Searching for monopoles in volcanic matter

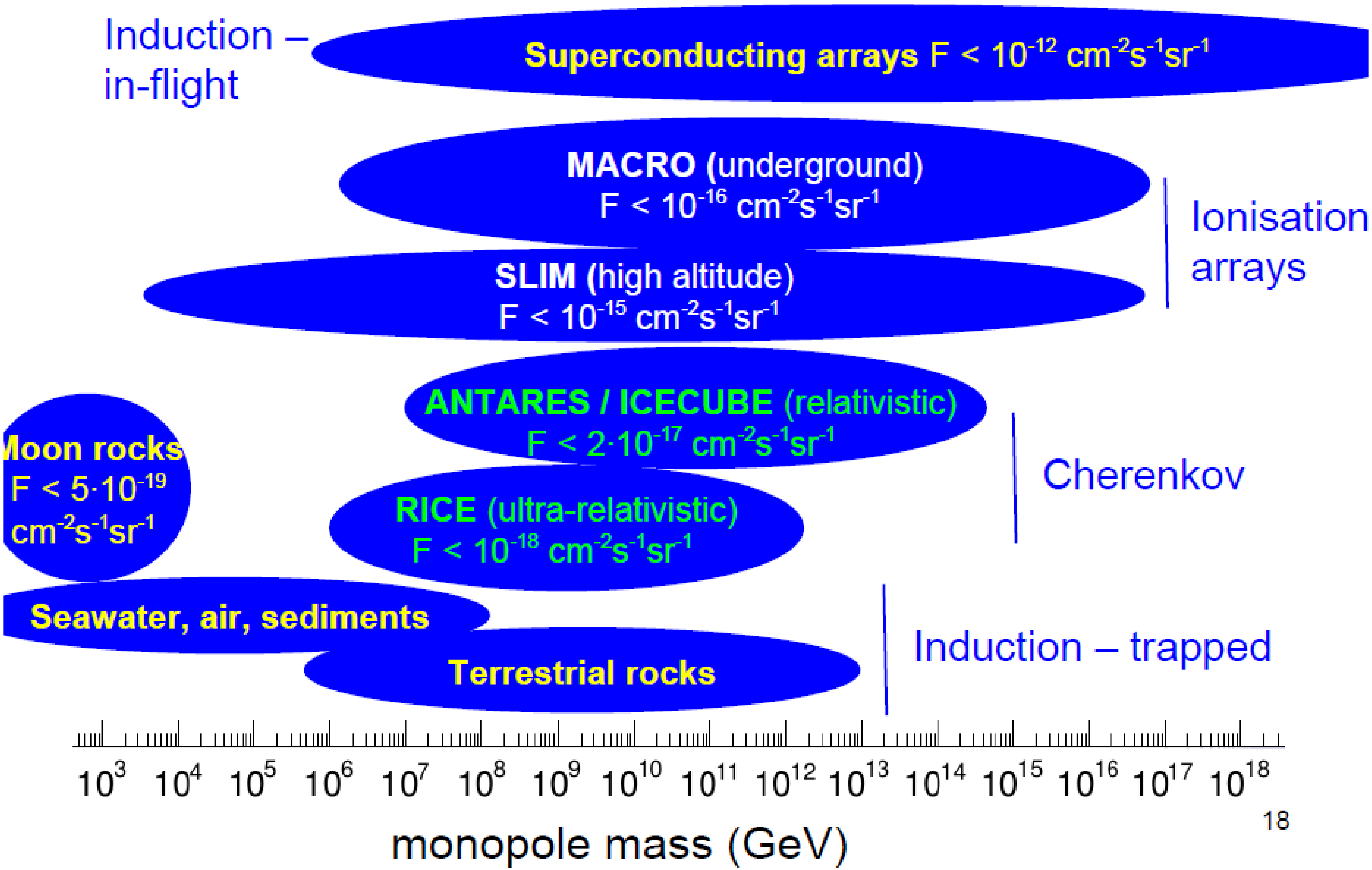
D. Milstead

Based on:
Bendtz et al. PRL 110 (2013) 121803
De Roeck et al., Eur.Phys.J. C72 (2012) 212

