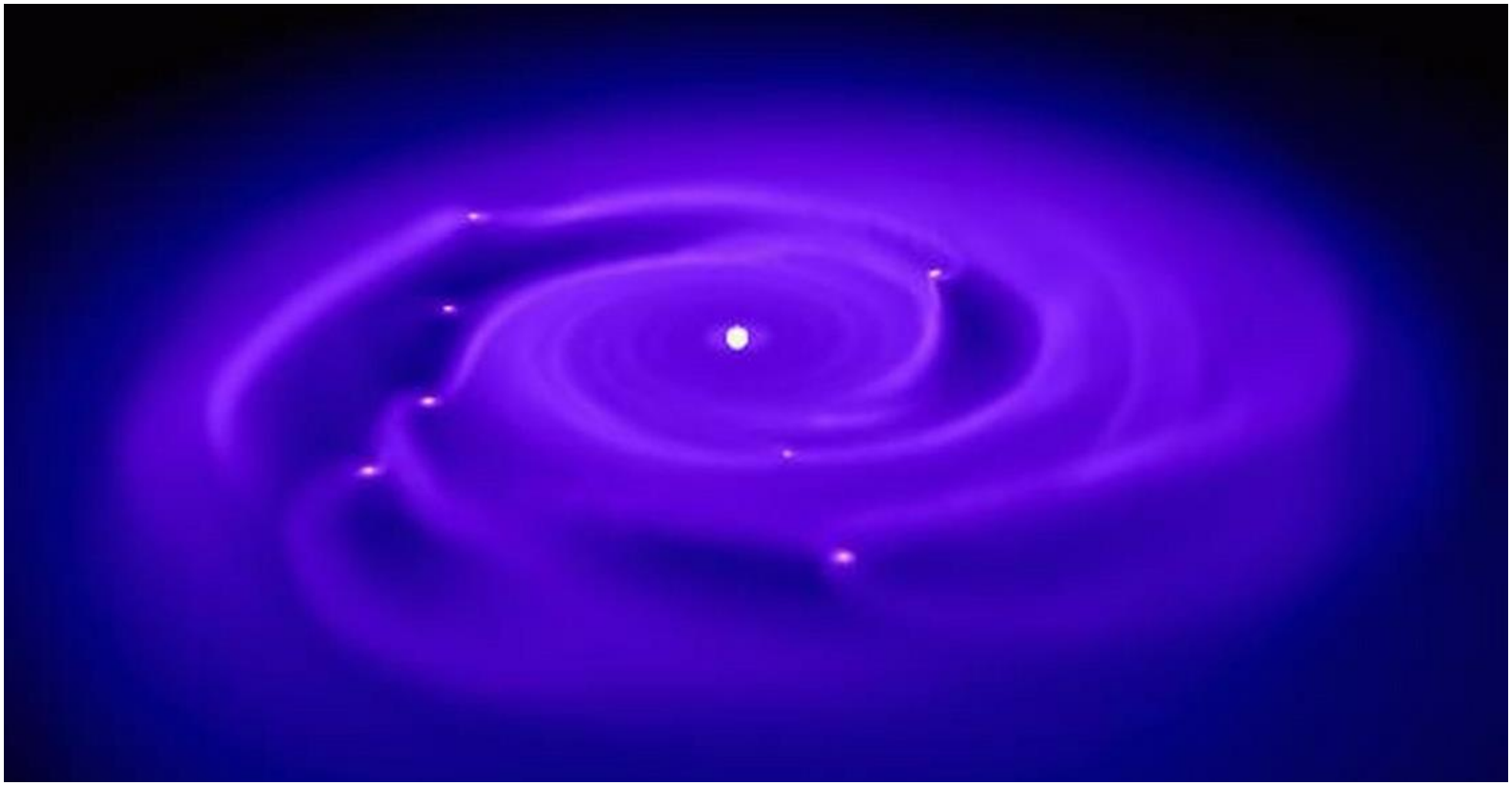
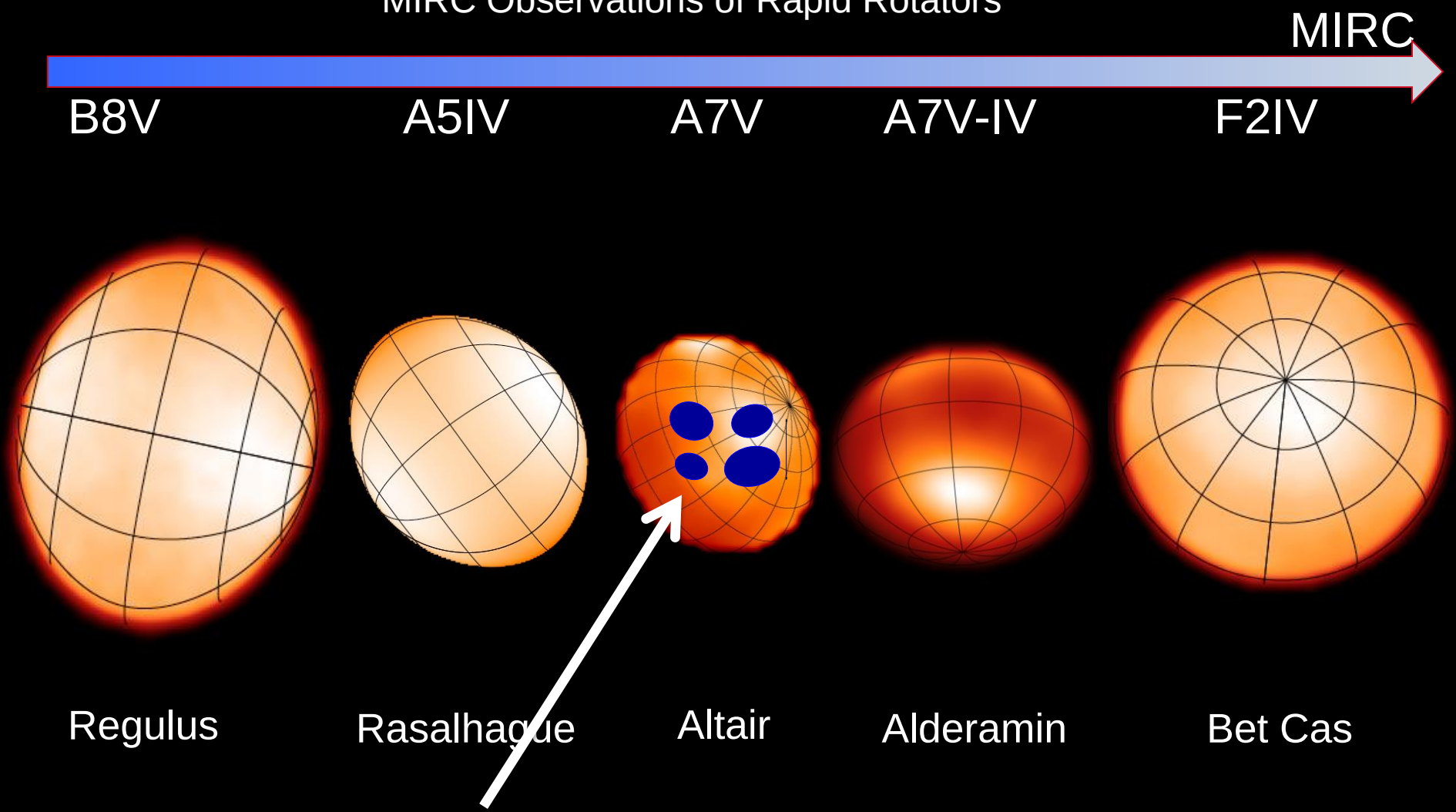
Towering Ambition: Planet Formation Imager and the High Antarctic Plateau

