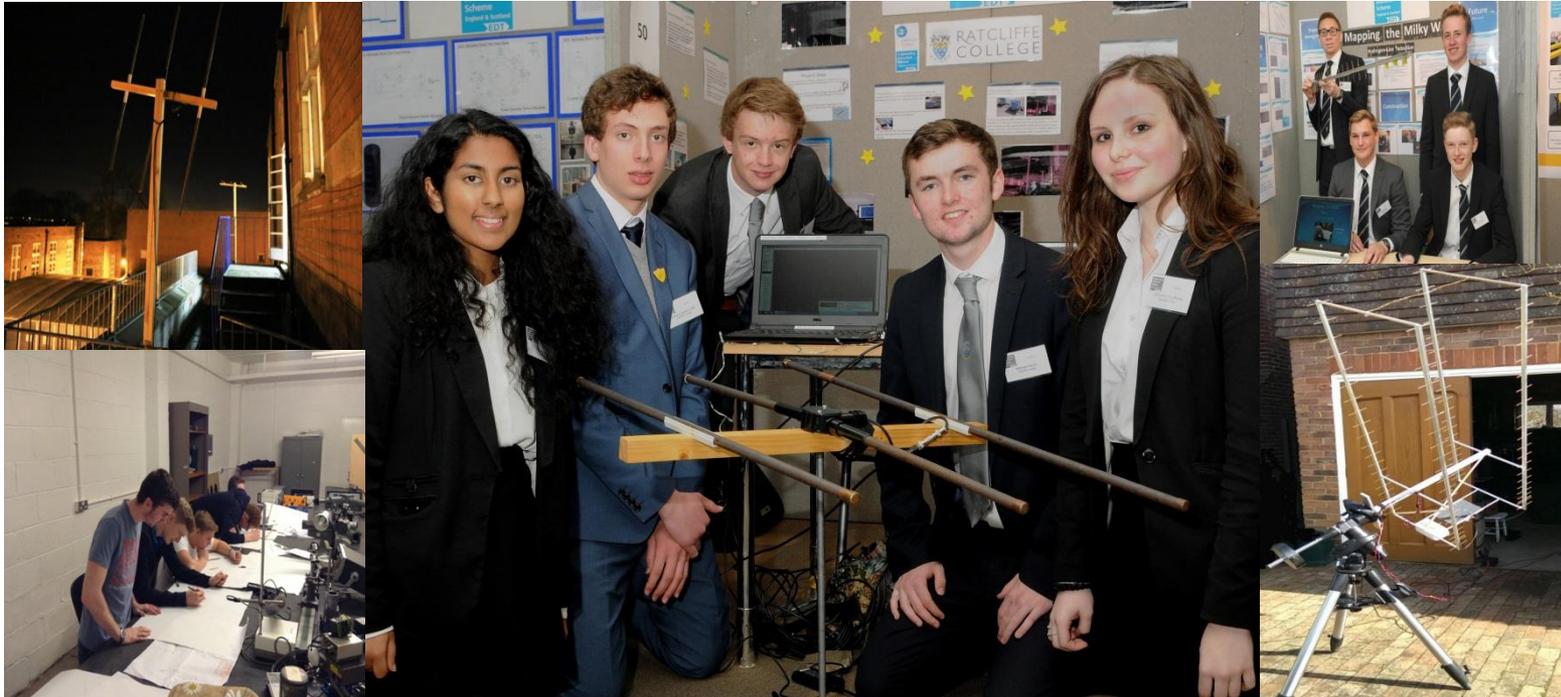


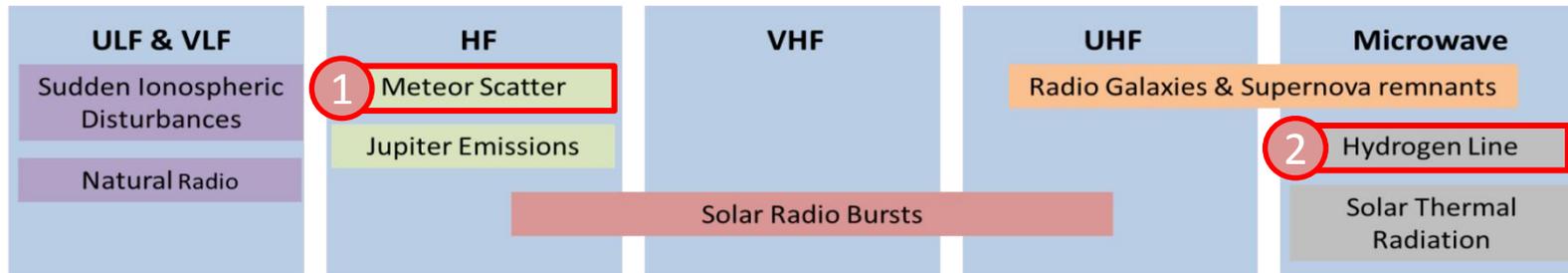
# Practical Radio Astronomy

*for Science & Engineering Students*



# Challenges for Amateur Astronomers

## *Opportunities for young Engineers & Scientists*



**Antennas:** Magnetic loops, Dipoles, Yagis, Log Periodics, Horns, Helicals, Dishes

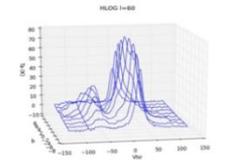
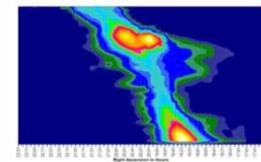
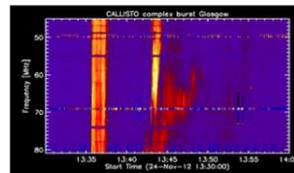
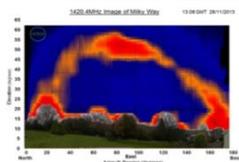
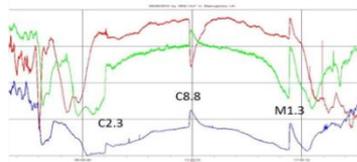
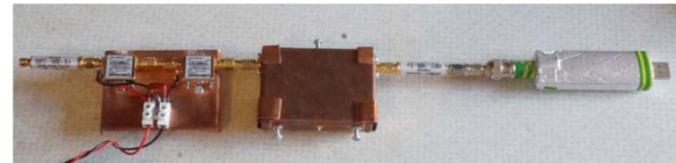
Low noise, high gain receivers having long-term stability in gain and noise performance

RFI countermeasures, filtering

Combining low-cost SDR hardware with innovative software

Data process and image rendering

**Outputs:** Spectrogrammes, stripcharts, FITS, .wav, .csv





# College & University Activity

## EDT EES Projects



*Projects require student groups to self organise and overcome engineering challenges, last year our project was to establish and run a meteor detection system.*

- *Project Management*
- *Team Working*
- *Meetings, Minutes & Actions*
- *System & Subsystem thinking*
- *Design, BOM & Costing*
- *Test*
- *Down Selection/Optimisation*
- *Reporting of Results*
- *Presentation*

*Projects culminate in formal assessment and presentation to a crowd of 300-500 parents and engineers.*





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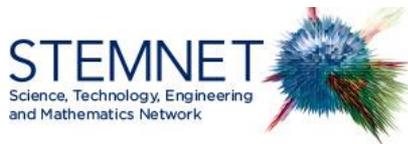
# Partners & Acknowledgements

## *EDT EES Projects*

- The **BAA RAG** (British Astronomical Association Radio Astronomy Group) support Amateur Radio Astronomy and Geophysics.
- The **RSGB** (Radio Society of Great Britain) teach and support the operation of radio equipment by amateurs.
- The **EDT** (Engineering Development Trust) run the **EES** (Engineering Education Scheme) Nationally providing engineering projects to 16-18 year olds this scheme has been running 30 yrs and has helped 30,000+ students to date.
- **Loughborough University** host the EES and have supported our work annually since 2012.
- **Ratcliffe College** have supported our projects for 4 years.
- The **British Science Association** supporting over 32,000 CREST (CREativity in Science & Technology) Awards undertaken by 11-to-19-year-olds annually.