Searching for free magnetic charge

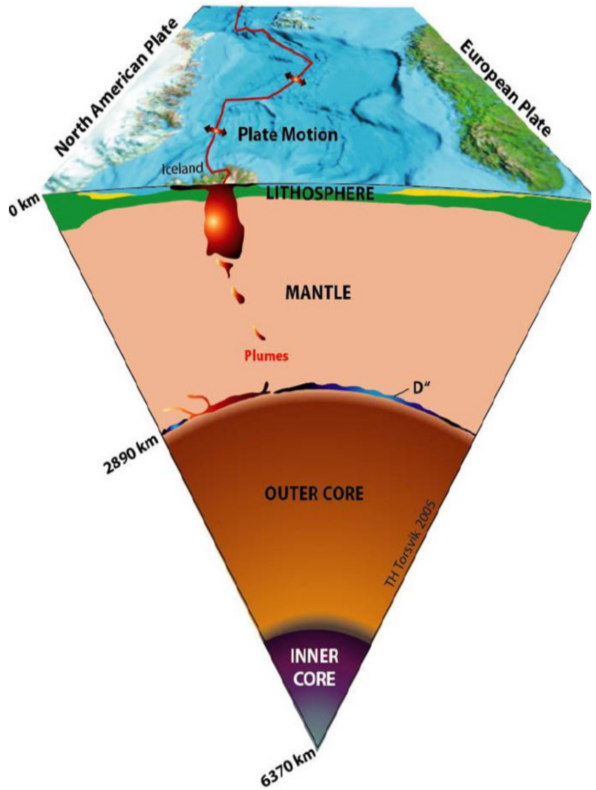
- Why bother ?
  - Existence of a magnetic charge addresses the electric charge quantisation problem (Dirac)
    - Scale for magnetic charge g_D
  - Monopoles are features of spontaneous gauge symmetry breaking models ('t Hooft/Polyakov)
  - Force a symmetry in the unsymmetric Maxwell equations
  - We don't understand why we can't see them

Non-collider searches



Stellar monopoles and the earth

- Carrigan et al.
- Earth's dipole field since ~3.5 billion years (paleomagnetic data)
- Monopoles bind to nuclei. Form part of core formation – preferential movement in pole directions
- Mantle convection for monopoles to the surface
- Equilibrium position above core-mantle boundary for $m<4\times10^{14}$ GeV
- Expect far higher monopole concentrations from polar rock



Sample locations

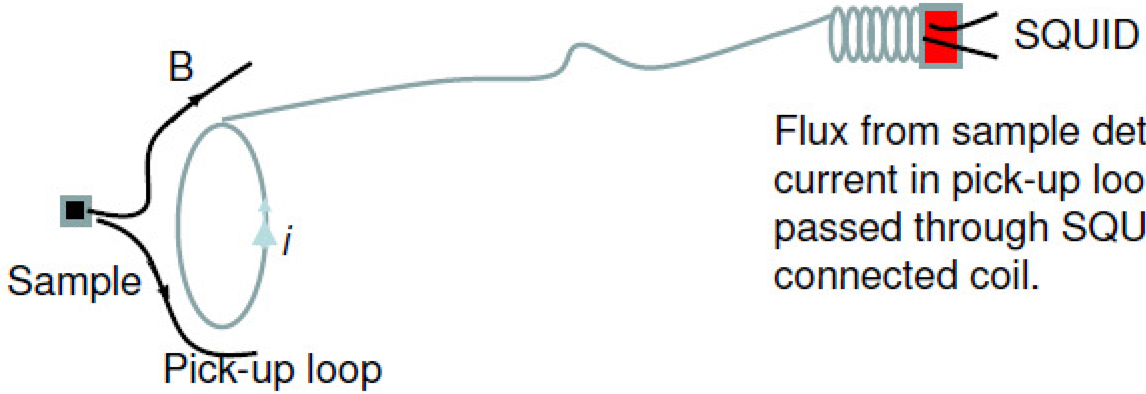
High latitude (>63°) , mantle derived.

