Toward a joint array and polarization processing from IMS 3-component stations data:

Seismic wavefield polarization and its spatial coherency

Claire LABONNE*[12], Olivier SÈBE[1]

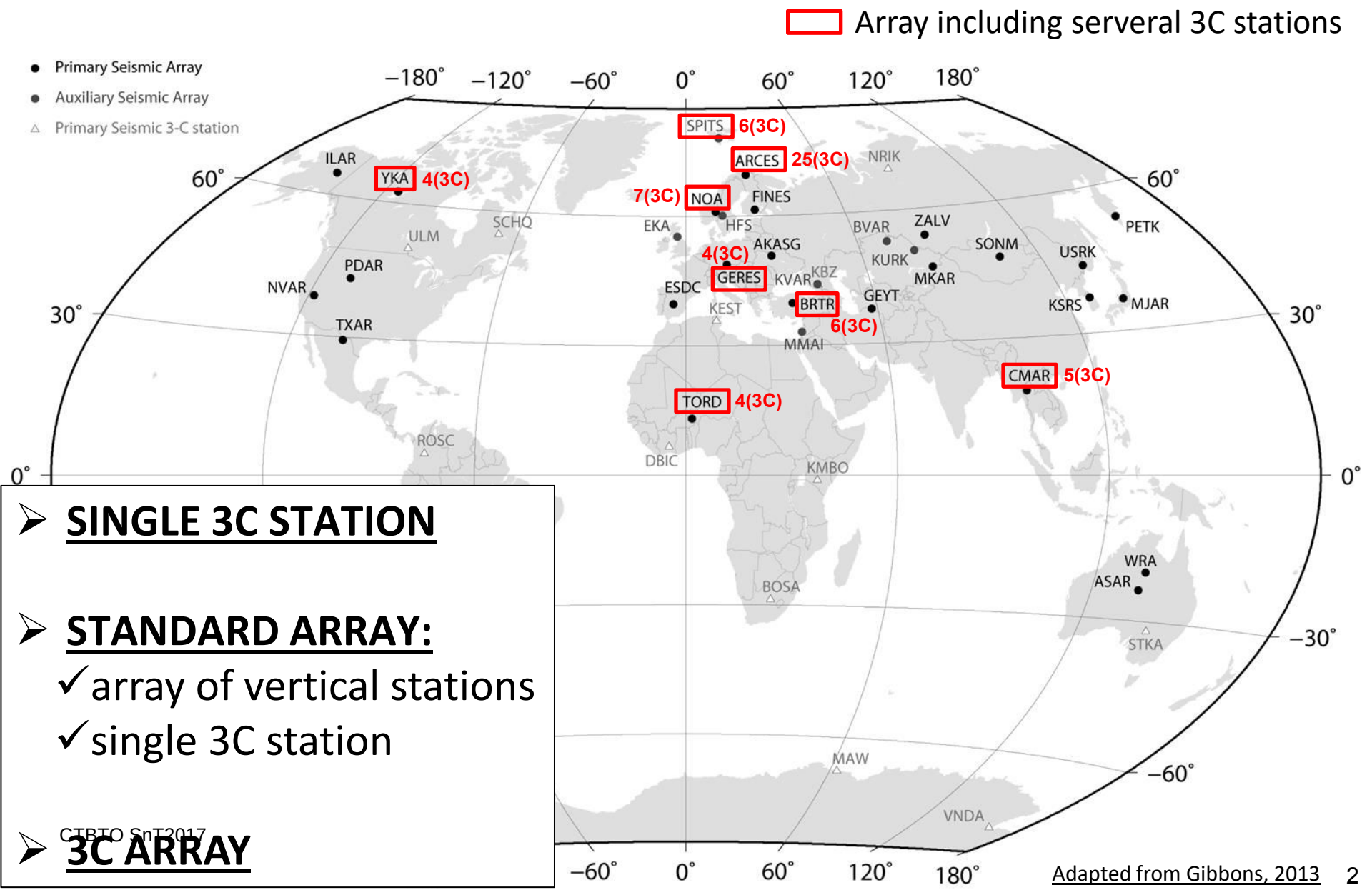
Stéphane GAFFET[23], François SCHINDELÉ[1]

* Now at Departement of Seismology, IPGP, France (labonne@ipgp.fr)

1. CEA, DAM, DIF, F-91297 Arpajon, France
2. Univ. Nice Sophia Antipolis, CNRS IRD, OCA, France
3. LSBB, Rustrel, France

29 June 2017

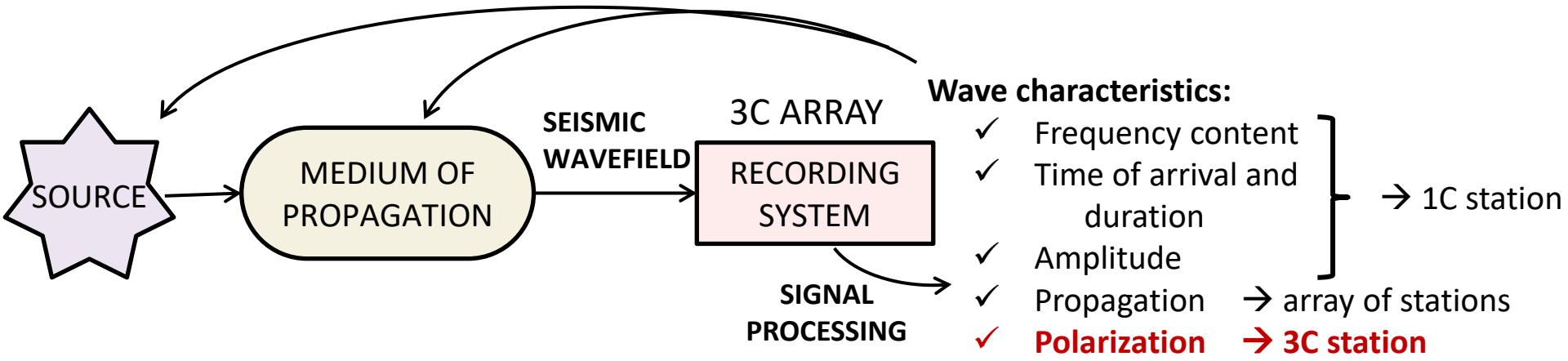
IMS SEISMIC STATIONS AND ARRAYS



- **SINGLE 3C STATION**
- **STANDARD ARRAY:**
  - ✓ array of vertical stations
  - ✓ single 3C station
- **3C ARRAY**

Adapted from Gibbons, 2013

WAVE CHARACTERISTICS (from 1C to 3C)