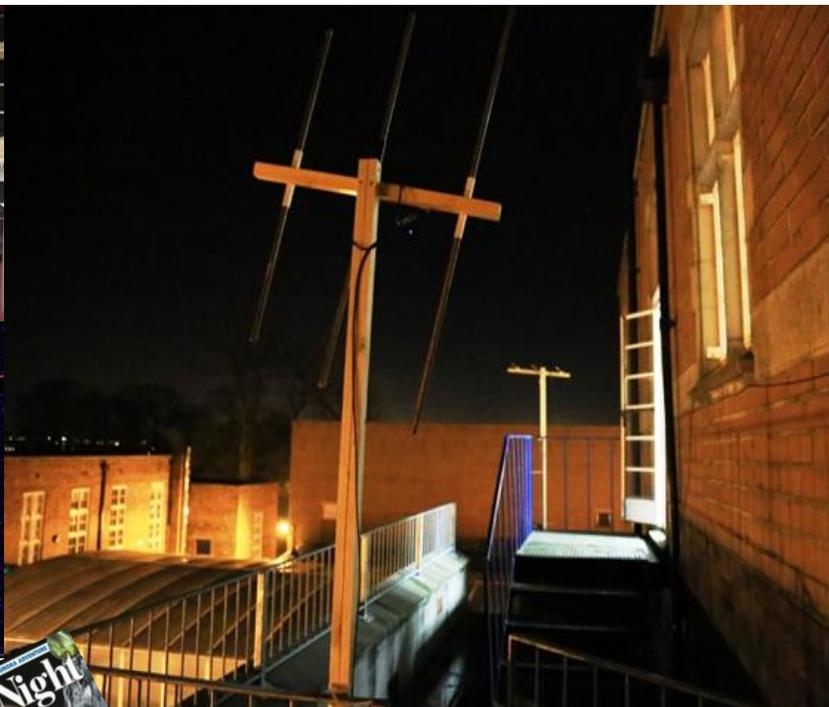
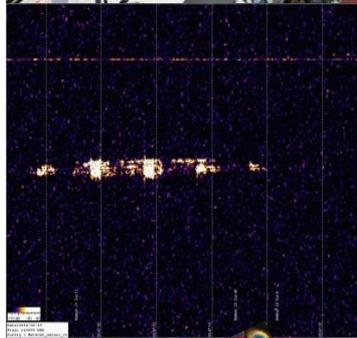
British Astronomical Association





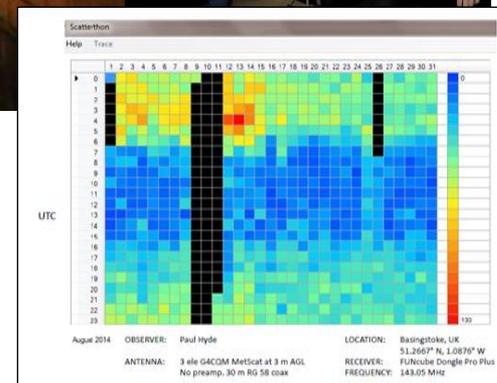
# Practical Meteor Observing

## Meteor Station Development



2015

Dr Chris Jackson (2E0JXL) & Victoria Penrice (2E0JXV),  
07415094820, [info@radioastro.org.uk](mailto:info@radioastro.org.uk)





# Running Order

## *Meteor Station Development*



*The objective of today's discussion is to explain our projects, the information that we have covered with our students and explore the steps required to develop a working meteor station.*

1. *The Basics*
2. *Where to find practical help*
3. *System Components*
4. *Antenna Fabrication & Location*
5. *SDR Dongles*
6. *Software Set-up*
7. *DATA !*
8. *What to do with our data ...*
9. *Next Steps*
  
10. *Stimulating the Network*





# The Basics

## Meteor Showers & Sporadics



*It is not uncommon to see images taken by astronomers and photographers at periods of high meteor activity, known as meteor showers. Indeed there are networks who use videography from multiple sites*



*to ensure (subject to weather) that national coverage is achieved, in so far as is possible.*

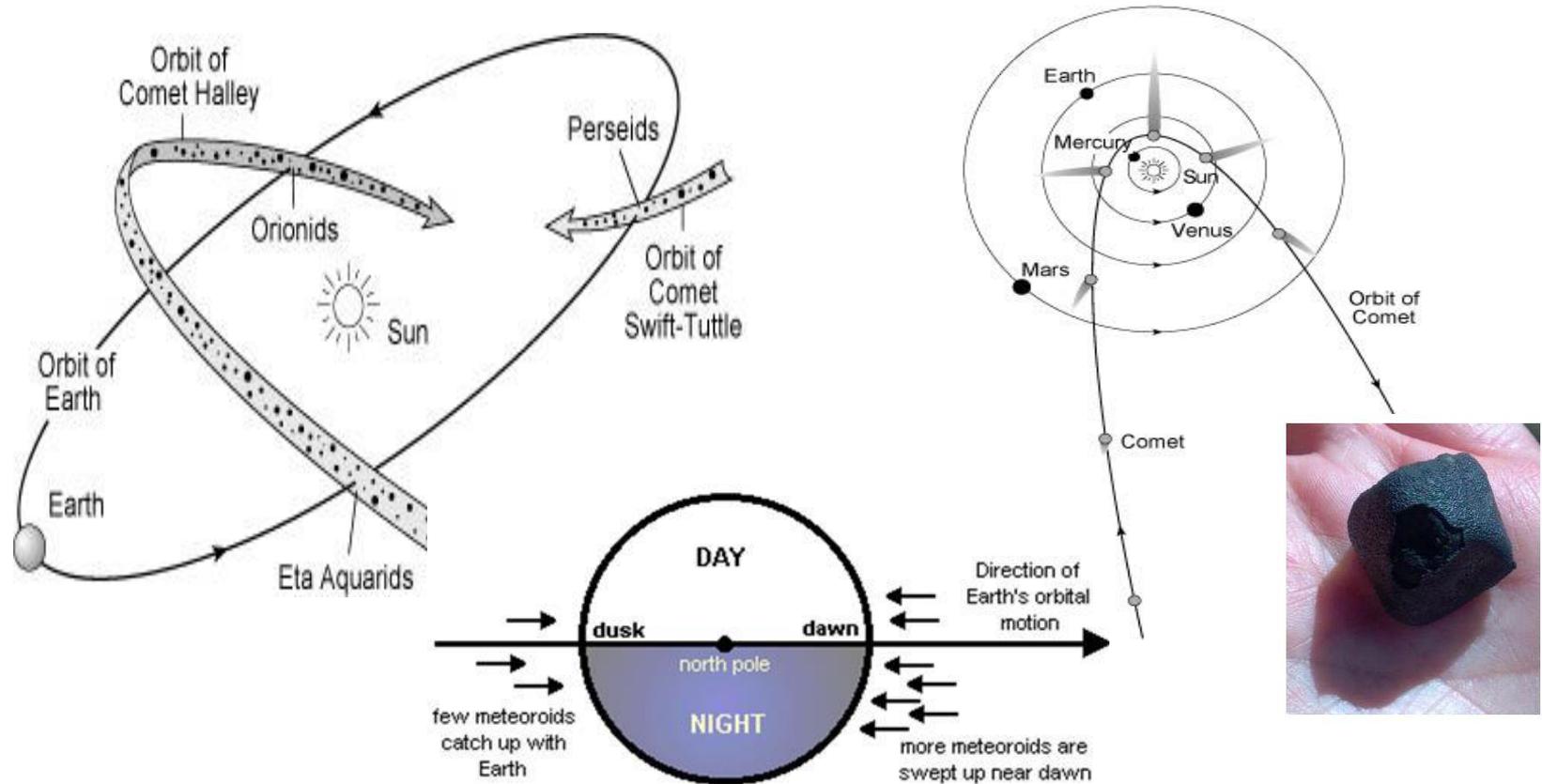


# The Basics



## Meteor Showers & Sporadics

The earth orbits the sun and in so doing collides with debris on a semi continuous basis from several sources. This nominal background is known as Sporadic Meteor Activity.



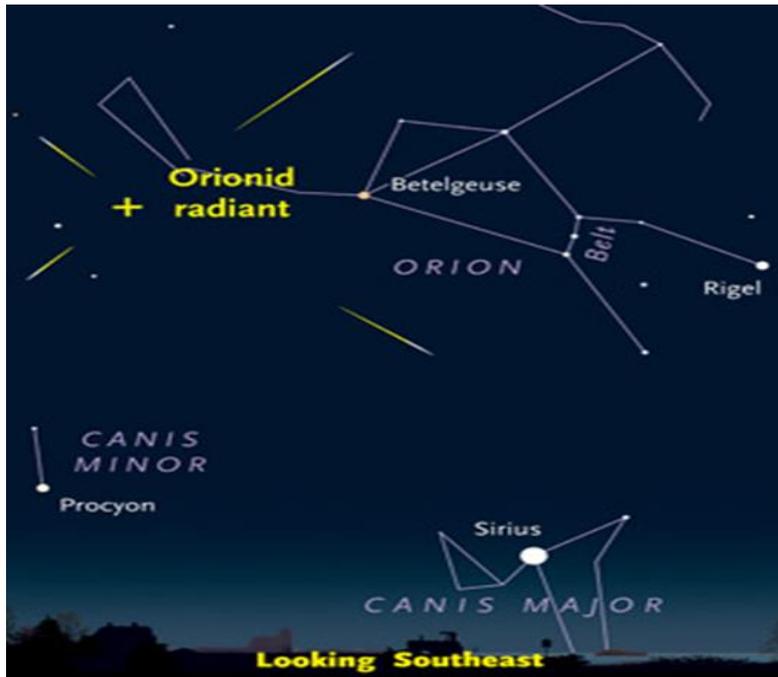


# The Basics



## Meteor Showers & Shower Radiants

*In addition, the earth passes through the debris trails left by the paths of comets approaching and retreating from the sun. When looking skyward at these times meteors will appear to radiate from the*