- Hotspot (volcanic region with warmer mantle)
- Rift volcanic zones
- Large igneous province
- Isotopic content for deep origins

TABLE I. Characteristics of the rock samples used in this search. If not otherwise specified, they were emplaced during the Cenozoic era. Control samples are indicated with (c). The latitude corresponds to the location at the time of emplacement.

site	latitude	tectonic setting	rock type	samples	mass (kg)
Iceland [56]	64° N	hotspot, mid-ocean ridge	basalt	144	5.916
			gabbro	26	1.404
Jan Mayen Island [47]	71° N	hotspot	alkali basalt	6	0.139
Hawaii (c)	21° N	hotspot	tholeiitic basalt	17	0.610
North Greenland [57]	72° N	LIP, 71-61 million years old	alkali basalt, trachyte, trachyandesite, rhyolite	73	1.779
East Greenland [58]	68° N	LIP, intrusion	gabbro	39	1.830
Gakkel Ridge	84° N	mid-ocean ridge	tholeiitic basalt	26	0.707
Mid-Atlantic Ridge (c)	33° S	mid-ocean ridge	tholeiitic basalt	8	0.207
East Pacific Rise (c)	28° S	mid-ocean ridge	tholeiitic basalt	7	0.241
South. Victoria Land	77° S	hotspot	basalt, basanite	233	8.163
North. Victoria Land	72° S	intraplate volcanism	basalt, trachyte	12	0.335
Marie Byrd Land [55]	76° S	intraplate volcanism	alkali basalt (HIMU)	50	2.184
			lherzolite	3	0.148
			basalt, trachyte	17	0.440
Ellsworth Land	74° S	intraplate volcanism	basalt	11	0.300
Horlick Mountains	87° S	intraplate volcanism	basalt	1	0.021
Antarctic Peninsula (c)	63° S	subduction zone	basalt	5	0.146
Total search				641	23.366
Total control (c)				37	1.204

Method for analysing samples



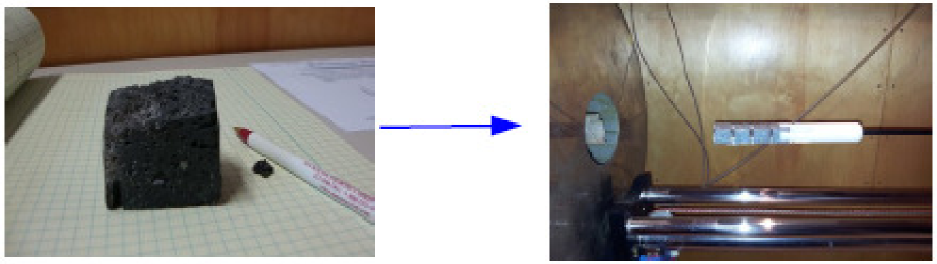
Flux from sample detected by current in pick-up loop. Flux passed through SQUID via connected coil.

2G 755-R SQUID
Cryogenic rock long core rock magnetometer
ETH, Zurich
Nominal sensitivity << g_D

Signature of a persistent induced current/flux long after sample has passed through the loop.

Sample treatment

- 24 kg of samples
- Problems with magnetisation
- Samples crushed



- 680 samples
- 12 days
- ~5 people required for sample preparation and magnetometer shift work

Calibration

Solenoid coils and dipole calibration samples

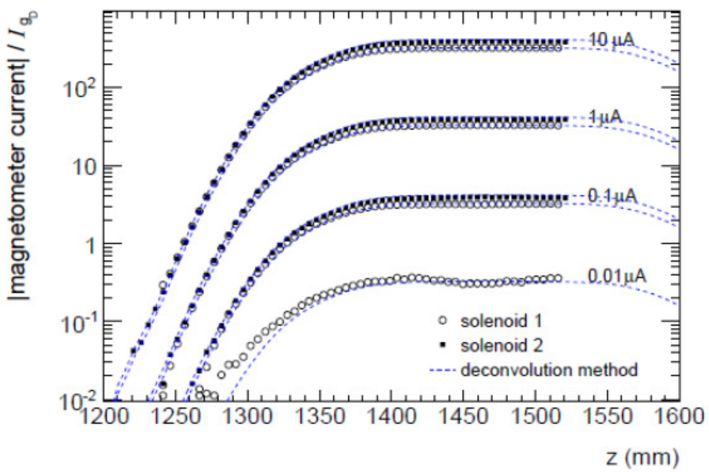
Calibration coil	1	2
Pseudopole strength/current ($g_D/\mu A$)	32.4	41.4
Coil length l (mm)	250	250
Number of turns n	2750	7500
Wire diameter (mm)	0.18	0.10
Number of wire layers	2	3
Mean coil area S (mm^2)	9.7	4.5
Uncertainty in area	6%	10%

