Discovery of a massive Supercluster in Vela

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- First hints of existence of massive overdensity
- SALT & AAOmega spectroscopic results
  - Discovery of Vela Supercluster hidden by ZOA
- First assessment
- Future Plans
  - MeerKAT & other proposed/ongoing follow-up surveys

LSS & Galaxy Flows
3-9 July, Vietnam
Suspicion of existence of massive overdensity in ZOA
just beyond boundaries of current surveys 16-22000km/s

Various follow-up redshift observations of optically detected galaxies in ZOA in Vela (KK et al):

Two adjacent 6dF fields; ~370z
6dFGSv results: pec velocities from FP (N=9000)

- Bulk-flow within 160 Mpc/h: \( V = 365 \text{ km/s} \rightarrow (l,b) = 313^\circ, 15^\circ \)
- Residual flow of: \( V = 292 \text{ km/s} \rightarrow (l,b) = 313^\circ, 36^\circ \)

Hints of structure influencing local dynamics outside of survey volume

Springob et al 2014; Figure from Magoulas, Cosmic Flow meeting, 2013, Marseille
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Various follow-up redshift observations of optically detected galaxies in ZOA in Vela (KK et al):

Two adjacent 6dF fields; ~370z

First SALT then AAOmega proposals to consolidate & map extent of overdensity (with M Cluver, T Jarrett, M Bilicki, M Colless)
SALT & AAOmega observations of optically and 2M galaxies to map extent of overdensity \((l,b) = 240^\circ – 290^\circ; \pm (4^\circ-10^\circ)\)

2012-2014:
- About a dozen fields of prospective cluster cores
- Most confirmed as clusters at Vela overdensity distance

2014: 6 nights in February:
- 4300 redshifts in 25 AAOmega fields:
  overdensity extends over vast region
On-sky redshift coverage along ZOA survey region

20 o/o 25 AAOmega fields show peak around ~18’000 km/s

Redshift coding:
- 0 – 8000 km/s;
- 8 - 16000 km/s;
- 16 – 20000 km/s
- 20 - 24000 km/s;
- 24 – 32000 km/s
- 32 - 40000 km/s

Still very sparsely sampled – and only at intermediate latitudes (between 5° - 10°)

Where $A_B > 2$-mag $\rightarrow$ hard to get redshifts, even for 2MASX galaxies

Massive overdensity traced over 25° and 20° degrees on either side of the GP
Results from AAOmega, SALT, older 6dF & Optopus ± literature
Over ZOA region of \((l,b) = 245^\circ - 285^\circ; \pm 10^\circ (4^\circ - 10^\circ)\)

**Results 4756 redshift**  \(~\) only 5% ZOA redshifts known before

→ Velocity histogram shows highly significant peak centred at \(~18000\text{km/s}\)

*just beyond boundaries of current surveys 16-22000km/s*

Despite sparse sampling, prominence bears remarkable similarity to Shapley SC survey *(Proust et al 2006)*
Comparison of Redshift histograms of Vela versus Shapley:

- ~ 4000 in 20° x 20°; sparsely sampled
- ~ 8600 in 12° x 30°; fully sampled

- Massive overdensity traced over \((\Delta l, \Delta b) > \sim 20° \times 20°\)

- Redshift histogram similar to Shapley SSC
  \((Proust et al 2006, N \sim 8600)\);

- Velas SCL is \(f \sim 1.2\) more distant → quite extended on the sky:

  \[12° \times 30° \leftrightarrow \sim 20° \times 20°\]
  \[30 \times 75 \leftrightarrow 65 \times 65 \text{ Mpc/h}\]
Combined ZOA redshift survey divided above and below the Galactic Plane

- Velocity histogram shows highly significant peak centred at $\sim 18000$ km/s

- *just beyond boundaries of current surveys* 16-22000 km/s

- Overdensity equally prominent above and below optical ZOA

- Numerous clusters at 18-20000 km/s

- Embedded in broader wall-like structure (16-24000 km/s)
Redshift slices for ZOA Survey area

4756 redshifts from AAOmega + SALT + 6dF + Optopus + 1.9m SAAO & Literature

~ 95% unpublished data

within ZOA: |b| < 10°

Above GP: 0° < b < +10°

Below GP: -10° < b < 0°
Redshift slices for ZOA Survey area

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within ZOA: \(|b| < 10^\circ\)

Above GP: \(0^\circ < b < +10^\circ\)

Below GP: \(-10^\circ < b < 0^\circ\)
Heavily contaminated by Galactic foreground; but many star-forming galaxies
VC04 in X-ray (ROSAT) overlaid on DSS2 R

prepared by H Boehringer
WISE image plus X-ray (ROSAT) around clusters (VC 04)

X-ray contours determined by H Boehringer
Composite prepared by T Jarrett
In addition to Vela SNR which covers about 8 x 8 degrees

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Massive overdensity traced over \((\Delta l, \Delta b) \sim 20^\circ \times 20^\circ\)

Assume continuity
At 18-22000 km/s
\(\Rightarrow 70 \times 70 \text{ Mpc}/h\)

Where extinction reaches \(\sim A_B > 2\text{mag}\)
\(\Rightarrow\) hard to get redshifts, even for 2MASX galaxies
\(\Rightarrow\) Area of \(\sim |b| < \pm 5-7^\circ\) unsampled

Vela SNR
What have we found – what does it signify?