Major annual meteor showers				
Name	Peak date 2014 (UTC/Australia)	Origin	Constellation (radiant point)	Viewing conditions
Eta Aquariids	6 May / 7 May	Comet 1P/Halley	Aquarius	Primarily southern hemisphere. Starts around 1 am, best view at 3 - 5 am.
Perseids	11 Aug / 12 Aug	Comet 109/Swift-Tuttle	Perseus	Primarily northern hemisphere, although may be visible from Darwin/Far North Queensland.
Orionids	21 Oct / 22 Oct	Comet 1P/Halley	Orion	Both northern and southern hemisphere. Starts around 1 am, best 3 - 5 am.
Leonids	17 Nov / 18 Nov	Comet 55P/Tempel-Tuttle	Leo	Both northern and southern hemisphere but meteor show
Geminids	14 Dec / 15 Dec	Asteroid 3200 Phaethon	Gemini	
Quadrantids	3 Jan 2015 / N/A	Asteroid 2003 EH1	Boötes	



*Point at which the Earth is colliding with the stream of debris, giving rise to the constellation based naming convention.*

*... photography & videography are however, subject to weather conditions and time of day*

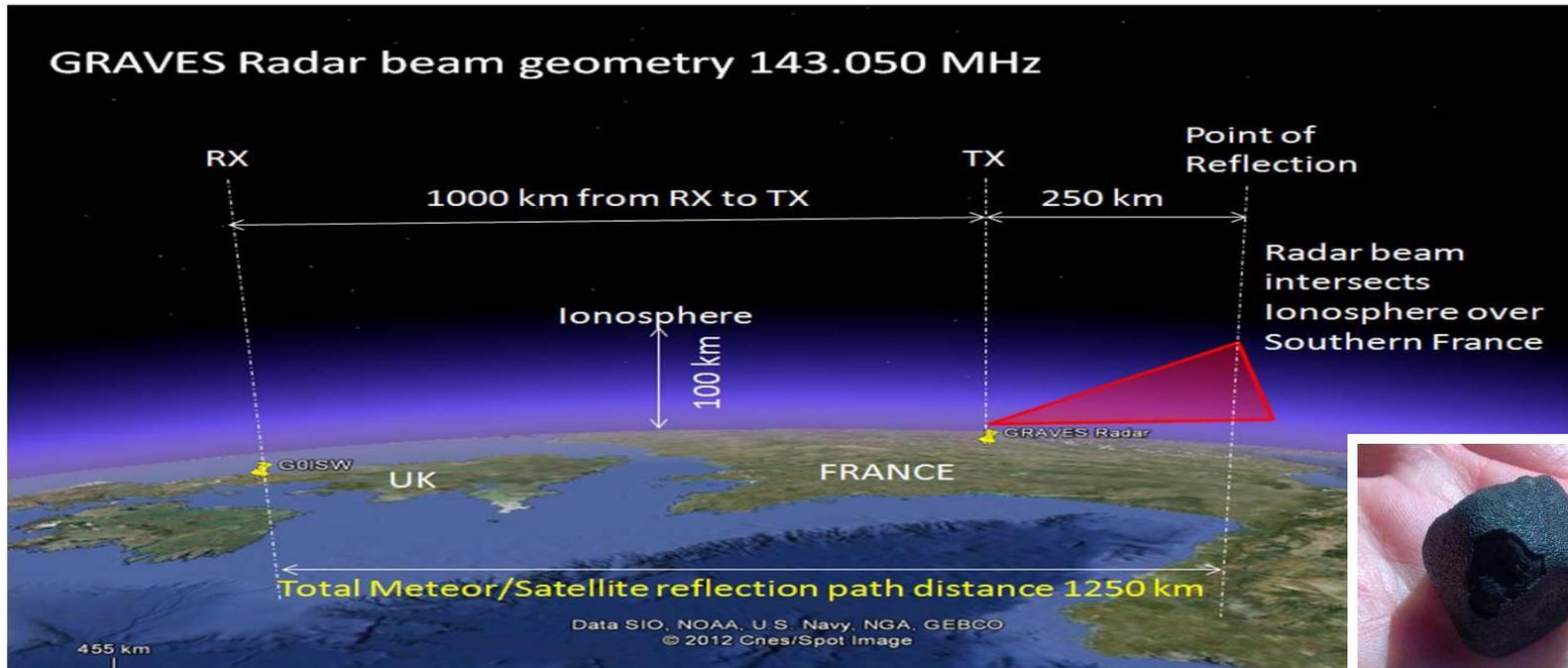


# The Basics

## Illumination



*GRAVES (Grand Réseau Adapté à la Veille Spatiale) is a French radar-based space surveillance system near Dijon. The Station transmits on 143.050MHz and is useful to many amateur radio experiments.*



*There are other transmitters that can be similarly useful including BRAMS (Belgian Radio Meteor Stations) transmitting on 49.97MHz.*



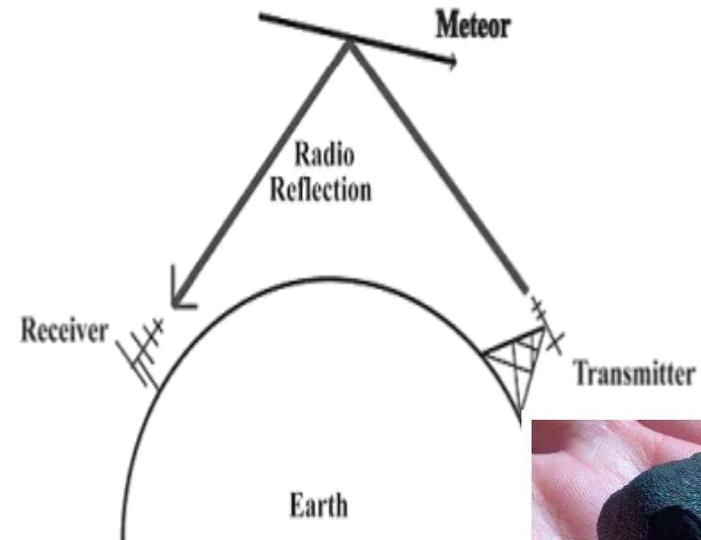


# The Basics

## Reflection (Forward Scatter)



*As GRAVES lies outside of our line of sight, we do not nominally detect it's signal. However, Ionised gas (Meteor trains) reflect radio signals and hence a tuned receiver is able to register a "reflected signal."*



*The unmodulated CW Signal is close to Amateur Radio 2m Band and therefore allows use of compact, low cost antenna designs.*



# Where to find Practical Help



## Sources of Information

Several organisations describe the process of collecting so called forward (meteor) scatter data. Our projects refer mainly to the very practical “how to” details provided by BAA RAG, in particular those by Paul Hyde (G4CSD) & Dr David Morgan (2W0CXV).



www.britastro.org/radio/projects/meteorproj.html

British Astronomical Association  
Radio Astronomy Group

Home Radio Astronomy Projects Observations Resources About

Introduction

Antenna Projects

Radio Jove

Meteor Projects

Solar Astronomy Projects

Radio Astronomy Projects

Test Equipment and Tools

**Meteor Detection Projects**

Project	Download Link
Identifying VLF Transients from Meteors Part 1 - Dr David Morgan	<a href="#">Download</a>
Identifying VLF Transients from Meteors Part 2- Dr David Morgan	<a href="#">Download</a>
The Generation of VLF Emissions by Meteors - Dr David Morgan	<a href="#">Download</a>
A Preliminary Note on Detection of Aircraft VOR Navigation Beacons - Dr David Morgan	<a href="#">Download</a>
Meteor Radar Using SDR Radio - Dr David Morgan	<a href="#">Download</a>
Antennas for Meteor Radar - Dr David Morgan	<a href="#">Download</a>
BRAMS Meteor Radar - Dr David Morgan	<a href="#">Download</a>
Detection of Meteors by RADAR - Dr David Morgan	<a href="#">Download</a>
Techniques for using the RTL Dongle for Detecting Meteors - Dr David Morgan	<a href="#">Download</a>

Last updated: Thursday 03 September, 2015  
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- BAA RAG Website: <http://www.britastro.org/radio/projects/meteorproj.html>
- Sky at Night Magazine (May, June & July 2014): Designs and Spectrum Lab Software scripts



# Where to Start

## System Components



Several organisations describe the process of collecting so called forward (meteor) scatter data. Our projects refer mainly to the very practical “how to” details provided by BAA RAG, in particular those by Paul Hyde (G4CSD) & Dr David Morgan (2W0CXV).



- <http://www.britastro.org/radio/projects/meteorproj.html>
- Designs and Spectrum Lab Software scripts described in *Sky at Night Magazine* (May, June & July 2014)



# Where to Start

## Antenna Fabrication



Components are available from B&Q and Wickes, and doubtless many online retailers. Pre-terminated Coax cable is available from Westlake Electronics and BNC couplers etc., from Maplin and ebay.



