



Hammersmith
Imanet

STIR

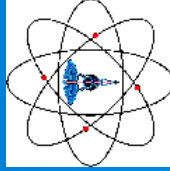
*Software for Tomographic
Image Reconstruction*

<http://stir.HammersmithImanet.com>
<http://stir.sourceforge.net>



Contents

- What is it and how did it happen?
 - Kris Thielemans
- Software overview
 - Kris Thielemans
- Single Scatter Simulation in STIR
 - Charalampos Tsoumpas
- FORE: implementation and results
 - Oliver Nix
- Conclusion
 - Kris Thielemans





Hammersmith
Imanet

STIR: Part I

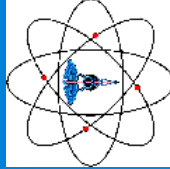
What is it and how did it happen?





STIR objectives

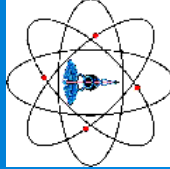
- Open Source software for image reconstruction and data manipulation in medical imaging
- Extendable and modular





STIR current features

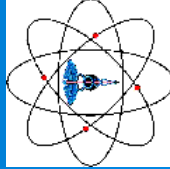
- **Users' perspective**
 - PET (2D/3D)
 - Support for any cylindrical PET scanner (GE-Advance, ECAT HR+, 953 etc.)
 - Analytic and iterative 3D reconstruction algorithms
 - FBP, SSRB, OS-MAP-OSL (including MRP)
 - Various utilities (e.g. precorrection. ROI, ...)
 - Data formats: Interfile, ECAT Matrix and partially GE VOLPET
 - Multi-platform (Unix, Linux, Windows, MacOS X)
 - Test suite
- **Developers' perspective**
 - Object-oriented (C++) and modular
 - Fully documented (doxygen)





History: PARAPET

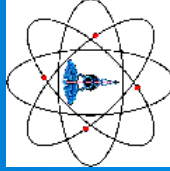
- European Union funded project (ESPRIT)
- 3 year (end March 2000)
- Aim: Implementation and Evaluation of Reconstruction algorithms for fully 3D PET with feasible run-time
 - Algorithm development, parallel hardware
- Partners
 - Hammersmith Hosp. - MRC, London, UK, Terry SPINKS
 - Brunel Univ, Dept of Math. Sciences, London, UK, Gautam MITRA
 - Ospedale San Raffaele (HSR), Milan, Italy, Maria Carla GILARDI
 - Technion - Israel Inst of Techn, Optimization Center, Haifa, Israel, Aharon BEN-TAL, Roni LEVKOVITZ
 - ELGEMS Ltd., Haifa, Israel, Michael WILK
 - Geneva Univ Hosp (HUG), Div. of Nucl. Med., Geneva, Switzerland, Christian MOREL
 - Parsytec GmbH, Aachen, Germany, Carsten RIETBROCK, Stefan KAISER, Volkmar FRIEDRICH





PARAPET Programmers

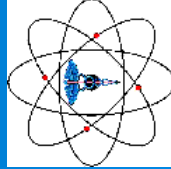
- Zverovich, Alexey (Brunel)
- Zibulevsky, Michael (MOC)
- Zaidi, Habib (HUG)
- Valente, Patrick (Brunel)
- Thielemans, Kris (MRC)
- Sauge, Damien (HUG)
- Sadki, Mustapha (Brunel)
- Pagani, Elizabetta (HSR)
- Mustafovic, Sanida (MRC)
- Labbe, Claire (HUG)
- Jacobson, Matthew (MOC)
- Hague, Darren (Brunel)
- Gordon, Ekaterina (MOC)
- Belluzzo, Damiano (HSR)





PARAPET results

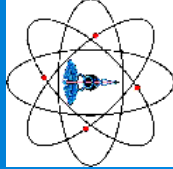
- Publications
- New algorithms (OS-Mirror, OS-Conjugate Barrier)
- Software
 - Design I (never released)
 - Design II (June 2000)
 - Open Source
 - More ambitious
 - Not completely backwards compatible
 - Consequences:
 - Design II is much more mature and flexible
 - Not all software reimplemented





STIR over the years

- *PARAPET* is Dead, Long Live *STIR!*
- stir.irsl.org (December 2001)
 - Sanida Mustafovic and Kris Thielemans
- **Now**
 - Registrations ~ 260
 - Users' mailing list ~ 70 subscribers
 - Developers' mailing list ~ 30 subscribers
- **Future**
 - More algorithms (including list mode reconstructions)
 - More modules
 - Self-contained (normalisation, randoms, scatter)
 - Parallelisation (already prepared for it, was in *PARAPET*)
 - SPECT
 - GUI
 - Sound effects





