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

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On behalf of the CRAFT collaboration
Overview

• 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?

- **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”

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

Shannon et al. (2018, Nature) found 23 FRBs in 14 months during ASKAP commissioning.
• 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.
• $\sim 1$ mag brighter in $R$ than FRB 121102 host + no continuum radio emission comparable to the persistent source.
FRB 171020

J221621.59-191829.9  
z = 0.024


ESO 601-G036  
z = 0.00867
The search begins

Two weeks of searching in interferometric mode in Sep 2018 turned up nothing, until…
FRB 180924

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

Dec = $-40^\circ 54' 00''.1 \pm 0''.1$

No repeat burst, or persistent radio counterpart observed.
The host galaxy of FRB 180924

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

![Galaxy Image]
A single fast radio burst localized to a massive galaxy at cosmological distance


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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

5 days later...

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A fast radio burst localized to a massive galaxy


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FRB 190523
• Foreground galaxy has $M^* = 10^{10.7} \, M_\odot$
• Seyfert nuclear spectrum $\Rightarrow$ expect temporal smearing of FRB pulse due to turbulence in halo.
Halo? What halo?

$\tau_{\text{scatt}} < 40 \, \mu\text{sec}$ constrains $\langle n_e \rangle < 10^{-3} \, \text{cm}^{-3}$ (cf. $\sim 0.1 \, \text{cm}^{-3}$ for pressure equilibrium with $T \sim 3 \times 10^6 \text{K}$ halo gas) and low turbulence.

$\text{RM} = 10.9 \, \text{rad m}^{-2} \Rightarrow B_{\parallel} (\text{max}) < 0.8 \, \mu\text{G}$ (cf. $\sim 10 \, \mu\text{G}$ from RM of Mg II absorbers in halos of normal galaxies probed by QSOs – Bernet+08).
The low density and magnetization of a massive galaxy halo exposed by a fast radio burst

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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?

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**T + 10d**
Are FRBs associated with SN-like optical transients?

- 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

• 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.