Programme

16 October 2017, Monday

9:25 Ue-Li Pen Welcome and opening remarks

Chair - Ue-Li Pen "Topical Overview"

9:30	Norbert Bartel	VLBI - a historical perspective
10:00	Dan Stinebring	Scintillation arc basics - I
10:30	Barney Rickett	Scintillation arc basics - II
11:00 - 11:30		*Coffee break*
11:30	Jim Cordes	Magnetoionic properties of the ISM
12:00	Jean-Pierre Macquart	VLBI scintillometry - an overview
12:30	Marten van Kerkwijk	Scintillometry for special pulsar systems

13:00 - 14:00 *Lunch break*

Chair - Jim Cordes "Scattering and Lensing Models"

14:00	Barney Rickett	Scintillation arcs: comparison of observations with scattering and lensing models
14:20	Dana Simard	A predictive model of pulsar scintillation from grazing incidence sheets
14:40	Jean-Pierre Macquart	The effects of plasma birefringence on pulsar scintillation
15:10 - 16:10		*CITA Seminar* by Kenta Hotokezaka, CCA
16:30	Daniel Baker	Statistical tools from CMB for scintillometry
16:50 - 17:30		Discussion
18:30		*Workshop dinner*

17 October 2017, Tuesday

Chair - Dan Stinebring "VLBI Scintillometry"

9:30	Norbert Bartel	Substructure in the scatter-broadened image of PSR 0329+54
9:50	Olaf Wucknitz (remote)	Resolving an interstellar echo with low-frequency interferometry
10:10	Alexey Rudnitskiy	Radioastron pulsar observations: scattering parameters measured for five pulsars
10:30 - 11:00		*Coffee break*
11:00 - 11:30		Discussion
11:30	Franz Kirsten	VLBI on Crab giant pulses at 160 MHz
11:50	Michael Johnson	Scintillometry with VLBI at extreme angular resolution
12:10	Jason Dexter	Locating the intense interstellar scattering towards the inner Galaxy
12:30 - 13:00		Discussion
13:00 - 14:00		*Lunch break*
15:00 - 15:30		*Coffee*
15:30 - 17:00	**Chair - Jean-Pierre Macquart**	Structured discussion

18 October 2017, Wednesday

Chair - Barney Rickett "Single-dish Scintillation Arc Studies"

9:30	Adam Jussila	A scintillation arc survey with the Green Bank Telescope
9:50	Lars Kuenkel	Scintillation studies with LOFAR
10:10 - 10:40		*Coffee break*
10:40	Stella Koch Ocker	Multiple scintillation arcs in a nearby pulsar, B1133+16: crucial clues?
11:00	Dan Stinebring	A zoo of scintillation arcs
11:20 - 12:00		Discussion
12:00 - 13:00		*Lunch break*
15:10 - 16:10		Vladimir Soglasnov - *Dunlap Colloquium* Resolving scattering disks with ground-space VLBI
15:30 - 16:30	**Chair - Marten van Kerkwijk**	Open discussion

19 October 2017, Thursday

Chair - Vladimir Soglasnov "Black Widow and Other Special Objects"

9:30	Robert Main	A black widow up close
9:50	Fang Xi Lin	Unravelling the lensing geometry of the black widow
10:10	Dongzi Li	Constraining magnetic fields with a birefringent lens
10:30 - 11:00		*Coffee break*
11:00 - 11:30		Discussion
11:30	Nikhil Mahajan	Descattering the black widow
11:50	Matthew Kerr	Two extreme scattering events towards young pulsars
12:10	Stefan Oslowski	Probing the extreme conditions in the ionized interstellar medium towards PSR J1509+5531
12:30 - 13:00		Discussion
13:00 - 14:00		*Lunch break*
14:10 - 15:10		*CITA Seminar* by Brian O'Shea, MSU

Chair - Rene Breton "Special Objects (cont.)"

15:30	Elliot Polzin	Scintillometry of the black widow J1810+1744
15:50	Artem Tuntsov	Caustics in dynamic spectra, annoying but useful
16:10 - 17:10		Structured discussion

20 October 2017, Friday

10:00	Ue-Li Pen	Workshop summary
11:00 - 11:30		*Coffee break*
11:30	Jean-Pierre Macquart	The future of scintillometry: questions, avenues and prospects
13:00 - 14:00		*Lunch*
		---------- *Workshop concludes* ----------
16:00 - 17:00		*CITA Desserts*

Book of abstracts

Scattering and lensing models

Barney J. Rickett, UC San Diego.

