Tentative synthesis of the NenuFAR workshop

P. Zarka, M. Tagger & all participants

• NenuFAR was definitely not born to satisfy the ego of a few (frog) radioastronomers

• The idea emerged "naturally" in the wake of LOFAR installation, due to several existing prequisites:
  - LOFAR station in Nançay, insertion of our community in LOFAR
  - Experience in VLF (NDA, UTR-2)
  - Nançay radioastronomy station: engineers, room, experience
  - We had mostly an existing expertise in receivers + microelectronics, wish to (re-)develop
    instrumental experience in antennas, arrays… in order to be able to rebuild (radio)telescopes, not
    only participate to instruments built elsewhere
  - First we developed the concept of LSS, then the Standalone concept: both together = NenuFAR

• Then other advantages/interests appeared:
  - Need to develop the national LF community for SKA & other new-generation LF instruments
  - Relative ease to insert NenuFAR in LOFAR (LBL input, dialog with LOFAR, support and exchanges
    with ASTRON: e.g. interest of LOFAR in NenuFAR antennas)
  - Parallel development track with GURT → tight technical collaborations for developing/testing
    optimized hardware
  - ANR support for the full study
  - LOFAR data + processing center set up in Nançay

• Support from OP (& INSU) progressively builds up, e.g. via the RT21@OP axis, DIM-ACAV …
• Support from UO and Région Centre (to consolidate the Nançay-Orléans-Paris axis)

• We don't want to oversell NenuFAR
  - Some studies will not be doable with NenuFAR (e.g. cosmic polarization studies with NenuFAR
    Standalone, because of too low resolution → spatial depolarization ; conversely focussing on the
    LSS mode will permit to measure small scales with high sensitivity ; in Standalone mode, only
    measurements on point sources are relevant, and good polarization calibration will be needed in
    order to correct – at least partly - non orthogonal dipole projection on the sky – use of an artificial
    star e.g. ExPRI ?)

• NenuFAR is <5 M€ :
  - Compare to 7-8 M€/year for SKA-1 (and NenuFAR budget comes from different funding sources)
  - No competition with LOFAR (different scale : 150 M€, 100’s FTE)

• NenuFAR Science :
  - We want to do the best science with NenuFAR, possibly focussing on high-visibility subjects, early
    enough to stay “in the race”
  - We already attracted attention from foreign colleagues, with strong contributions to the science case
    (e.g. “Dark Ages”)
  - NenuFAR is definitely not optimized for Standalone imaging (low resolution), except slow transient
    searches
- High resolution imaging will be reached in LSS mode
- Propagation effects are very large at LF (dispersion, temporal broadening) → need for high spectral resolution and/or waveform measurements
- LF remain a very prospective domain
- We will have full polarisation measurement capability

• There are clearly doable science drivers:
- Fast transient (RRATs, sporadic/intermittent pulsars, Lorimer burst/FRBs, etc.) searches with LaNewBa + "ARTEMIS"
- Exoplanets: blind searches in the Mini-Array analog beam in Standalone correlation mode ; 7 follow-up observations (e.g. of GMRT candidates or other)
- Flaring/dwarf/young stars (PNPS – colloquium prospective 24-27/2/2014 Besançon – opportunity ? or collaboration with foreign teams ?)
- Dark Ages ? (with efforts in foregrounds/confusion removal)
- Gravitational Waves ?
- Local emissions: Cosmic Ray showers, TGFs, Meteors… ?
+ Solar system studies (Sun, planetary magnetospheres, planetary lightning, scintillations, Faraday rotation in Solar wind & ionosphere…)

• Structure of NenuFAR community:
- Large “Science” group with possibly specialized subgroups (Dark Ages, Exoplanets, Fast Radio Bursts dedispersion…) ?
- Separate discussion groups for “LSS” and “Standalone” science (2 instruments in 1 ; the “Standalone” group should be concerned with the capabilities/performances of the Standalone receiver: δf, multi-FoV, incoherent sum, …) ?
- “Development” group, closely related to Nançay (there are still open questions about some functionalities: incoherent sum ? multi-FoV – having NenuFAR mini-arrays pointing in various directions …) ?
- “Calibration” group tbd, perhaps divided in mini-array response and confusion/imaging ? (possible issues to address is e.g. the displacement of the more external mini-arrays to larger distances for a gain of x2 to x4 in resolution ; methods for beating the confusion: related effort with LOFAR, SKA, LWA → take advantage and provide feedback – possible coordination by C. Ferrari)
- “Waveform analysis / CR mode” (TBBs, multi-FoV, …) ; buffer lengths ? Reflexion to start soon, coordinated by S. Corbel, I. Cognard, R. Dallier)
- Testing the instrument on the sky at all phases (starting now)
- Data format, data policy
- Teaching ? Student projects ?…
→ all groups must interact : annual NenuFAR day ?