Hammersmith
Imanet

Some Results

Illustrative



Whole Body Study [18F]FDG PET

OSEM
Sub.7

It.1

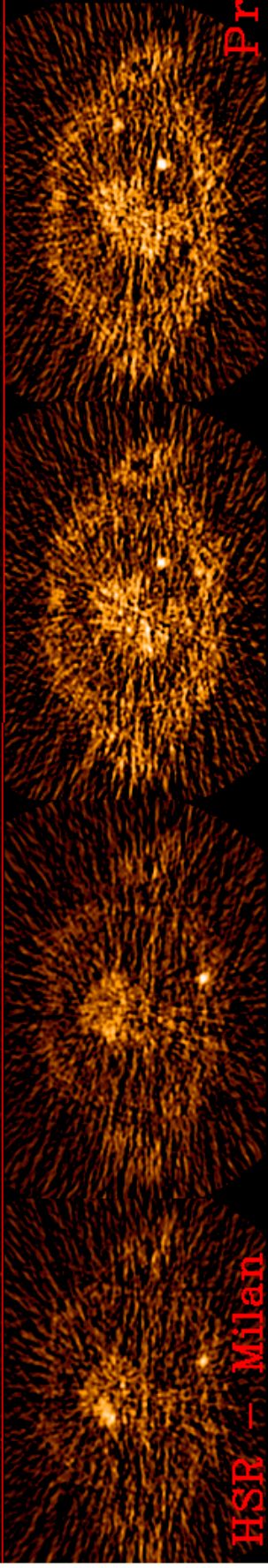
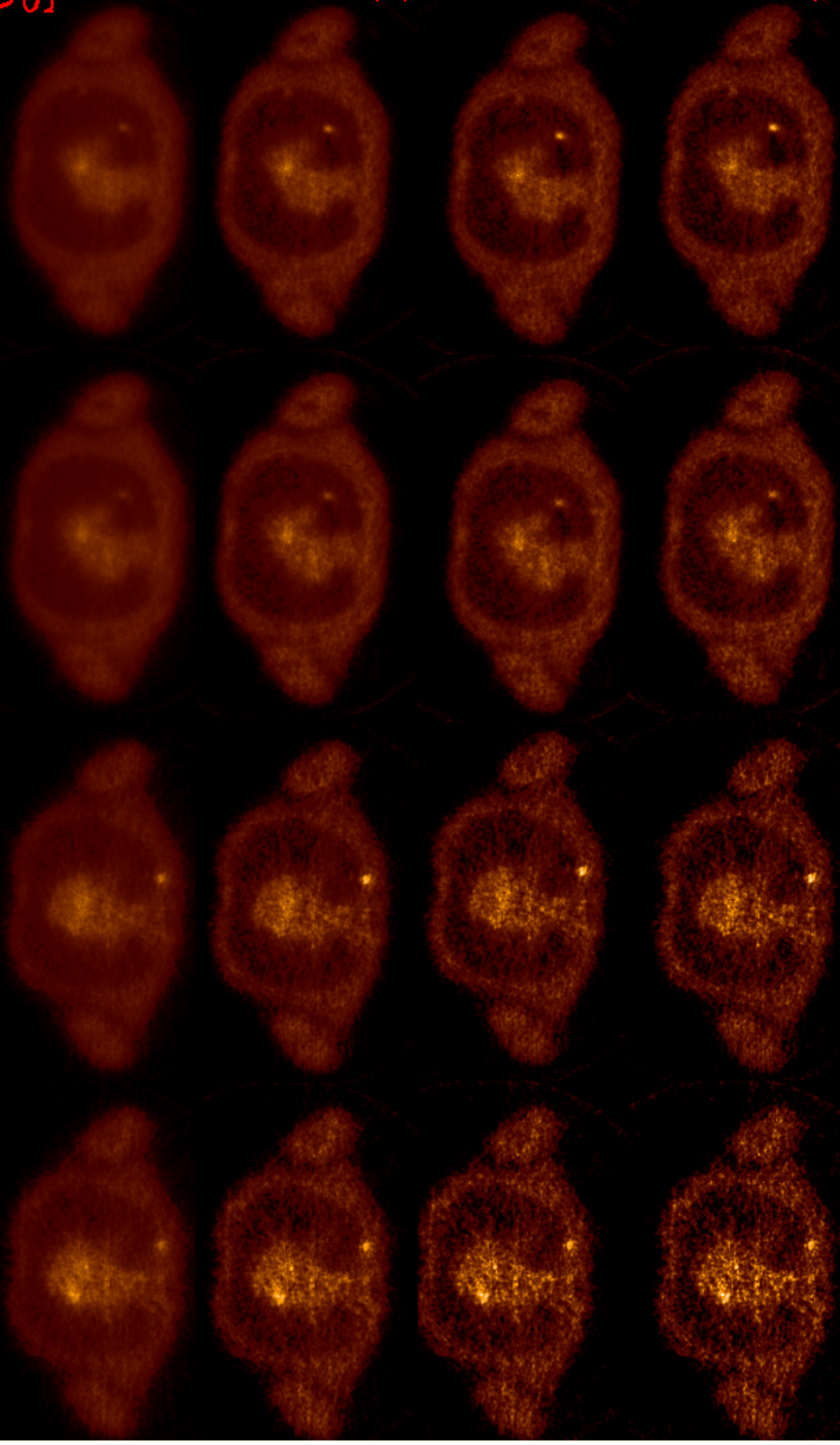
It.2