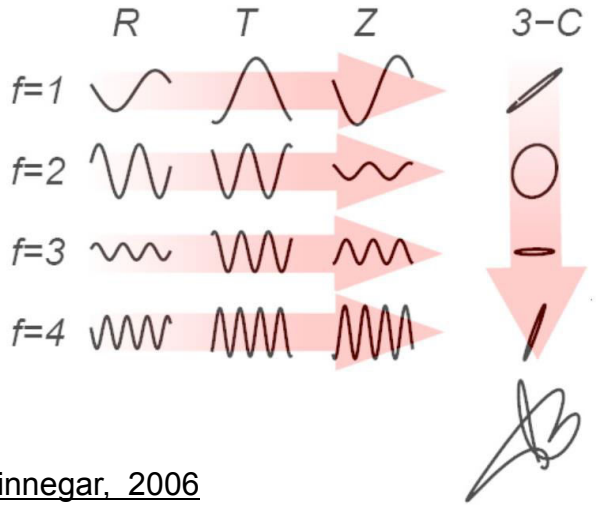
- Signal processing techniques do not manage to use the **full potential** of the 3C array which mainly **under-used the polarization**

- **Complexity to extent** 1C to 3C array processing
  → High order **optimization problem**
  → Require **strong assumptions** on the polarization model
  [Wagner, 1996], [Hobiger 2011]

- **Objectives: Better exploitation of the 3-component stations and arrays large potential by focusing on polarization**

DEFINITION OF POLARIZATION PARAMETERS

❖ By Fourier analysis, the seismic wavefield records can be decomposed into a sum of elliptical motions