### Metscat BOM

#	Description	Unit	Quantity	Unit Cost
1	RG-58 coaxial cable (BNC terminated)	20m	1	£ 20.00
2	15mm copper pipe	3m	1	£ 9.00
3	32mmx32mm smooth timber	1.8m	1	£ 1.80
4	16mmx16mm electrical mini trunking	2m	1	£ 1.35
5	20mm electrical conduit	5m	1	£ 2.00
6	20mm three way electrical junction box	each	1	£ 1.29
7	20mm cable gland	each	1	£ 1.49
8	BNC Female Coupler	each	1	£ 3.59
9	BNC Male Connector	each	1	£ 2.49
<b>TOTAL (excluding)</b>				<b>£ 23.01</b>

- Antenna cost ca. £25, Coax Cable: £20, Dongles £5 - £130
- Designs and Spectrum Lab Software scripts described in Sky at Night Magazine (May, June & July 2014)



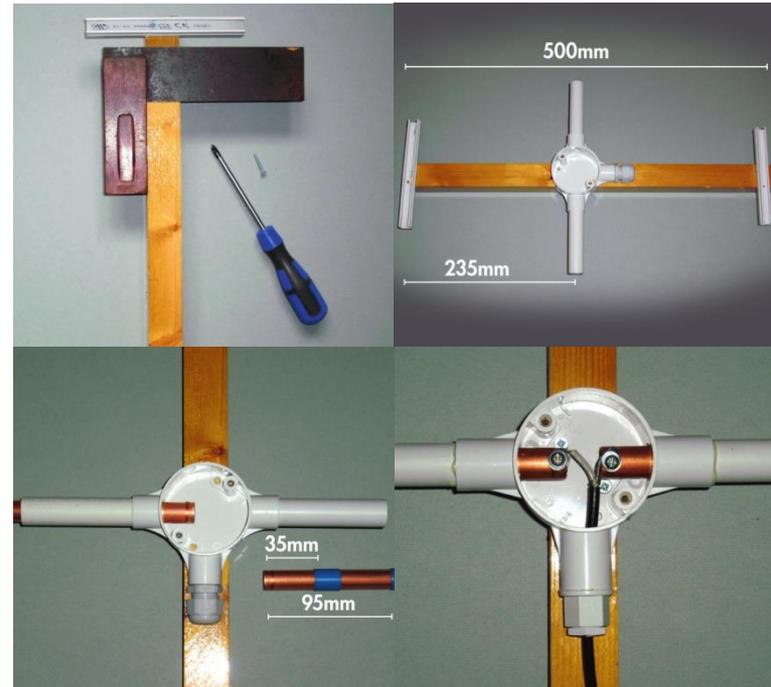
# Where to Start

## Antenna Fabrication



The “Metscat” antenna design was created by Derek Hilleard (G4CQM) and is optimised for 15mm diameter copper tubing.

1. Cut timber boom to length & varnish
2. Cut copper elements to length, solder caps & use tube cutter to mark centre line
3. Cut trunking & conduit sections to length
4. Drill holes in trunking & screw to boom
5. Glue conduit lengths to conduit fitting
6. Screw conduit fitting to boom
7. Prepare coax lead and fit BNC adapter to one end, crimp other ends
8. Drill small connector holes in driven elements
9. Feed driven elements and crimped coax into conduit fitting



- <http://www.britastro.org/radio/projects/meteorproj.html>
- Designs and Spectrum Lab Software scripts described in Sky at Night Magazine (May, June & July 2014)



# Where to Start

## Antenna Fabrication



*The “Metscat” antenna design was created by Derek Hilleard (G4CQM) and is optimised for 15mm diameter copper tubing.*

- 10. Cut additional small length of trunking (as wide as internal void of conduit)*
- 11. Ensure driven elements are spaced 15mm apart and centred.*
- 12. Drill holes in trunking to match those in driven elements.*
- 13. Clip trunking over driven elements align holes and screw to crimps.*
- 14. Screw on conduit lid.*
- 15. Clip reflector and director into the trunking screwed onto the boom.*
- 16. Mount antenna in suitable location.*



- *<http://www.britastro.org/radio/projects/meteorproj.html>*
- *Designs and Spectrum Lab Software scripts described in Sky at Night Magazine (May, June & July 2014)*



# Where to Start

## Commonly used Software



Currently we have used MS Windows based machines with the following Software to assist in SDR dongle calibration, data capture & processing, and troubleshooting.

### Related Specifically to Metscat:

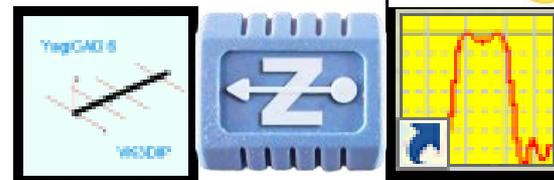
- *Funcube Dongle Drivers*
- *Spectrumlab*
- *Spectrumlab Scripts*
- *Scatterthon*
- *SDR#*
- *Colourfrmob*

### Helpdesking

- *Skype - real time screenshare for helpdesking*
- *Jing - Screenshots, assists in recording issues*

### Other Useful Packages:

- *YagiCAD 6*
- *Zadig Drivers*
- *VB-AudioCable*

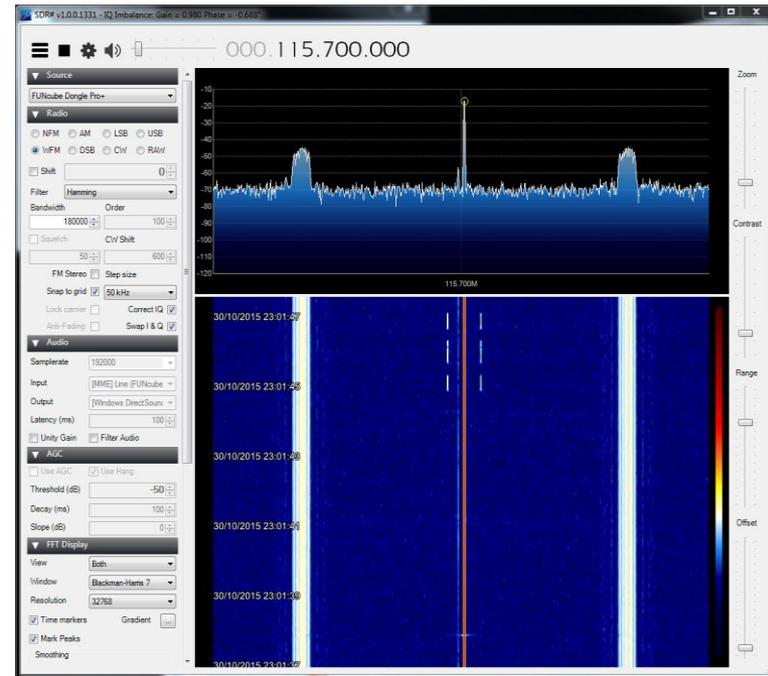
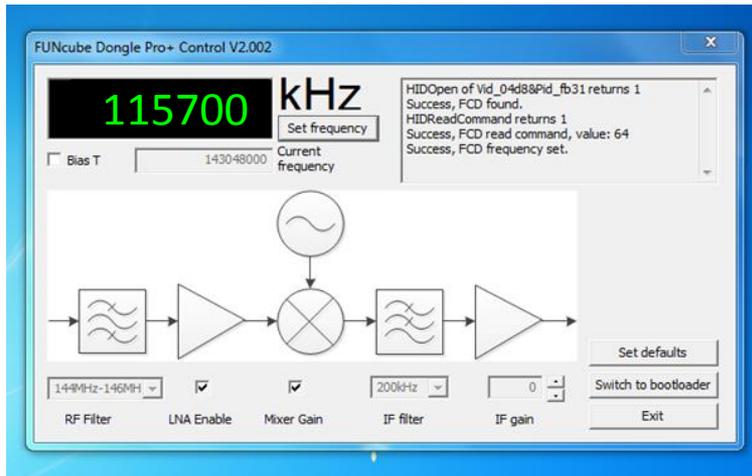




# Where to Start Calibration (Dongle Offset)



In order to calibrate SDR Dongles we configure the dongle for a target frequency, and then check the offset against a known standard, in our case Trent Beacon on 115.7MHz.



