

S. Covino, K. Wiersema, Y. Z. Fan, K. Toma, A. B. Higgins, A. Melandri, P. D'Avanzo, C. G. Mundell, E. Palazzi, N. R. Tanvir, M. G. Bernardini, M. Branchesi, E. Brocato, S. Campana, S. di Serego Alighieri, D. Gotz, J. P. U. Fynbo, W. Gao, A. Gomboc, B. Gompertz, J. Greiner, J. Hjorth, Z. P. Jin, L. Kaper, S. Klose, S. Kobayashi, D. Kopac, C. Kouveliotou, A. J. Levan, J. Mao, D. Malesani, E. Pian, A. Rossi, R. Salvaterra, R. L. C. Starling, I. Steele, G. Tagliaferri, E. Troja, A. J. van der Horst, R. A. M. J. Wijers

(Submitted on 16 Oct 2017)

The merger of two dense stellar remnants including at least one neutron star (NS) is predicted to produce gravitational waves (GWs) and short duration gamma ray bursts (GRBs). In the process, neutron-rich material is ejected from the system and heavy elements are synthesized by r-process nucleosynthesis. The radioactive decay of these heavy elements produces additional transient radiation termed "kilonova" or "macronova". We report the detection of linear optical polarization P = (0.50 +/- 0.07)% at 1.46 days after detection of the GWs from GW170817, a double neutron star merger associated with an optical macronova counterpart and a short GRB. The optical emission from a macronova is expected to be characterized by a blue, rapidly decaying, component and a red, more slowly evolving, component due to material rich of heavy elements, the lanthanides. The polarization measurement was made when the macronova was still in its blue phase, during which there is an important contribution from a lanthanide-free outflow. The low degree of polarization is consistent with intrinsically unpolarized emission scattered by Galactic dust, suggesting a symmetric geometry of the emitting region and low inclination of the merger system. Stringent upper limits to the polarization degree from 2.45 - 9.48 days post-burst are consistent with the lanthanides-rich macronova interpretation.

and follow-up

The origin of polarization in kilonovae and the case of the gravitational-wave counterpart AT 2017gfo

