The Host Galaxies of Fast Radio Bursts with ASKAP and the VLT

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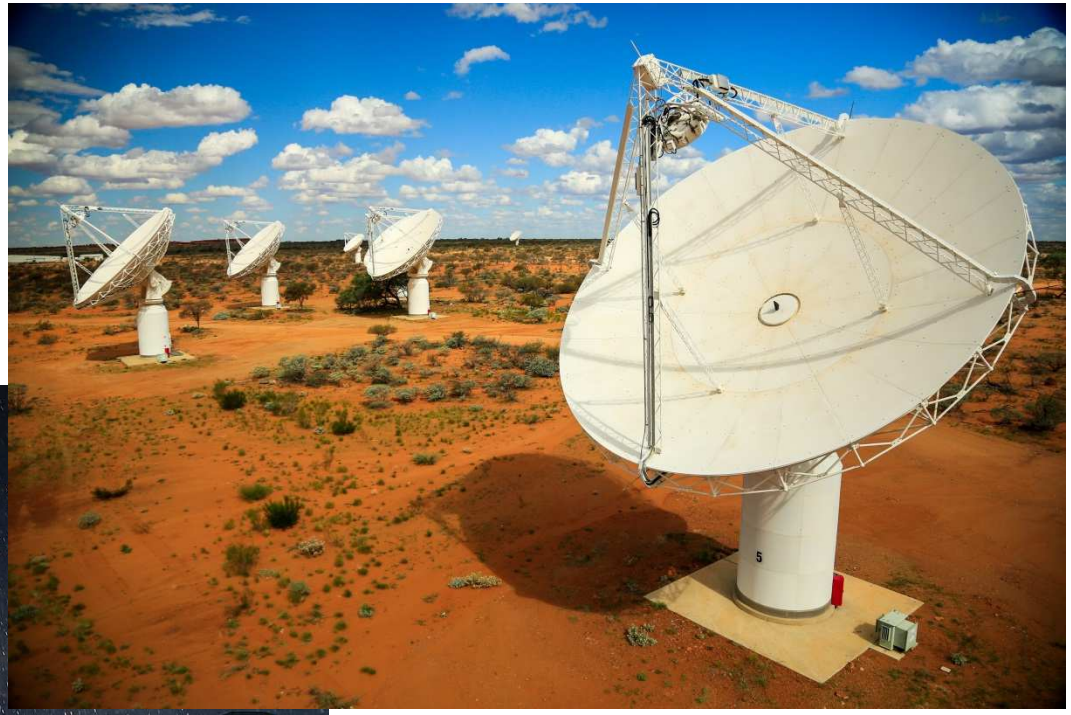

On behalf of the CRAFT collaboration

Overview

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- What is a Fast Radio Burst (FRB)?
- Circumstantial localisation: FRB 171020.
- The first ASKAP localisation: FRB 180924.
- Probing a galaxy halo with FRB 181112.
- Do FRBs have SN-like optical counterparts?
- Recap

What is an FRB?

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- *Fast:* typically < 10 milliseconds.
- *Radio:* detected at 0.5–10 GHz, no counterparts at other wavelengths.
- *Bursts:* (almost) never repeat, flux densities 10^{10} x greater than pulsars.
- Rate of 10^{3} – 10^{4} sky^{-1} day^{-1}.
- Occur at cosmological distances.

The “Repeater”

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- FRB 121102 (Spitler et al. 2014) displays sporadic repeat bursts with same DM $\Rightarrow$ not cataclysmic.
- Enabled localisation to 0.01" with JVLA & EVN.
- Host is a low-metallicity, star-forming dwarf *r* ~25 mag galaxy at z=0.2 (Tendulkar et al. 2017).
- FRB associated with a persistent, compact radio source and star-forming knot $\Rightarrow$ magnetar?

“Flys eye” FRB survey

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Shannon et al. (2018, Nature) found 23 FRBs in 14 months during ASKAP commissioning.

FRB 171020

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- FRB 171020 had DM = 114 pc cm^{-3}, so expect $z < 0.08$.
- Spectroscopy with VLT/X-shooter all but eliminated WISE/SuperCOSMOS sources as host.
- Most likely host is ESO 601-G036, an Sc galaxy at z=0.009, with signs of tidal interaction.
- ~1 mag brighter in *R* than FRB 121102 host + no continuum radio emission comparable to the persistent source.