Peter Tuthill

Sydney Institute for Astronomy

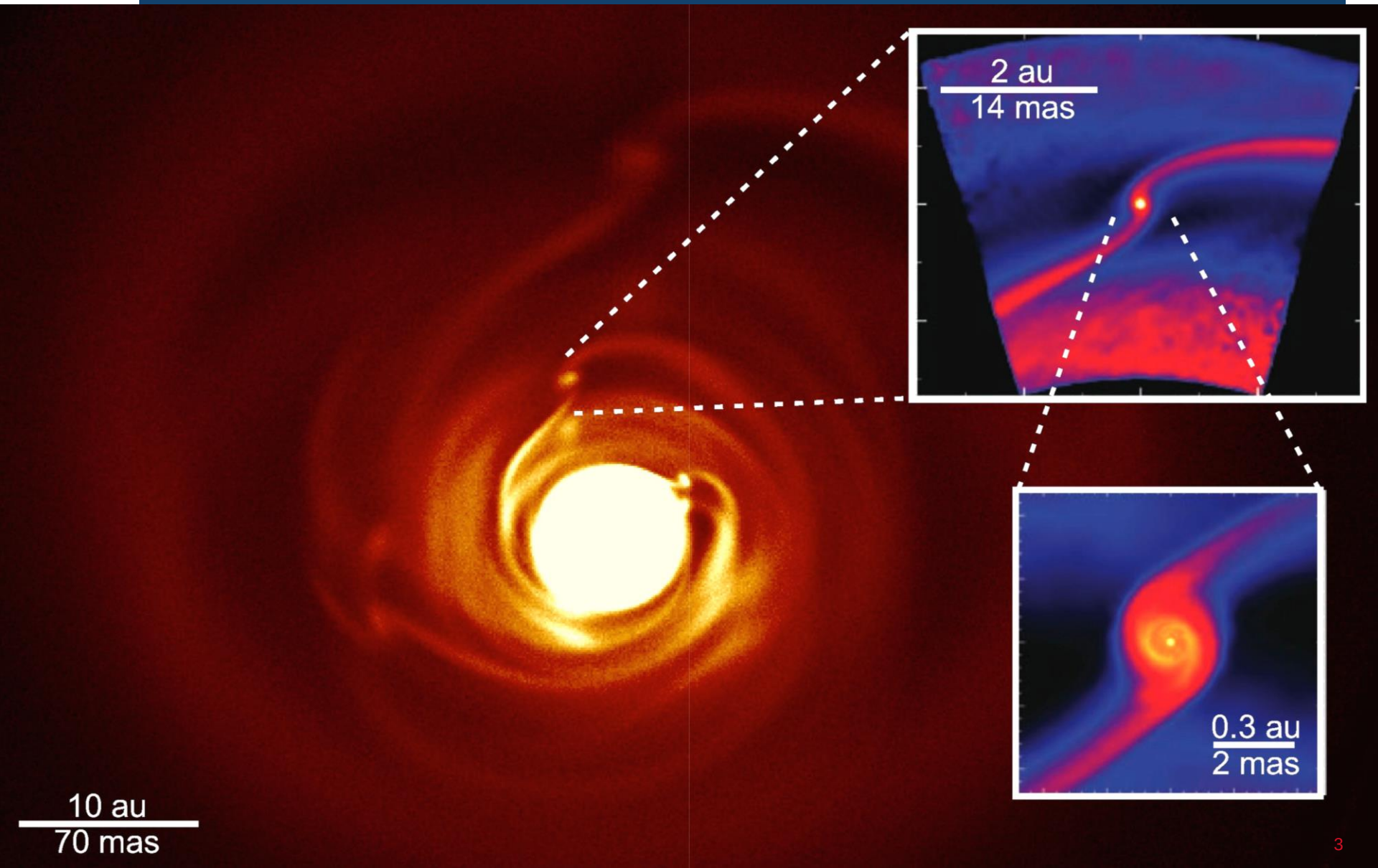


Opeical Interferometry has come of age:
MIRC Observations of Rapid Rotators



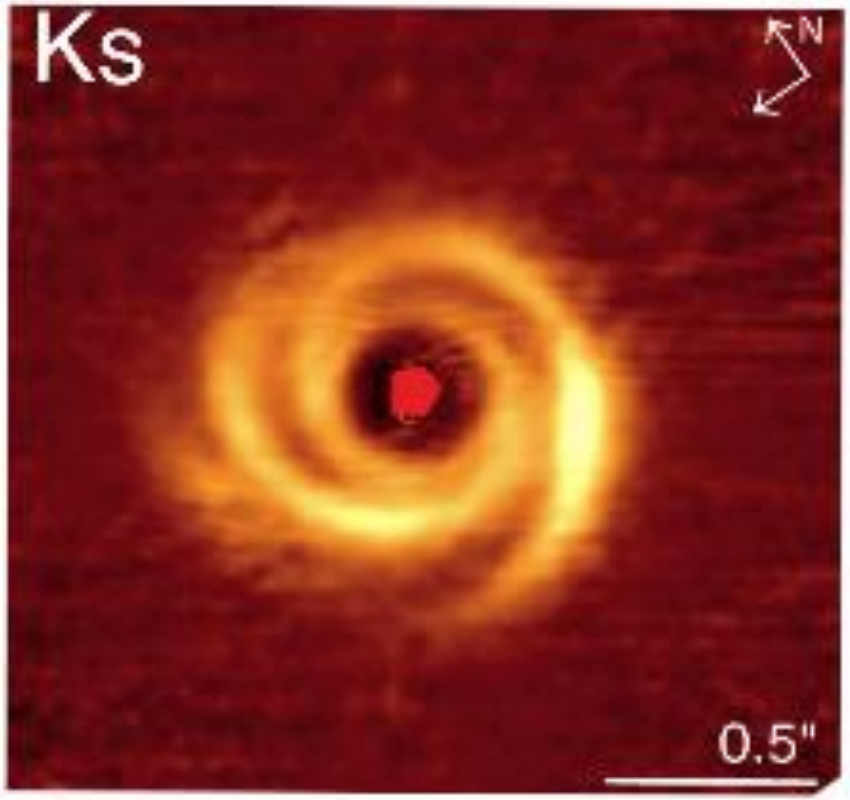
From CHARA array and U. Michigan group (Monnier,, Che)