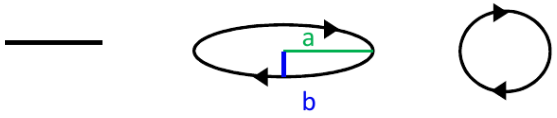


Pinnegar, 2006

❖ Polarization state is characterized by a **shape** and an **orientation**

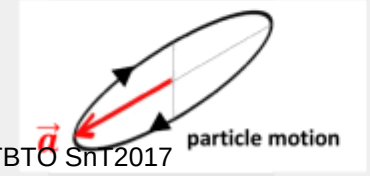
✓ **Ellipticity ρ**

$\rho = 0$ $\quad 0 < \rho = \frac{b}{a} < 1$ $\quad \rho = 1$



✓ **$\vec{a}$ linearity vector**

→ orientate the major displacement

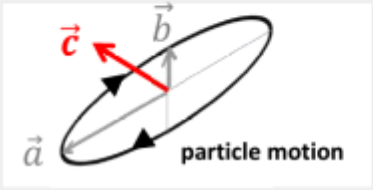


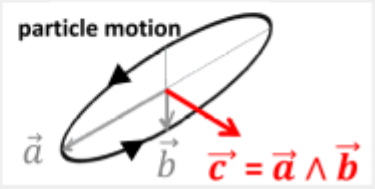
✓ **$\vec{c}$ planarity vector**

orthogonal to the elliptical motion

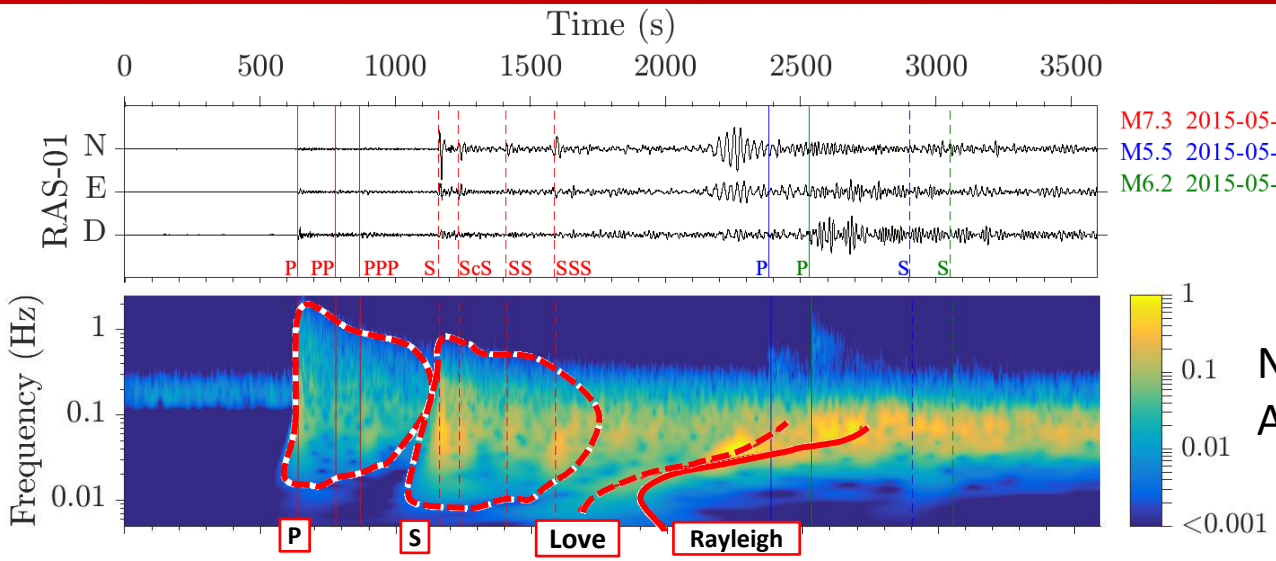
→ orientate the polarization plane

→ take into account the direction of rotation





CASE STUDY

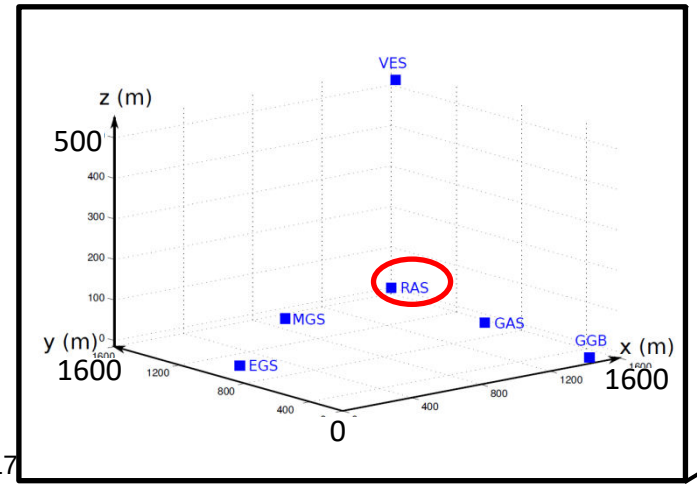


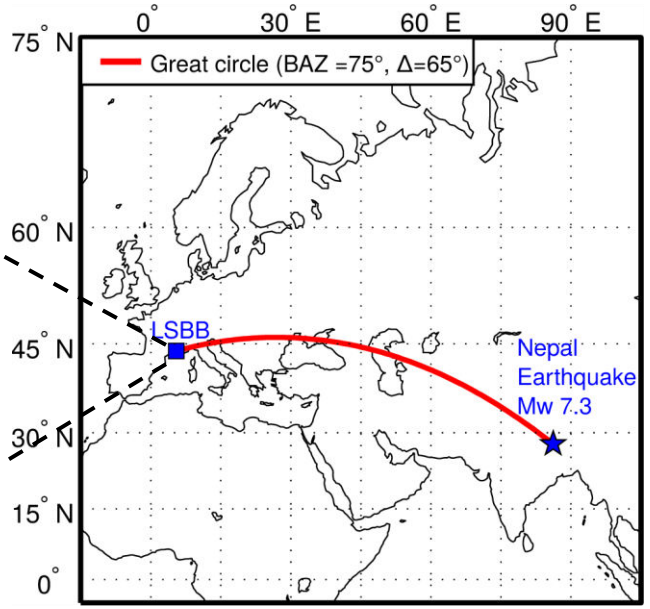
→ Gorkha Earthquake
Second main shock

Normalized
Amplitude (An)

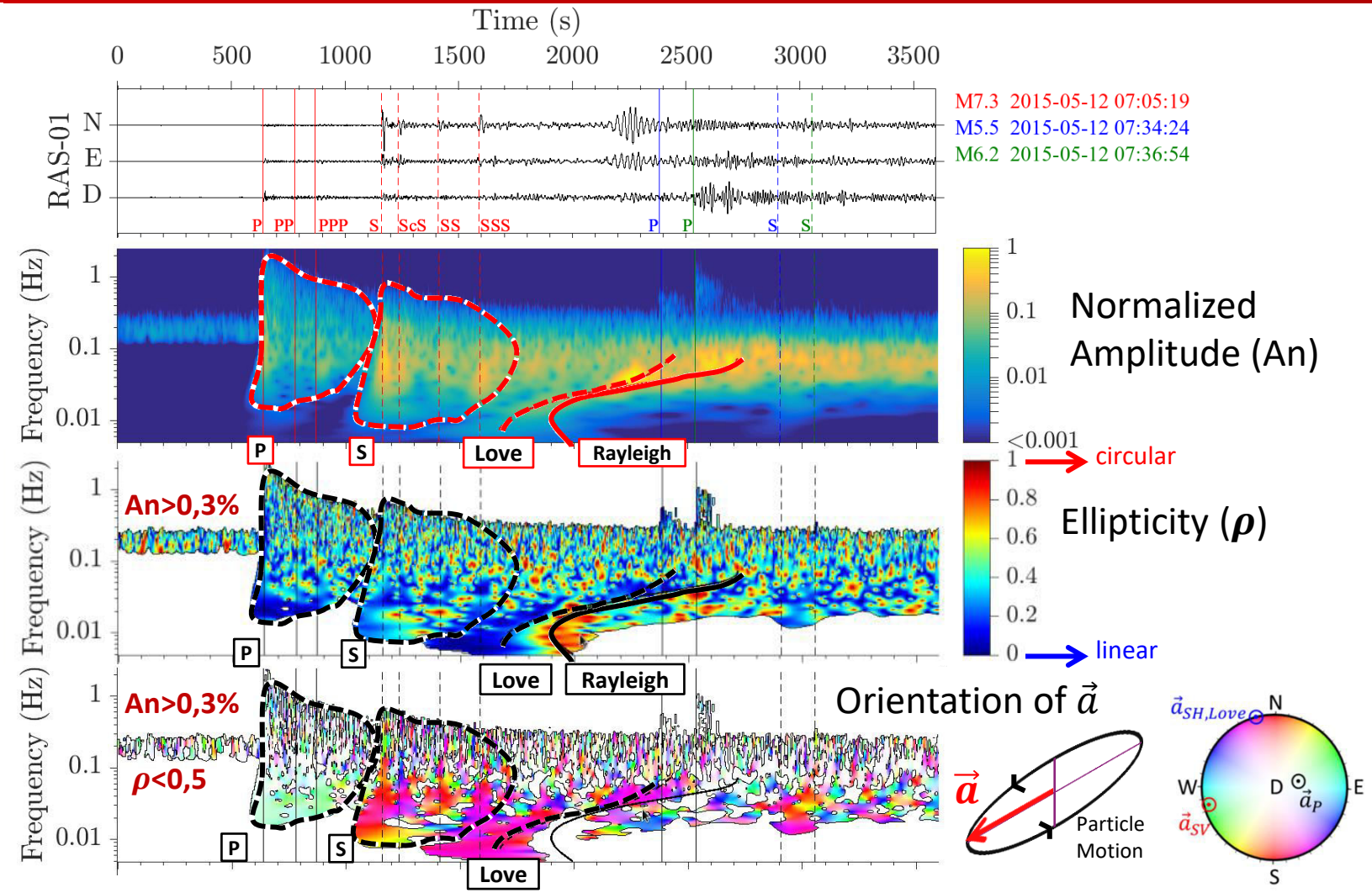
Stockwell 1996

LSBB broad-band 3C seismic array





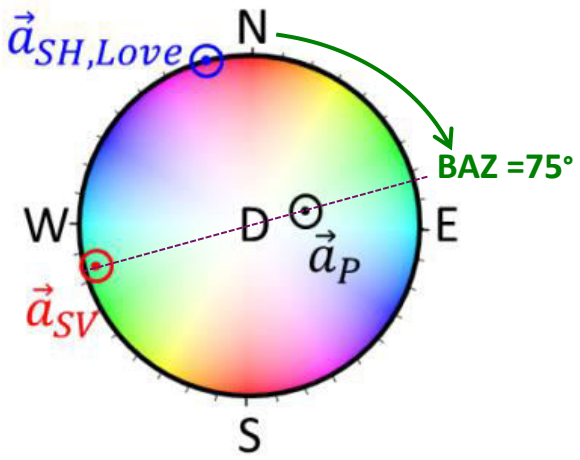
VISUALIZATION OF POLARIZATION



Energy based mask:
→ Selection of relevant information

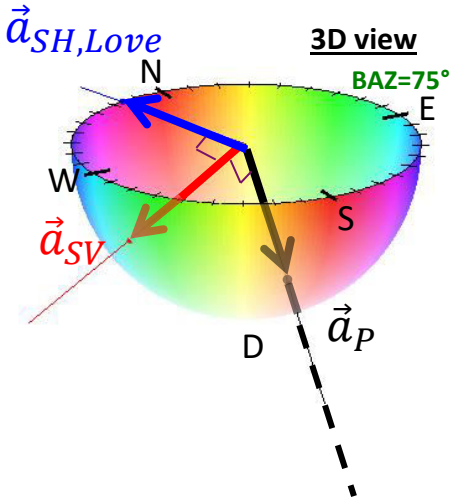
Ellipticity based mask:
→ Selection of relevant polarization parameter