It.3

It.4

HSR - Milan

Promis

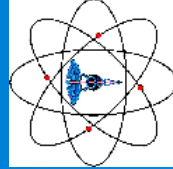
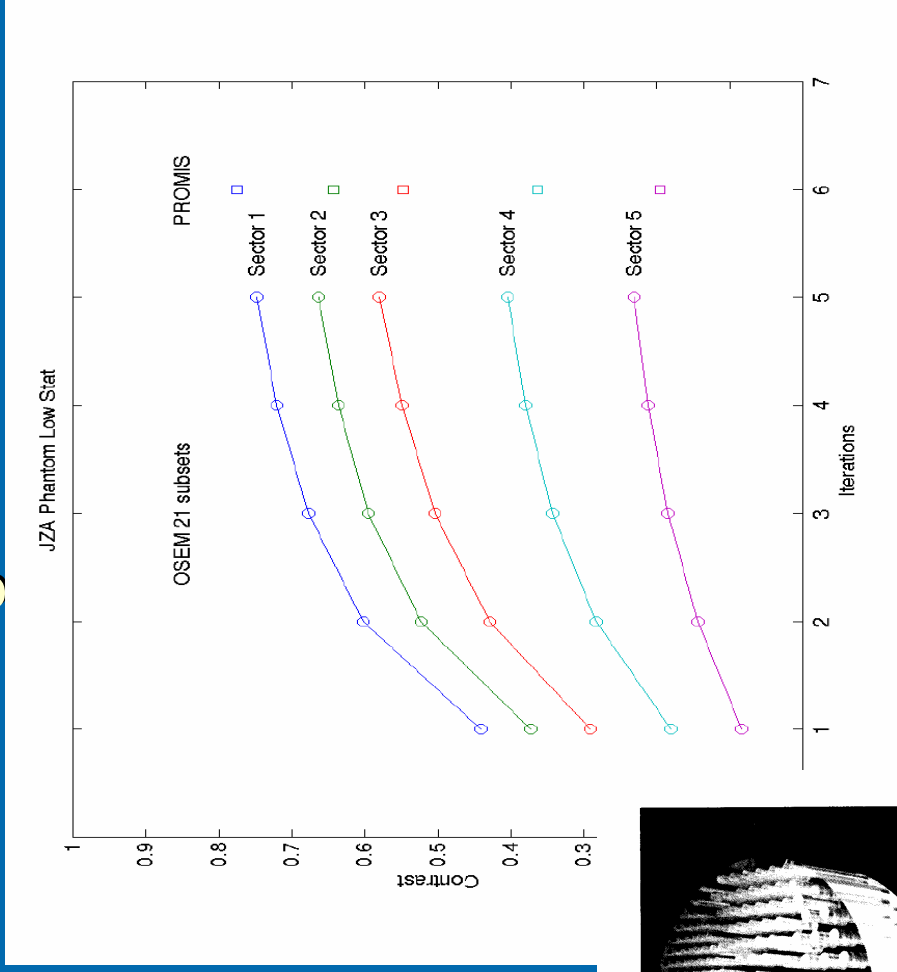
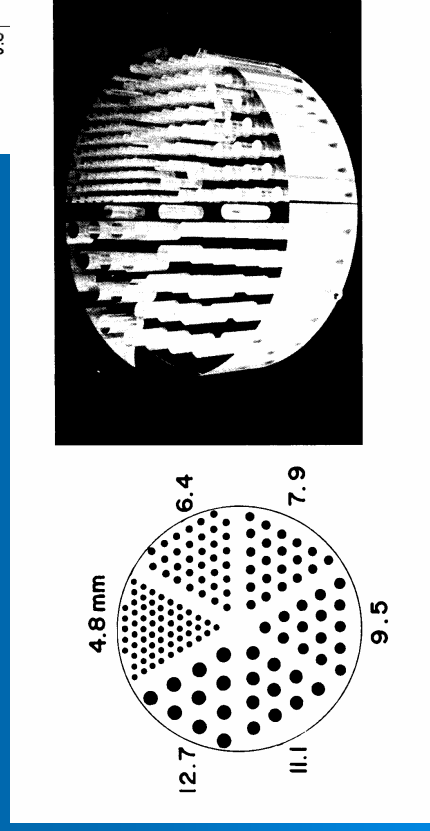