What is Planet Formation Imager (PFI)?



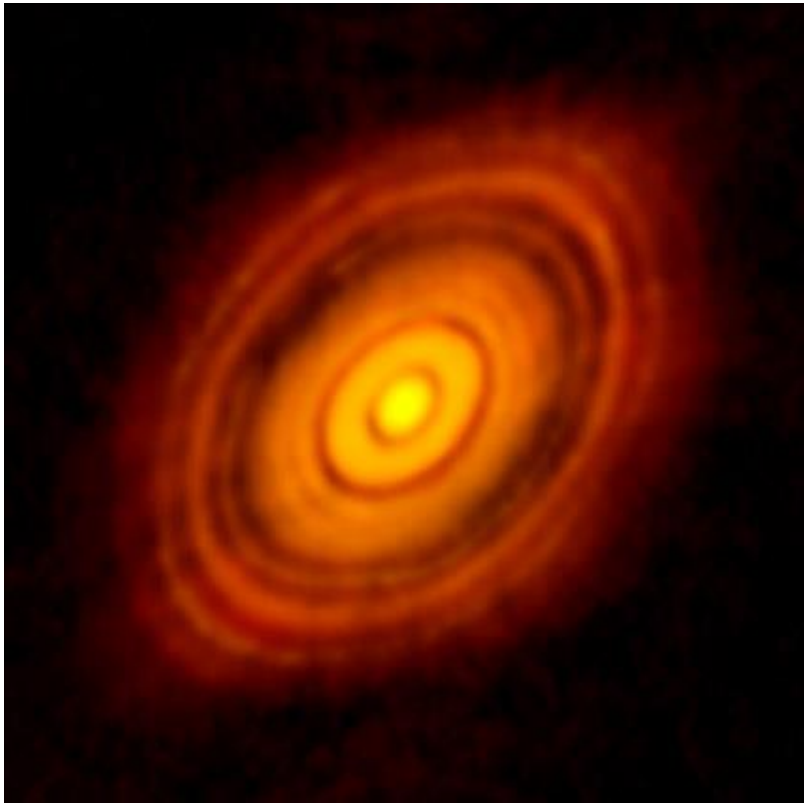
Complexity Requires Imaging

Scattered light SAO206462



Garufi et al 2013

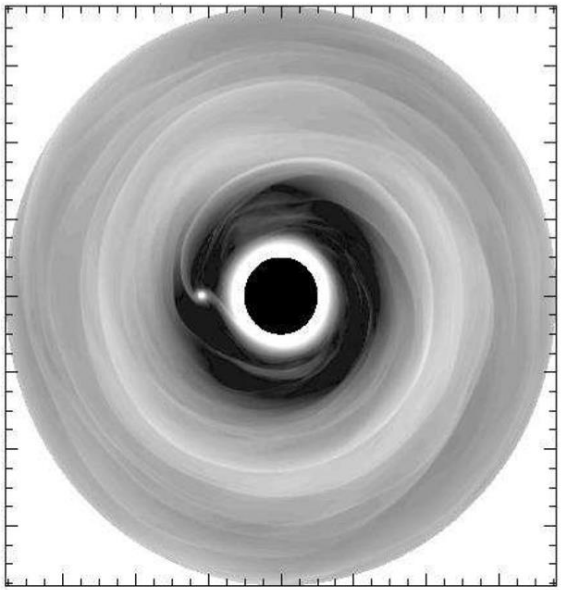
HL Tau w/ ALMA



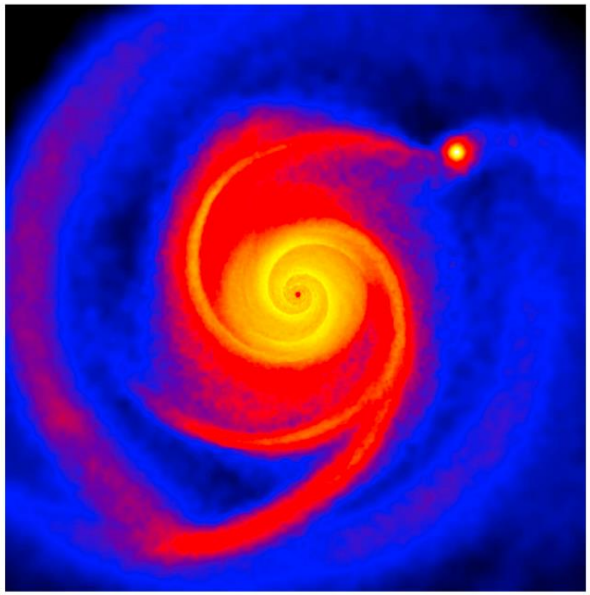
The physics of planetary formation in stellar disks

Planet formation alters the disk structure, causing
disk gaps, spiral arms, resonance effects, disk warping, …