Scintillation arcs: comparison of observations with scattering and lensing models.

Both the forward and reverse parabolic arcs observed from nearby pulsars imply highly elongated brightness distributions due to scattering or refraction in localized plasma concentrations. I fit models of these angular distributions to Dan Stinebring's recent observations from Arecibo. The strong wavelength scaling of the angular width derived from the forward arcs in pulsar B1133+16 are contrasted with the wavelength independence in the reverse arclets from B0834+06. The results are compared with predictions from both scattering and lensing models.

Dana Simard, University of Toronto.

A predictive model of pulsar scintillation from grazing incidence sheets

The origin of the highly-anisotropic scattering evident in the secondary spectra of some pulsars is still debated, but one proposed explanation draws parallels with the reflection of light off of a lake where, if the angle of incidence is low, we see many reflected images form along a rough line. If the ISM contains many thin, corrugated sheets, then when a sheet is closely aligned with our line-of-sight to the pulsar this same selection effect applies, and images of the pulsar are created along a line. Using ray optics, we have constructed a model of such a sheet that makes quantitative predictions of the evolution of the secondary spectrum with time and frequency, allowing the model to be tested with observations and providing a possible method of accounting for scintillation in observations. I will present an overview of this model and our progress in comparing it to observations.

Jean-Pierre Macquart, ICRAR, Curtin University, Perth

The effects of plasma birefringence on pulsar scintillation

Interstellar scintillation is usually treated using a scalar wave equation in which the scintillation properties are independent of the polarization of the propagating wave. However, when the medium contains spatial inhomogeneities in the anisotropic response of the plasma (i.e. when there are spatial rotation measure fluctuations) the propagation can, in principle, depend upon the polarization of the incident wavefront. I will detail the possible effects associated with this birefringence, both on the linear and circular polarization, from a formal perspective. I will also discuss a simple model that illustrates these effects. One particular application is the generation of time variable circular polarization, which ought to observable if there is appreciable variation in the Faraday depth on scales comparable to the refractive scale.

Daniel Baker, University of Toronto
Statistical tools from CMB for scintillometry
The dependence on transverse velocity of the scintillation features in dyanamic spectra provides a valuable measurement tool for the inclination of pulsar binaries by measuring periodic changes in scintil duration. For strongly varying systems, like the double pulsar
J0737-3039, direct fitting for a scintillation timescale in short time bins around the orbit is sufficient to measure the effect of orbital motion and fit for an inclination. For systems with slower orbits relative to their center of mass velocity, such as B1957+20, more powerful statistical tools are required. We explore the application of the Hu and Okamoto estimator, used to measure statistical changes in the properties of features in the CMB temperature map due to gravitational lensing, to characterize the fluctuations of scintil duration for such
weakly modulated systems.

VLBI scintillometry

Norbert Bartel, York University, Toronto.
Substructure in the scatter-broadened image of PSR 0329+54
Pulsars can be used to probe the interstellar medium. Since they are almost ideal point sources, any observation of structure in the images can be directly attributed to the interstellar medium along the path to the observer. PSR 0329+54 is the strongest pulsar at frequencies below 1 GHz in the northern hemisphere. Previous observations determined only upper limits on the size of the scattering disk. Space-VLBI observations at 324 MHz with RadioAstron could for the first time resolve the scattering disk and detected visibilities at long projected baselines where none were expected from the scattering disk. I will report on these results and their implications.

Olaf Wucknitz, MPIfR, Bonn. (remote)
Resolving an interstellar echo with low-frequency interferometry
The profile of the pulsar B1508+55 shows puzzling additional components that shift relative to the main pulse with time. A plausible hypothesis explains them as echoes caused by the interstellar medium, either by diffractive scattering or by lensing. The parameters of this system are such that resolving the echoes should be possible with international LOFAR-baselines in the band 100-200 MHz. With this motivation we have been monitoring this system weekly with German LOFAR stations since October 2016 and monthly since May 2017 with a more extended array including the Dutch core. The analysis of the first epoch already confirms the hypothesis: There is an angular offset of the echo from the main pulse. In this talk I will explain the observations, the analysis and first results. It is our hope that we will also be able to correlate the voltages of main pulse and echoes in the future for true interstellar interferometry.