FRB 171020

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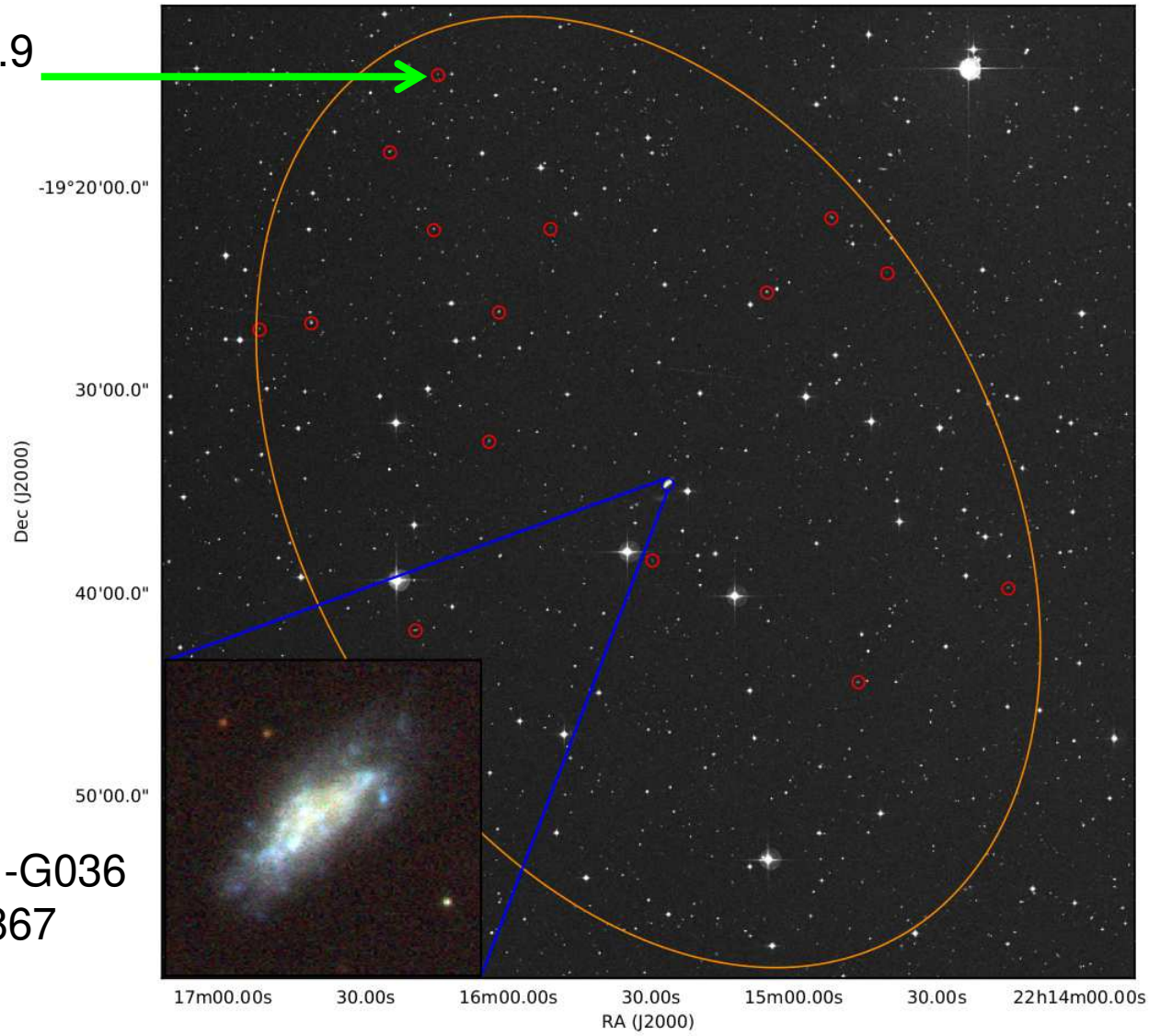
J221621.59-191829.9
z = 0.024

Mahony et al. 2018,
ApJL, 867:L10

ESO 601-G036
z = 0.00867



The search begins

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Two weeks of searching in interferometric mode in Sep 2018 turned up nothing, until…

FRB 180924

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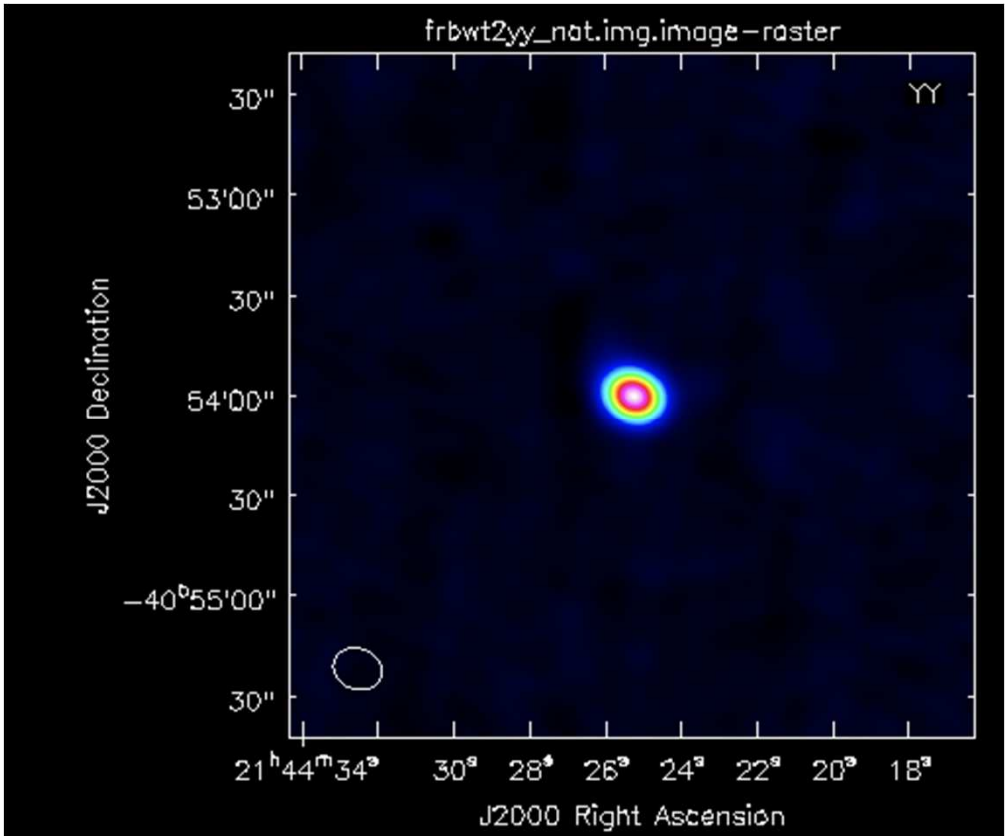
RA = $21^h\ 44^m\ 25.255^s \pm 0.008^s$