Gap clearing



Disk fragmentation



Disk warping

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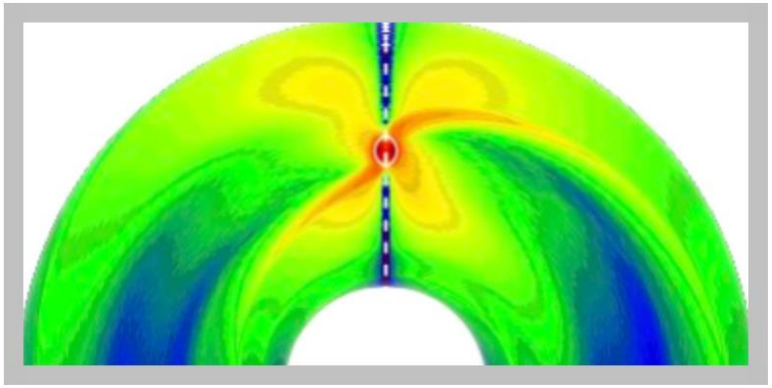
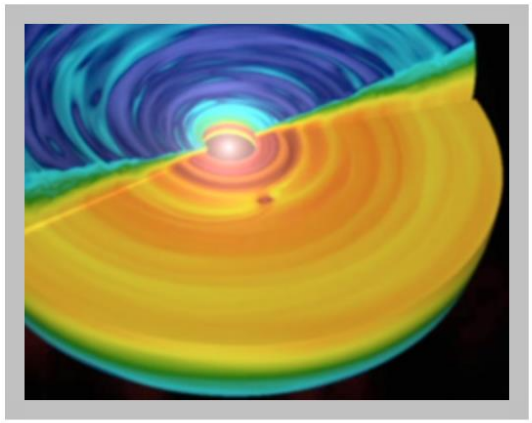
www.planetformationimager.org

Home News Science Technology Collaboration Resources Mailing List

Planet Formation Imager PFI

- What is Planet Formation Imager (PFI)?
- What is the status of the project?
- How can I get involved?
- When might PFI be built?





What is Planet Formation Imager (PFI)?

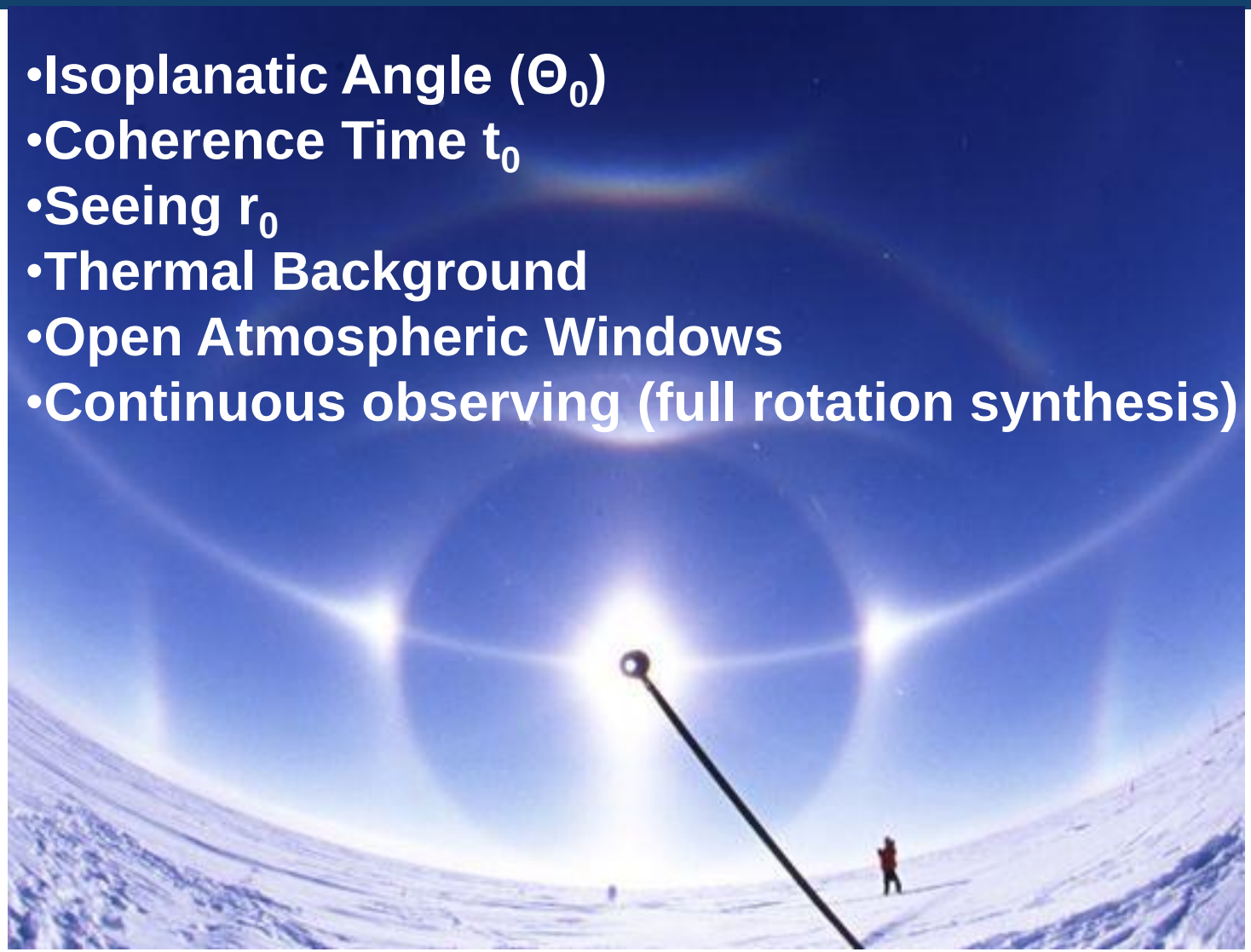
Among the most fascinating and hotly-debated areas in contemporary astrophysics are the means by which planetary systems are assembled from the large rotating disks of gas and dust which attend a stellar birth. Although important work is being done both in theory and observation, a full understanding of the physics of planet formation can only be achieved by opening observational windows able to directly witness the process in action. The key requirement is then to probe planet-forming systems at the natural spatial scales over which material is being assembled. By definition, this is the so-called Hill Sphere which delineates the region of influence of a gravitating body within its surrounding environment. The Planet Formation Imager project has

PFI: meeting the challenge

- Probably **10 microns** for science (but not settled)
- 1AU/1MJup “Hill Sphere” (=0.03AU) @140pc => **0.2 mas**
- **0.2 mas** at **10 µm** => **10km** interferometer baselines
- Need to image complex scenes (400px X 400px)
- Sensitivity is critical (intrinsically faint/low surface brightness)
- Architecture presently wide open
- Likely some form of long baseline interferometer (science requirements more or less dictate this)
- Site is wide open (Ground/Space/Antarctic)
- High Plateau offers huge advantages, and some risks
- Cost obviously vague (~half billion ?)
- Timescale “After ELTs and JWST”