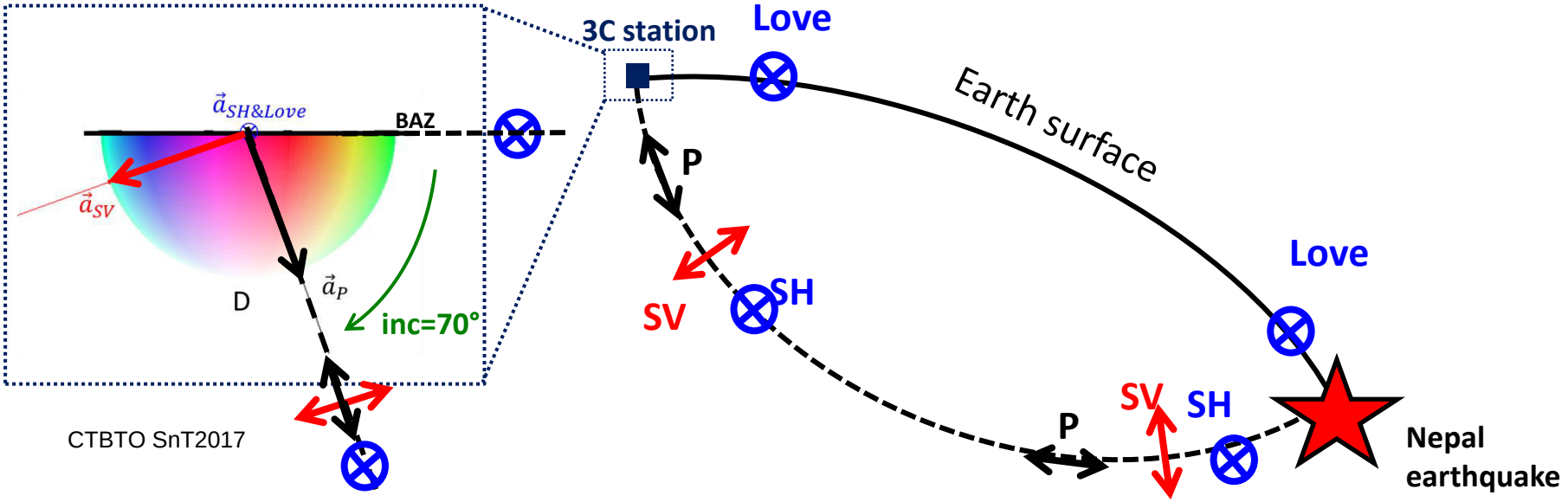
VISUALIZATION OF POLARIZATION



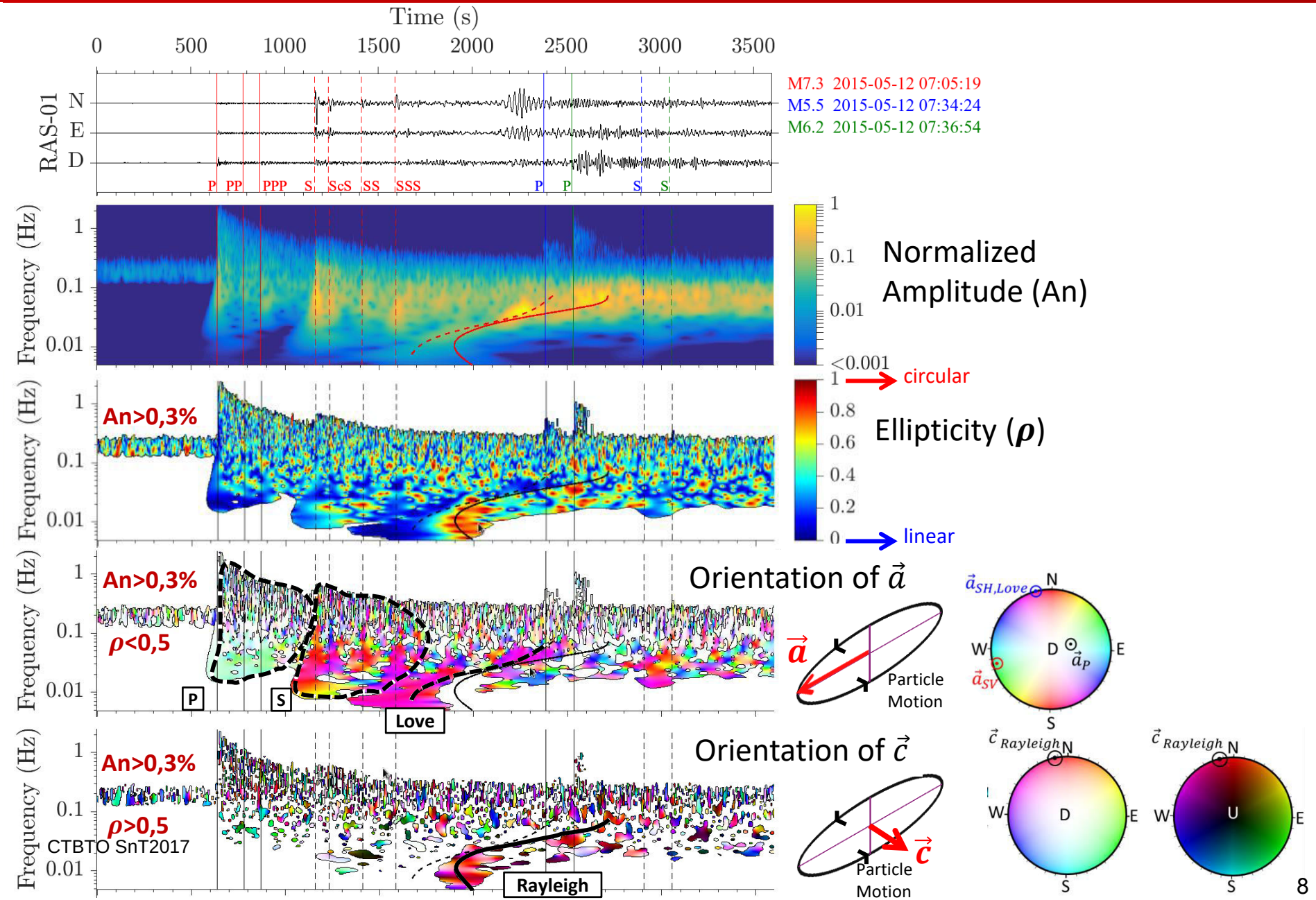
1D Earth model

Direct ray path with
- an azimuth of 75°
- an incidence of 70°

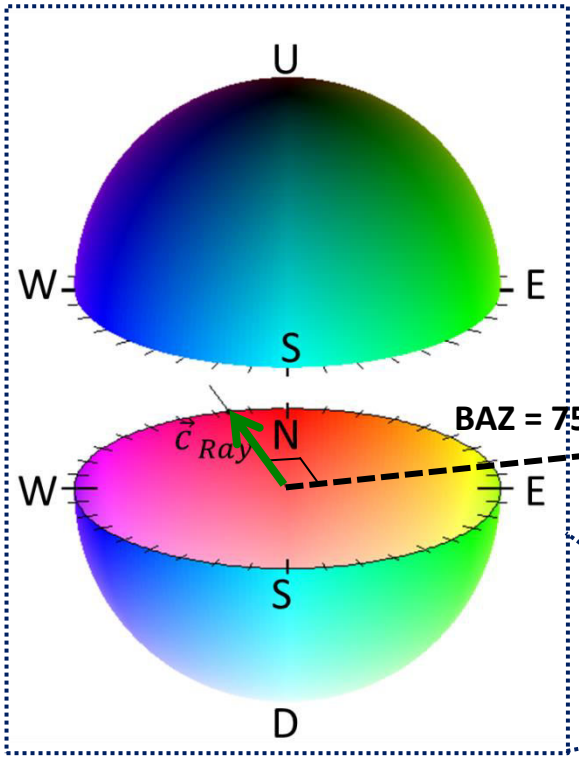




VISUALIZATION OF POLARIZATION

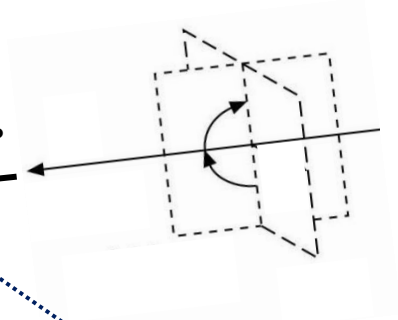


VISUALIZATION OF POLARIZATION



Direct ray path with
- an azimuth of 75°

BAZ = 75°



3C station

Love