Dec = –40° 54' 00".1 ± 0".1

No repeat burst, or persistent radio counterpart observed.



The host galaxy of FRB 180924

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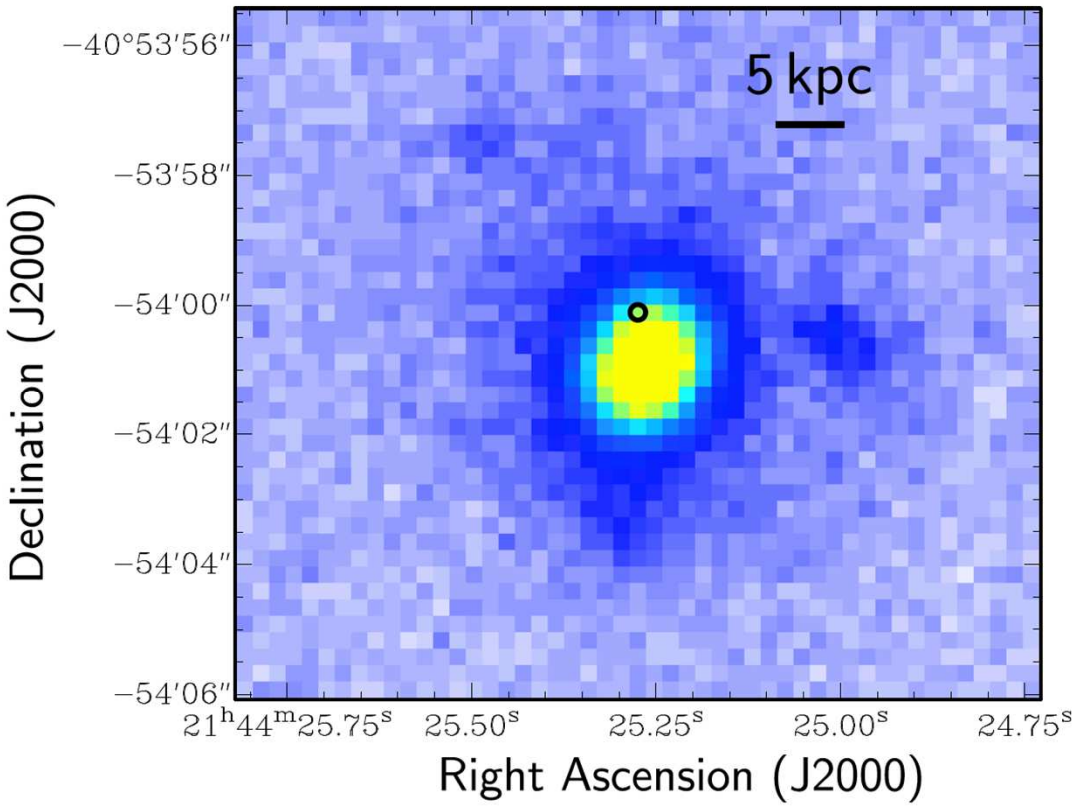
- VLT FORS2 *g*-band 2500s exposure.
- DES J214425.25–405400.81.
- $r = 20.54 \pm 0.02$.
- z = 0.3214 (KCWI)
  $\Rightarrow D$ ~ 1300 Mpc.
- $M_* \sim 2.2 \times 10^{10}\ M_\odot$.
- SFR < 2 $M_\odot\ yr^{-1}$.



