Instrumentation for helioseismology

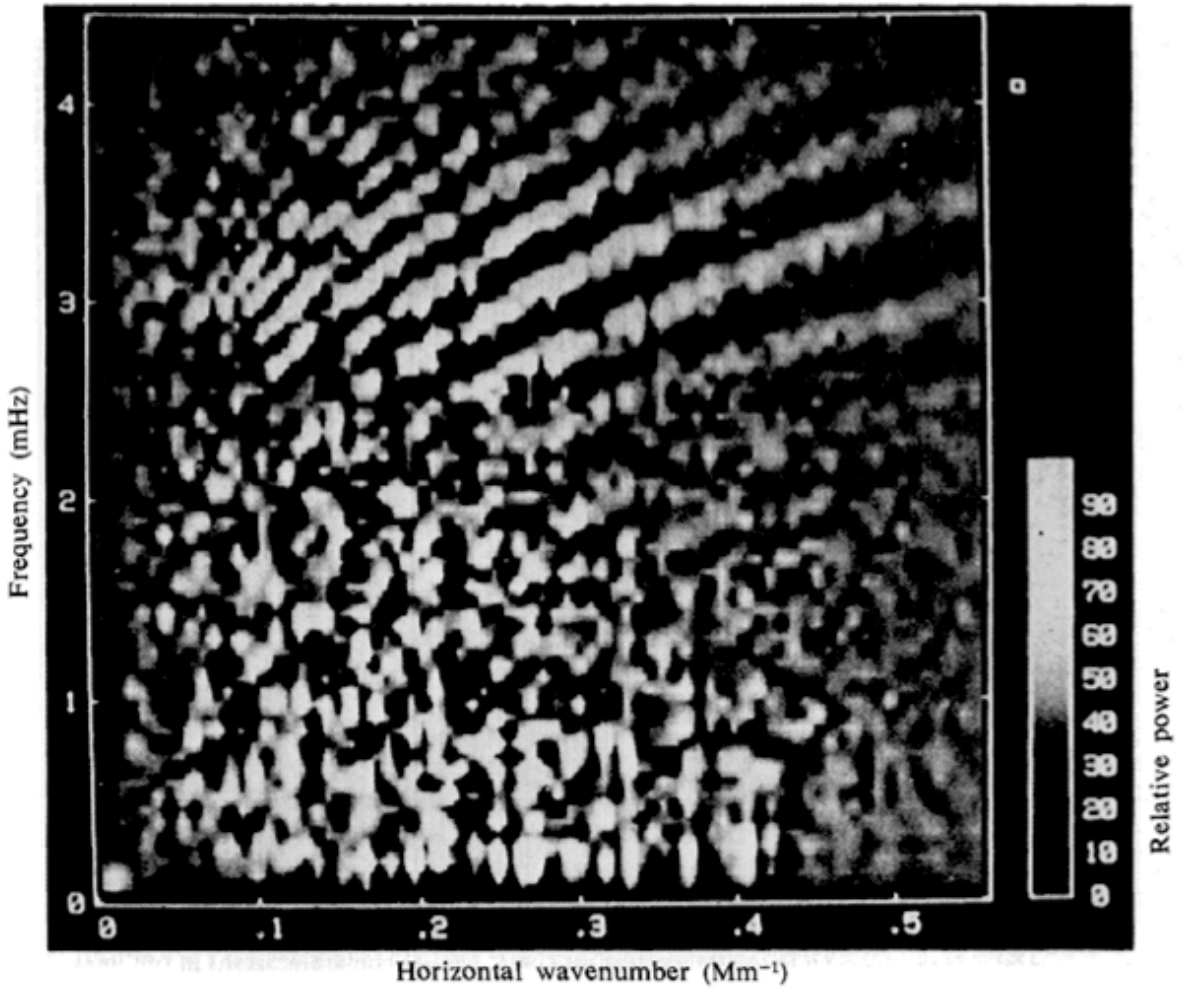
T.Appourchaux

Institut d'Astrophysique Spatiale, Orsay, France

Content

- The novelty with Plan-A
- Helioseismic instrumentation
- What can be done for Plan-A ?
- Conclusion

Nishikawa et al (1986)



The novelty: stereoscopy

- Idea originates back from the 80's for avoiding spatial gaps (full hemisphere instead of half hemisphere)
- Best way to probe the core (besides g-mode detection)
- What is the best instrumentation?
  - Resolution, observable, angle separation (TBD)
- At least another instrument required (SDO, Solar orbiter)