M. Bulla, S. Covino, K. Kyutoku, M. Tanaka, J. R. Maund, F. Patat, K. Toma, K. Wiersema, J. Bruten, Z. P. Jin, V. Testa

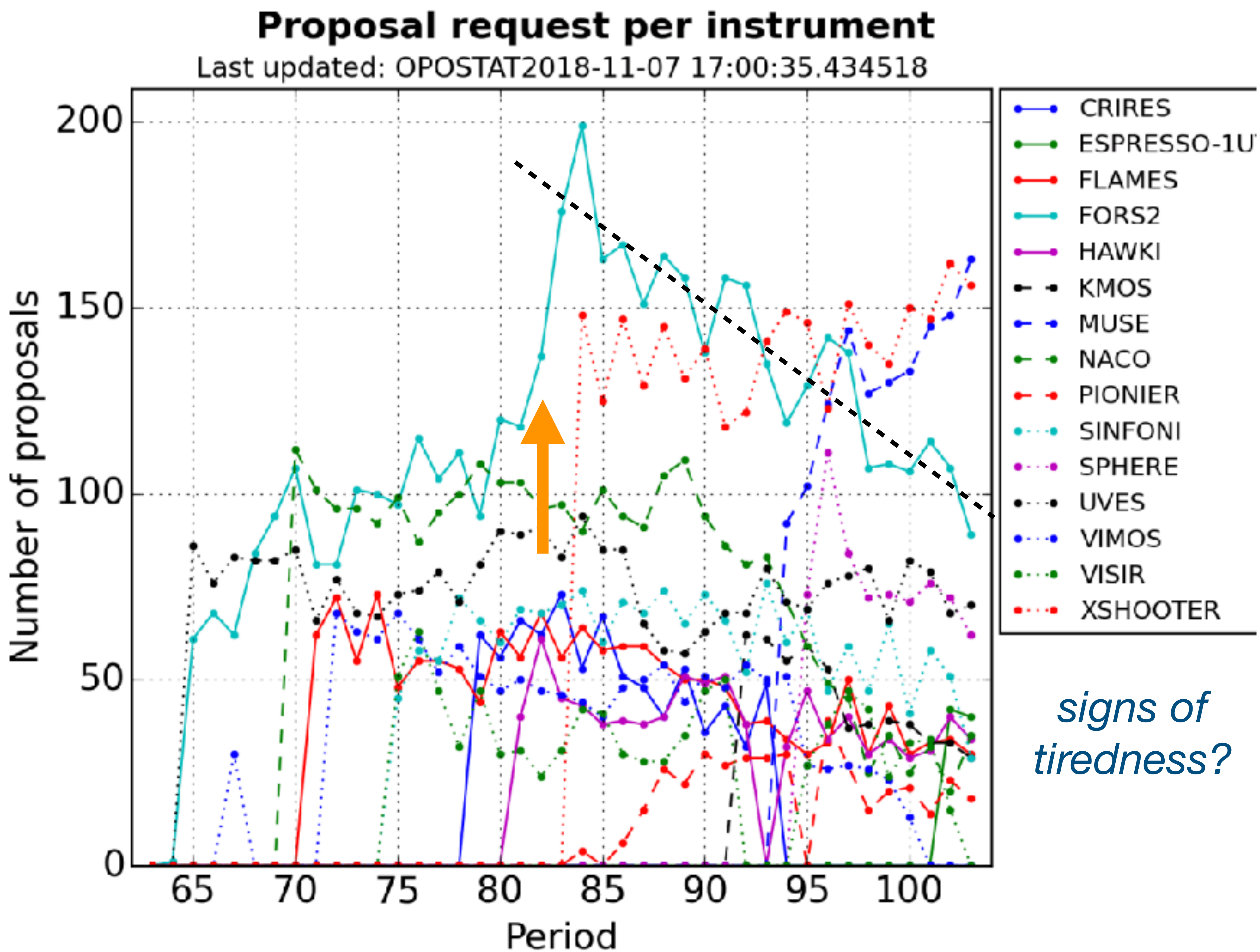
(Submitted on 11 Sep 2018 (v1), last revised 20 Nov 2018 (this version, v2))

The Gravitational Wave (GW) event GW 170817 was generated by the coalescence of two neutron stars (NS) and produced an electromagnetic transient, labelled AT 2017gfo, that was target of a massive observational campaign. Polarimetry, a powerful diagnostic tool for probing the geometry and emission processes of unresolved sources, was obtained for this event. The observed linear polarization was consistent with being mostly induced by intervening dust, suggesting that the intrinsic emission was weakly polarized ($P < 0.4 - 0.5$ %). In this paper, we present and discuss a detailed analysis of the linear polarization expected from a merging NS binary system by means of 3D Monte Carlo radiative transfer simulations assuming a range of possible configurations, wavelengths, epochs and viewing angles. We find that polarization originates from the non-homogeneous opacity distribution within the ejecta and can reach levels of $P \sim 1$ % at early times (1–2 days after the merger) and in the optical R band. Smaller polarization signals are expected at later epochs and/or different wavelengths. From the viewing-angle dependence of the polarimetric signal, we constrain the observer orientation of AT 2017gfo within ~65° from the polar direction. The detection of non-zero polarization in future events will unambiguously reveal the presence of a lanthanide-free ejecta component and unveil its spatial and angular distribution.

- Very appealing to the GW community, for better constraining the system configuration.