Science 27 June 2019

RESEARCH ARTICLES

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A single fast radio burst localized to a massive galaxy at cosmological distance

K. W. Bannister[1*], A. T. Deller[2], C. Phillips[1], J.-P. Macquart[3], J. X. Prochaska[4,5], N. Tejos[6], S. D. Ryder[7], E. M. Sadler[1,8], R. M. Shannon[2*], S. Simha[4], C. K. Day[2], M. McQuinn[9], F. O. North-Hickey[3], S. Bhandari[1], W. R. Arcus[3], V. N. Bennert[10], J. Burchett[6], M. Bouwhuis[1,11], R. Dodson[12], R. D. Ekers[1,3], W. Farah[2], C. Flynn[2], C. W. James[3], M. Kerr[13], E. Lenc[1], E. K. Mahony[1], J. O'Meara[14], S. Osłowski[2], H. Qiu[1,8], T. Treu[15], V. U[16], T. J. Bateman[8], D. C.-J. Bock[1], R. J. Bolton[1], A. Brown[1], J. D. Bunton[1], A. P. Chippendale[1], F. R. Cooray[1], T. Cornwell[17], N. Gupta[18], D. B. Hayman[1], M. Kesteven[1], B. S. Koribalski[1], A. MacLeod[1], N. M. McClure-Griffiths[19], S. Neuhold[1], R. P. Norris[1,20], M. A. Pilawa[1], R.-Y. Qiao[1], J. Reynolds[1], D. N. Roxby[1], T. W. Shimwell[21], M. A. Voronkov[1], C. D. Wilson[1]

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Alien signal? Cosmic mystery of 'fast radio bursts' from space baffles astronomers

ASTRONOMERS have pinpointed the location of unexplained radio signals from a distant galaxy – but could this be proof of alien life?

By TOM FISH

PUBLISHED: 18:29, Thu, Jul 4, 2019 | UPDATED: 19:35, Thu, Jul 4, 2019

5 days later…

MACQUARIE University

nature
International journal of science

Letter | Published: 02 July 2019

A fast radio burst localized to a massive galaxy

V. Ravi ✉, M. Catha, L. D Addario, S. G. Djorgovski, G. Hallinan, R. Hobbs, J. Kocz, S. R. Kulkarni, J. Shi, H. K. Vedantham, S. Weinreb & D. P. Woody

Nature (2019) | Download Citation ⬇

FRB 190523

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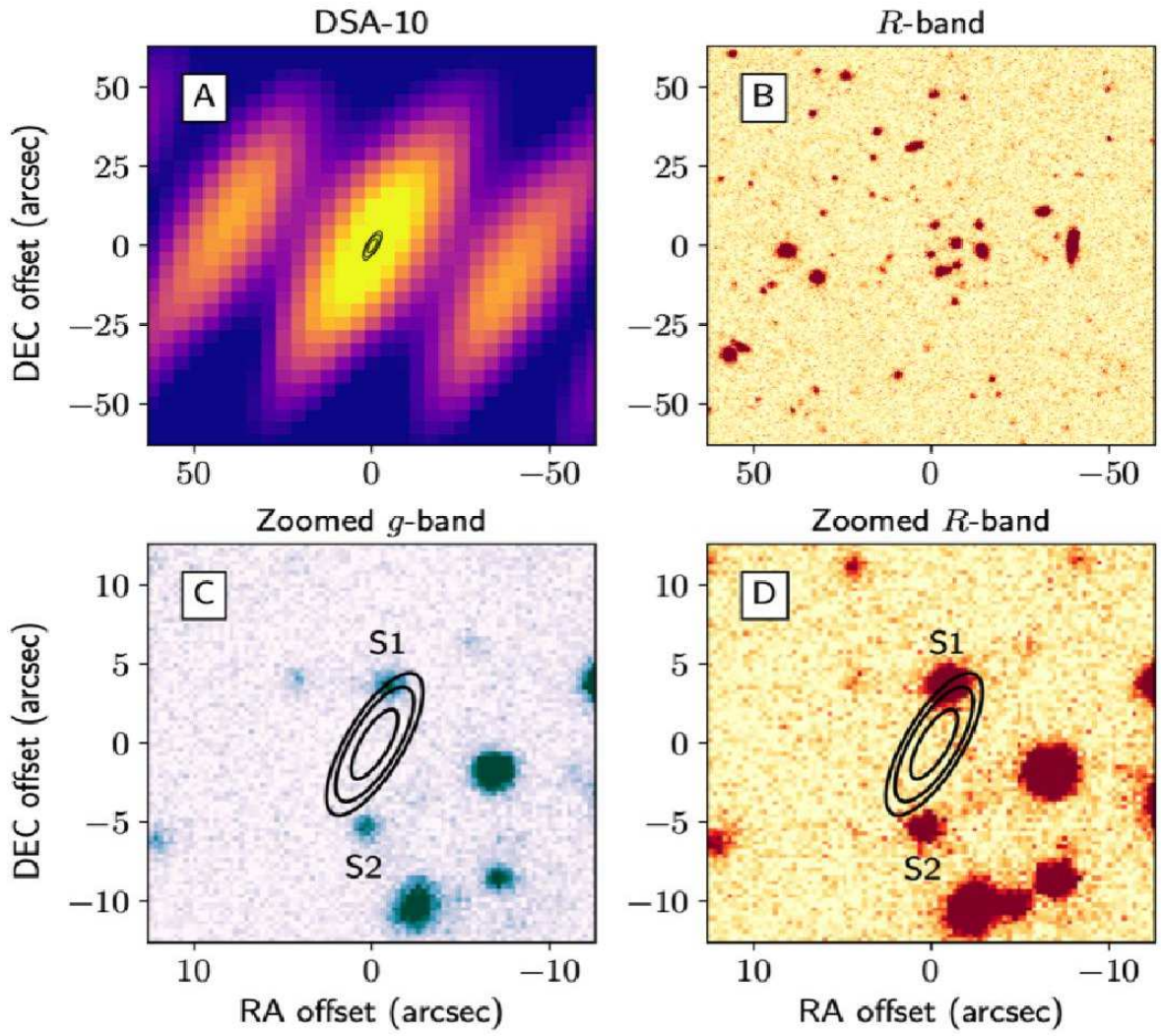