Helioseismic instrumentation

- Ground based:
  - Global Oscillation Network Group (GONG)
  - Taiwan Oscillation Network (TON)
  - Magneto-Optical filters (LOWL, ECHO)
- Space based:
  - Luminosity Oscillations Imager (LOI / SOHO)
  - Michelson Doppler Imager (MDI / SOHO)
  - Solar Optical Telescope (SOT / Hinode)
  - Helioseismic and Magnetic Imager (HMI / SDO)
  - Polarimetric and Heliseismic Imager (SO / PHI)

Instruments	Array	Pixel (in arcsec)	Pupil (in cm)	Wavelength (in nm)	Technique
GONG	1k x 1k	2.5	2.8	676.9 (Ni I)	Velocity (tachometer)
TON	1k x 1k	1.8	9	K line	Intensity
ECHO	0.7k x 0.1k	25	1	770 (K)	Velocity (MOF)
LOI	16 (total)	480	5	500	Intensity
MDI	1k x 1k	2	12.5	676.9 (Ni I)	Velocity (tachometer like)
SOT / BFI	4k x 2k	0.05	50	Ca II, R, G, B	Intensity
SOT / NFI	4k x 2k	0.08	50	Mg IIb, Fe I	Velocity (Lyot)
HMI	4k x 4k	0.5	14	617.3 (Fe I)	Velocity (tachometer like)
PHI / HRT	2k x 2k	0.5	14	617.3 (Fe I)	Velocity (Fabry-Perot)
PHI / FDT	2k x 2k	3 - 6	1	617.3 (Fe I)	Velocity (Fabry-Perot)

Instrument	Mass (kg)	Telemetry (kbps)	Power (Watt)	Dimensions (cm^3)	Built
LOI	2.5	0.01	2.5	30 x 9 x 9	ESA / SSD
MDI	56.5	5 - 160	38	78 x 40 x 24 (OP)	Stanford / Lockheed
SOT	46 (OP)	1400	-	-	Japan / USA
HMI	45	50000	60	118 x 53 x 24 (OP)	Stanford / Lockheed
PHI	30.5	20	35	75 x 40 x 29 (OP)	MPS / INTA / IAS

What can be done for Plan-A ?

- Solar radial velocity:
  - Better signal-to-noise ratio (300)
  - Low-frequency modes
  - Polarimetry as a « by-product »
  - Wavelength stability demanding
  - Large space experience
  - Require a lot of glass (mass)
- Intensity:
  - Lower signal-to-noise ratio (30)
  - High-frequency modes
  - No polarimetry
  - Photometry not very demanding
  - Space experience
  - Light

Solar Radial Velocity for Plan-A ?

- LYOT / Michelsons:
  - Well space proven but heavy (>30 kg, <20kg ?)
- LYOT only
  - Space proven (besides the bubbles) but heavy?
  - Several wavelength (if UBF like)
- Magneto-Optical Filters
  - Not space provenbut Na cell aboard SOHO (GOLF)
  - Various gases: Na, K, Ca, He
  - Require magnets (2 of them, heavy?)
  - No moving parts
- Fabry-Perot
  - Space proven (but not for solar physics)
  - Light if Lithium Niobate is used (solid etalon)
  - Several wavelengths

Intensity for Plan-A ?

- Various wavelength and various passbands
  - All space proven
  - Light
  - Use of CCDs, photodiode or APS

What can be done for Plan-A ?

- A strawman design:
  - Entrance pupil of 10 cm dia (1 arcsec resolution)
  - Detector: at least 4k x 4k (10 μm pitch)
  - Full disk
- Observables:
  - Velocity: various wavelengths
  - Intensity: wide passbands
- Several instruments:
  - 2 different wavelengths / heights for velocity
  - 1 wavelength for intensity
- Mass / ressources:
  - Total 25 kg for 1 instrument or 3 instruments?
  - If 3 instruments: 10 kg for each wavelength (realistic?), 2 kg for intensity (well feasible)

Conclusion

- Ressources will drive the design (not new), especially mass
- Solar radial velocity preferred
- …but intensity easier
- Do we want to do a better-than instrument?
- Stereoscopy:
  - What is the best instrumentation?
  - At least another required (SDO, Solar orbiter)

Comments on mission profile

- > 45 deg: 70 deg after 10 years of Scenario A_Ballistic 1: THANK YOU !
- Observation during cruise phase : YES !
- Circular orbit: BETTER !

Plan A vs Plan B

- Competition with an other mission in Japan?
  - If no, Solar-C could also be appealing to solar physicists outside Japan
  - If yes, Solar-C must be appealing to non-solar physicists in Japan