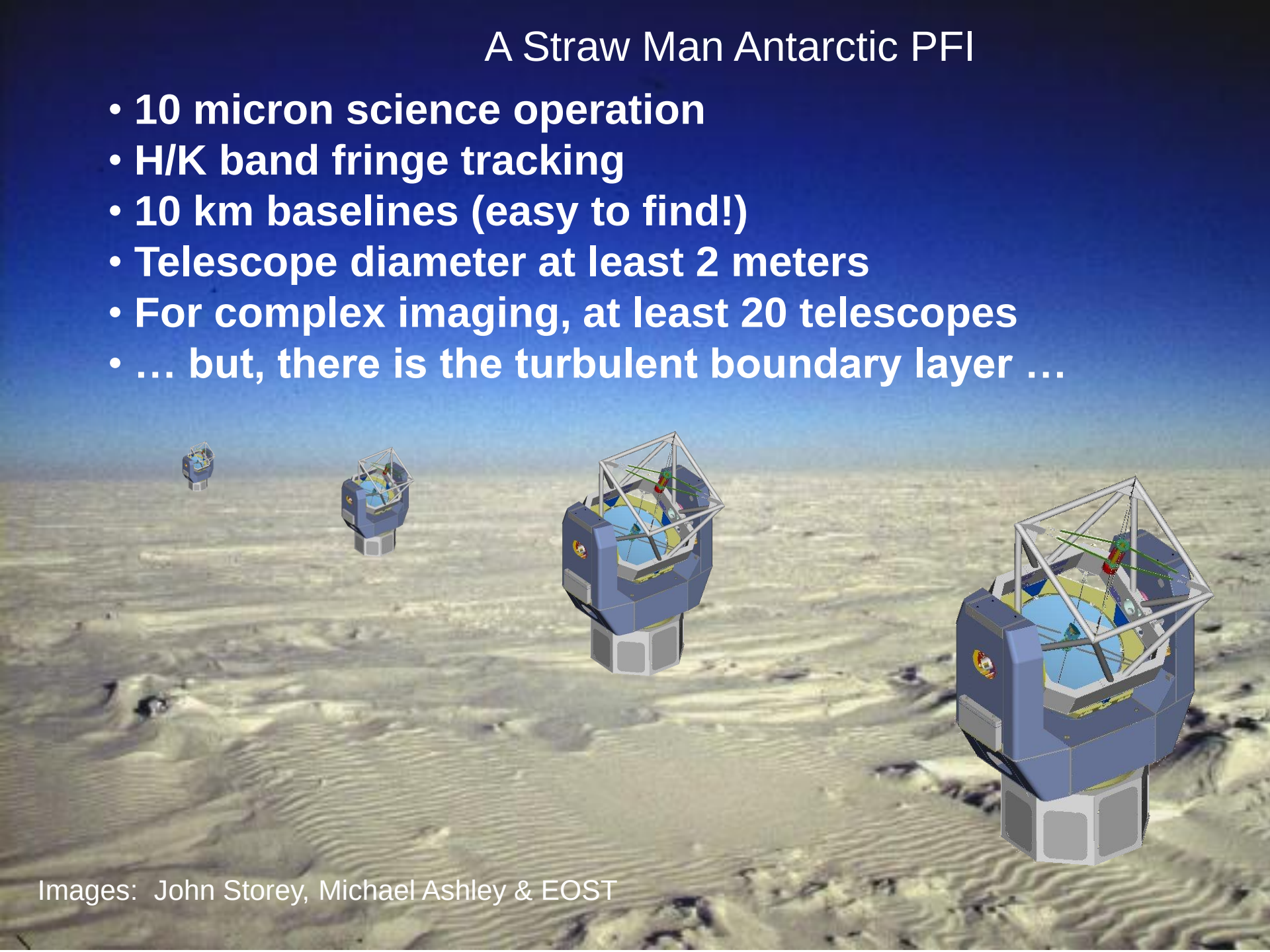
Antarctica is ideally suited to Interferometry

- **Isoplanatic Angle (Θ_0)**
- **Coherence Time t_0**
- **Seeing r_0**
- **Thermal Background**
- **Open Atmospheric Windows**
- **Continuous observing (full rotation synthesis)**