FRB 181112

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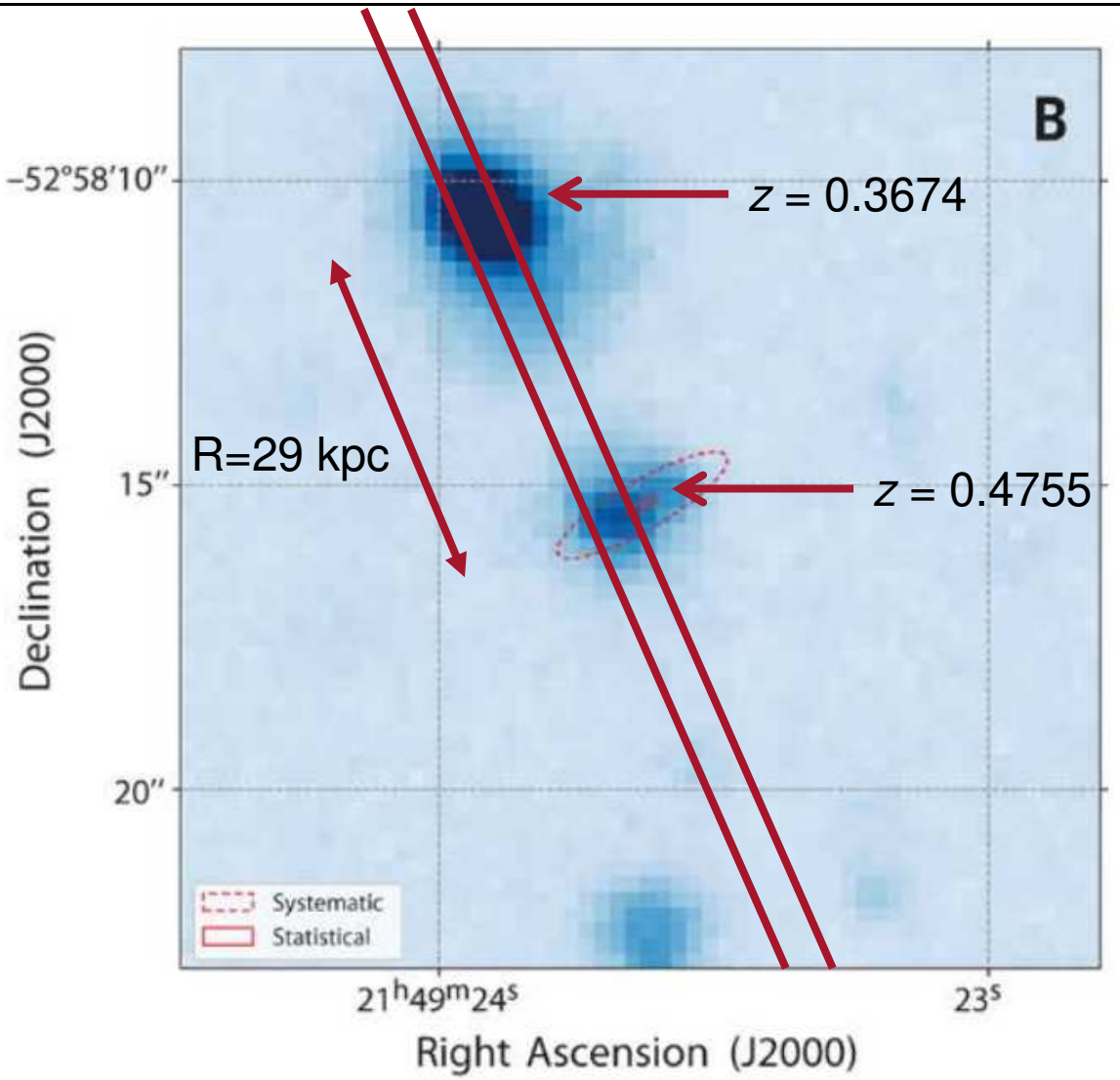
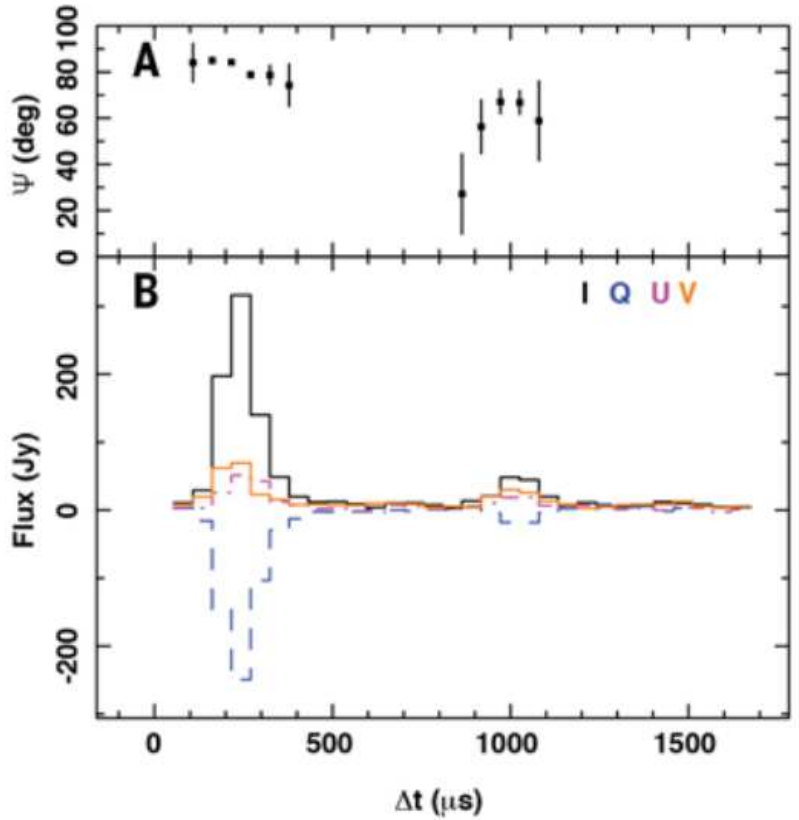
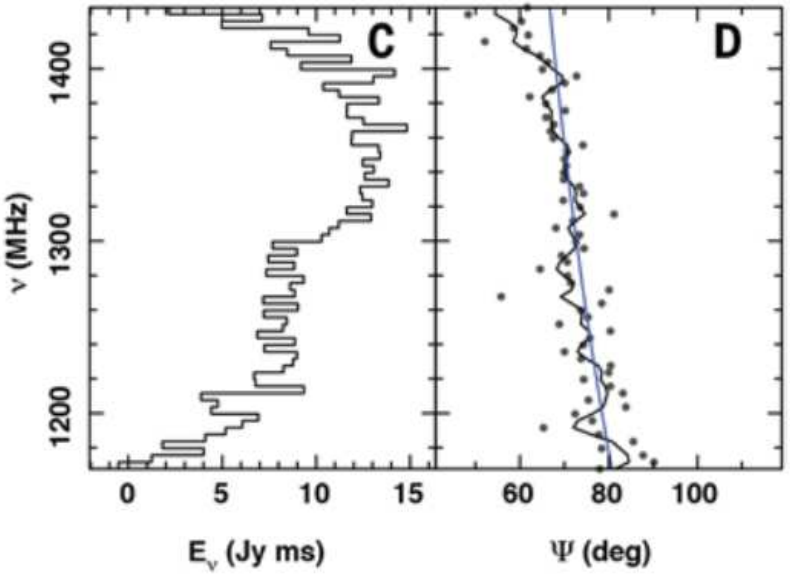
- Foreground galaxy has $M^* = 10^{10.7}\ M_\odot$
- Seyfert nuclear spectrum ⇒ expect temporal smearing of FRB pulse due to turbulence in halo.