Alexey Rudnitskiy, ASC, LPI Moscow
On behalf of Radioastron pulsar group, Rudnitskiy A. G., Fadeev E. N., Andrianov A. S., Zuga V. A., Popov M. V., Smirnova T. V., Soglasnov V. A., Shishov V. I.
Radioastron pulsar observations: scattering parameters measured for five pulsars
Scattering parameters were measured for five pulsars: B0823+26, B0834+06, B1237+25, B1929+10 and B2016+28 using Radioastron space-ground VLBI observations. Estimation of scattering disk size and scattering time for each pulsar provided the information on the distance to the effective scattering screen. Scattering time was measured from the half-width of visibility function along the delay. Parabolic arcs were detected in dynamic spectrum for several pulsars. In this case we have estimated independently the distance to the scattering screens from using parabolic arcs curvature. The location of scattering screens was compared then with the location of the objects and ISM structures in our Galaxy.

Franz Kirsten, Onsala Space Observatory, Chalmers University, Sweden
VLBI on Crab giant pulses at 160 MHz
I will give an update on our simultaneous observations of the Crab pulsar between the MWA and the GMRT. In the meantime we found fringes on about 10 bright giant pulses whose fringe amplitudes are consistently on the 1%-level. We do not see any evolution of the fringe amplitude as a function of pulse phase, but do see a trend of increasing amplitude as a function of frequency. I will discuss our findings both in terms of a two-screen scattering model and in terms of Kolmogorov turbulence.

Michael Johnson, CfA, Harvard.
Scintillometry with VLBI at extreme angular resolution
Interstellar scattering sets a fundamental limitation on the angular resolution of radio observations. Nevertheless, the scattering also enables new measurements of intrinsic structure, including precise estimates of brightness temperature and core shift with sparse data. I will discuss the effects of refractive interstellar scintillation for microarcsecond imaging with RadioAstron and the Event Horizon Telescope, new techniques to mitigate the scintillation, and new measurements enabled by the scintillation.

Jason Dexter, Max-Planck Institute for Extra-terrestrial Physics, Heidelberg, Germany
Locating the intense interstellar scattering towards the inner Galaxy
VLBI imaging of pulsar scattering screens combined with measurements of their pulse broadening can locate the scattering along the line of sight. We have applied this technique to a small sample of the most intensely scattered pulsars towards the Galactic center (GC) and inner galaxy. I will show that i) the GC scattering region has multiple physical origins on scales of ~0.1 degree and ii) in 3 objects, the inferred 3D scattering location matches that of a known HII region. A model of scattering by a single HII region can also explain the scattering properties of the GC magnetar and Sgr A*.

Single dish scintillation studies

Adam Jussila, Oberlin College.

A scintillation arc survey with the Green Bank Telescope

Using Green Bank Telescope observations of 18 pulsars, we performed a statistical study to determine the prevalence of scintillation arcs among pulsars along typical lines of sight. The pulsars were selected to have dispersion measures less than 50 pc cm−3 and S400 greater than 25 mJy. We observed at 340 MHz and 850 MHz, with a 40 MHz bandwidth at each frequency. Of the 18 pulsars observed, 15 had signal strength adequate to characterize the behavior in the secondary spectrum. Of these, 13 showed distinct scintillation behavior, including numerous instances of multiple scintillation arcs in a single observation. Many of the pulsars showed sharply delineated boundaries to the scintillation arcs, indicating elongated scattering structures on the sky, and several pulsars showed arclet behavior. We are investigating whether a combination of scattering measure and wavelength squared is a predictor of arclet behavior, as it should be in one version of the "waves on a sheet" model (Pen and Levin 2014).