• Other remarks:
- We clearly need strong technical support (construction in Nançay, computing for post-processing of Standalone data …) : involvement of participating laboratories ? other partners tbd ?
- stay LOFAR compatible !
If NenuFAR does good science, it will be an encouragement to have other NenuFARs in Europe (or beyond). NenuFAR design should be open (~ creative commons …)

**Tools:**
  (”private section” : user=lss , pass=anr090509 )
  All presentations online (and on [http://nenufar.sciencesconf.org/](http://nenufar.sciencesconf.org/))
- Updated instrument description online all the time (cf. web site)
- Dictionary of standard terms: NenuFAR, LSS, Standalone, LaNewBa … (first glossary below)
- Analysis software

**Actions:**
- Formally label NenuFAR as a SKA pathfinder ? (cf. S. Torchinsky’s talk) → a letter has been addressed by P. Zarka et al. to Phil Diamond (response waited for…)
  Purposes = clarify the relation NenuFAR / SKA-Low in France (path), prepare scientifically the community, exchange technical/analysis expertise , northern hemisphere facility (with LOFAR)
- Label NenuFAR development as SO2/3 (+6 space weather/environment?) CNAP service : M. Tagger
- MoU with VIRGO-LIGO (E. Chassande-Mottin, C. Ferrari), follow-up PLATO (P. Zarka), support JUNO/Solar Orbiter/SP+, TARANIS, multi-LOFAR-stations (Chilbolton…) …
  (on the longer term, organize synergies with different domains – eg ONERA)
- Pursue collaboration (technical & scientific) with UTR-2/GURT (PICS) : software developments ?
- Contact GLOW for correlating NenuFAR + stations e.g; in Jülich : M. Tagger
- Contact A. Karastergion (Oxford) for joining the project : P. Zarka, J.-M. Griessmeier
- Formal invitation to Ukrainian & Austrian teams : P. Zarka
- Prepare NenuFAR Science Case for INSU prospective : ~ observation proposals for early phases (commissioning phase expected to start in 2015) + scientific goals for full NenuFAR : we will contact you, please be prepared to contribute.
**Acronyms & definitions:**

- **ANR**: Agence Nationale de la Recherche
- **ARTEMIS**: LOFAR post-backend for transients (Oxford: http://www.oerc.ox.ac.uk/projects/artemis)
- **ASTRON**: Netherlands Institute for Radio Astronomy
- **CNAP**: Conseil National des Astronomes et Physiciens du globe
- **DIM ACAV**: Domaine d’Intérêt Majeur: Astrophysique et Conditions d’Apparition de la Vie (Région Ile-de-France)
- **ExPRI**: Expérience de Propagation Radio Ionosphérique (project of small embarked radio emitter)
- **FoV**: Field of View
- **FRBs**: Fast Radio Bursts
- **FTE**: Full Time Equivalent (= homme.an)
- **GLOW**: German LOng Wavelengths consortium
- **GMRT**: Giant Meterwave Radio Telescope (India)
- **GURT**: Giant Ukrainian Radio Telescope
- **INSU**: Institut National des Sciences de l’Univers (CNRS Institute for Astronomy)
- **LaNewBa**: NenuFAR’s dedicated backend
- **LBL**: LOFAR’s Low Band Low (10-50 MHz)
- **LF**: Low Frequencies (here typically ≤1 GHz)
- **LIGO**: Laser Interferometer Gravitational-Wave Observatory (USA)
- **LOFAR**: the LOw Frequency ARray
- **LSS**: LOFAR Super Station
- **NDA**: Nançay Decameter Array
- **NenuFAR**: New extension in Nançay upgrading LOFAR : NenuFAR = LSS + Standalone
- **OP**: Observatoire de Paris
- **OSUC**: Observatoire des Sciences de L’univers en région Centre
- **PNPS**: Programme National de Physique Stellaire
- **RRATs**: Rotating Radio Transients
- **RT21@OP**: Scientific priority axis “RadioTélescopes du 21ème siècle” of Observatoire de Paris
- **SKA**: Square Kilometer Array
- **TBB**: LOFAR’s Transient Buffer Board
- **TGFs**: Terrestrial Gamma-ray Flashes
- **UO**: Université d’Orléans
- **UTR-2**: Ukrainian T-shape Radiotelescope mark 2 (Kharkov)
- **VIRGO**: European Gravitational waves Interferometer Observatory
- **VLF**: Very Low Frequencies (here typically ≤100 MHz)