Halo? What halo?





τ_{scatt} < 40 μsec constrains $\langle n_e \rangle$ <~10^{-3} cm^{-3} (*cf.* ~0.1 cm^{-3} for pressure equilibrium with T~3 × 10^6K halo gas) and low turbulence.

RM = 10.9 rad m^{-2} ⇒
$B_{||}$ (max) < 0.8 μG
(cf. ~10 μG from RM of Mg II absorbers in halos of normal galaxies probed by QSOs – Bernet+08).

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REPORTS

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The low density and magnetization of a massive galaxy halo exposed by a fast radio burst

J. Xavier Prochaska[1,2]*, Jean-Pierre Macquart[3], Matthew McQuinn[4], Sunil Simha[1], Ryan M. Shannon[5], Cherie K. Day[5,6], Lachlan Marnoch[6,7], Stuart Ryder[7], Adam Deller[5], Keith W. Bannister[6], Shivani Bhandari[6], Rongmon Bordoloi[8], John Bunton[6], Hyerin Cho[9], Chris Flynn[5], Elizabeth K. Mahony[6], Chris Phillips[6], Hao Qiu[10], Nicolas Tejos[11]

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Are FRBs associated with SN-like optical transients?

Lachlan Marnoch, MRes 2019, Macquarie University

Are FRBs associated with SN-like optical transients?