Some results II

- Contrast: cold spots in hot background

$$1 - \frac{Cold}{Hot}$$

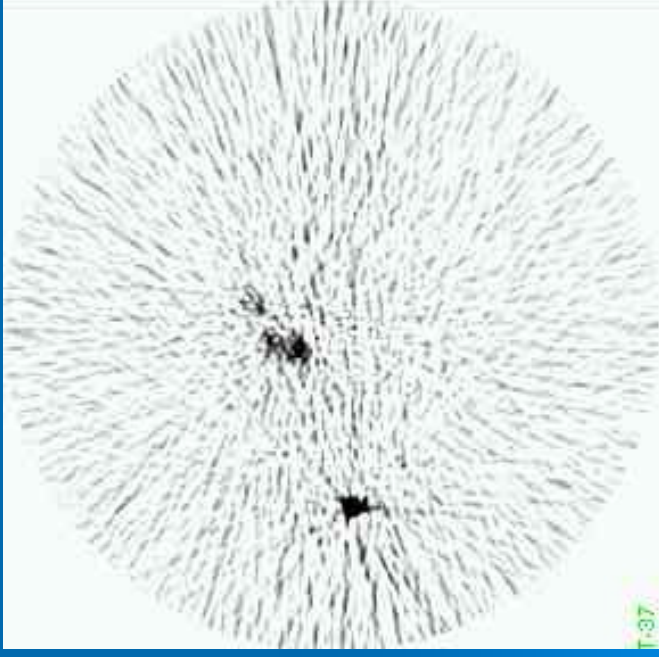




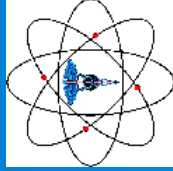
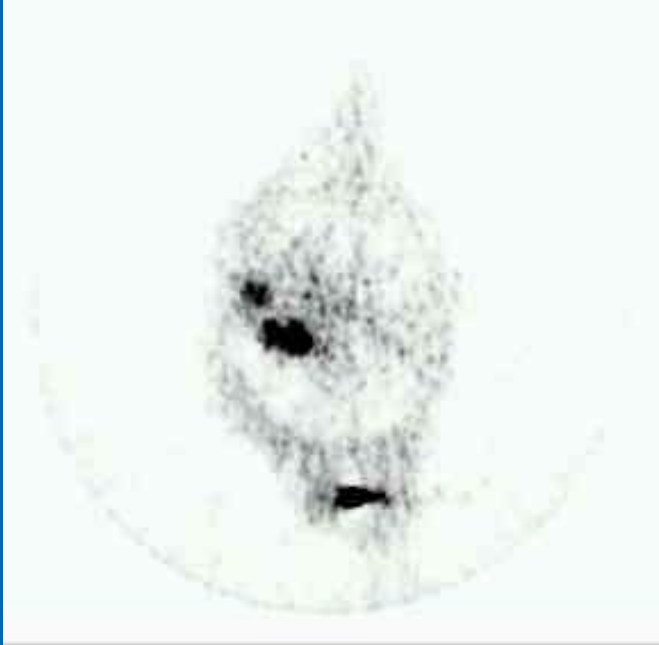
Some results III

