RADAR OBSERVATIONS

W.J. BAGGALEY
Physics and Astronomy Department,
University of Canterbury, Christchurch,
New Zealand

1. Back–Scatter Geometry

Radar techniques can be a powerful adjunct for studying meteor storms in general because of their sensitiv ty, capacity for continuous observations and their use of current techniques facilitating the handling of data. While some radars are limited to only a range–time presentation (and so adequate for a time–profile description of a storm event), some facilities have the additional capacity to determine directional information or orbital elements which are valuable in delineating the dynamics and spatial structure of stream meteoroids. The following outlines the application of radar techniques to meteor storm recording and summarizes current and planned facilities.

For back–scatter geometry and the meteoroid trajectory *transverse* to the radar–meteor path the reflection process can be analysed in terms of the formation of Fresnel zones near the specular point. As an ablating meteoroid crosses successive zones the phase contributions of zones results in amplitude oscillations from which the meteor atmospheric speed can be determined. For a phase coherent radar system phase oscillations before the specular condition provide a more useful measurement since wind distortion effects are then minor. Many HF radars have antenna systems that are designed to illuminate angles of ground elevation between $\sim 20°$ and $\sim 60°$ so that with specular reflection geometry there exists an optimum geographic latitude at which to site a radar to enable efficient sampling of the Leonid stream near its local transit. There are two latitude bands; 42° N to 82° N and 2° N to 38° S.

For back–scatter geometry and the meteoroid trajectory *radial* to the radar–meteor the conditions are quite different: radio scattering can take place from a plasma ball created immediatly behind the ablating meteoroid. This moving plasma target can produce a well–defined doppler signal for phase–sensitive radars yielding an accurate meteor speed (and *e.g.* identification as a Leonid) and atmospheric deceleration. Recent descriptions of radar facilities can be found in: Brown *et al.* (1997), Jones and Brown (1994), Watanabe (1997), Kuong and Chu (1996), Baggaley *et al.* (1994) and Jenniskens (1997b). Several Leonid projects have been proposed to take advantage of the Arecibo facility. Data from two radar campaigns (Springhill and Ondrejov) have been anaysed by Brown *et al.* (1997) to present the Leonid influx characteristics over time–scales of decades. Of particular importance is the 1996 storm event (observed over the eastern part of the USA) which was recorded at Springhill and for which the duration width was only 23 min corresponding to a solar longitude change of $\sim 0°.01$: for adequate recording of such storms it is clear that a rather large number of radar facilities in geographic longitude is required.

2. Forward–Scatter Geometry

The importance of FS to Leonid observations is that an adequate longitudinal coverage might exist to provide the tight time resolution required to delineate short–lived storm events. Most passive operations use station separations of about 500-1000 km and employ a variety of commercial transmitters operating in the 50 to 100 MHz frequency range: television video carriers; radio FM and utility traffic. Only one operation is known that employs a dedicated TX; the CNR–FISBAT (Bologna Italy) facility (Foschini *et al.* 1995). Many of the stations in the available network are associated with essentially amateur organisations: the American Meteor Society's Radio Meteor

J. Andersen (ed.), Highlights of Astronomy, Volume 11B, 1015–1016.

https://doi.org/10.1017/S1539299600019481 Published online by Cambridge University Press

TABLE 1. Backscatter Radars

Institute/Location	Lat	Status	Type	Brief Description
Ondrejov, Czech Rep	50 N	1960–	T	37.5 MHz steerable Yagi
Springhill, Canada	45 N	1964–67	T	32.8 MHz crossed dipole All-sky
Univ WO, Canada	43 N	1996–	T	40.68 MHz radiant image mapping
Univ WO, New Mexico	35 N	1997–	T	Proposed mobile 20–30 MHz,
MU Radar, Japan	35 N	1996–	T, R	46.5 MHz phased array, zenith–look
JSC, Houston, USA	30 N	1996–	T	49.92 MHz steerable Yagi
Chung–Li, Taiwan	25 N	1996–	T, R	52.0 MHz phased array, zenith–look
Arecibo, Puerto Rico	18 N	pending	R	430 MHz 305m dish near-zenith
Christchurch, New Zea	43 S	1990–	T	26.3 MHz multi–station orbits
NASA–Ames, CA, USA	—	1997–	T	Proposed airborne multi–mission

Project; the Global Meteor Scatter Network and the International Meteor Organisation. See *e.g.* Richardson and Meisel 1997, Jenniskens 1997a and several recent reports in the IMO publication WG. There are several stations recently established in Japan and Southern Hemisphere facilities are planned.

TABLE 2. Forward–Scatter Stations

Location	Long	Lat	Location	Long	Lat
Kuusankoski, Finland	26.4 E	60.9 N	Budrio–Lecce, Italy	11.1 E	40.3 N
Luebeck, Germany	10.9 E	53.9 N	Greenbelt, USA	76.8 W	39.0 N
Appingedam, Netherlands	6.9 E	53.3 N	Lisbon, Portugal	9.2 W	38.7 N
Roden, Netherlands	6.4 E	53.1 N	West Point, USA	120.6 W	38.4 N
Groningen, Netherlands	6.6 E	53.1 N	Raton, USA	104.5 W	36.9 N
Ghent, Belgium	3.7 E	51.0 N	Nagano, Japan	137.9 E	36.1 N
Deurle, Belgium	3.6 E	51.0 N	Santa Fe, USA	105.9 W	35.7 N
Winnipeg, Canada	97.0 W	50.0 N	Poplar Springs, USA	85.6 W	30.9 N
Villach, Austria	13.9 E	46.6 N	Hawaii, USA	155.7 W	19.3 N

References

Baggaley, W.J., Bennett, R.G.T., Steel, D.I. and Taylor, A.D. (1994) The Advanced Meteor Orbit Radar: AMOR, *Quart. J. Roy Astro. Soc*, **35**, 293–999

Brown, P., Šimek, M. and Jones, J. (1997) Radar Observations of the Leonids: 1964–1995, *Astron. Astrophys*, **322**, 687–695

Foschini, L., Cevolani, G. and Trivellone, G. (1995) Radar Observations of the Leonid meteoroid stream in 1994, *Il Nuovo Cimento C*, **18**, 345–349

Jenniskens, P. (1997a) Meteor Stream Activity V, *Astron. Astrophys*, **317**, 953.

Jenniskens, P. (1997b) An airborne platform for instruments targeting the 1998 Leonid Storm, *this volume*.

Jones, J.and Brown, P. (1994) The Radiant Distribution of Sporadic Meteors, *Planet. Space Sci.*, **42**, 123–126

Kuong, R.M. and Chu, Y.H. (1996) The New Meteor Receiving System Implemented at the Chung–Li VHF Radar Site: System Description and Preliminary Results, *Proceedings of the Seventh Workshop on Technical and Scientific Aspects of MST Radar*, pp. 477–478

Richardson, J.E. and Meisel, D.D. (1997) The AMS Radiometeor Project, *American Meteor Society Bulletin.*, **203**

Watanabe, J. (1997) Radar Observations in Japan *this volume*.