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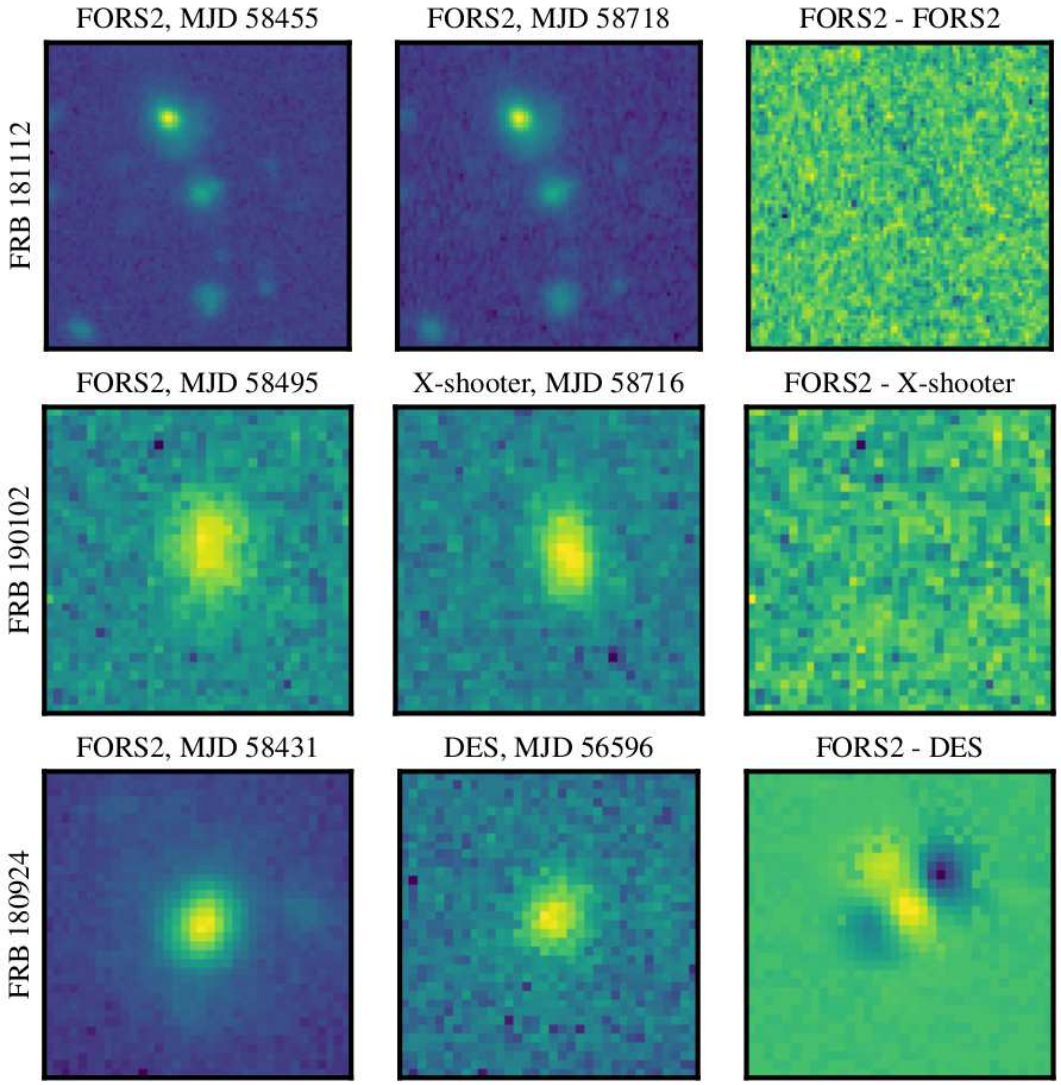
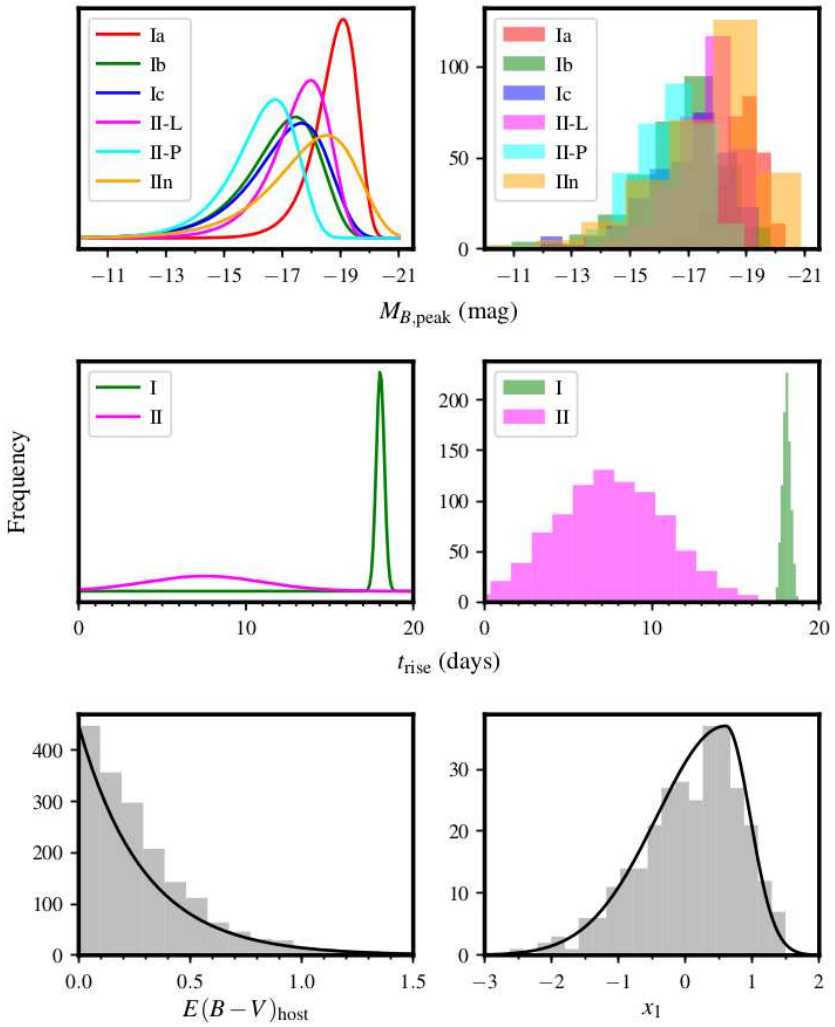
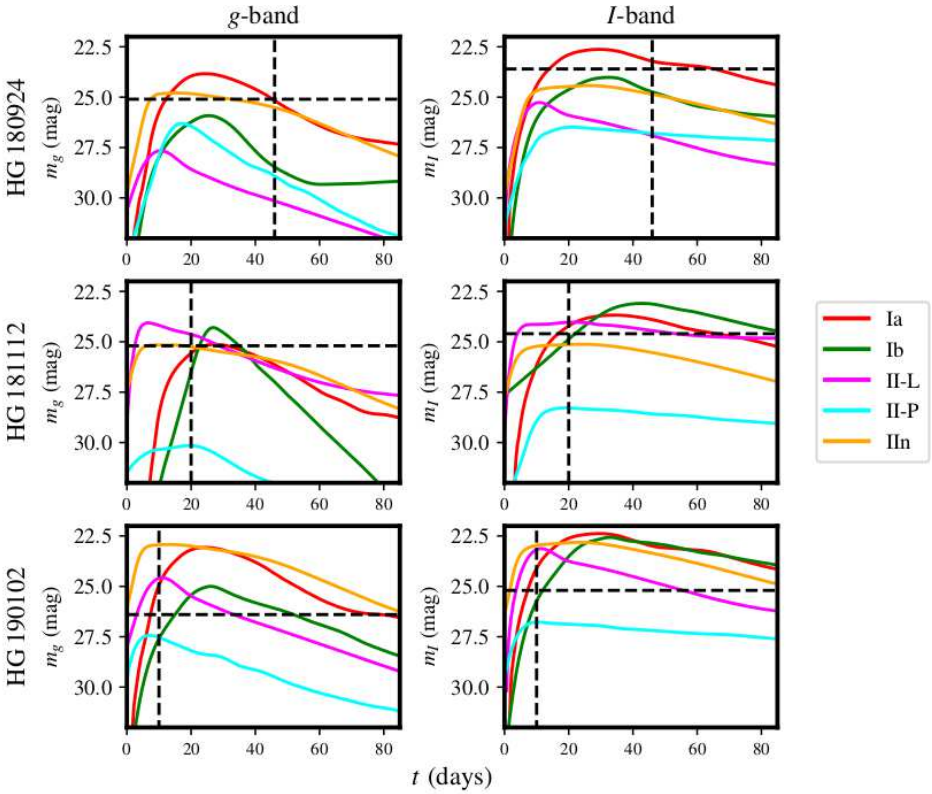