Cardiac Blood Flow (^{15}O -labelled water) *single frame from a kinetic study*

3DRP/PROMIS



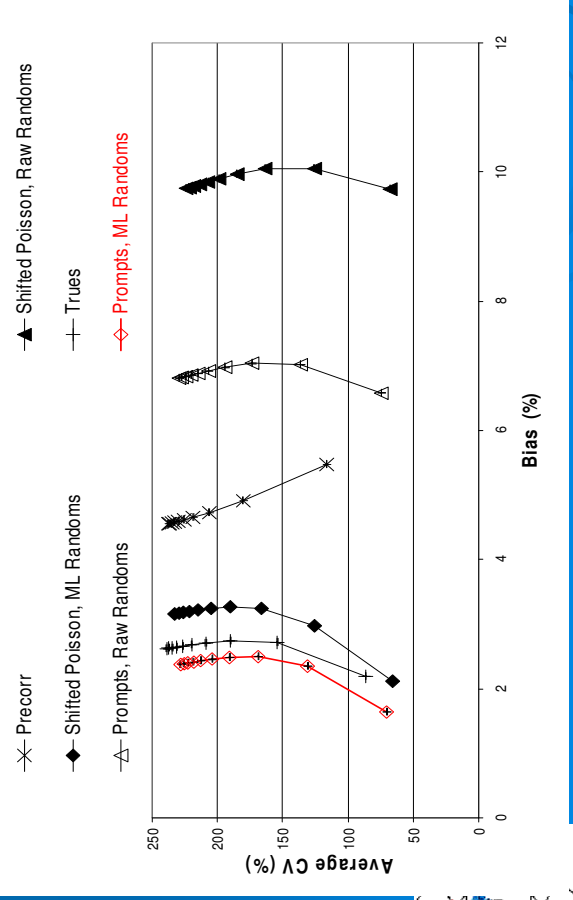
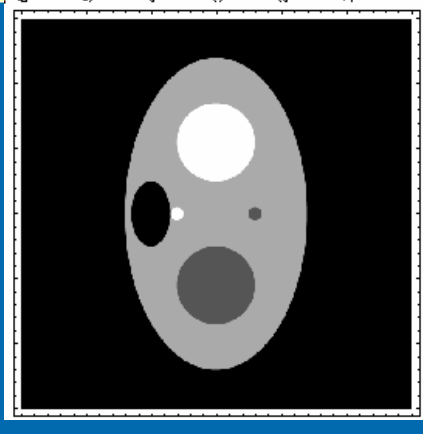
3D OSEM (no pre-corrections,
with interfiltering)





Quantitative iterative reconstructions? Imanet Simulations (mean and stdddev on ROI mean)

	Original	FBP		EMML with background (2000 iterations)	
		less noise	more noise	less noise	more noise
spine	1.5	1.57 ± 1.19	1.58 ± 2.15	1.57 ± 1.58	1.57 ± 2.25
Right lung	3	3.00 ± 1.15	3.00 ± 2.57	3.00 ± 2.01	2.99 ± 3.20
Left lung	1	1.00 ± 0.78	1.00 ± 2.28	1.01 ± 0.96	1.02 ± 1.42
Zero region	0	0.00 ± 0.64	0.00 ± 1.43	0.09 ± 0.26	0.19 ± 0.56



Coefficient of Variation vs. Bias over multiple simulations for different reconstruction algorithms. Each mark corresponds to an iteration. FBP (not shown) had 0 bias, but CV of 415%.





Hammersmith
Imanet

STIR: part II

Software Overview



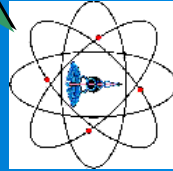


STIR content (highlights)

- **Data structures**
e.g. n-dimensional arrays, images, sinograms, list mode data ...
- **Registries and Parsing classes**
For setting/saving parameters at run-time
- **Reconstruction classes**
 - Analytic: FBP, 3DRP; SSRB, FORE
 - Iterative: OSEM, OSL (including MRP), OS-SPS
 - all sharing common code-base
 - either 2D/3D sinograms (list mode data soon)
 - inclusion of terms for normalisation, attenuation, scatter and randoms

➤ Utilities

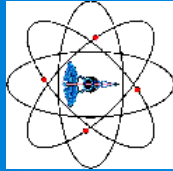
pre-correction, filtering, arithmetic processing of image or sinogram data, ROI evaluation etc.





Object-oriented programming

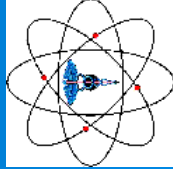
- Principle
 - self-contained objects with public 'interface'
 - hide internal data-structure
 - `complex.real()`, `complex.imag()`,
`complex.norm()`, `complex.phase()`
 - inheritance allows specialisation
 - `Car` -> `SportsCar` -> `F1-Car`
 - `Car.drive(distance)`