Rayleigh with retrograde motion

P

SV

SH

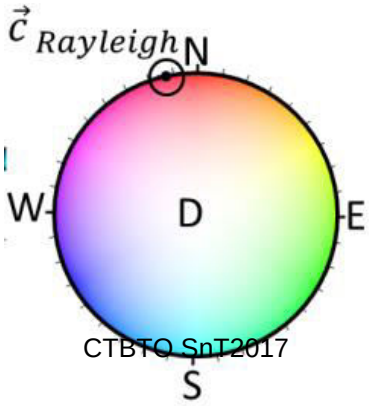
Love

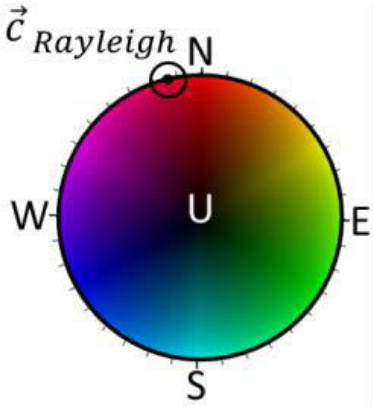
P

SV

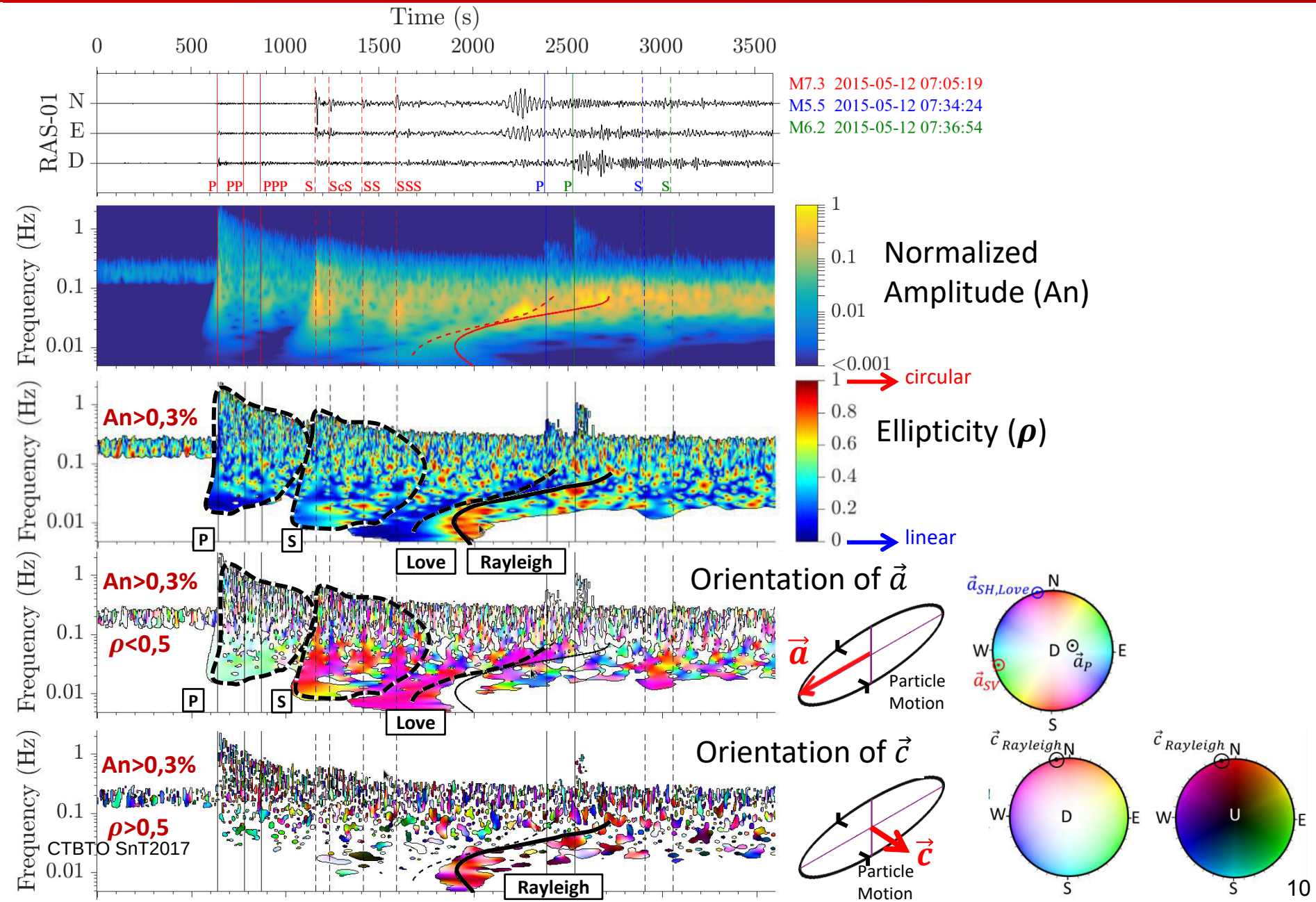
SH

Nepal earthquake

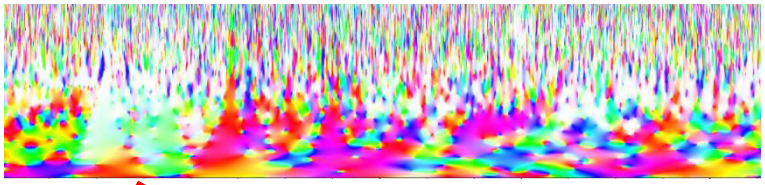




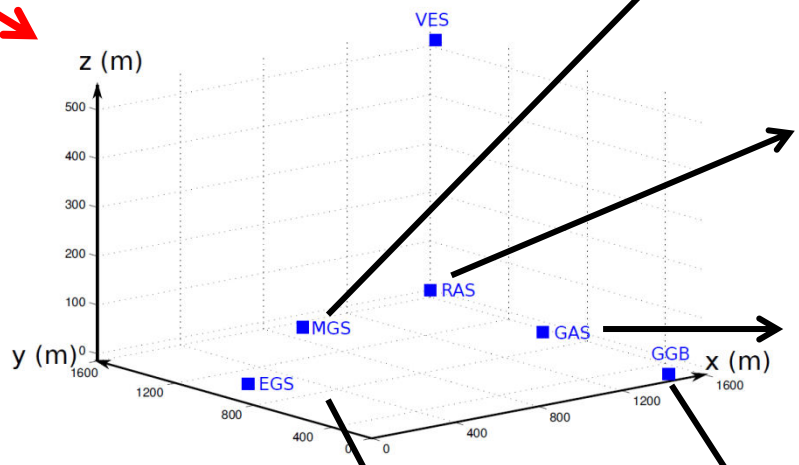
VISUALIZATION OF POLARIZATION

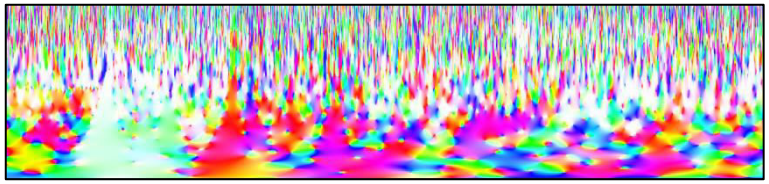


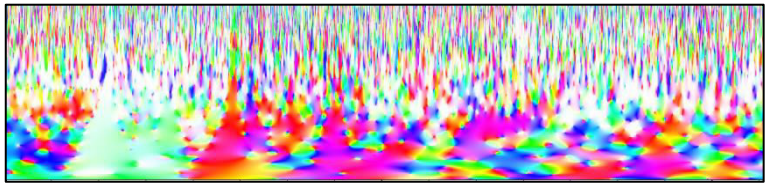