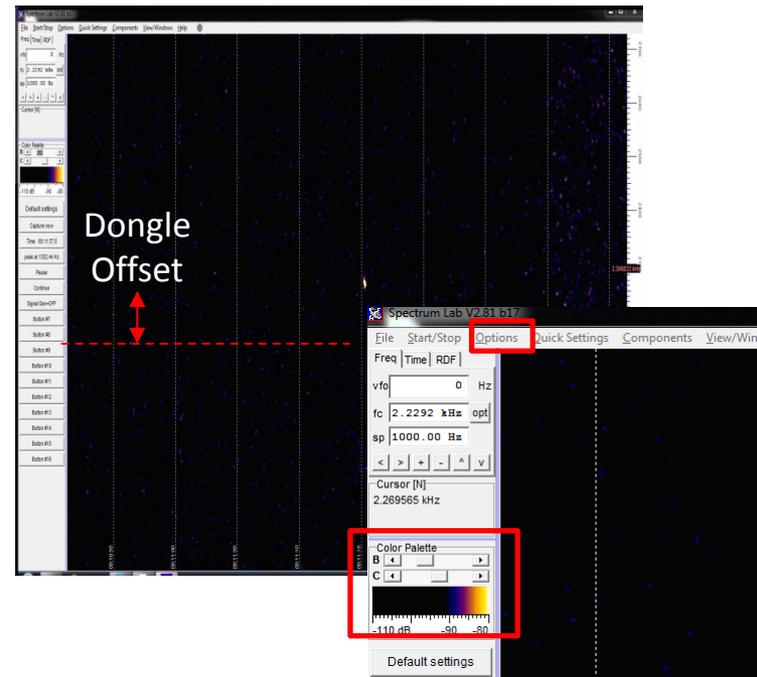
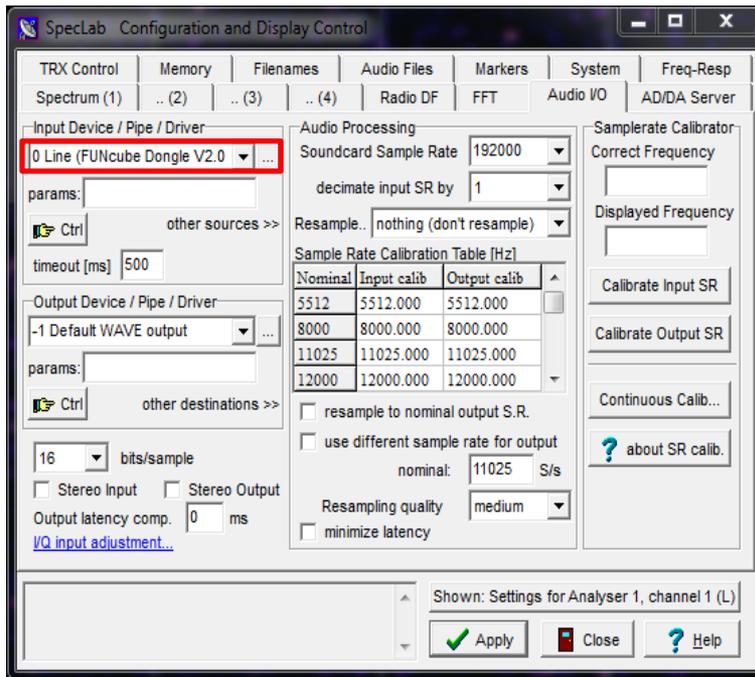
During the lunch break we will demonstrate how to use these software packages.



# Where to Start Configuration



Ultimately we use SpectrumLab developed by Wolf Büscher (DL4YHF), with the FUNcube Dongle selected as the Input Device to collect data according to the spectrumlab scripts published in BBC



Sky at Night magazine. The current process generates a tabular “event log” with a time stamp for each (suspected) meteor detected, this data can be interrogated and cross referenced against “screen captures” that marry-up with the event log and “show” the meteor signal detected.

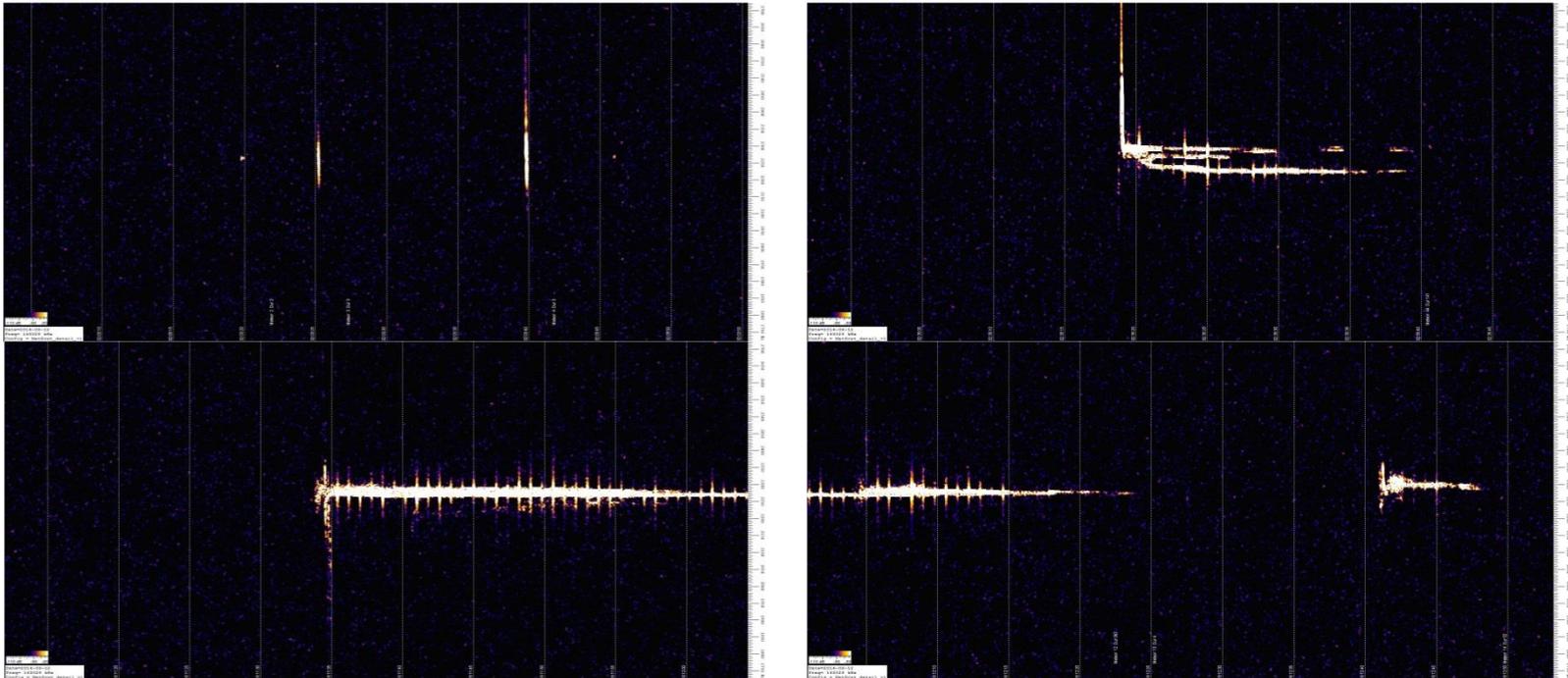


# Data Processing

## Meteor Detection



*Most common detections are short lived (top left), head echos are also reasonably common. Head echos can occasionally leave reflecting trains for several seconds (top right).*



*During meteor showers there is an increase in all commonly observed forms, with much larger and longer events (bottom) so called “radio fire-balls” very much more frequent.*

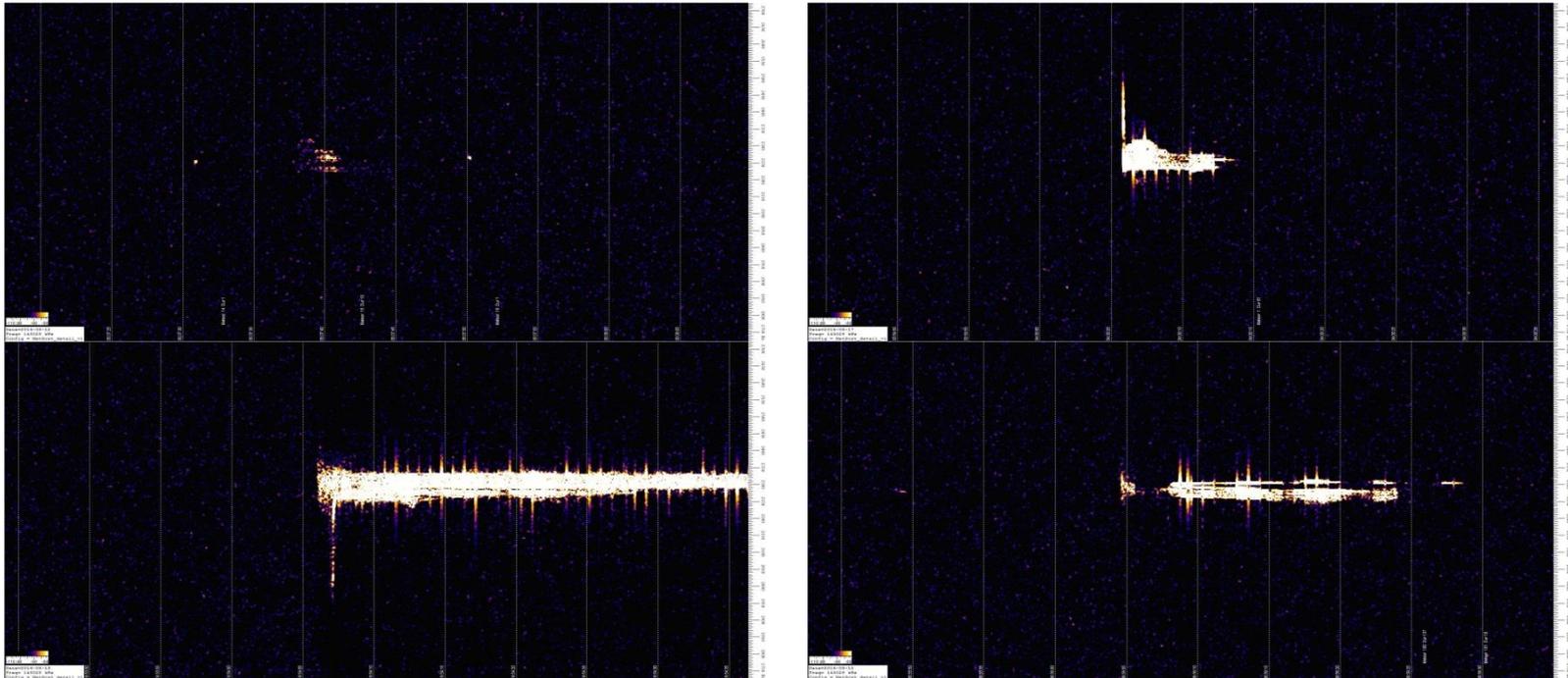


# Data Processing

## Meteor Detection



*Most common detections are short lived (top left), head echos are also reasonably common. Head echos can occasionally leave reflecting trains for several seconds (top right).*