Object-oriented programming

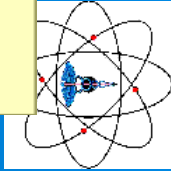
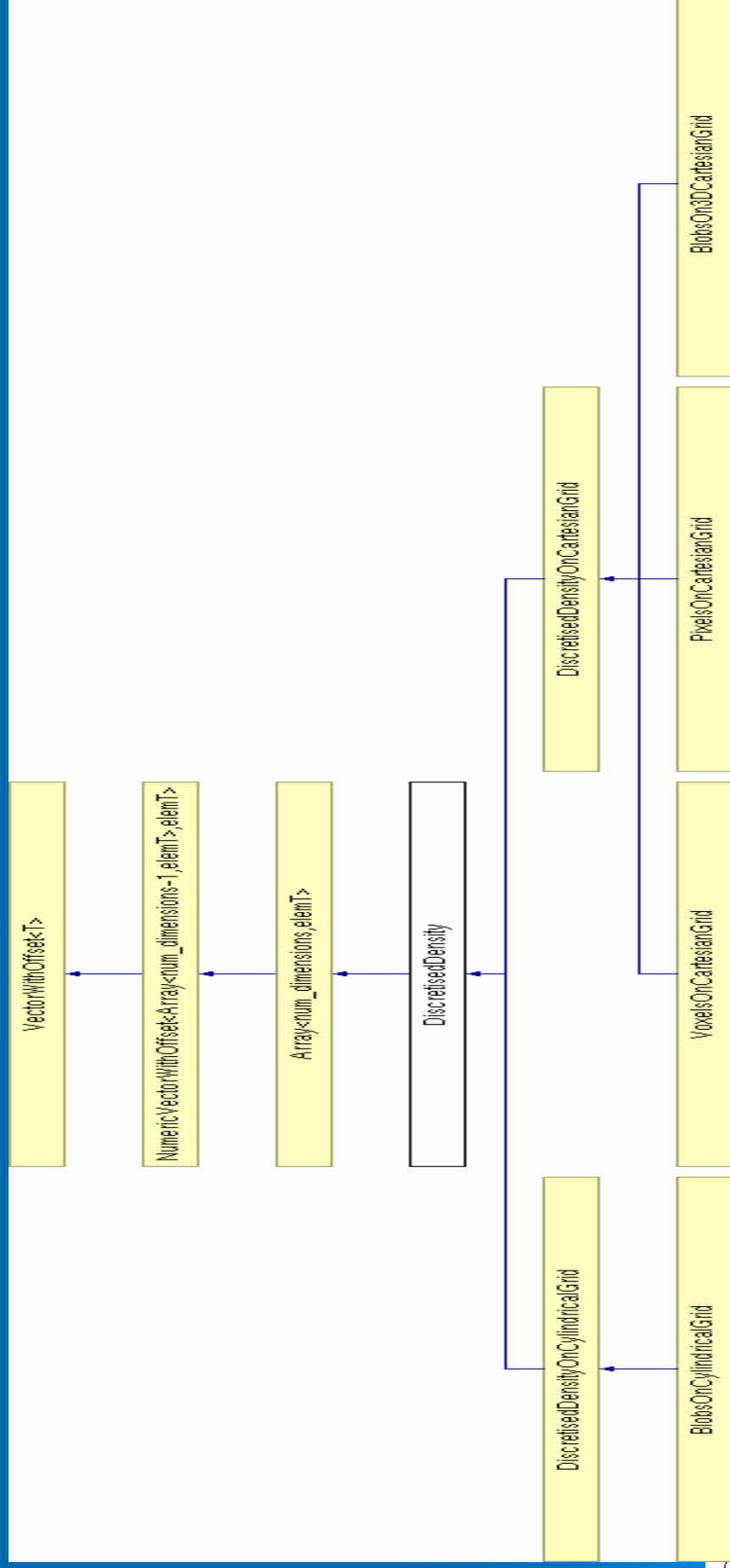
- Advantages
 - modularity & robustness:
each class can be developed/tested 'independently'
 - flexibility:
data-representation can be adapted to situation
 - generality:
'generic' programming in terms of base-classes
 - extendability:
new extensions can benefit from old code by inheritance
 - ease-of-use for the 'user'