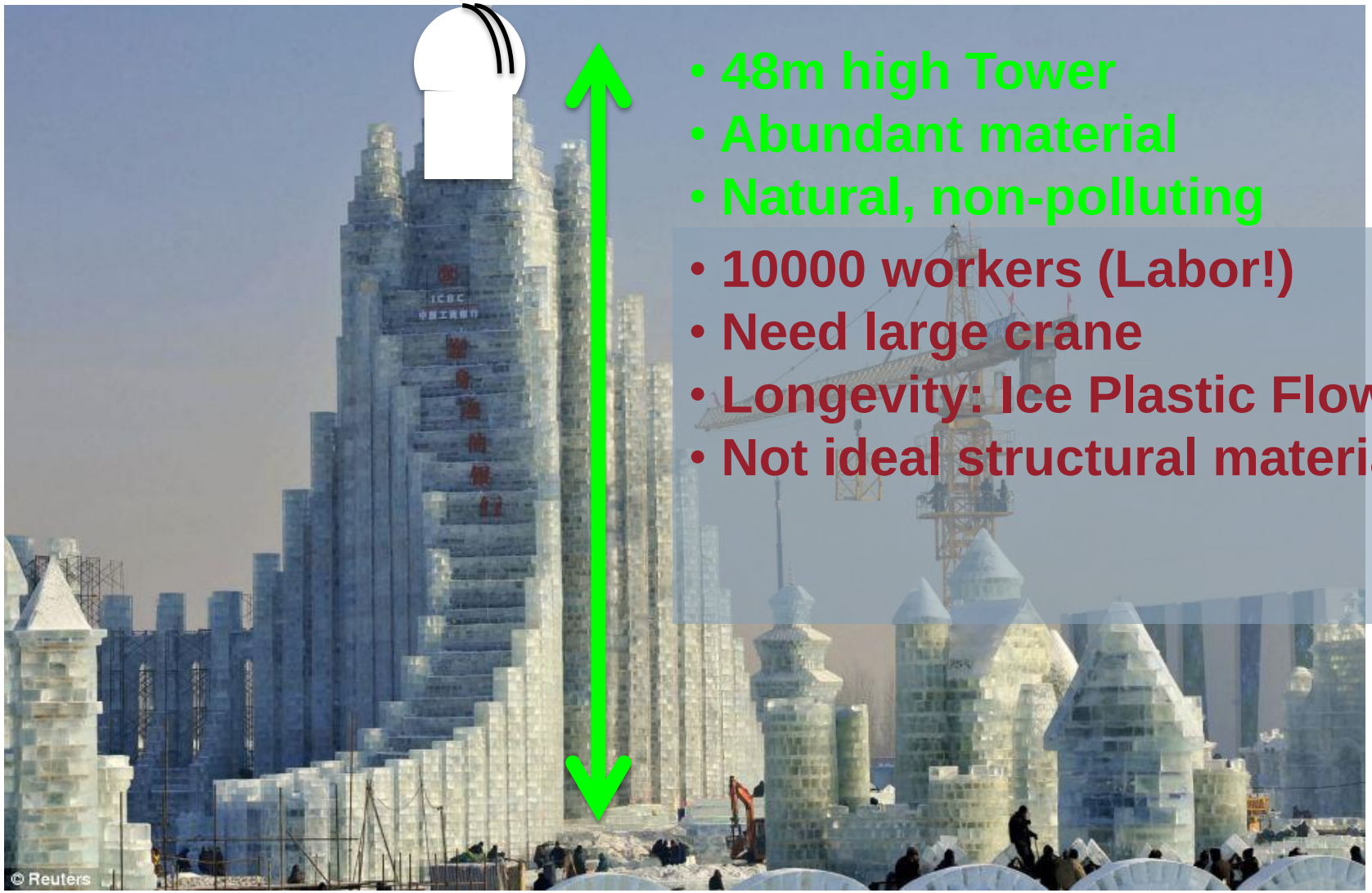
A Straw Man Antarctic PFI

- **10 micron science operation**
- **H/K band fringe tracking**
- **10 km baselines (easy to find!)**
- **Telescope diameter at least 2 meters**
- **For complex imaging, at least 20 telescopes**
- **… but, there is the turbulent boundary layer …**



Images: John Storey, Michael Ashley & EOST

Harbin Ice & Snow Festival, China, 2014



- 48m high Tower
- Abundant material
- Natural, non-polluting
- 10000 workers (Labor!)
- Need large crane
- Longevity: Ice Plastic Flow
- Not ideal structural material

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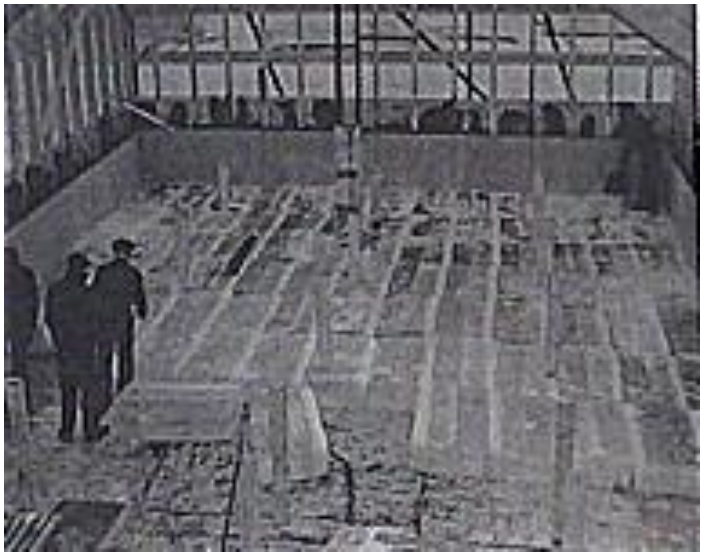
Do you need a magic ice princess?

Not really … Nature erects ice towers without magic (or even humans)

Engineered Ice: Pykrete and Project Habakkuk



Geoffrey Pyke

WWII Testbed in Jasper National Park

A modern Pykrete revival: Technical University Eindhoven

Arno Pronk

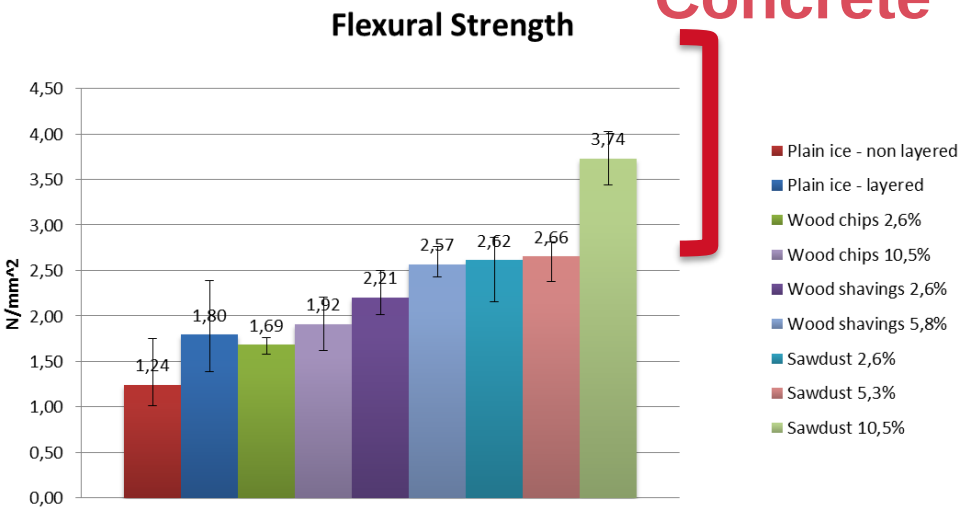
Patrick Teufffel

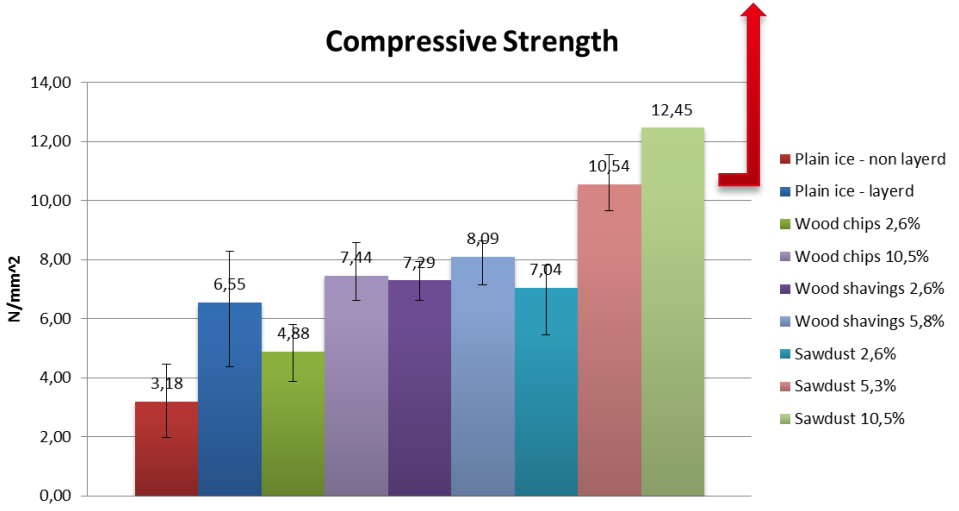
Technische Universiteit Eindhoven University of Technology