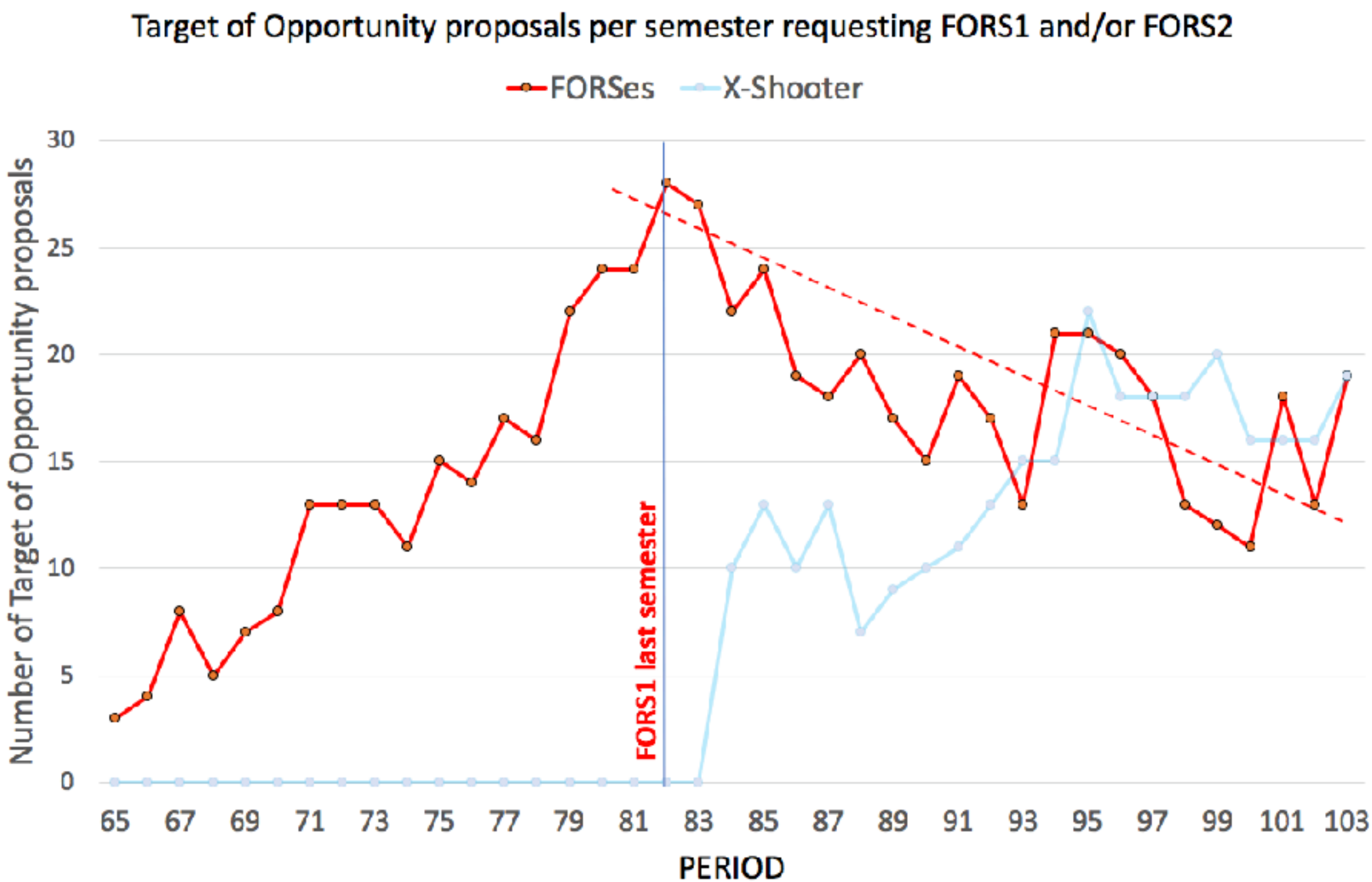
The FOReSeeable Future

- Is FORS becoming obsolete?



signs of tiredness?

FORS TOO Science too?



Where do we go from here?

- FORS remains a chief instrument for ToO science at ESO (often also requested to compensate the unavailability of X-S)
- The imaging [and polarimetric] capabilities somehow balance out the spectral coverage of X-Shooter, but…
- There are indications of a loss-of-interest for ToO science with FORS, with a possible gradual "migration" to X-Shooter
- Ideally, one would like to have a ForShooter, combining spectral range, imaging and polarimetric capabilities all in one.

May the FORSes be with you