Basic ingredients

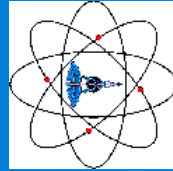
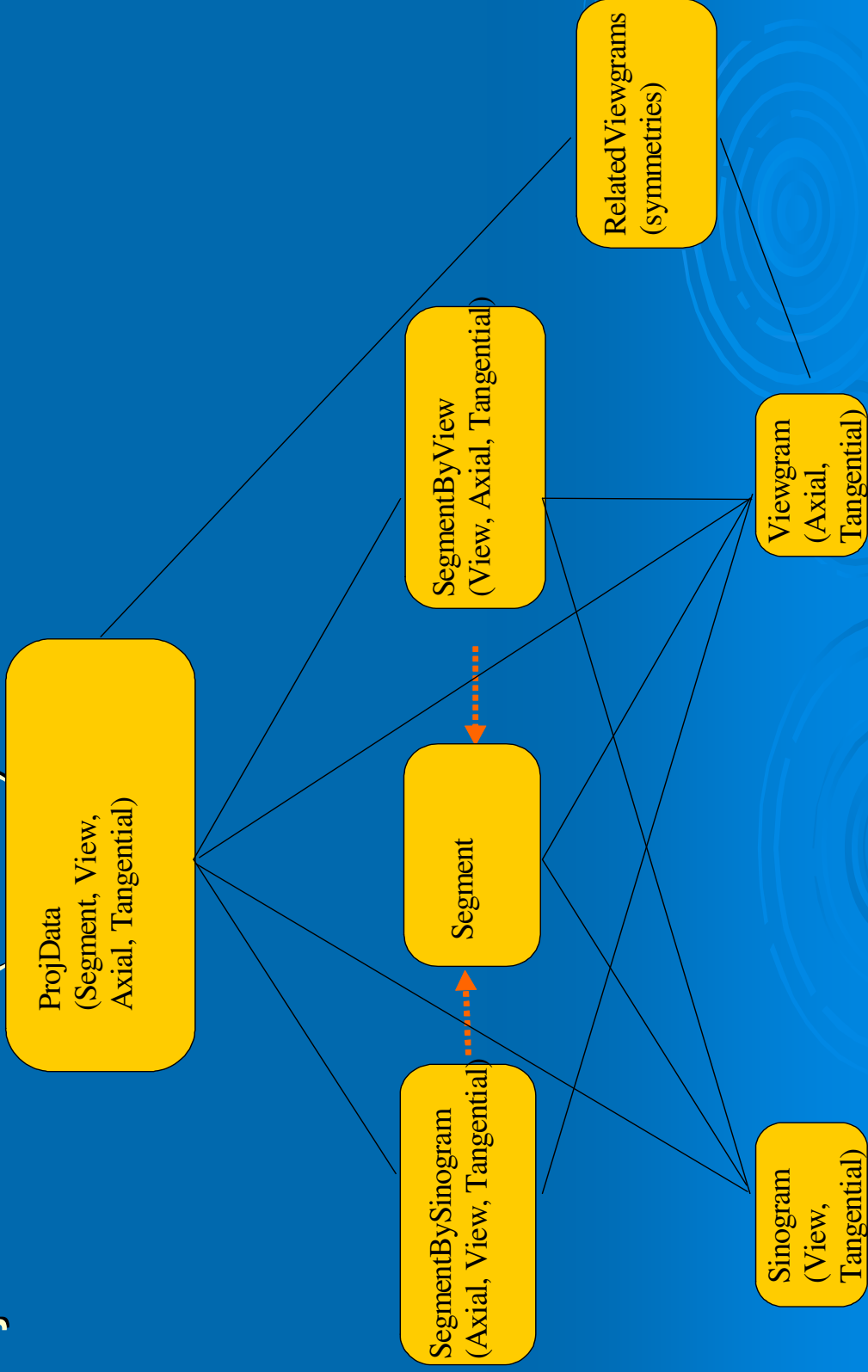
➤ Image data