Where innovation starts

Modern Engineering testing

Concrete





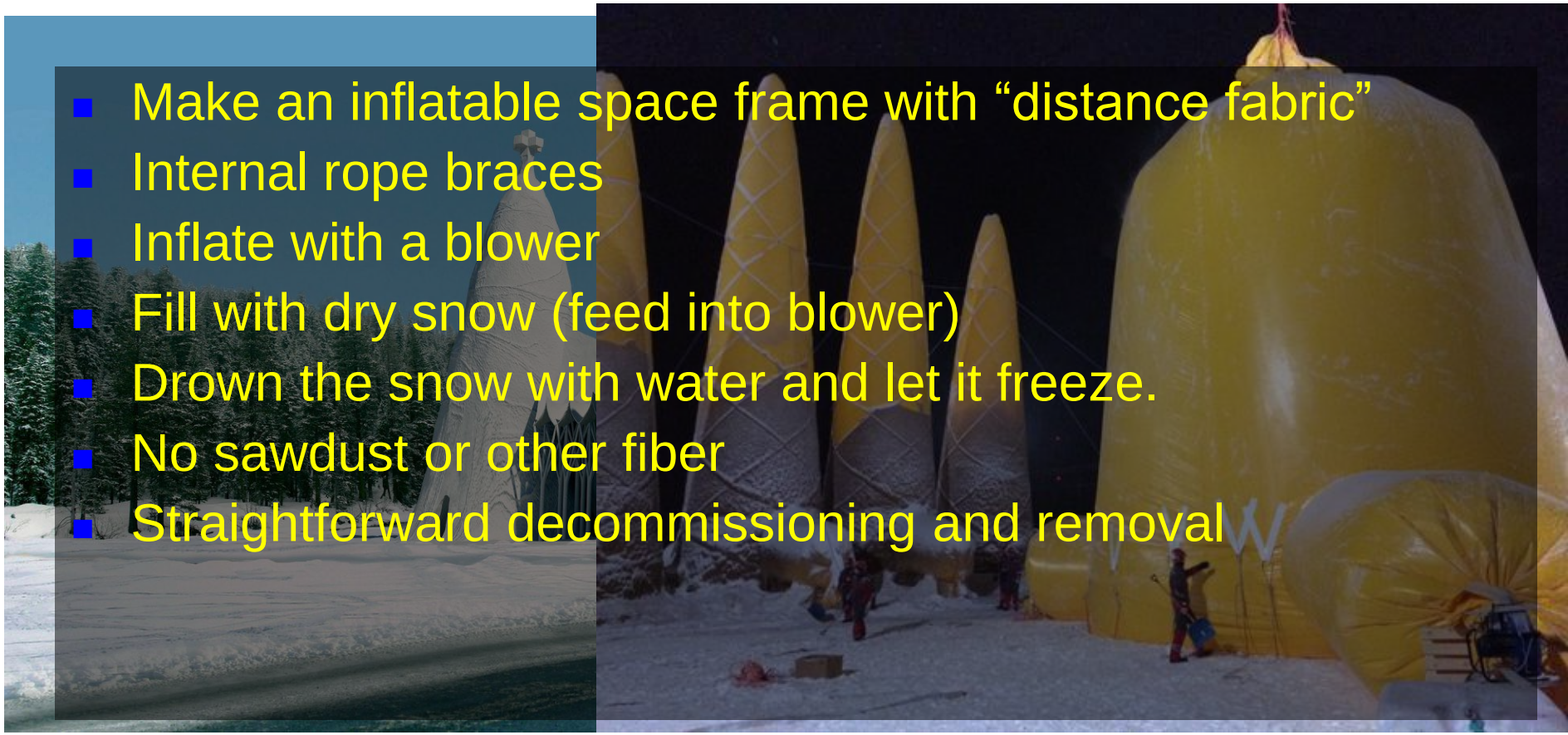
The ideal Antarctic building material?

See: **www.structuralice.com**

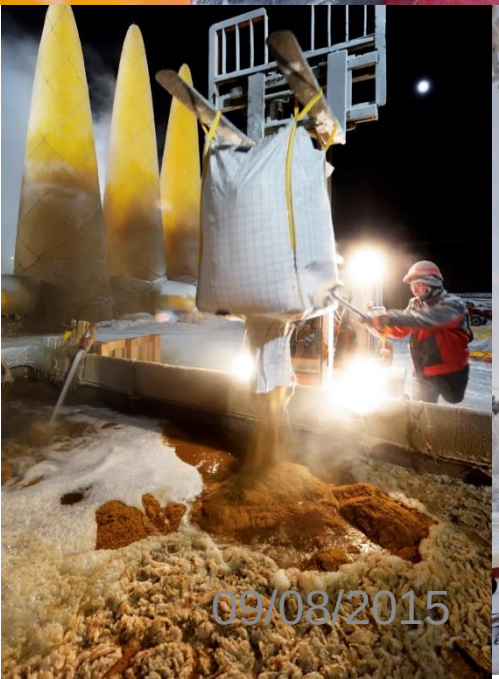
er ice dome TU/e 2014 Photo: Joep Rutgers