Lars Kuenkel, U. Bielefeld, Germany

Scintillation studies with LOFAR

Scintillation studies of pulsars enable us to probe the properties of the interstellar medium . We use the Low Frequency Array (LOFAR) to measure pulsar scintillation in the frequency range between 110 MHz and 185 MHz with frequency resolutions of up to 5 kHz. These low frequencies allow us to measure scintillation parameters with relatively little observing time. We investigate the evolution of scintillation parameters on time scales from hours to years.

Stella Koch Ocker, Oberlin College

Multiple scintillation arcs in a nearby pulsar, B1133+16: crucial clues?

We have made multi-frequency observations of the nearby (350 pc) pulsar B1133+16 with the Arecibo telescope over 20 epochs with an approximately weekly cadence. This pulsar is nearby enough, and its scintillation arc structure simple enough, that it is an excellent test case against which to compare models. At most epochs we observed at 430 MHz and either 327 MHz or 1450 MHz. We detected multiple scintillation arcs at most epochs, and these are consistent in curvature with the four arcs reported earlier by Stinebring (2006). We will present modeling of the thickness (in theta_x) of the arcs at multiple frequencies. Our goal is to test the inclined sheet model of Pen and Levin (2014) for consistency with the frequency development of the arcs.

Dunlap Colloquium

Vladimir Soglasnov, Astro Space Center, Lebedev Physical Institute, Russian Academy of Sciences, Moscow

Resolving scattering disks with ground- space VLBI

Ground -- Space VLBI observations of pulsars with baselines up to ~20 Earth diameters show surprising view of visibility (delay --fringe rate plot, or delay -- Doppler in "secondary spectra" nominating). At low & medium baselines, besides main peak in the origin it contains a number of needle-like spikes at non-zero delays. At long baselines, main peak is absent, it decades completely into a cloud of spikes within delay range corresponding to "scattering disk" diameter. Such uncommon structure is created because a scattered image of pulsar is essentially a number of coherent copies of a single original source (PSR) which are distributed within "scattering disk" area. Ground -- Space baselines with Radioastron are favorable for ISS studying from nearby pulsars, with a little scattering angle and small number of scattered rays, so it becomes possible give an adequate interpretation of observational data.

Black widow system B1957+20

Robert Main, University of Toronto.

A black widow up close

The "Black Widow" pulsar B1957+20 is an millisecond pulsar that strongly irradiates and ablates its brown dwarf binary companion, and is eclipsed through its companion's outflow. I will talk about the of the discovery and properties of extreme lensing of the pulsar's radio emission by the outflow. Both before and after radio eclipse, the pulsed flux becomes strongly variable, being magnified by factors up to 30 across our 48 MHz band. The magnification is often highly chromatic, for some events rising to two orders of magnitude at specific frequencies. Many of the strongest events affect the main pulse and interpulse differently, with some affecting only part of the pulsar's wide interpulse beam. The required scales imply resolutions of order 1 km at the pulsar, and hence it may be possible to map the pulsar magnetosphere in a way akin to what is done for stars using gravitational microlensing.

Fang Xi Lin, University of Toronto

Unravelling the lensing geometry of the black widow

The original Black Widow Pulsar B1957+20 experiences an eclipse for 10% of its 9.2h orbit. In the ingress and egress of the eclipse, we measure extra dispersion measure (DM) through folded pulse profiles and find that it varies by $\sim 5 \times 10^{-4} pc/cm^3$ on the order of a minute and has smaller inhomogeneities of $\sim 5 \times 10^{-5} pc/cm^3$ on the order of $\sim 2s$. At the smaller scales, the column density of plasma naturally acts as an aberrated chromatic lens

which strongly lenses the background pulsar. We map the measured DM to dynamic spectra and the simulated spectra are found to be highly chromatic, forming caustics and cusp catastrophes with ~ 30 magnification across a 16MHz band of and up to ~ 70 at peak frequencies, qualitatively matching our data. The simulation is sensitive to the dimensionality of the lens and and speed of the outflow, and more quantitative comparisons against the data will constrain these parameters.

Dongzi Li, University of Toronto
Constraining magnetic fields from a birefringent lens
The presence of eclipse in B1957+20 is confusing. Currently the favoured explanation at low frequency is cyclotron absorption from a region mixing high magnetic field from pulsar wind and high electron density from companion. The linear polarization fraction of B1957+20 is very low, making it difficult to see the Faraday rotation directly. However, multiple highly magnified events in the region near eclipse give us good opportunity to test the theory. From the lens structure of two circular polarization, we can not only give a constraint on average magnetic field but also infer its small scale variance in the projected plane.