*During meteor showers there is an increase in all commonly observed forms, with much larger and longer events (bottom) so called “radio fire-balls” very much more frequent.*



# Data Processing

## *False Positive Meteor Detection*



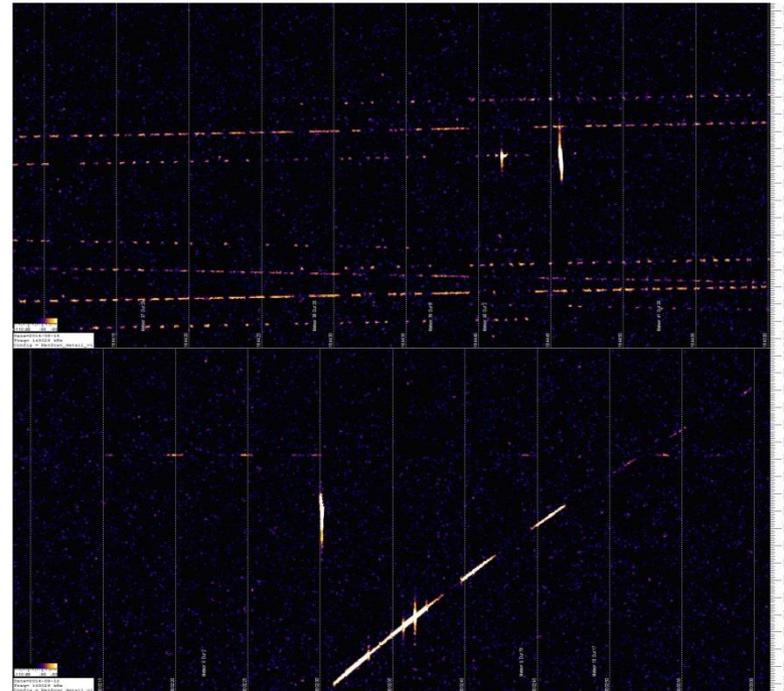
*False positive triggering of meteor detections is dependent upon the sophistication of scripts used by Spectrumlab software. There are many sources of signals that can trigger false positive results.*

- *Moon Bounce*
- *Satellites*
- *Aircraft*
- *Lightning*
- *Tropospheric*
- *Domestic Interference*
- *Local Man made interference*  
(Sensitivity of individual stations)

*when reviewing ones data vs screen captures – false triggers can often be identified.*

*In order to improve our data quality a 2 pronged approach is needed:*

1. *Improvement in our Spectrumlab algorithms and in the mean time*
2. *Visual verification that we have not classified common false positive sources*



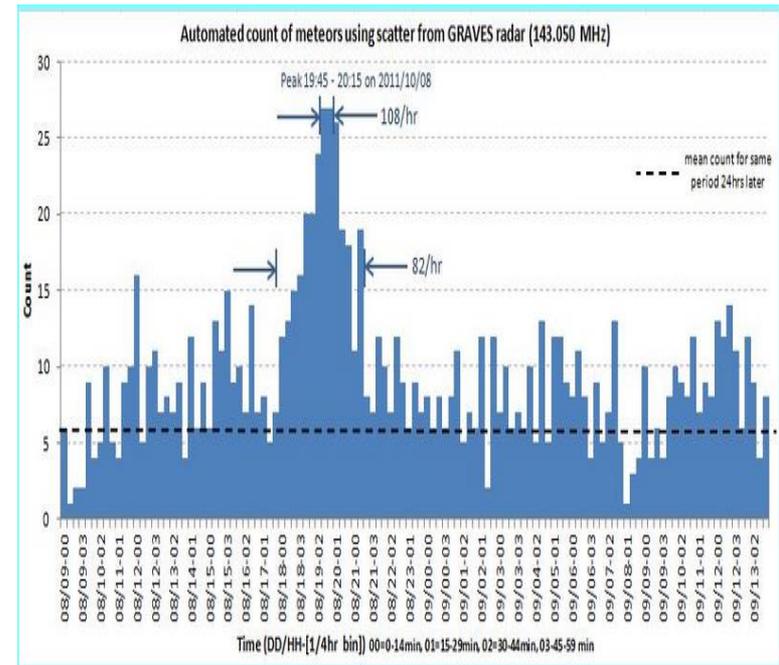
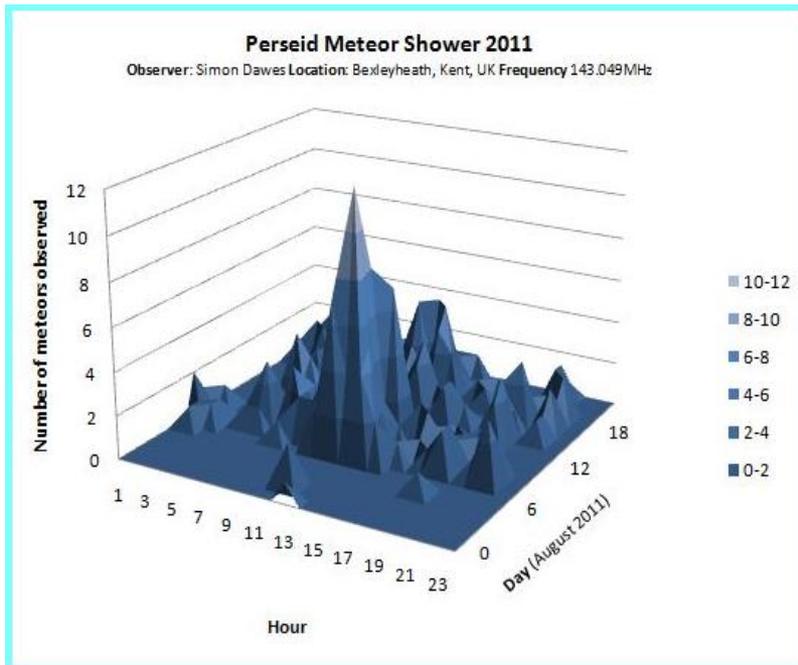


# Data Processing

## Agglomeration



Data recorded to log files by Spectrumlab "scripts" can be very simply be binned into time frames and then plotted in MS Excel and similar charting tools. Scripts can vary greatly in sophistication, examples



from Simon Dawes and others can be found at: <http://cmhas.wikispaces.com/Perseids>.

Above we can see Simon's his Perseid 2011 data plotted simply in MS Excel showing time of shower peak and rate (Meteors logged per hour).

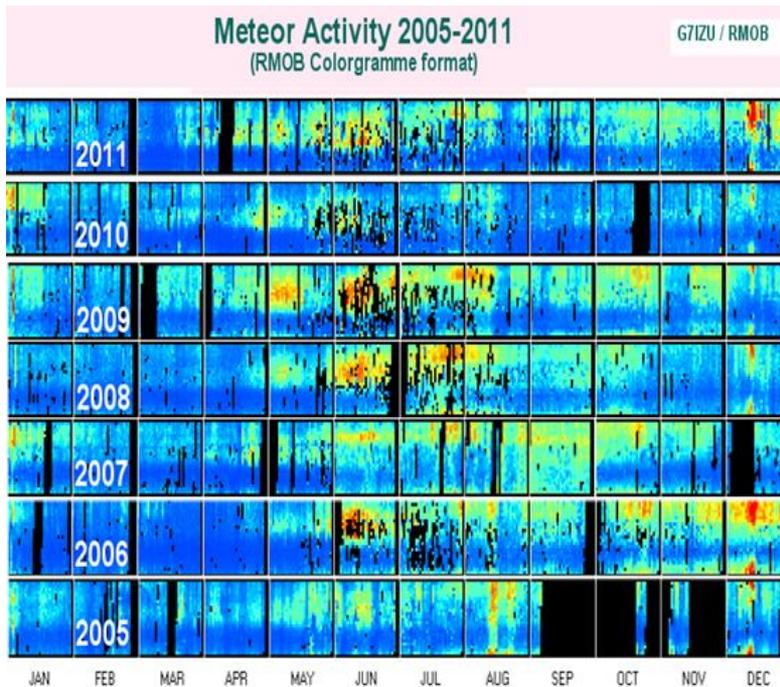


# Data Quality & Use

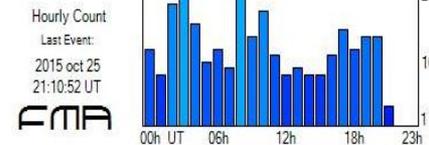
## Agglomeration



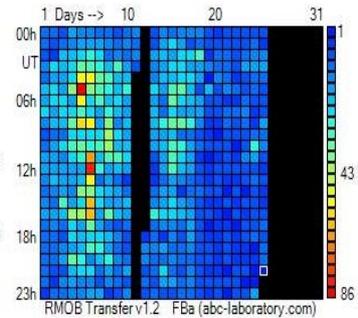
Currently it is common for meteor event frequency data to be charted as a Histogram or Colourgramme Plot. The aspirational target is set by Andy Smith's (G7IZU) multiple years RMOB data (Left).