Are FRBs associated with SN-like optical transients?





Are FRBs associated with SN-like optical transients?

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FRB	180924		181112		190102		Combined		190608	
Band	*g*	*I*	*g*	*I*	*g*	*I*	*g*	*I*	*g*	*I*
Limit at burst position (mag)										
FORS2 template	25.1	23.6	25.2	24.6	26.4	25.2	-	-	-	-
X-shooter template	24.7	22.7	25.9	24.0	24.3	-	-	-	22.6	22.5
Probability of non-detection					T + 10d					
Type Ia	34%	12%	44%	34%	78%	88%	12%	4%	95%	69%
Type Ib	94%	54%	91%	91%	99%	99%	85%	49%	98%	77%
Type Ic	94%	49%	88%	80%	98%	98%	82%	39%	97%	81%
Type IIn	40%	41%	34%	47%	39%	65%	6%	13%	82%	70%
Type II-L	69%	48%	78%	79%	63%	76%	34%	29%	90%	79%
Type II-P	89%	73%	75%	89%	74%	90%	50%	59%	96%	86%

Are FRBs associated with SN-like optical transients?

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- Type Ia / IIn in all 3 hosts? Almost certainly not.
- Type Ib/c, IIL, IIP? Possible, but unlikely.
- Superluminous SNe? No.
- Kilonovae? Can’t say.
- TDEs/AGN flares? No, radial offsets too large.

In summary

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- Localising FRBs to/within host galaxies is shedding new light on the nature of progenitors, and the IGM.
- Galaxy halos may not be as turbulent, or magnetically supported as we assumed.
- We can already all but rule out some progenitors (Type Ia & IIn SNe, AGN) to FRBs.
- ASKAP + ESO/VLT are ideally suited to exploiting FRBs as cosmological tools.