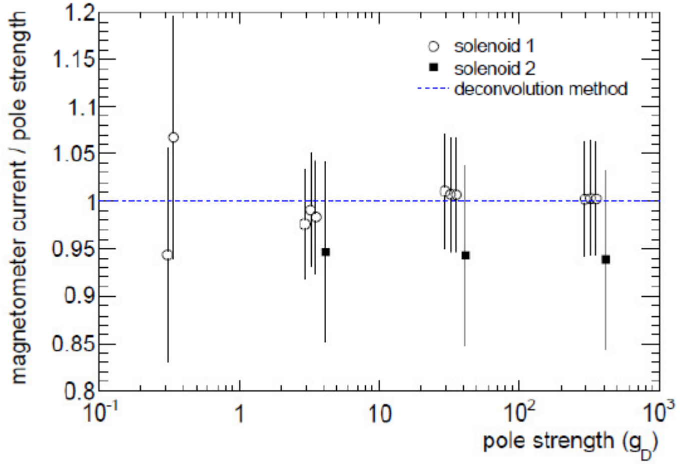
Dipole moment :

$$NiS = gL$$

$$\Rightarrow \text{pseudopole strength } g = \frac{NiS}{L}$$

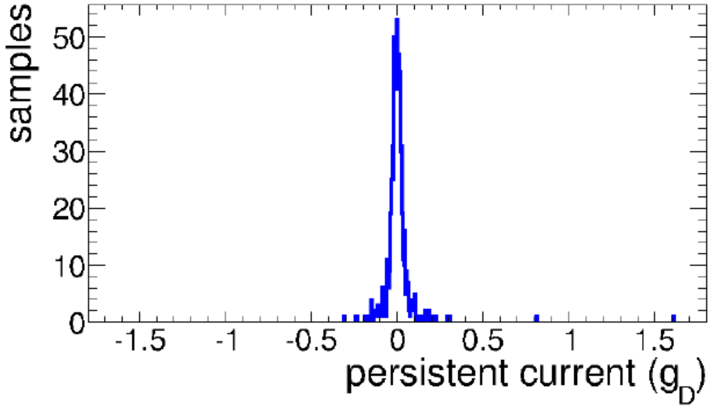
Uncertainties on area 6 - 10%



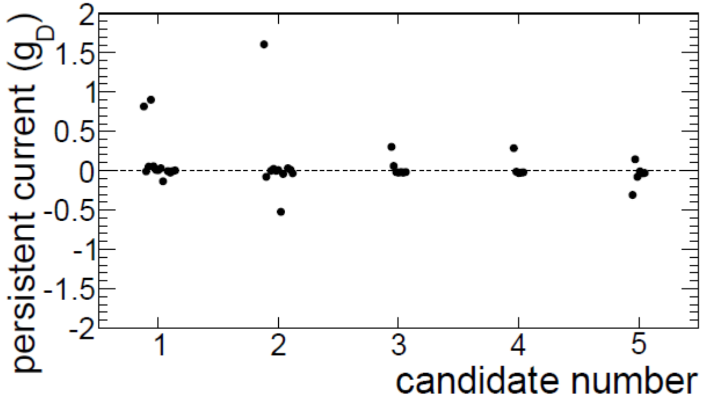


Flat behaviour once solenoid is extended into the sensing region
Linear and charge symmetric
5-6% differences between solenoids.
Nominal sensitivity to ~$0.32 g_D$

Results



Persistent current



Persistent current for candidates ($> 0.25\ g_D$)

No candidates remain after remeasurement:

Concentation limits: 9.8×10^{-5}/grams (samples)

Better sensitivity than extensive meteorite searches.

Summary

- The possible existence of free magnetic charge is one of the major open questions in modern physics
- Search undertaken with volcanic rock to look for trapped stellar monopoles
- Induction method with SQUID technology used
- Concentration limits