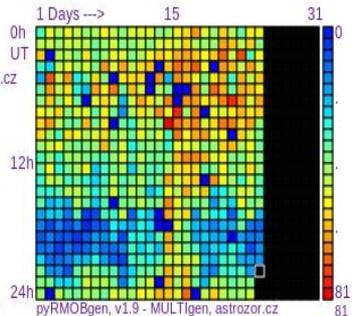
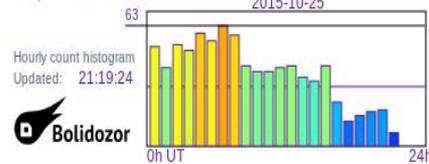
Observer: Fredi Bachmann\_GRAVES Location: 007°45'09 East  
 Country: Switzerland 047°23'52 North  
 City: Oberdorf BL Frequency: 143.05MHz  
 Antenna: Quadrifilar Helix AZ: 360° El: 90°  
 RF Preamp: none  
 Receiver: NESDR Mini2 R820T2  
 Computer: NUC D54250wYKH Q1.7GHz i5 8GB



Back Top



Observer: ZVPP-R3 Location: 48d 59" 13'  
 Country: Czech republic 14d 28" 3'  
 City: Ceske Budejovice Frequency: 143 050 000 Hz  
 Antenna: 1/4GP Email: roman-dvorak@email.cz  
 RF preamp: LNA01A www.mlaf.cz Month: 2015\_10  
 Receiver: RMD501B www.mlaf.cz  
 Computer: IonPC Atom



Note however that if we applied this approach to our results, **unchecked**, we would see significant variation & errors in meteor counts between different stations (Right).

RMOB: Radio Meteor Observing Bulletin: <http://www.rmob.org/livedata/main.php>

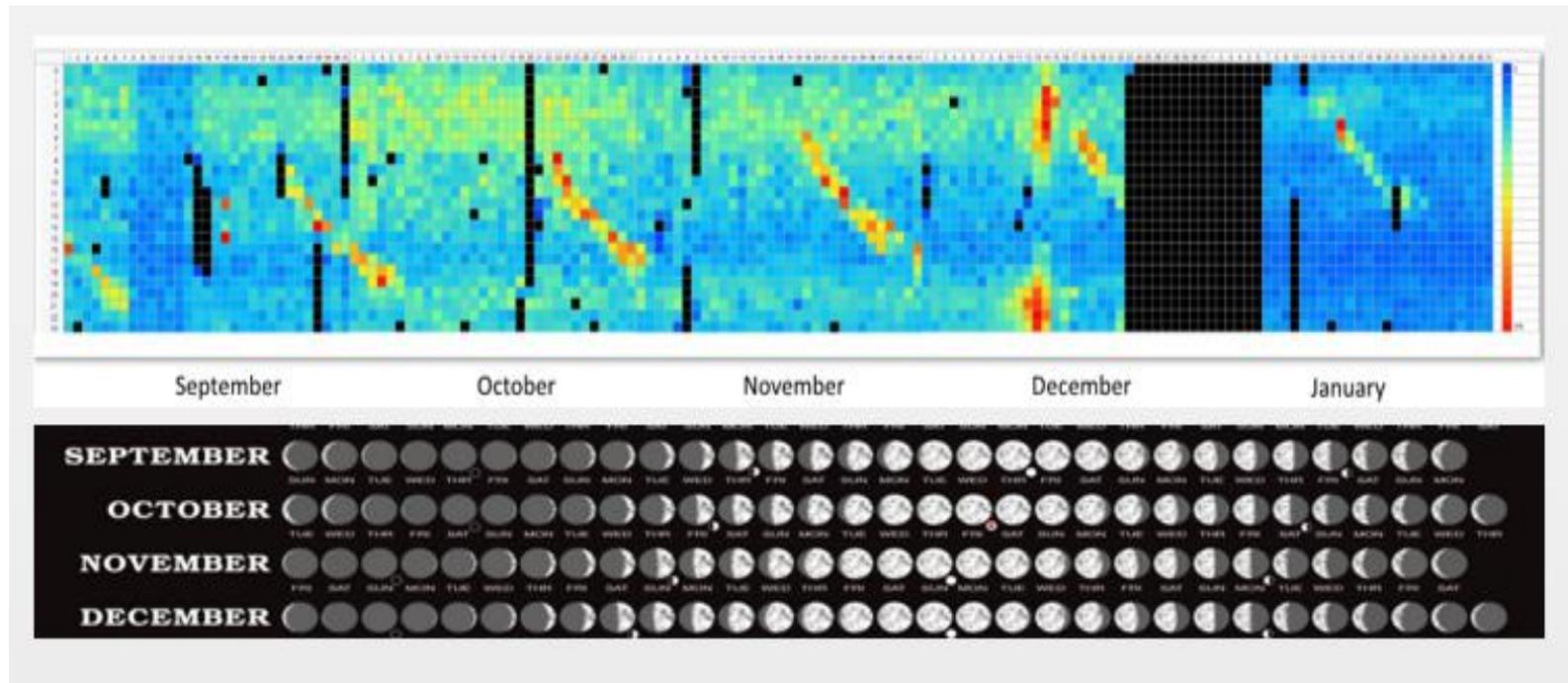


# Data Quality & Use

## False Positive Meteor Detection



Referring to our earlier slide regarding false positive meteor reflections captured by spectrumlab scripts, when plotted as a colourgramme without any data processing – errors can easily be made ...



For example the passage of the moon, progressively transiting our southern view, as expected.

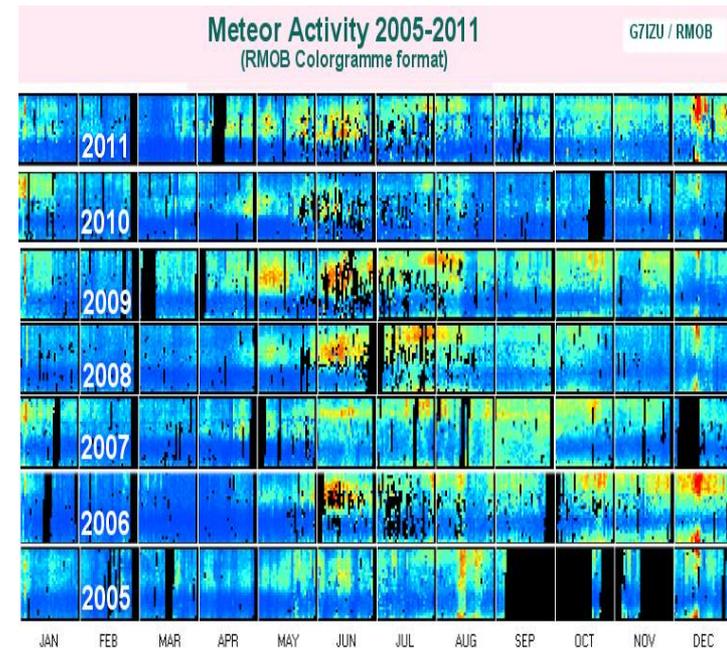
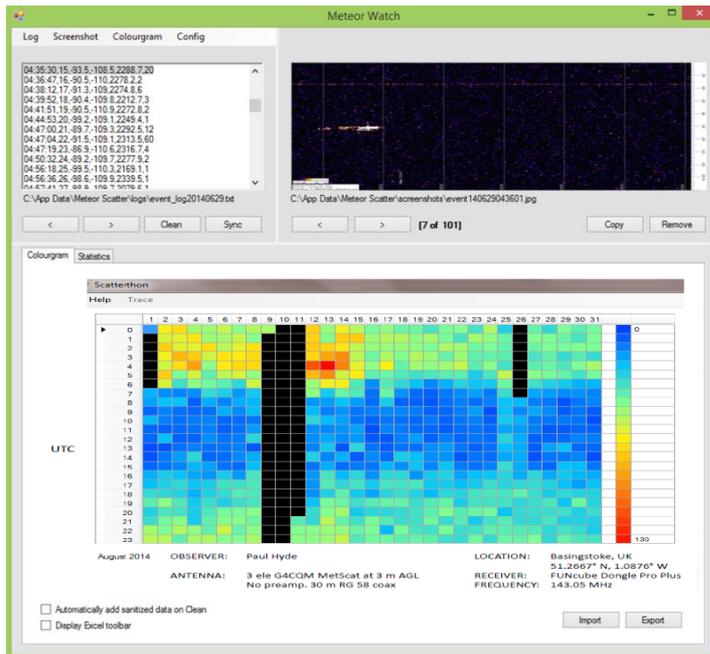


# Next Steps

## Scatterthon Development



Scatterthon is under development to screen and classify our “meteor” detections. By understanding our various false positive detections, our scripts can be improved and our data be filtered before use.