DEFINITION OF COHERENCY PARAMETERS

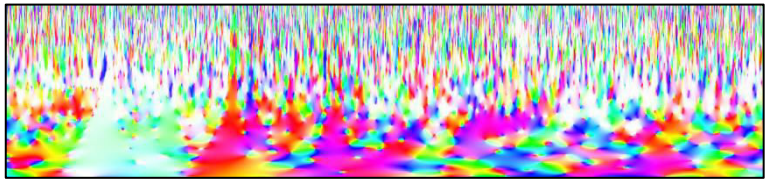


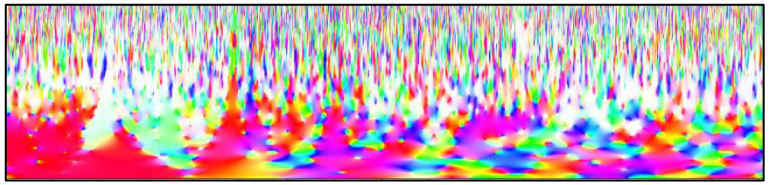
Plane wave: same polarization pattern



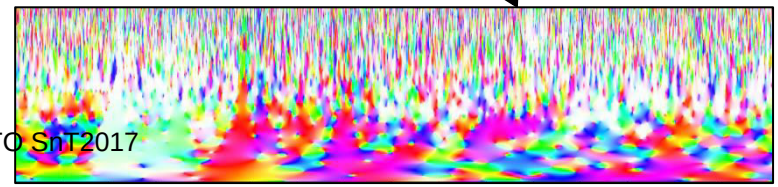






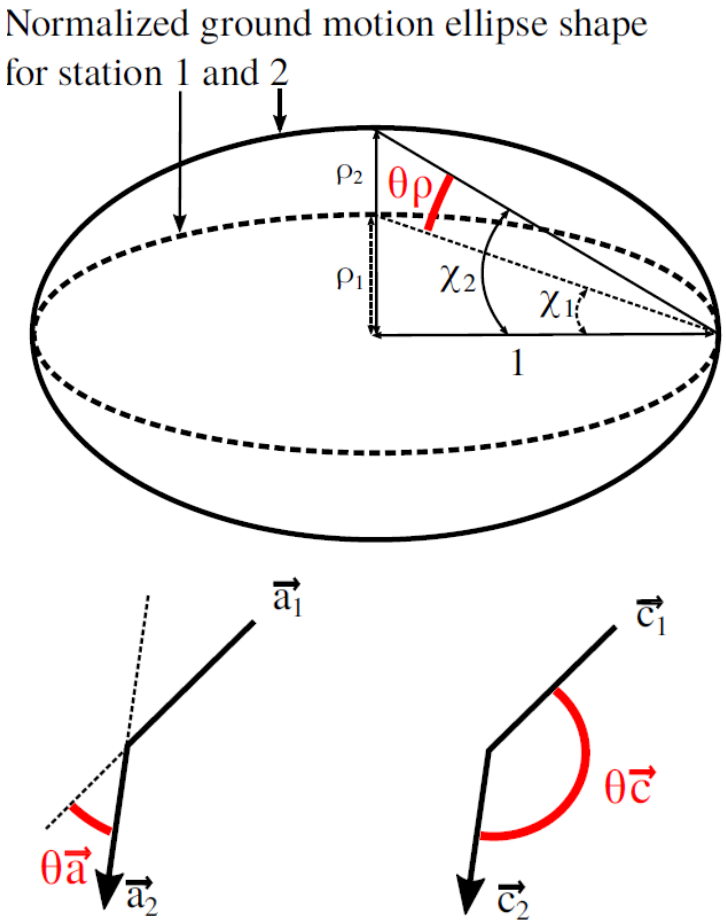


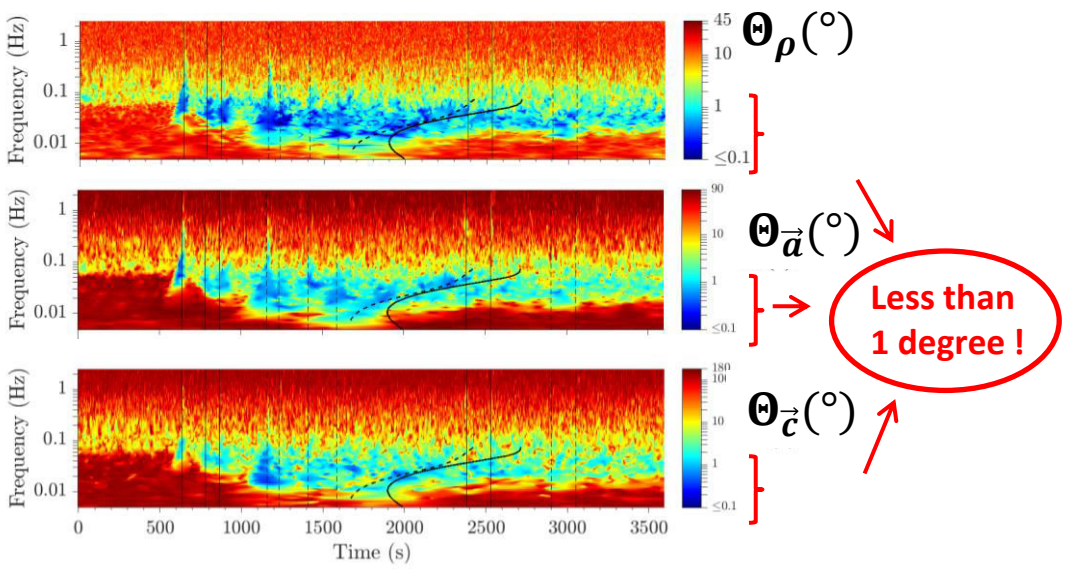
→Array aperture <u>smaller</u> than 2km



DEFINITION OF COHERENCY PARAMETERS

→ Deviation in polarization shape and orientation