Basic ingredients

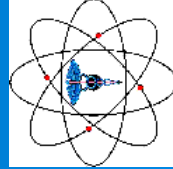
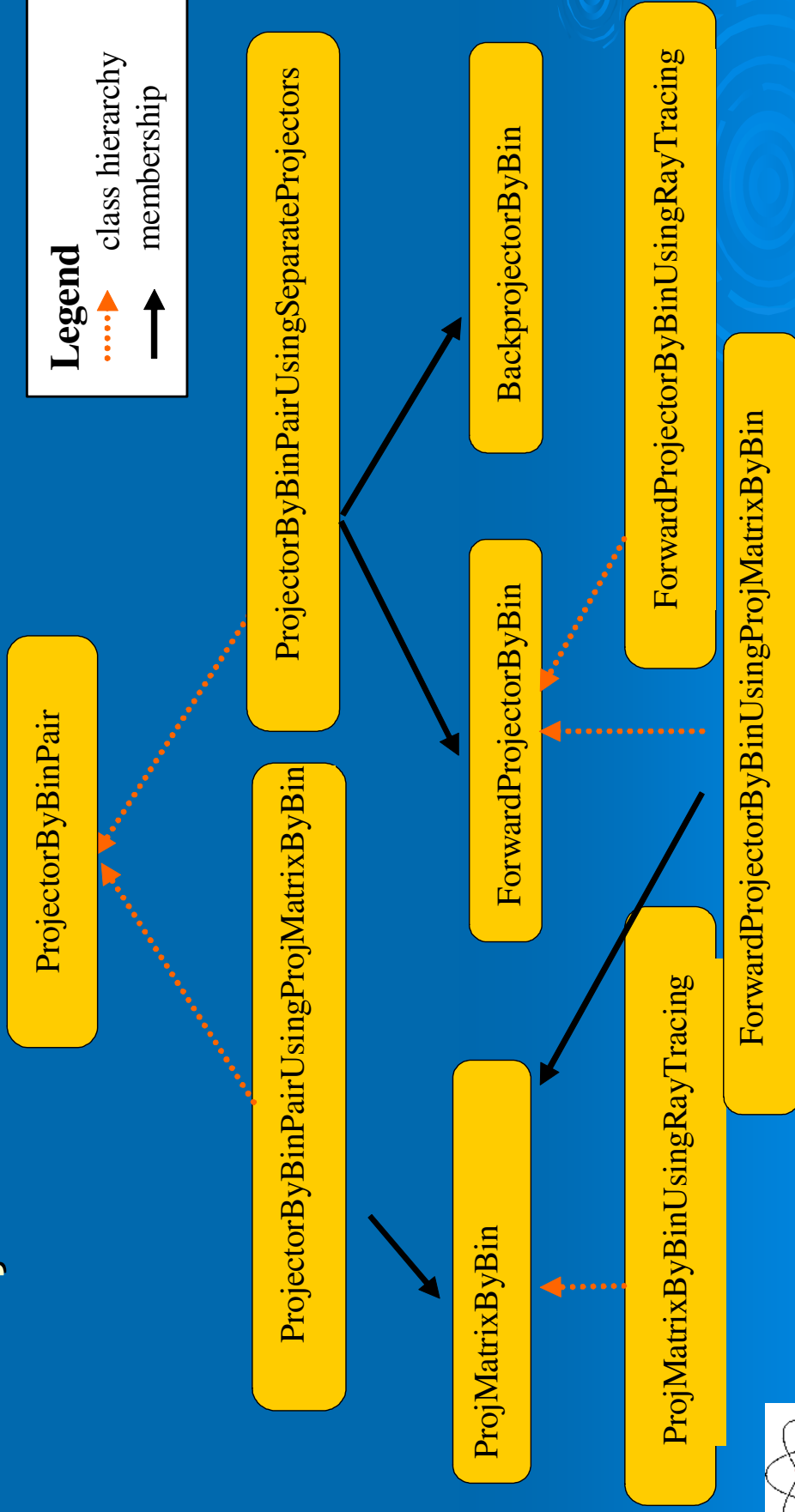
➤ Projection data (dense)





Basic ingredients

➤ Projectors





imagination at work

Hammersmith
Imanet

Live demonstration





Hammersmith
Imanet

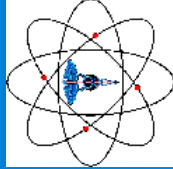
STIR: Conclusion





License

- PARAPET license
 - No restrictions, but give credit
- Lesser GNU Public License (LGPL) for library
 - ‘free’, redistributions: source code must be available and modifications have to be included (and LGPL’ed)
- GNU Public License (GPL) for applications
 - LGPL+ redistribution: whole application must be GPL
- CTI license for ECAT IO
 - Only usable for research purposes

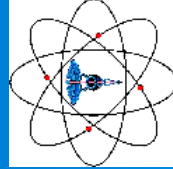


Free, but NO warranty



How to get it?

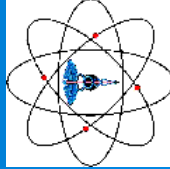
- Email registration process via
<http://stir.HammersmithImanet.com>
<http://stir.sourceforge.net>
- Join mailing lists
 - Stir-announce
 - Stir-users
 - Stir-devel





How to contribute?

- **Software**
 - Make sure you are allowed to distribute code under (L)GPL license
- **Time**
 - Help out on mailing lists
- **Money**
 - The *STIR* foundation:
Surfing and a good Time in Interesting Resorts





Hammersmith
Imanet

STIR

*Software for Tomographic
Image Reconstruction*

<http://stir.HammersmithImanet.com>
<http://stir.sourceforge.net>