2015 Sagrada Familia in ICE

Eindhoven Engineered Pykrete Structures



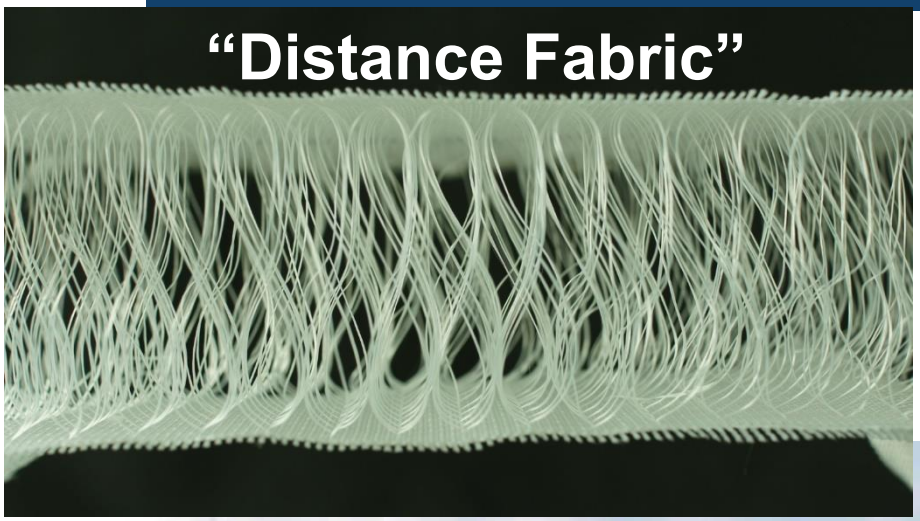
- Make an inflatable space frame with “distance fabric”
- Internal rope braces
- Inflate with a blower
- Fill with dry snow (feed into blower)
- Drown the snow with water and let it freeze.
- No sawdust or other fiber
- Straightforward decommissioning and removal


09/08/2015

Inflatable Trusses

With inflatables you can make almost any shape you want

Ice-filled internally-structured inflatables are very strong



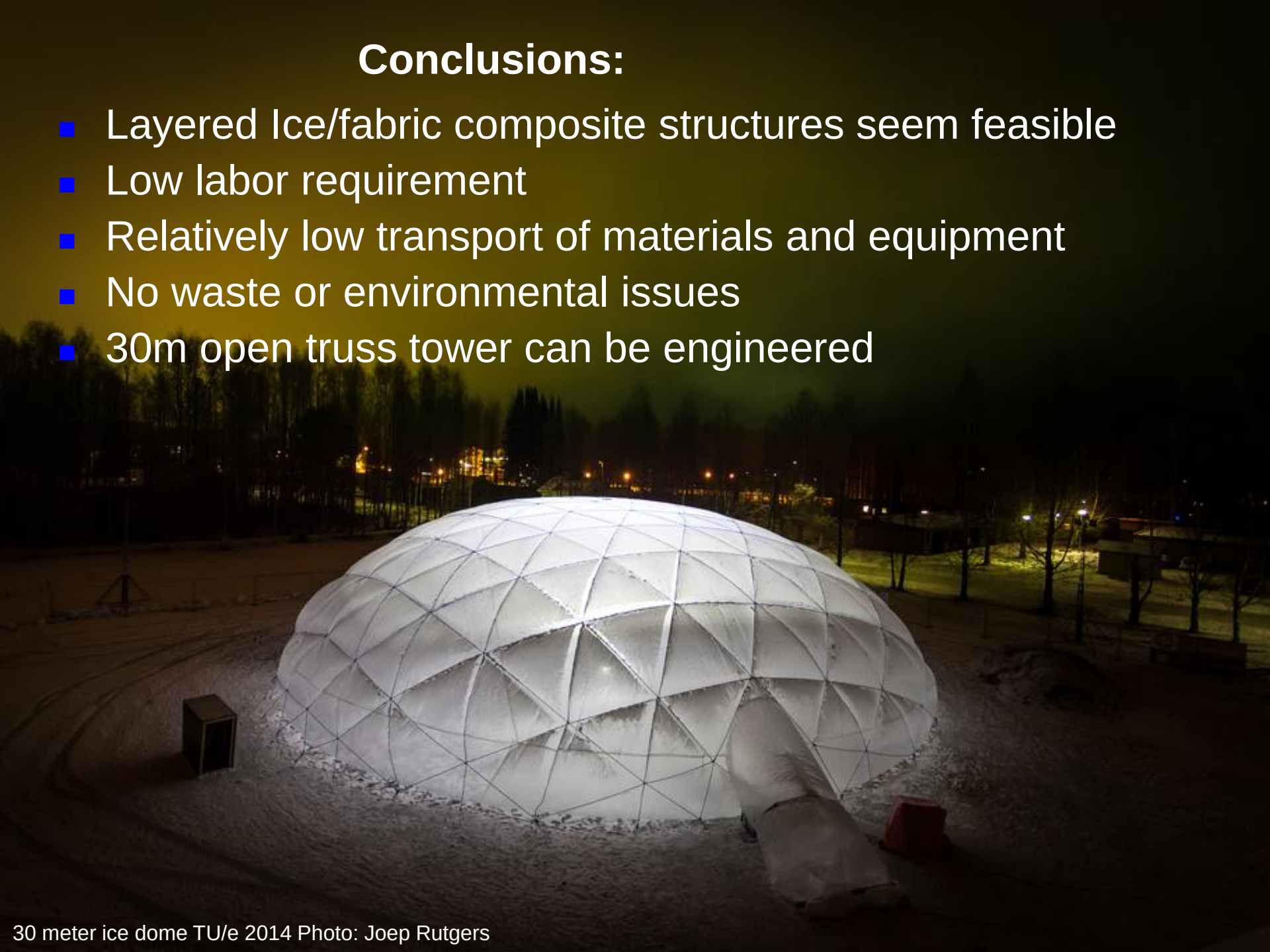
Eindhoven's next gig: Da Vinci Ice Bridge

- How to get Water?
- 20 Tons of water for a 200l drum of jet fuel (approx X100)
- 1 m^2 of Solar flux will melt 8kg of ice per hour
- Or approx 1 Tonne per day for 10 m^2 of collector
- Ideally can be done with a passive "solar still" at ice level
- Solar concentrator also a (more complicated) option

Da Vinci's BRIDGE in ICE

Conclusions:

- Layered Ice/fabric composite structures seem feasible
- Low labor requirement
- Relatively low transport of materials and equipment
- No waste or environmental issues
- 30m open truss tower can be engineered



30 meter ice dome TU/e 2014 Photo: Joep Rutgers

Engineered Ice Towers: A Progressive Roadmap

Stage 1: Proof of concept prototype.
- **Small structure (<2m high)**
- **demonstrate feasibility & structural integrity / longevity**

Stage 2: 15m tower for AST telescope.

Stage 3: 25m tower for KDUST telescope.

The Great Seal of the new world order …

An idea for AAA: a student matchmaking website?