Nikhil Mahajan, University of Toronto.
Descattering the black widow
Descattering the pulse emission of a pulsar is useful on two fronts: Extracting the intrinsic pulse emission of the pulsar which will aid in our study of pulsar emission mechanisms, and extracting the impulse response function of the ISM which can be used in a miriad of ways to study both the ISM and the pulsar itself. We have had some success with using giant pulses and cyclic spectral analysis in descattering the Black Widow Pulsar's pulse emission, which I will talk about in this talk.

Special Objects

Matthew Kerr, CSIRO, Sydney
Two extreme scattering events towards young pulsars
We time over 150 young pulsars once a month with the Parkes telescope. These snapshot observations are calibrated to yield both dynamic spectra and average flux density values. The data set spans almost ten years, long enough to resolve refractive time-scales for some distant pulsars. In an initial review of the data, we found evidence for two historical extreme scattering events. One, towards the modestly-distant PSR J1740-3015, shows the now-classic double dip attributed to large-scale lensing. The other, towards the nearby PSR J1057-5226, manifests through a strong decrease in the scintillation bandwidth and dramatic brightness variations that may be associated with the edges of the scattering structure. We present details and interpretation of these two ESEs and brief plans for an analysis of the full timing data set.

Stefan, Oslowski, Centre for Astrophysics & Supercomputing, Swinburne University of Technology

Probing the extreme conditions in ionized interstellar medium towards PSR J1509+5531

German LOFAR stations used in GLOW mode are an excellent tools for monitoring the ionized interstellar medium (IISM) due to the high availability of observing time and low observing frequency. Owing to the former we can monitor a large number of pulsars at high cadence and due to the latter we are more sensitive to a variety of propagation effects. Among the pulsars we monitor we found some interesting cases which demonstrate the extremes of the IISM environments. In particular, the ionized interstellar medium towards PSR J1509+5531 shows remarkable variability. The integrated column density changes significantly on short timescales. We also see a new components in the pulse profile which we believe are images of the pulsar propagating towards Earth along different paths. I'll summarize our findings for this pulsar along with some implications. I will briefly summarize other related results from GLOW observations as well.

Elliot Polzin, U Manchester / Jodrell Bank Observatory

Scintillometry of the black widow J1810+1744

Black widows and redbacks are two classes of binary pulsar systems that can be identified by characteristic irradiation, and possibly subsequent ablation, of the companion, which in many cases results in the eclipsing of the pulsed radio emission for a portion of the orbits. These systems provide the unique opportunity to investigate a variety of key processes that are yet to be fully understood, such as the ablation of the binary companion and subsequent evolution of the binary, the eclipse mechanism, and possible intra-binary shock regions between the pulsar and companion. Here I will present a study of the eclipses of the black widow pulsar J1810+1744 at low frequencies, where the eclipse mechanism is most pronounced. Utilising the simultaneous dual beamforming and interferometric mode of LOFAR HBA, pulsar flux variations throughout the orbit are compared for the two observing techniques to test for the presence of scattering and absorption at eclipse orbital phases. Dispersion measure variations are used as a sensitive probe into outermost edges of the eclipsing material surrounding the companion star.

Artem Tuntsov, Manly Astrophysics, Australia

(Artem Tuntsov for Australia Telescope Extreme Scattering Events collaboration: K. Bannister, H. Bignal l, S. Johnston, C. Reynolds, J. Stevens, A. Tuntsov, M. Walker)

Caustics in dynamic spectra, annoying but useful

The dynamic spectrum of a scintillating pulsar is sculpted by both diffractive and refractive effects of scattering and for extragalactic sources the latter dominate. We have been systematically recording dynamic spectra of ~1000 flat spectrum sources in the course of ATESE project for over three years now and discovered a few Extreme scattering events and, more recently, extreme Intra-day and Intra-hour variables. I will explain what we learnt from the interpretation of dynamic spectra and how the caustics of the refractive mapping in the spectra

can be powerful probes of both the source and the lens, with a view on making these findings useful for pulsar scintillation.