→ Observation of spatial polarization coherency through the LSBB array

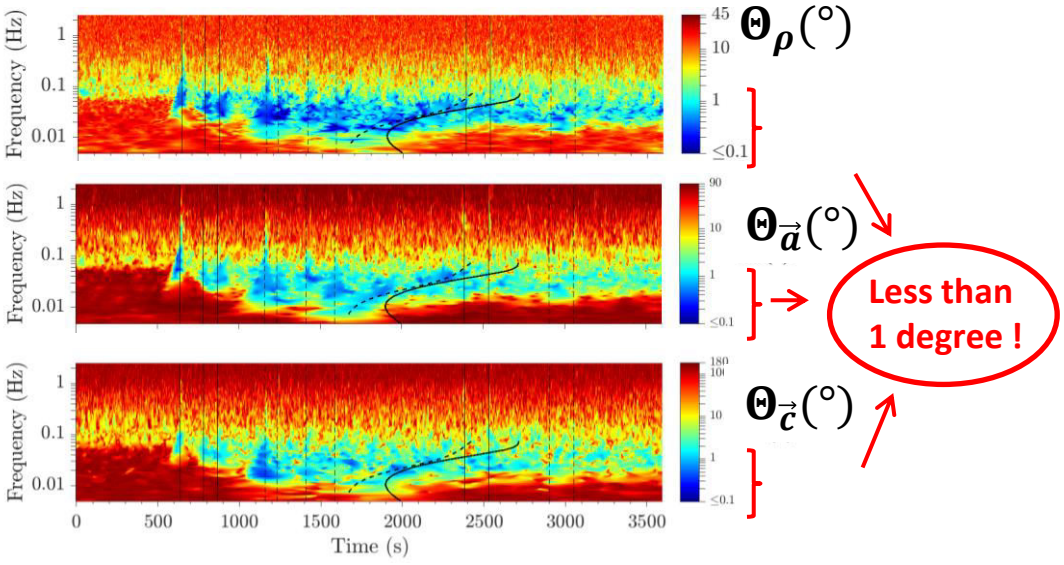
PRECISE ORIENTATION REQUIREMENT

- ✓ Station orientation with Fiber Optic Gyrocompass Precision < 1°

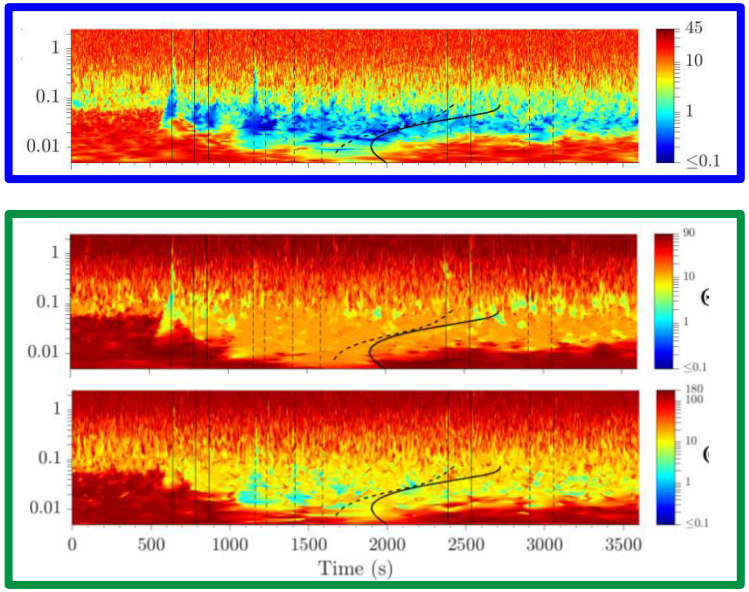

WITH gyrocompass orientation correction ⇩

- ✓ Surface stations orientation with magnetic compass
  Error > 5°
- ✓ Gallery stations orientation with surveyor
  Error ± 5°