# “Scatterthon”

... RSGB Endorsed

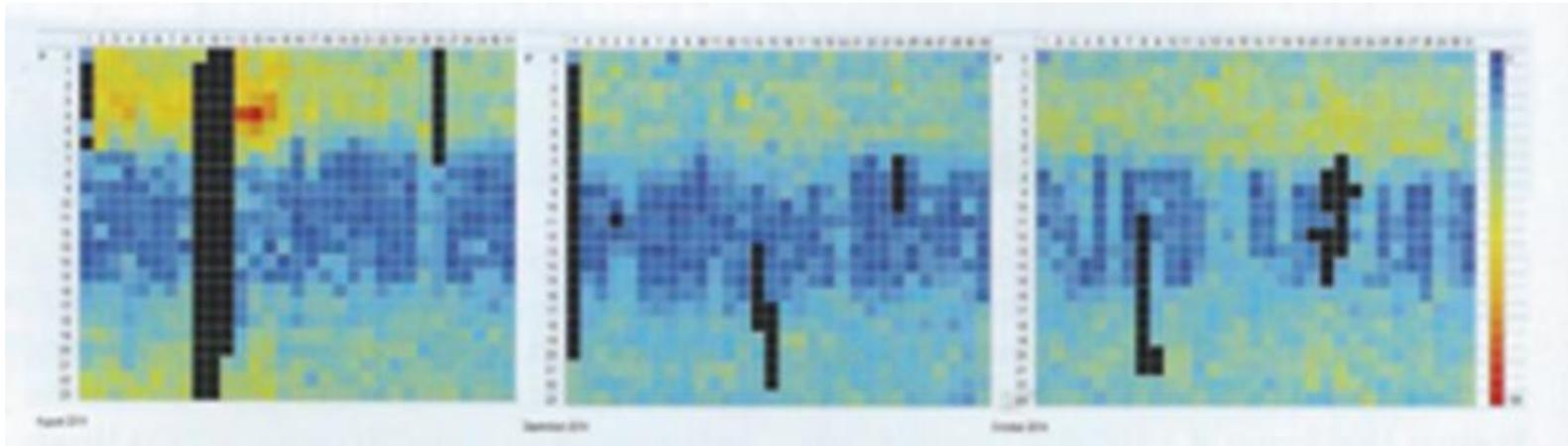


# Next Steps

## Scatterthon Development



*Scatterthon is windows based, has thus-far been tested by 4 testers and will be tested by an additional team in the next 3-6 months ahead of release. Victoria will demo Scatterthon later.*



# “Scatterthon”

**OBSERVER:** Paul Hyde  
**LOCATION:** Basingstoke, UK  
51.2667° N, 1.0876° W  
**ANTENNA:** 3 ele G4CQM MetScat at 3 m AGL  
No preamp. 30 m RG 58 coax  
**RECEIVER:** FUNcube Dongle Pro Plus  
**FREQUENCY:** 143.05 MHz



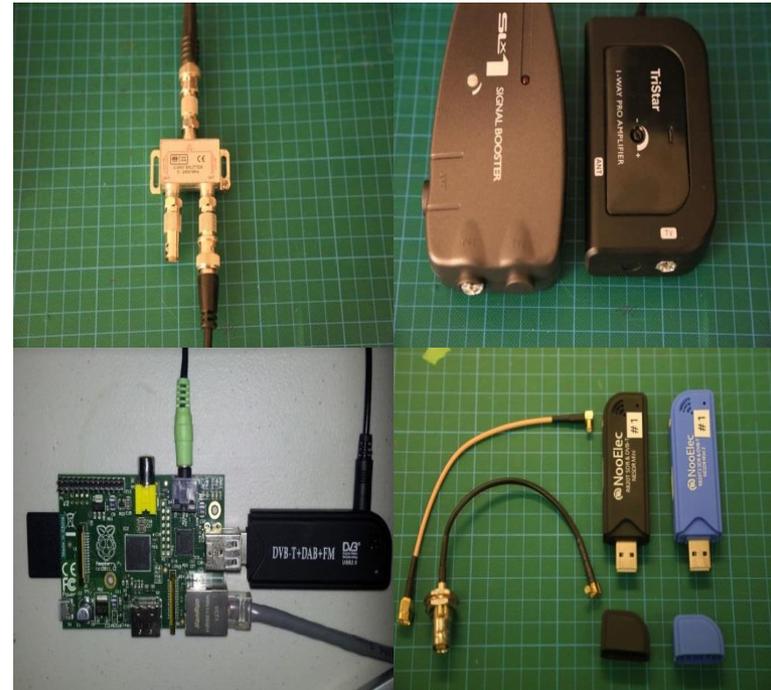
# Next Steps



## Hardware Cost Reduction

*Current systems rely on 24hr desktop or laptop computer operation. Hence the costs of a dedicated machine and energy consumption are targets for system cost reduction.*

- *Remove need for expensive dedicated computers (**Single Board Computers e.g. RaspberryPi**) – **ASSISTANCE WELCOME!!!***
- *Allow for multiple low cost arrays*
- *Low power requirements allow for battery powered remote / distributed monitoring*
- *Investigate removal of expensive Funcube Dongles at 150GBP each & replace with **lower cost SDR dongles**.*
- *RTL2832U TV dongles do not have filtering and amplifiers – low cost solutions to be investigated including TV amplifiers*
- *Relative assessment of higher vs. lower cost components*
- *Use of signal splitter for comparative experiments*





# Stimulating the Network

## *Station & Workshop Events*



*Within the last year we have assisted ca. 15 people locally to set up their own stations following instructions published in Sky at Night Magazine and in trouble shooting local interference.*



- *Members of Leicester, Nottingham, Mansfield, Burton on Trent & Litchfield Astronomical Societies have all established stations.*
- *They are all interested in a network which can process and put the data collected to use.*



# Stimulating the Network

## *Joining the dots ...*



*Having run an Astronomical Society and introduced technical interest groups including imaging and radio, it has become clear that there is both interest and skills in key areas of imaging, radio,*



*electronics and software within both the RSGB & Astronomical Societies. What is needed is practical guidance, demonstration and a support network to bring radio and astronomy enthusiasts into radio astronomy.*

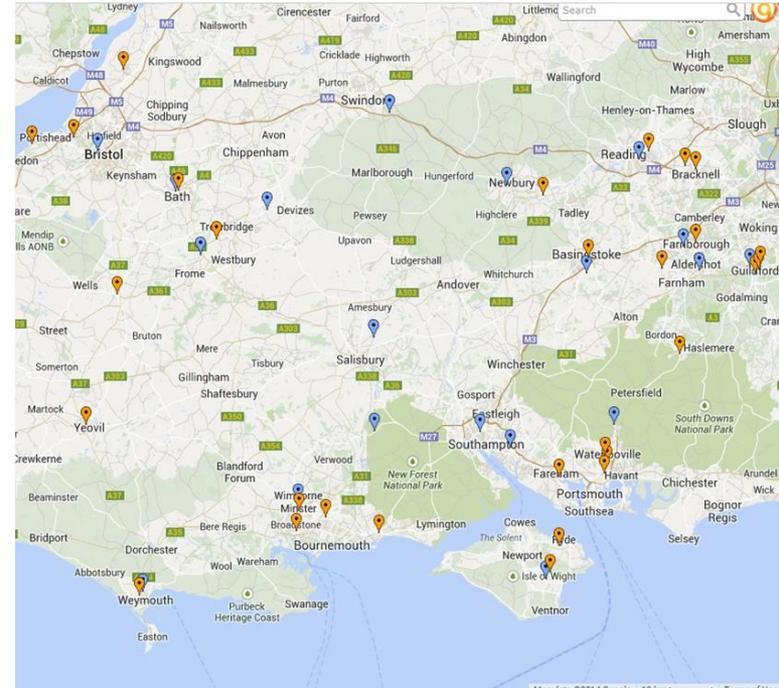


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*Who else is out there?*



*Following success in the Midlands regarding connecting RSGB and Astronomical Societies with an interest in Meteorscatter, we considered how closely located RSGB and AS's Groups were nationally.*



*It appears that there is enormous scope up and down the UK for collaboration ...*



# Practical Meteor Observing

## Meteor Station Development



# Questions?



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