Clear evidence for a galaxy supercluster in Vela;

→ possibly a supercluster in formation
   (two merging walls, many young clusters, many star-forming galaxies in clusters)

Vela SCL redshift histogram similar to the SSC

Forms Big Circle of SCL’s across the sky:
   Vela SCL → Shapley SCL → Ara/Triangulum?

It’s impact on bulk flow may be significant ….

→ But difficult to assess properly with sparse sampling

How much remains hidden behind ZOA?
Does the Milky Way hide further surprises?
AAOmega proposal
for further observations at intermediate latitudes
MeerKAT M32 Early Science survey scenario

- Survey of fully opaque part of Vela SCL ZOA crossing
- With some overlap of high density Vela cluster regions on either side of GP

Survey area of about

(l x b) ~ 17° x 14° ~240°

To trace Vela SCL across ZOA

Goal: Map all galaxies log $M_{\text{HI}} > 9.5 M_\odot$ with 16-24000 km/s

Previous ZOA survey experience with WSRT of hidden cluster in PP-SCL complex

450 hrs
Mosaic of 35 pointings
$\rightarrow$ 9.6°
2200 - 16500 km/s
rms $\sim 0.4$ mJy / beam

**MeerKAT**

64 dishes over 8 km baseline
13.5-m with Gregorian offset
single pixel receiver (0.9-1.7 GHz)
Compact core, extended baseline

**MeerKAT roll-out:**
- AR1 (M16) : mid-July 2016 *(fully operational – verification concluded)*
- AR2 (M32) : end March 2017 *(early science operations starting)*
- AR3 (M64) : end 2017 *(science ready)*

**Time allocation (goal):** 70% for Large-Survey Projects; 30% open time
Recent MeerKAT pictures
MeerKAT M32 Early Science survey scenario

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Goal: identify “all” galaxies complete to log $M_{HI} > 9.5 \ M_\odot$
for VSC redshift range ($18000 \text{ km/s} \sim 250 \text{ Mpc}$)

$\rightarrow$ $F(\text{HI}) = 0.2 \ \text{Jy km/s}$
$\rightarrow$ For a $5\sigma$ detection limit over $\Delta v = 200 \ \text{km/s}$
$\rightarrow$ Requires: $\text{rms} = 1 \text{mJy/beam in 10 km/s channel}$

Updated MeerKAT Specifications for L-band:

$T_{\text{sys}} = 22 \ \text{K}; \ \frac{A_e}{T_{\text{sys}}} \sim 424 \text{m}^2/\text{K};$

Nyquist sampling: will require 960 pointings $\rightarrow$ but reduce $T_{\text{int}} \rightarrow 15 \text{min}$

$\rightarrow$ Full survey: 240 hours with M32
Galaxies at 16-24000 km/s in simulated HI-data cube of 30°

Simulations by Ed Elson (UCT) based on semi-analytic models $S^3$-SAX (Obreschkow et al 2009, 2014)

Will we recognise the supercluster wall/filamentary structure?

For 16-24000 km/s and 30°
- VSC > 5-σ  $\lg M_{\text{HI}} > 9.5$
- 5072  465  118

For 240° survey area
- 40000  3720  950

Goal: determine mass overdensity based on HIMF
Steps towards a full census of the Vela SCL
... to determine its extent, richness and mass overdensity
→ and contribution to bulk flow

- Further AAOmega & SALT observations
- Analysis of clusters in VSCL (K-band LF, mass - possibly peculiar velocities using WISE TF over the MeerKAT HI survey area)
  - deep IRSF (JHK) imaging study of clusters with 1.4m telescope at Sutherland (12 done within 0.8 $R_{abell}$)
  - WISE photometry on mosaics of cluster fields galaxies (4 surveyed)
- Early Science Survey with MeerKAT (M32) to cover optically obscured part of Vela SCL ($|b| < 6^\circ$)
  - First simulation show that this is feasible in about 240 hrs with M32
  - With M64: extend survey, and include 2\textsuperscript{nd} hidden part of Big Circle towards TriAu clusters