⇩ **WITHOUT** gyrocompass orientation correction



Not affected by orientation

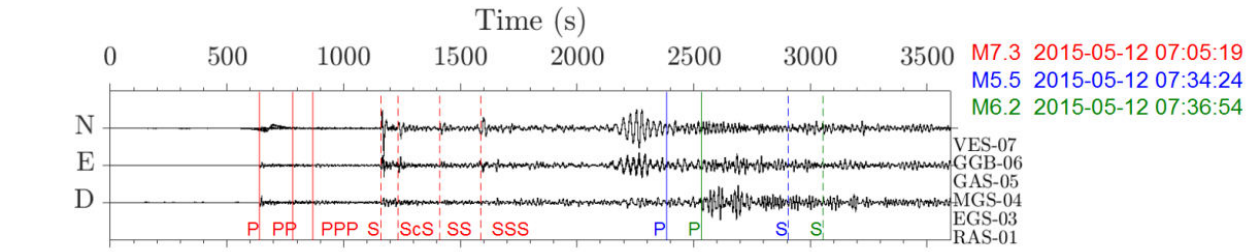


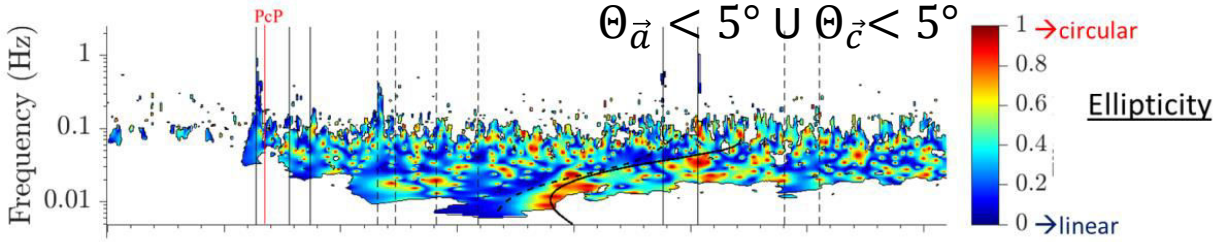
affected by orientation

→ Observation of spatial polarization coherency through the LSBB array

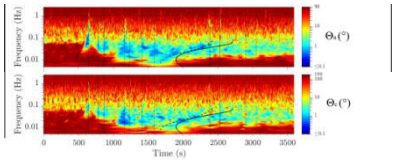
→ Inverse process of optimization to orientate the stations of an array relativeley to each other

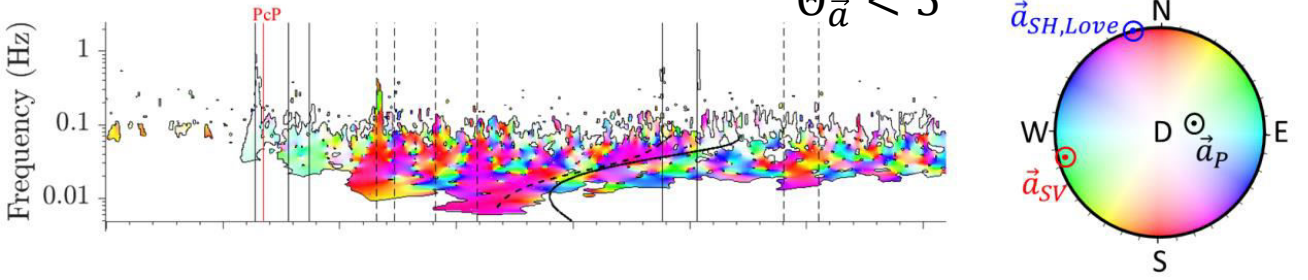
ARRAY AVERAGED POLARIZATION

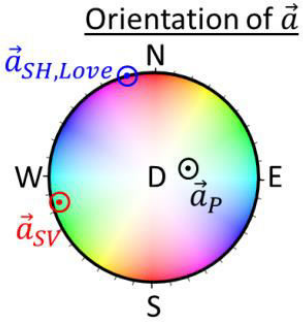


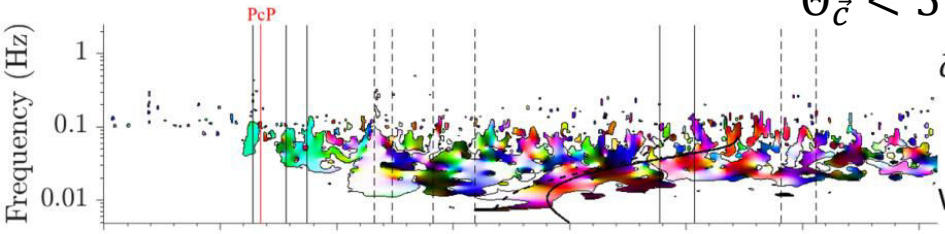


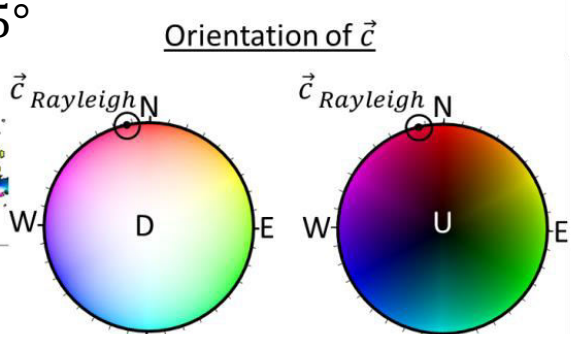
→ **COHERENCY based mask**











CTBTO SnT2017

→ Selecting seismic phases according to their coherent polarization parameters!

Summary: 3C-2D array processing

❖ Complexity to extent 1C to 3C :

→ High order optimization problem
→ Require strong assumptions on the polarization model

IMS seismic network:

❖ Single station polarization analysis:

→ Vectorial parameter system [Labonne et al., E3S 2016a&b]
→ time – frequency – pola representation
→ Energy – ellipticity based masks [Labonne et al., Part I, GJI, submitted]

single 3C station

❖ Array polarization analysis

→ Time – frequency – pola – coherency representation
→ Coherency based mask
→ Precise orientation orientation requirement [Labonne et al., Part II, GJI, submitted]

3C array
low frequency events

Objectives:

❖Method improvement:

→ take into account time delays between stations
→ Post-doc: Array processing and polarization analysis joint method

3C array
high frequency events

❖Full data analysis of standard IMS array data:

→ array of vertical stations colocated to a 3C station
→ Master Thesis: Kazakhtsan seismic array use

standard array

❖ Automatically identify phases

→ regroup time-frequency cells into families
→ distance function using cell time-frequency closeness and similarity in polarization

All 3C data